CRUSTAL SOURCES OF ATMOSPHERIC METHANE ON MARS: THE ASSOCIATION WITH GROUND ICE AND THE POTENTIAL ROLE OF LOCAL THERMAL ANOMALIES. M. D. Max[1] and S. M. Clifford[2], MDS Research, [1]1601 3rd St. South, St. Petersburg, FL 33701, mmax@mdswater.com, [2]Lunar & Planetary Institute, 3600 Bay Area Blvd., Houston TX 77058, clifford@lpi.usra.edu.

Introduction: The recent detection of methane in the Martian atmosphere (Muma et al., 2004; Krasnopolsky et al., 2004; Formisano and Cottini, 2004) has led to considerable speculation regarding the nature of its source. Methane can originate from both biotic and abiotic processes, the most plausible sources being emissions from subsurface methanogens or recent volcanic activity (Fisk and Giovannoni, 1999; Wallendahl and Treiman, 1999; Max and Clifford, 2000; Krasnopolsky et al., 2004). The need for recent activity is because the photodissociation of atmospheric methane by solar UV limits its lifetime to only 340 yrs. Thus, for methane to be detectable today, some process for its active replenishment must exist (Krasnopolsky et al., 2004).

Observations by the Planetary Fourier Spectrometer (PFS) onboard ESA's Mars Ex-press spacecraft, suggest that the concentration of methane and water vapor in the lower atmosphere are both correlated and enhanced in three broad equatorial regions -- Arabia Terra, Elysium Planum and Arcadia-Memnonia (Formisano and Cottini, 2004). This association is interesting in that these regions appear to correspond to areas where the Gamma-Ray Neutron Spectrometer onboard NASA's Odyssey spacecraft has detected a local enrichment in the abundance of hydrogen in the top meter of the regolith (possibly in the form of ice), an observation that Formisano and Cottini (2004) suggest may be indicative of a common subsurface source.

A possible explanation for the apparent association of atmospheric methane and water vapor is that it may result from the decomposition of a subsurface ice-like compound known as methane hydrate. Gas hydrates (also known as clathrates) can form when molecules of methane (and other gases, like CO_2 and H_2S), are concentrated under condi-tions of high pressure and low temperature in the presence of H_2O – where they can become trapped in the crystalline cages formed by water ice molecules. Such conditions might conceivably result from the presence of methanogens in sub-permafrost aquifers, whose gas emissions, confined by the cryosphere, could yield methane hydrate in concen-trations ranging from a dispersed contaminant to massive deposits (Max and Clifford, 2000). In this regard, the stability field of methane hydrate extends from ~15 m beneath the Martian surface (corresponding to a confining pressure of ~140 kPa, at 200 K), to a maximum depth of as much as much as a kilometer below the base of the cryosphere.

Alternatively, atmospheric methane might also originate from direct emissions from the subsurface via pathways associated with local thermal anomalies, such as those which occur on the Earth's seafoor. Wood et al. (2004) describe modeling of heat flux at fluid and gas seep localities in the northern Gulf of Mexico. The seeps, which are associated with low upwelled mud mounds and circular depressions 200 and 500 m across, are associated with mounds and pockmarks in the Atwater Valley at about 1300 m water depth. Heat flow gradients in the deepest measured sections indicate that advection has been minimal for at least several decades. The presence of free gas below the mounds is interpreted from seismics to be from 60-70 mbsf while the top of free gas away from the mounds that hosted the seeps is on the order of 200-300 mbsl. The top of the gas defines the base of the hydrate stability zone, within which natural gas, principally methane, is found in the form of gas hydrate. Upwelling of the gas and fluid has altered the local thermal strcuture of the crust, 'pulling up' the base of the gas hydrate stability zone in the immediate subsurface below the seep as the warmer deep fluids and gas (which drives the buoyancy of the fluid) ascend.

Geothermometry of the seafloor and heat flow measurements have identified clear thermal anomalies associated with fluid and methane venting in the northern Gulf of Mexico (Hagen et al., 2004) and off the coast of Chile (Gardner et al., 2004). Measurements showed seafloor temperatures near the vents that were elevated by up to 0.3 °C relative to the surrounding seafloor, while heat flow values of around 160 mW/m^2 at one location and 132 mW/m^2 at another, are much higher than the usual 40 – 50 mW/m^2 values of the surrounding sediments.

The heat transfer conditions at the seafloor locations (seafloor temperatures below 4 °C) are considerably different from the heat transfer conditions that are likely exist on Mars. Nonetheless, it may well be that crustal thermal anomalies on the order of up to several hundred meters across and on the order of 0.25°C may exist on Mars in the vicinity of methane seeps.

The presence of such anomalies may be identified by high-resolution thermal mapping of the planet's surface – potentially occurring in association with

pockmarks and faults. Faults or pillar seeps would provide the structural breaks through which fluids and gas could propagate, and buoyancy from the gas could provide a substantial upward driving force far in excess of normal percolation. Near the locations of the most active seeps on Mars, the subjacent geothermal gradients can be expected to be greatest, as they are on Earth. The shallowest deep biosphere on Mars may be found in these seep-related thermal domes.

References: Fisk, M. R. and S. J. Giovannoni, Sources of nutrients and energy for a deep biosphere on Mars, J. Geophys. Res., 104, 11805-11815, 1999; Formisano, V and V. Cottini, PFS observation of methane, formaldehyde and HF: Extant life on Mars? (abstract), International Mars Conference, Ischia Island, Italy, September 2004; Gardner, J.M., Diaz-Naveas, J., Pohlman, J.W., Hagen, R.A., Coffin, R.B. & Wood, W.T. 2004. Methane hydrates and fluid flow along the Chilean margin. In: Proceedings 85(47) AGU Fall Meeting, San Francisco, Ocean Sciences General Contributions: Gas Hydrates II OS41C-0496; Hagen, R.A., Gardner, J.M. & Wood, W.T. 2004. Thermal Measurements Over Hydrate Mounds in Atwater Valley, Gulf of Mexico (Poster). In: Proceedings 85(47). AGU Fall Meeting, San Francisco, Ocean Sciences General Contributions: Gas Hydrates II OS41C-0490; Krasnopolsky, V. A., J. P. Maillard, and T. C. Owen, Detection of methane in the martian atmosphere: Evidence for life?, Icarus, doi: 10.1016/j.icarus.2004.07.004; Max, M.D. & Clifford, S.M. 2001. Initiation of Martian outflow channels: Related to the Dissociation of Gas Hydrate. Geophysical Research Letters 28, 1787-1790; Muma, M. J., R. E. Novak, M. A. DiSanti, B. P. Bonev and N. Dello Russo, Detection and mapping of methane and water on Mars (abstract), AAS/Divisions for Planetary Sciences Meeting, Bulletin of the American Astronomical Society, 36, November 2004; Wood, WT., Gardner, J., Hagen, R.A., Coffin, R.B., Pohlman, J.W., Hart, P.E. & Hutchinson, D.R. 2004. Modeling Heat and Fluid Flux of Seafloor Mounds in the Gulf of Mexico (Abs). In: Proceedings 85(47) AGU Fall Meeting, San Francisco, Ocean Sciences General Contributions: Gas Hydrates I OS34B-08; Wallendahl, A. and A. H. Treimann, 1999. Geochemical models of low-temperature al-teration of Martian rocks, Lunar Planet. Sci. Conf. XXX, Abstract #1268, Lunar and Planetary Institute, Houston (CD-ROM).