

PROSPECTING FOR METHANE IN ARABIA TERRA, MARS – FIRST RESULTS.

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Introduction. Methane has been measured in the Martian atmosphere at concentrations of ~10 ppb [1-3]. Since the photochemical lifetime of this gas is ~300 years, it is likely that methane is currently being released from the surface. Possible sources for the methane include 1) hydrothermal activity, 2) serpentinization of basalts and other water-rock interactions, 3) thermal maturation of sedimentary organic matter, and 4) metabolism of living bacteria. Any such discovery would revolutionize our understanding of Mars.

Longitudinal variations in methane concentration, as measured by the Planetary Fourier Spectrometer (PFS) on Mars Express, show the highest values over Arabia Terra, Elysium Planum, and Arcadia-Memnonia, suggesting localized areas of methane release [3]. We are using orbital data and methodologies derived from petroleum exploration in an attempt to locate these release points.

Prospecting for Locations of Methane Release:

Most methane on Earth occurs in sedimentary basins, being produced either from extant, methanogenic bacteria or by thermal alteration of buried organic matter (kerogen). Kerogen on Earth is largely biogenic, being comprised mainly of organic remnants of past life. Since early Mars is thought to have been wetter than Mars today and similar to early Earth in climatic conditions, it is possible that life developed and flourished on early Mars, as it did on early Earth [4,5]. If life did develop on early Mars, then biogenic kerogen may have been preserved in Noachian, Hesperian, and possibly early Amazonian basinal settings. In parts of those basins, burial and heating - perhaps enhanced by impact processes [6] - might have provided the thermal maturation [7,8] to generate methane.

If the methane detected in Mars' atmosphere has been generated from the relatively deep subsurface, then there is a reasonable chance that some of the upwardly migrating gas will have accumulated in geologic traps. Such methane reservoirs may still exist, even if the methane initially accumulated far in the past.

On Earth, however, very few reservoirs are “perfectly sealed.” Most commonly, gas reservoirs leak to the surface through faults and fissures. Present-day gas seepage even occurs over methane traps that were filled hundreds of million years ago [9].

Evidence of methane seepage sometimes can be detected in the geochemical alteration of surface sedi-

ments. Such alteration can result in color and albedo changes such as red bed bleaching [10,11].

Approach: Our search for sources of Martian methane employs a “New Ventures” approach commonly used in the oil industry to optimize the discovery of hydrocarbons in virgin areas. New Ventures areas are typically remote, poorly studied, and lacking in well or ground control. Consequently, aerial and satellite data (such as gravity, magnetics, topography and bathymetry) form the basis of most New Ventures evaluations. These evaluations integrate aerial and satellite data with concepts of basin development to derive locations where oil or gas may have been generated, trapped, and released.

Study Area: Arabia Terra, approximately the size of Australia, was chosen for this initial study because it is one of the three areas of enhanced methane concentration [3], and because the region includes several features potentially indicative of a past, major sedimentary basin. Arabia Terra is the northernmost extension of the cratered highlands, and is approximately bounded by 0 to 40 N latitude and 20 W to 60 E longitude (Fig. 1). The area is dominated by a regional slope, descending from +4000 m in the SE to -2500 m at the dichotomy boundary in the in the NW [12]. It has been mapped as Noachian plains with minor Hesperian ridged units [13,14].

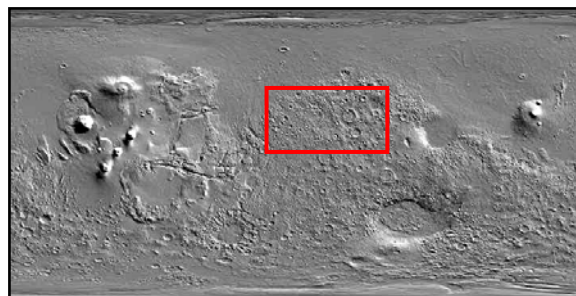


Fig. 1 Arabia Terra study area -- MOLA digital elevation model

High-resolution Mars Orbiter Camera (MOC) images reveal extensive layered sequences in Arabia that have been interpreted as potential remnants of sedimentary deposits [15-17]. Orbital gamma ray and neutron spectrometer data show that the near surface of Arabia Terra contains abundant hydrogen in water ice or hydrated minerals [18]. Either interpretation is consistent with the possibility that Arabia Terra once was the site of a major sedimentary basin – a view sup-

ported by observations of crater morphology, geomorphology, gravity, thermal inertia, and albedo [19,20].

Mapping from Viking images has revealed a small number of 100 km-scale faults as well as numerous wrinkle ridges, mostly trending NW-SE [13,14]. High resolution MOC images of Arabia Terra show evidence of multiple, smaller faults also trending NW-SE.

Craters with bright rims occur in Arabia Terra and Meridiani Planum, immediately to the SW. Analyses by the Opportunity rover demonstrate that bright crater rims are dominated by strongly altered rock units [21]. These bright rims may be the sites of impacted-induced alteration, possibly associated with buried organics [6]. They resemble bleached zones on Earth over areas of hydrocarbon seepage [11].

Arabia Terra Survey — First Results: We have completed a preliminary survey of Arabia Terra with MOC high resolution (5-12 m/pixel) images from sets AB1-M04, R03-R09, and R10-R15 [22]. We documented locations of layered deposits, faults displacing layers, and craters with bright rims. Maps in ArcGIS show overlaps of layers, faults, and bright rim craters.

A total of 1011 images were examined, and 811 showed layered outcrops. Layers were seen in every 10 x 10 degree latitude/longitude block. Layered outcrops occur both within craters and on the plains. The highest concentrations of layers overlie Noachian cratered plains units, while few layers overlie Hesperian and Noachian ridged units. Layers are concentrated in the western half of Arabia Terra, generally at altitudes above the -2000 m contour. Faults are rare, but are concentrated in the SW corner of the region. Craters with bright rims generally occur between 0 and 20 W.

Mapping of these datasets shows a unique region in the southwest of Arabia Terra where layered deposits, faults, and bright rim craters are concentrated. Thus, a “New Ventures” analysis suggests that southwest Arabia Terra, particularly in the area of 2 to 12 N, 5 to 12 W (Fig. 2), is a prime area for detailed exploration in the search for sources of Martian methane.

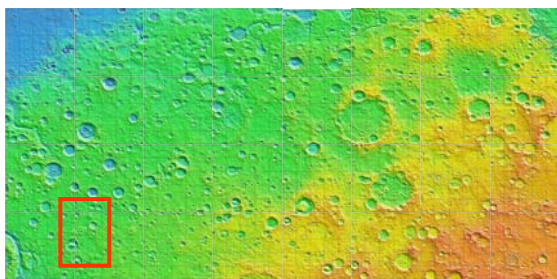


Fig. 2 Possible source area for methane release, based on New Ventures analysis – MOLA false-color elevation map

Next Steps: The area of southwest Arabia Terra “highgraded” in this first attempt at Martian methane prospecting is the subject of considerable ongoing research. Preliminary geologic mapping of an overlapping area reveals a complex history of deposition and large-scale erosion [23]. In addition, the Opportunity rover continues to provide ground truth on the nearby, likely related, rock units of Meridiani Planum [21].

Current and planned spacecraft have the potential to greatly improve our ability to prospect for methane. Further integration of PFS data may refine the locations of enhanced methane. The remote sensing suite on Mars Express is producing maps of minerals, including clays and hydrates, that are often found in terrestrial localities affected by hydrocarbons. The Mars Reconnaissance Orbiter, with meter-scale resolution and hyperspectral mapping capability, may permit identification of altered minerals and fossil hydrothermal deposits. The gas chromatograph and mass spectrometer selected for the Mars Science Laboratory should confirm the detection of methane and suggest whether or not the methane has a biogenic source. Orbital spacecraft in the next decade may refine knowledge of methane and pinpoint its sources for future exploration.

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