ENIGMATIC LANDFORMS IN CYDONIA: GEOSPATIAL ANISOTROPIES, BILATERAL SYMMETRIES, AND THEIR CORRELATIONS. M. J. Carlotto, Veridian Systems Division, 705 Broughton Dr., Beverly MA 01915 (mark.carlotto@veridian.com)

Introduction: Geospatial terrain statistics and object symmetries of enigmatic landforms in Cydonia are examined and correlations identified. Analysis of Viking image-derived MDIM data (1/256 deg./pixel) over Cydonia (37.5-42.5° N and 4.5-15.5° W) shows directional anisotropies in the spatial autocorrelation (variogram) at medium to long wavelengths (10-100 km.). One is in the direction of the crustal dichotomy in this part of Mars (~ 64.6°, or ~25.4° north of east), along with two others at 103.7° and 164.2°. Anisotropies in similar directions at shorter wavelengths (down to tens of meters) are evident in the variograms of Viking, THEMIS, and MGS images within this area. The spatial autocorrelation structure of selected regions in Viking images show indications of rectilinear geometry (directional anisotropies approximately 90 deg. apart) similar to that of highly eroded terrestrial archaeological ruins. Previous analyses of THEMIS and MGS imagery reveal a high degree of bilateral symmetry in several landforms. We show the axes of symmetry are roughly in line with the directional anisotropy at 164.2° noted above.

Geospatial Statistics: Variograms describe correlations in spatial data. The variogram of an image $i(x,y)$ is:

$$\begin{aligned} 2\gamma(u,v) &= Var\left[i(x,y) - i(x+u,y+v)\right] \\ &= E\left\{\left[i(x,y) - i(x+u,y+v)\right]^2\right\} - \\ &\quad \left\{E\left[i(x,y) - i(x+u,y+v)\right]\right\}^2 \\ &= E\left\{\left[i(x,y) - i(x+u,y+v)\right]^2\right\} \end{aligned}$$

for stationary random processes. The variogram and the autocorrelation function are related

$$\begin{aligned} 2\gamma(u,v) &= E\left\{\left[i(x,y) - i(x+u,y+v)\right]^2\right\} \\ \gamma(u,v) &= R(0,0) - R(u,v) \end{aligned}$$

where $R(u,v) = E\left[i(x,y)i(x+u,y+v)\right]$. For efficiency the autocorrelation function is computed using the Fast Fourier Transform (FFT):

$$\begin{aligned} R(u,v) &= i(x,y) * i(-x,-y) \\ &= \Im^{-1}\left\{\Im[i(x,y)]\Im^*[i(x,y)]\right\} \end{aligned}$$

The image formation model [1] relates the spatial statistics of an image to its underlying terrain surface. We are interested in the correlation structure of the terrain, specifically in its directional anisotropy. The autocorrelation function in polar coordinates is $R(r,\theta)$ where $r = \sqrt{u^2 + v^2}$ and $\theta = \tan^{-1}(v/u)$. The polar distribution function

$$F(\theta | r_1, r_2) = \int_{r_1}^{r_2} R(r,\theta) dr$$

expresses directional correlations in spatial data over a given scale range. Peaks in the angular distribution indicate directions along which correlations exist in the terrain.

Mars Crustal Dichotomy: MDIM data provide the appropriate spatial scale to illustrate long term directional trends in the terrain (Fig. 1a). The MDIM autocorrelation function is shown in Fig. 1b with a polar plot showing directional anisotropies for $9 < r < 115$ km. Three peaks occur at 64.7±2.5°, 103.2±3.9°, and 164.0±0.9°. The first (direction A) corresponds to the direction of the crustal dichotomy in this part of Mars [2]. The other two directions (B and C) are referenced later in the paper.

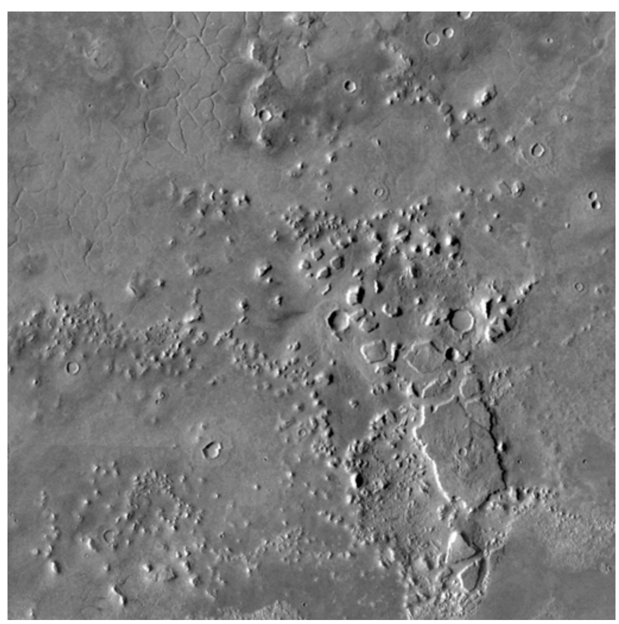


Fig. 1a Mosaic of two MDIM images at 1/256 degrees/pixel (231 m/pixel) in sinusoidal equal-area projection.

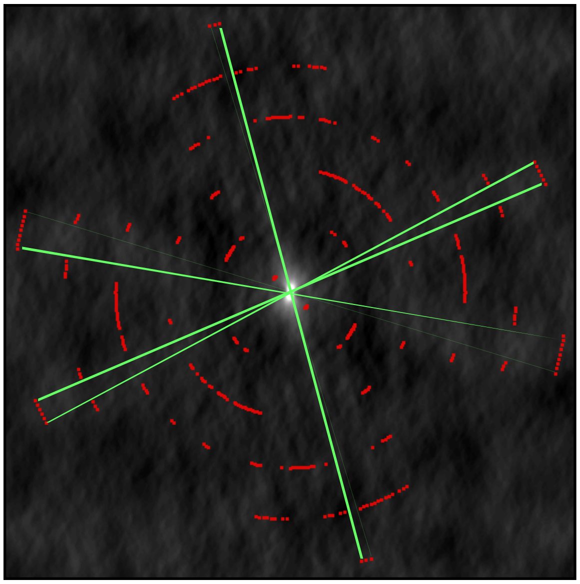


Fig. 1b Polar plot of MDIM autocorrelation function computed over distances of 9-115 km.

Shorter Scale Correlations: Anisotropies in similar directions at shorter wavelengths (down to tens of meters) can be found in the autocorrelation functions of THEMIS, Viking, and MGS images within this area. Fig. 2a shows two sections of a THEMIS image strip. This area is toward the northeast corner of the MDIM image in Fig. 1. A directional anisotropy exists in the autocorrelation at 153.5±3.7° over distances of 2-25 km (Fig. 2b). This is approximately 90° away from the direction of the Mars crustal dichotomy (direction A).

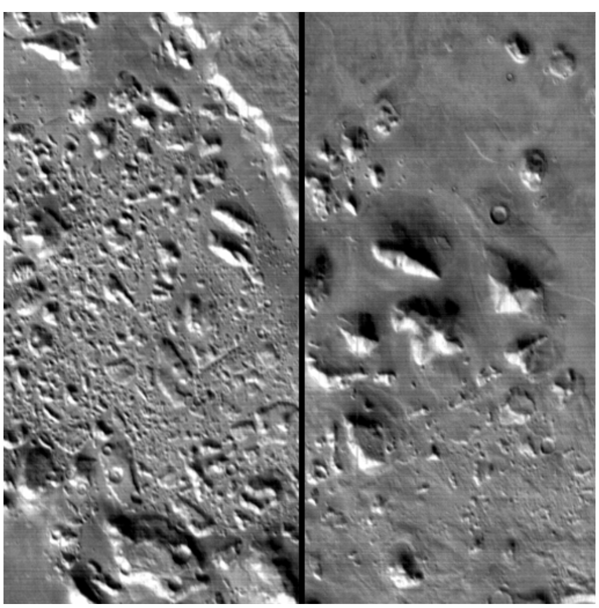


Fig. 2a Two sections of THEMIS image 20020413a over Cydonia

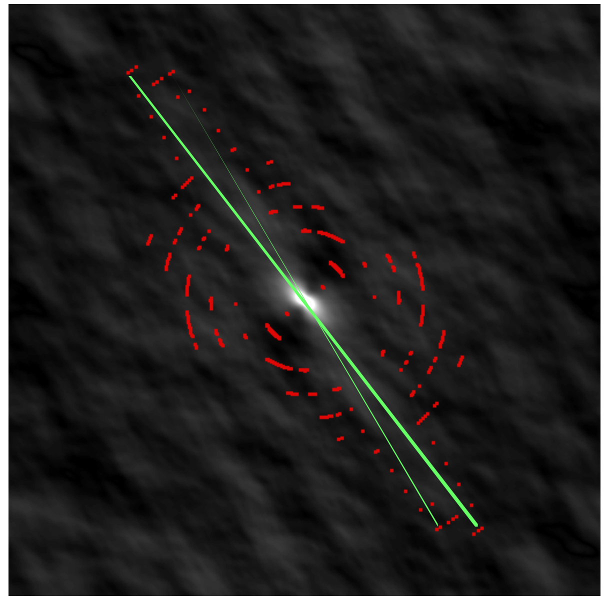


Fig. 2b Polar plot showing directional anisotropies in THEMIS image over distances of 2-25 km.

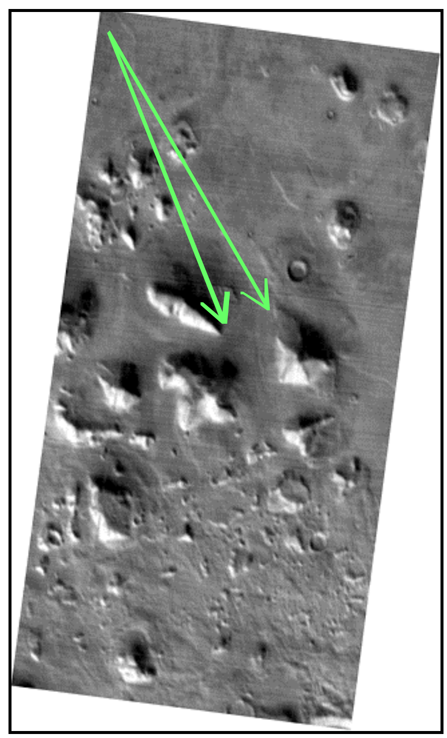
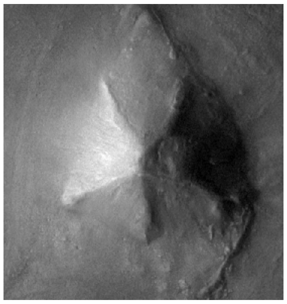


Fig. 2c Directions 149.8° and 157.2° (153.5±3.7°) overlaid on portion of THEMIS image

In Fig. 2c the directional interval 153.5±3.7° is represented by the two arrows overlaid on the portion of the THEMIS image strip which includes the two enigmatic landforms known as the D&M Pyramid and Face [3]. Both of these objects possess a high degree of bilateral symmetry (Fig. 3) with their axes of symmetry closely lined up with the 153.5±3.7° anisotropy.



"D&M Pyramid" from THEMIS image 20020413a

"Face" from MGS image E1701041

Fig. 3 Enigmatic landforms rotated so that their axes of symmetry are in the vertical direction

Analysis of Viking orbiter imagery (Fig. 4) reveals spatial correlations at 48° and 167.7±2.5° between 2.5-10 km. that coincide roughly with those seen in MDIM and THEMIS images.

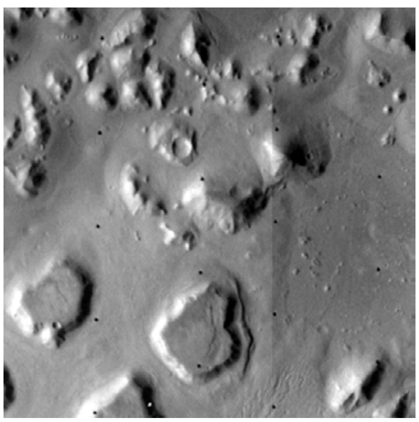


Fig 4a Mosaic of map projected Viking frames from orbit 35 over an area showing evidence of rectilinear organization

Fig. 4b. Portion of map projected Viking frame 35A72 showing the enigmatic landform known as the "City"

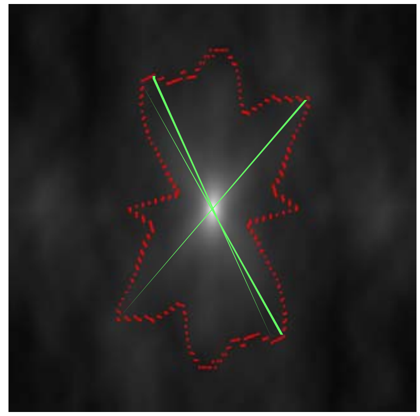


Fig. 4c Polar plot showing directional anisotropies in Viking images over distances of 2.5-10 km. (Peaks at 0° and 90° are edge artifacts that are a result of FFT processing.)

Finally in Fig. 5 we show a portion of an MGS image near 39.95° N 14.8° W containing small bumps oriented at 52.7±6.7° over scales of 150-580 meters. This area is about 250 km. away from the Cydonia landforms, in the southwest corner of the MDIM image in Fig. 1.

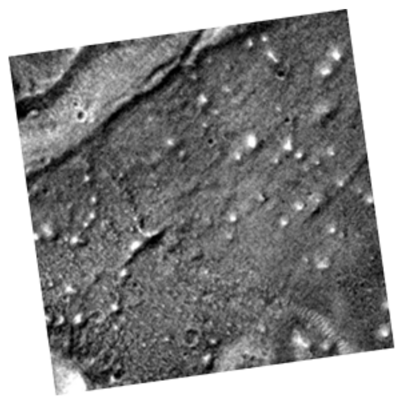


Fig. 5a Portion of MGS image SP249604 (area shown in about 1.4 sq. km.)

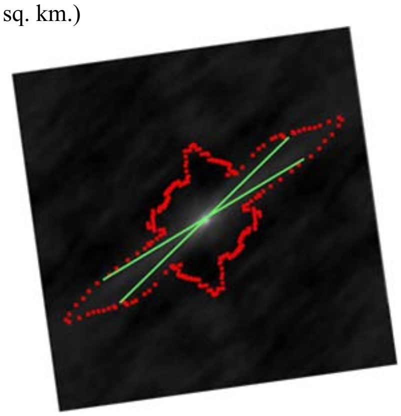


Fig. 5b Peak in polar plot of MGS autocorrelation function at 52.4±6.7°

Discussion: The results presented here lead naturally to three questions:

1) Why do directional anisotropies exist over such a wide range of spatial scale?

2) Why are some of them about 90° apart?

3) Why do their directions coincide roughly with the axes of symmetry of several enigmatic landforms in Cydonia?

While the Null Hypothesis -- that these correlations have a natural (geological) interpretation -- is to be preferred over others, we offer the hypothesis that this collection of features may represent the eroded remains of ancient archaeology on Mars. Fig. 6 shows an aerial image over an eroded site on the South coast of Peru [4]. Its rectilinear pattern of organization leads to a correlation structure with directional anisotropies 90° apart. Similar correlation signatures are observed in Cydonia.

Fig. 6a Aerial view eroded archaeological site (La Centinela, Peru)

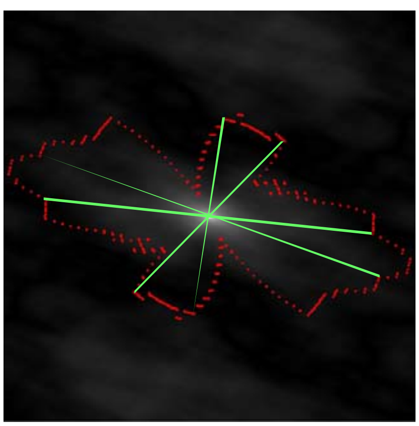


Fig. 6b Polar plot of spatial autocorrelation of La Centinela showing anisotropies about 90 degrees apart. Note angle difference differs from 90° in this image due to perspective foreshortening.

Following Sagan's criteria for detecting signs of planetary intelligence [5], deviation from fractal behavior was proposed as a measure for detecting anomalous (possibly artificial objects) in terrestrial [6] and planetary imagery. Positive detections were obtained in medium resolution Viking imagery over selected features in Cydonia [7].

The correlations described in this paper may be related to earlier fractal indications of artificiality in Cydonia. Although the alignment of the geospatial anomaly with the crustal dichotomy suggests a natural explanation, the origin of the dichotomy itself is not well understood. Furthermore, an explanation of the dichotomy would also have to explain the wide range of scales (10^2-10^5 meters) spanned by the anomaly, alignments in other directions (some about 90° apart), and their alignment with the symmetry axes of the "Face" and "D&M Pyramid".

References: [1] Pentland, A.P., and Kube, P. (1988), *IEEE Trans. PAMI 10,* 704-707. [2] Cattermole, P. (1992), *Mars - The Story of the Red Planet*, 191-193, Chapman and Hall. [3] Carlotto, M.J. (1988) *Applied Optics 27*, 1926-1933. [4] Bridges, M. (1991), *Planet Peru*, 83, Kodak/Aperture. [5] Sagan, C. (1975), *Proc. Royal Society 189*, 143-153. [6] Stein, M. C. *Proc. SPIE 845*, 293-300. [7] Carlotto, M.J. and Stein, M. C., (1990) *JBIS 43*, 209-216.