[Journal of Scientific Exploration, Vol. 11, No. 2]

Evidence in Support of the Hypothesis that Certain Objects on Mars are Artificial in Origin

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Abstract - Findings from a series of independent investigations are summarized and presented as evidence in support of the hypothesis that certain features on the Martian surface are artificial in origin. The discussion focuses on the Cydonia region in Mars' northern hemisphere. The features under investigation include a formation approximately 2.5 by 2 km in size that resembles a humanoid face staring up into space from the surface and a number of nearby objects. One set of objects located 10-20 km southwest of the Face which has been termed the "City" contains several unusual structures comparable in size to the Face and a number of smaller structures which together with the larger objects in the City appear to be arranged in an organized pattern. Several other anomalous features in the area are also examined. Three types of evidence are presented which support the hypothesis that the objects in question are artificial. The first is based on a detailed examination of the objects themselves, the second concerns spatial and angular relationships, and the third involves a comparative analysis of the shape of certain objects. Using a Bayesian inference model and assuming the above sources of evidence are mutually independent we show that the above evidence strongly supports the hypothesis that these objects may be artificial in origin.

Introduction

Since 1976 there has been growing interest in a collection of unusual surface features in the Cydonia region of Mars. It is the opinion of the planetary science community that these objects are natural geologic formations. However in a number of independent studies an alternative hypothesis has been suggested - that certain objects on the surface of Mars may be artificial in origin. This paper considers this hypothesis and presents evidence from a variety of sources to support it.

Background

The Face was first imaged by a Viking orbiter spacecraft in July 1976. Dismissed by NASA as an optical illusion the Face on Mars was soon forgotten. Several years later it was rediscovered in the NASA archives by DiPietro and Molenaar who first published the results of their analysis in 1982 (DiPietro and Molenaar 1988). At about the same time the Face had attracted the attention of individuals in Austria (Hain 1979) and in the former Soviet Union (Avinsky 1984). DiPietro and Molenaar's work led to the formation of the independent Mars investigation group (Pozos 1987). Subsequent threads of research involved O'Leary (1990), Brandenburg, DiPietro and Molenaar

(1991), Hoagland (1992), Hoagland and Torun (Hoagland 1992), and Carlotto (1992). An independent review of these research efforts was recently performed by McDaniel (1994).

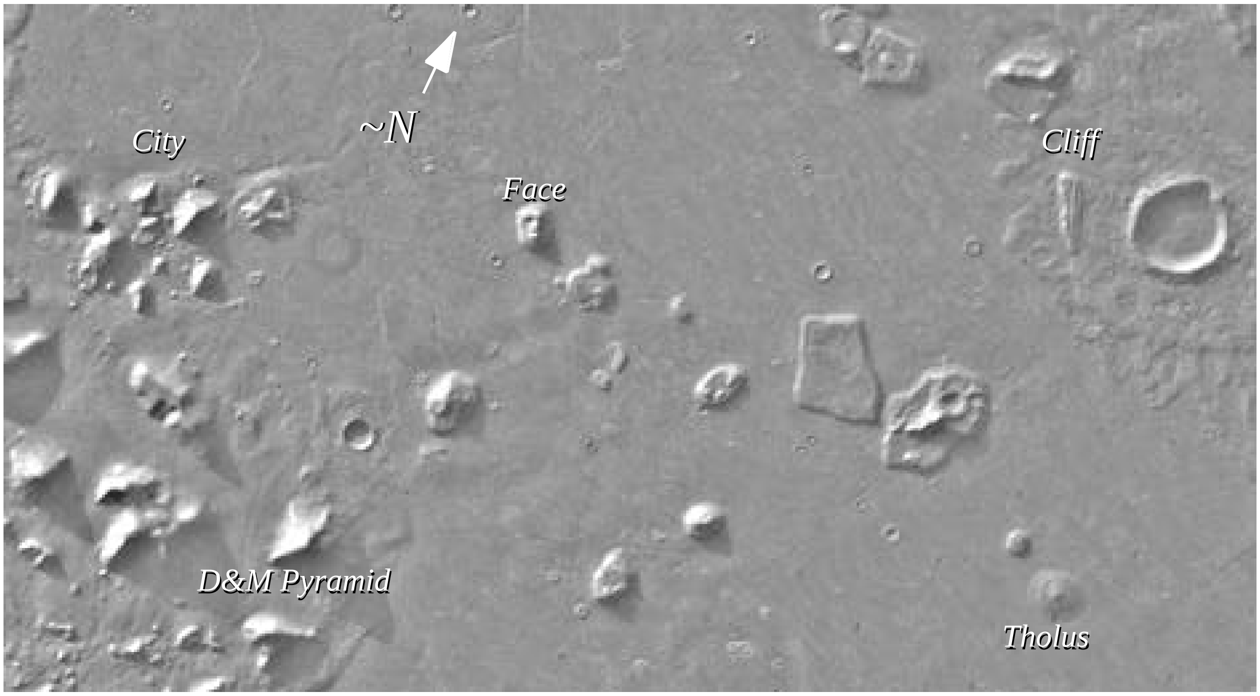


Figure 1 Mosaic of several Viking Orbiter frames from orbit 35 showing the objects under consideration on the surface of Mars. The image covers an area roughly 70 x 40 km in size. The Face, near the center of the picture, is located at approximately at 41° N latitude and 9.5° E longitude

The Hypothesis

Simply stated, our hypothesis is that the Face and other nearby objects in the Cydonia region of Mars may be artificial in origin. The objects under consideration are shown in Figures 1 and 2. These objects have been selected based on their shape, presence of internal detail, and similarity in size, shape, and orientation to other objects. Previously, four hypotheses have been put forth concerning these objects:

1. Cydonian Hypothesis (Brandenburg, et al 1991) - Conditions necessary to support life on Mars existed long enough for an indigenous race of Martians to evolve and build the objects in question.
2. Previous Technological Civilization Hypothesis (Lammer 1996) - The objects were constructed by a previous technological civilization from Earth.
3. Prior Colonization Hypothesis (Hoagland 1992, Carlotto and Stein 1990, Foster 1972) - The objects were constructed by visitors from outside of our solar system.
4. The Null Hypothesis - All of the objects are natural occurring geological formations.

Recently Lammer (1996) has argued that the Cydonian Hypothesis is not consistent with what we currently know about Mars' geological and climatic history. We believe that there is insufficient information at this time to differentiate between the second and third hypotheses. However estimates of extraterrestrial (ET) visitation in our solar system (Foster 1972) derived from a variation of the Drake Equation used to justify the search for extraterrestrial intelligence (SETI) by radio does suggest that ETs have may have visited our solar system in the last ten million years. If ETs did construct large artificial structures on Mars over this period (for whatever purpose) it is likely that they have been fairly well preserved by the Martian environment and are detectable by remote sensing (Foster 1972, Carlotto and Stein 1990). This in itself provides a plausible justification for our hypothesis. The null hypothesis that none of the objects are artificial represents the view of many in the planetary science community (e.g., Sagan, 1996).

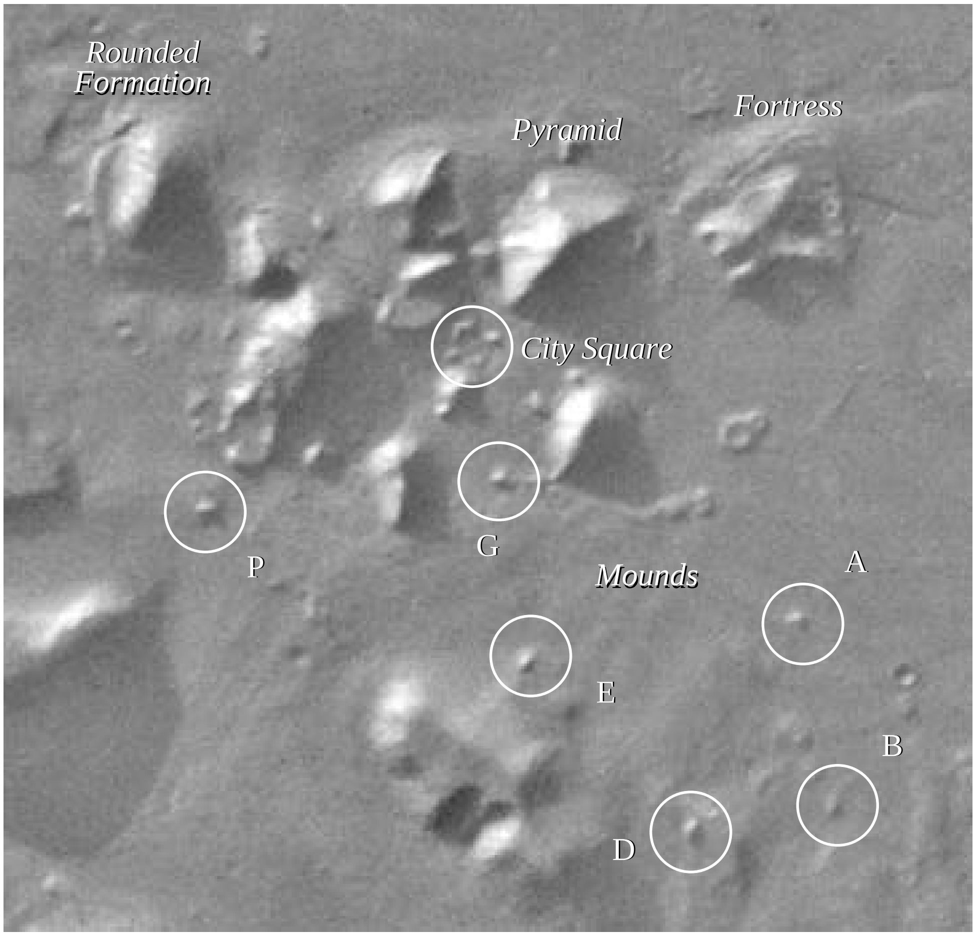


Figure 2 The City is a collection of formations located about 20 km southwest of the Face originally identified by Hoagland. Three objects comparable in size to the Face and a number of smaller mound-like objects shown above (from 35A72) are considered here.

Geological Context

The objects under consideration are located in northern portion of Cydonia Mensae bordering Acidalia Planitia and the northern plains. It is a region containing a variety of flat-topped prominences with cliff-like walls (mesas) and conical hills or knobs. The origin of the landforms in Cydonia has been attributed to erosional processes that have removed an overlying cratered plateau material, leaving a knobby terrain that is a combination of exhumed remnants of cratered terrain, igneous intrusives or cratered plateau material (Guest and Butterworth 1977). This explanation has simply been extended to explain the Face and other formations under investigation as by-products of differential erosion (McDaniel 1994). However it is not universally accepted that erosion has played as great a role in shaping the northern plains as suggested above.

The topography of Mars is asymmetric with the majority of the southern hemisphere rising above the reference datum and the northern hemisphere falling below it. The southern hemisphere is more heavily cratered and thus thought to be older than the northern plains. One explanation for this difference is the northern hemisphere was lowered by erosional processes that removed 2-3 km of older cratered material. But this raises the question as to where the material has been transported (Cattermole 1992). McGill (1989) used crater dimensional equations to conclude that only a slight to modest erosion of the northern lowland plains could have occurred since Middle Noachian times (~3.85-4.4 billion years ago) and that at best, 200 meters of material may have been stripped off the plains. (We note that many of the features under investigation are greater than 200 meters in height.) It is more likely that the lowering of the northern plains was due to an internal mechanism that affected the crust from below (Cattermole 1992).

But assume that all of the objects under study were formed by differential erosion. If so, the surrounding terrain should be eroded in a uniform fashion. Erjavec and Nicks (1997) analyzed crater counts over a 100,000 sq. km region in Cydonia consisting of knobby and cratered terrains (Guest and Butterworth 1977). They found that although the number of larger impacts (> 1 km) was similar, there was a significant difference (at least 2 to 1) in the number of small impacts (< 1 km) between the cratered and knobby terrains. The approximate line of demarcation between these two regions splits the area of interest (Figure 3). Objects in the City and the D&M pyramid lie in the knobby terrain while the Face, Tholus, and Cliff lie in the cratered terrain.

The difference in cratering statistics for the two terrains implies that more than one process has been at work to shape landforms in this part of Mars. Baker et al (1991) suggest that a great ocean covering the northern plains of Mars periodically forms and dissipates. Erjavec and Nicks (1997) have found evidence of the erosional and depositional effects of a large standing body of water on certain landforms in Cydonia. Although it is possible that the objects under consideration are natural geological formations, that differential erosion in itself was responsible for their formation seems unlikely.

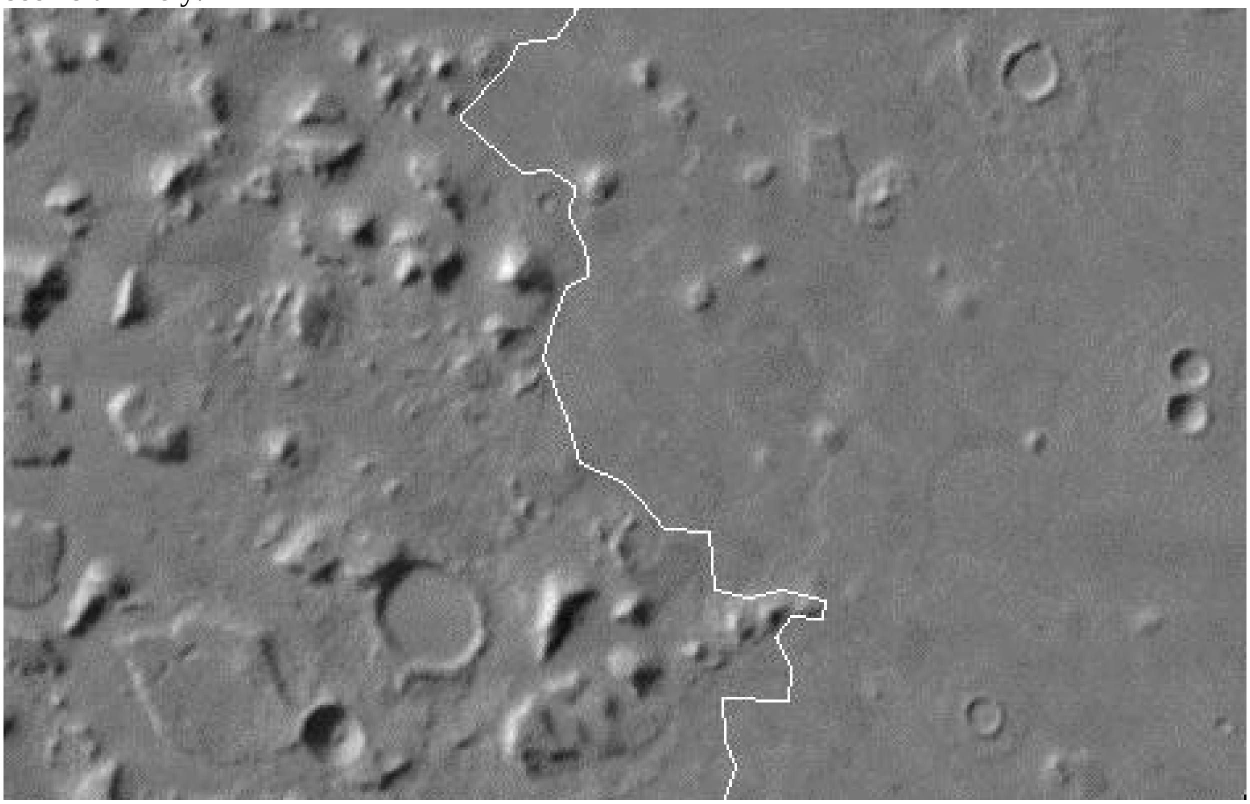


Figure 3 Boundary between knobby terrain (left) and cratered terrain (right). Face and City at top middle.

Evidence in Support of Artificiality

General Characteristics of the Face

Without a doubt, the humanoid face is a powerful and evocative symbol. The formation known as the Face possesses all of the salient features of a humanoid face: head, eyes, ridge-like nose, and mouth. This fact has been verified by two images taken (Figure 4) at slightly different sun angles (35A72 and 70A13). In 35A72 the sun angle is only 10 degrees above the horizon and so most of the right side of the Face is in shadow. But in 70A13 the sun is 15 degrees higher and reveals more of the Face’s right side. Instead of an ordinary rock formation, this second image not only confirms the facial features first seen in 35A72, but also reveals the overall symmetry of the head, the extension of the mouth, and a matching eye on the right side - features not visible in 35A72 because they were in shadow (DiPietro and Molenaar 1988).

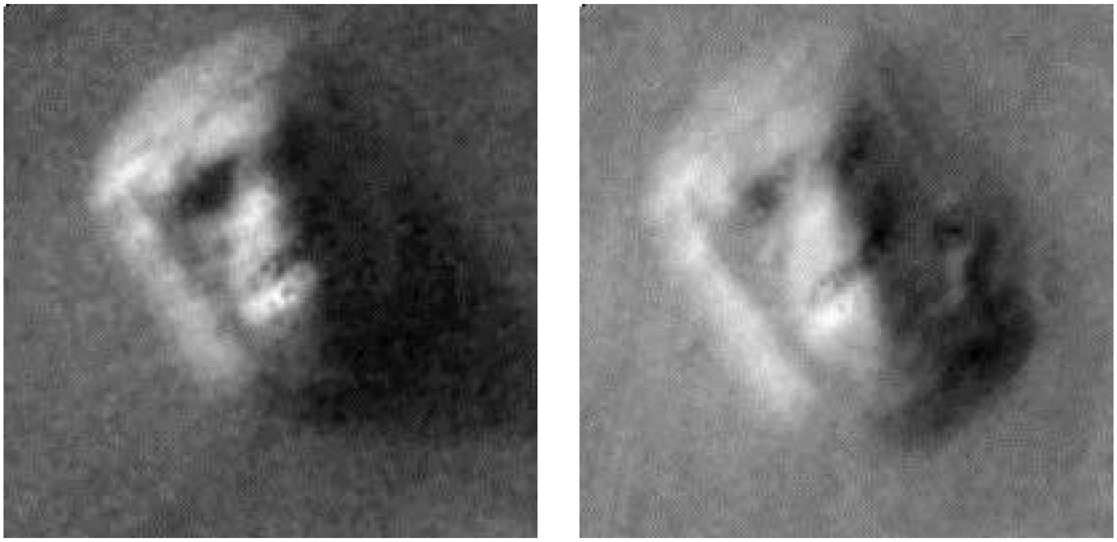


Figure 4 Two images of the Face from 35A72 (left) and 70A13 (right).

Facial Proportions

The artist uses certain proportions and relationships between facial features when constructing the human face. Measurements between the eyes, nose, mouth, chin, and crown of the head fall within conventional humanoid proportions (Hoagland 1992). Sagan (1985) has pointed out the human tendency to see faces in nature, i.e., random features which the brain organizes into facial forms. Although it is possible for natural rock formations to look like a face they typically do not possess all of the necessary features and are usually not correctly proportioned (Figure 5).

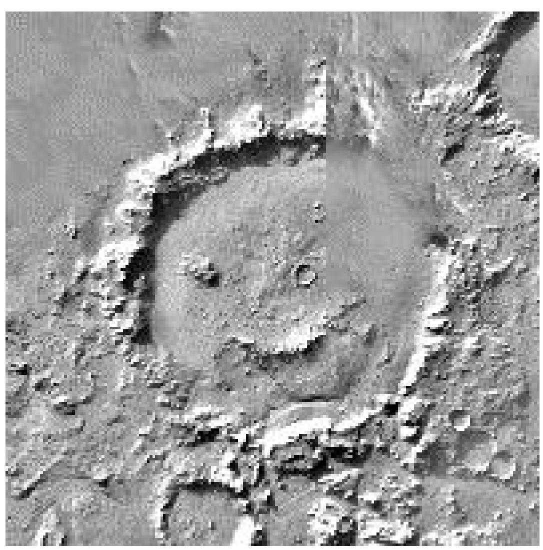


Figure 5 Crater with internal features resembling a "Smiley Face" used to illustrate human tendency to see faces in nature.

Architectural Symmetry of Face

The platform on which the Face is placed exhibits a high degree of architectural symmetry. Were the Face not present, one would still see in its supporting platform four sets of parallel lines circumscribing four sloped areas of equal size. Having these four equally proportioned sides at right angles to each other creates a highly symmetrical geometric rectangle (Hoagland 1992). It has been noted that the symmetry is not perfect, particularly on the right shadowed side of the Face (Figure 6). If the Face is an artificial object constructed long ago a certain amount of degradation can be expected and does not necessarily rule out the possibility that the object was originally much more symmetrical than it appears today.

Figure 6 Three highest resolution views of the Face from 35A72 (left), 70A13 (middle), and 561A25 (right) at 47.1. 43.3, and 162.7 meters/pixel. The apparent symmetry of the Face is distorted somewhat in 35A72 and 70A13 since is illuminated from slightly above left. A better indication of its overall shape is seen in 561A25 where the illumination is almost perpendicular to the axis of symmetry.

Subtle Details in Face

In addition to its gross humanoid features, the Face contains a number of subtle details or embellishments (Figure 7). They include a dark cavity within the eye socket that looks like an eyeball (DiPietro and Molenaar 1988), broad stripes across the face (Hoagland 1992), thin lines that intersect above the eyes, and fine structure in the mouth that appear as teeth (Carlotto 1988). These features are visible in both images and so it is very unlikely that they are due to noise in the imagery or artifacts of image processing. It is also noted that if erosional processes are responsible for the Face they would also have to explain these subtle details - details that one would expect to have been obliterated by erosion over time.

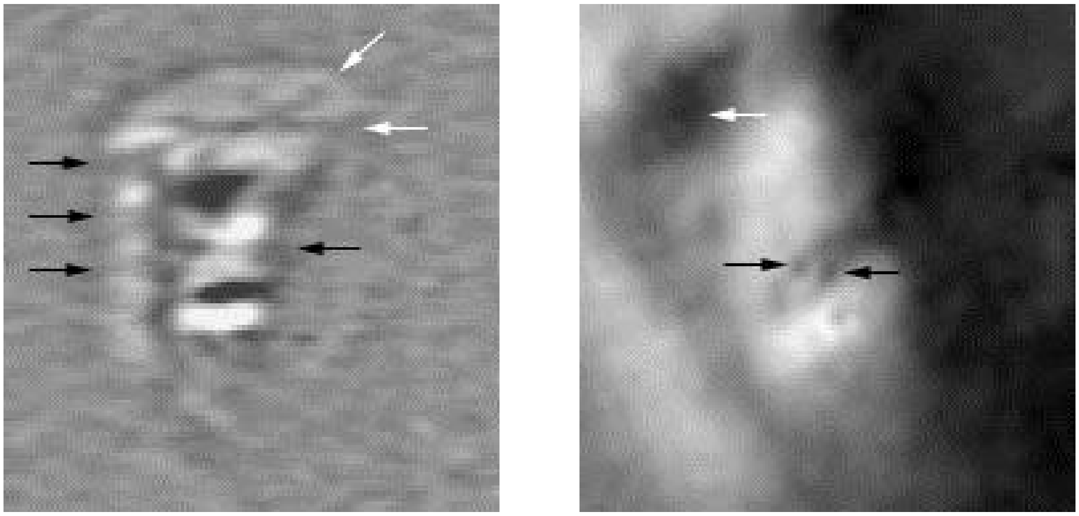


Figure 7 Subtle details in Face. Contrast enhanced image left showing broad stripes (black arrows) and crossed lines (white arrows). Magnified image on right shows eyeball (white arrow) and "teeth" (black arrows).

Persistence of Facial Features

The visual impression of a face persists over a wide range of sun angles and viewing geometries. Such is not the case for naturally occurring rock formations that look like faces when viewed in profile (Carlotto 1992). An image processing technique known as shape from shading was used to determine the three dimensional structure of the Face from its image (Carlotto 1988). Two images (35A72 and 70A13) were used to check the accuracy of the reconstructed surface by using the surface computed from one image to predict what the other should look like, and vice versa (O'Leary 1990). Computer graphics techniques were then used to predict how the surface would appear under different lighting conditions and from other perspectives. Results of this analysis showed that the impression of facial features is not a transient phenomena - that facial features seen in the image are also present in the underlying topography and produce the visual impression of a face over a wide range of illumination conditions and perspectives (Figure 8).

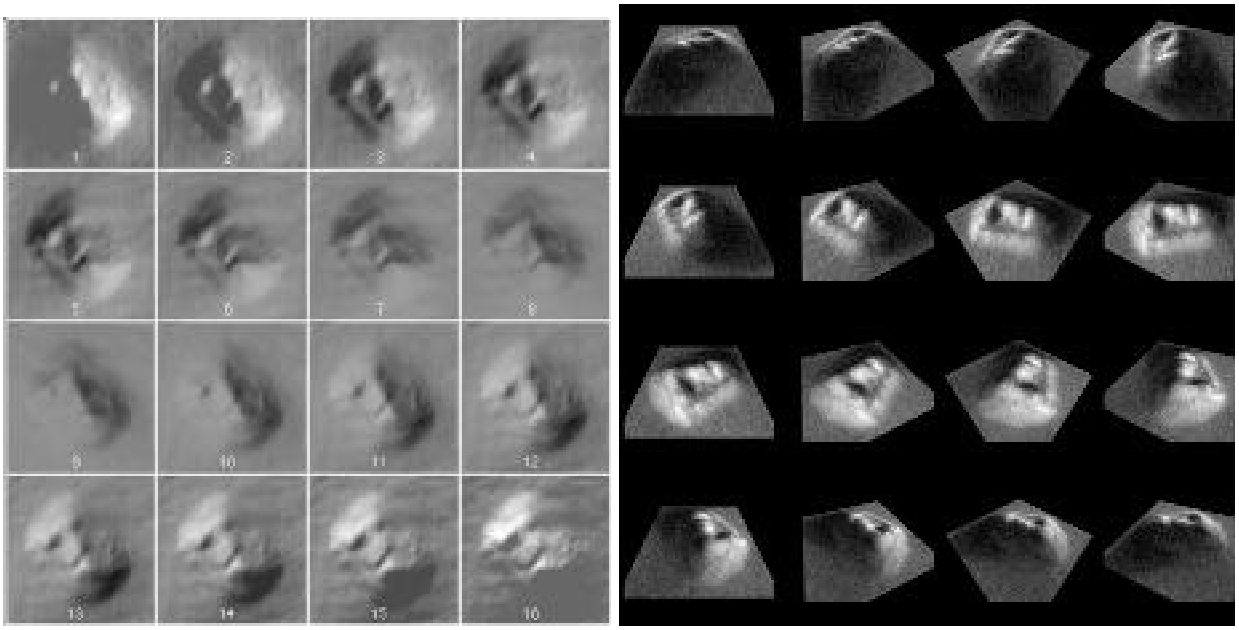


Figure 8 Face rendered under simulated summer lighting conditions (left) and from different perspectives (right).

Fractal Analysis of Face

By using fractals to model images, areas that are least natural can be identified according to how well they fit a fractal model (Stein 1987). The Face was found to be the least fractal object in Viking frame 35A72 and was also highly anomalous in frame 70A13 (Figure 9). Results of fractal analysis indicate that the Face is the least natural object over an area of about 15,000 square kilometers (Carlotto and Stein 1990). An analysis of the fractal technique in detecting man-made objects in high resolution terrestrial satellite imagery is examined in Appendix A for the purpose of estimating the weight of the evidence for artificiality provided by the technique.

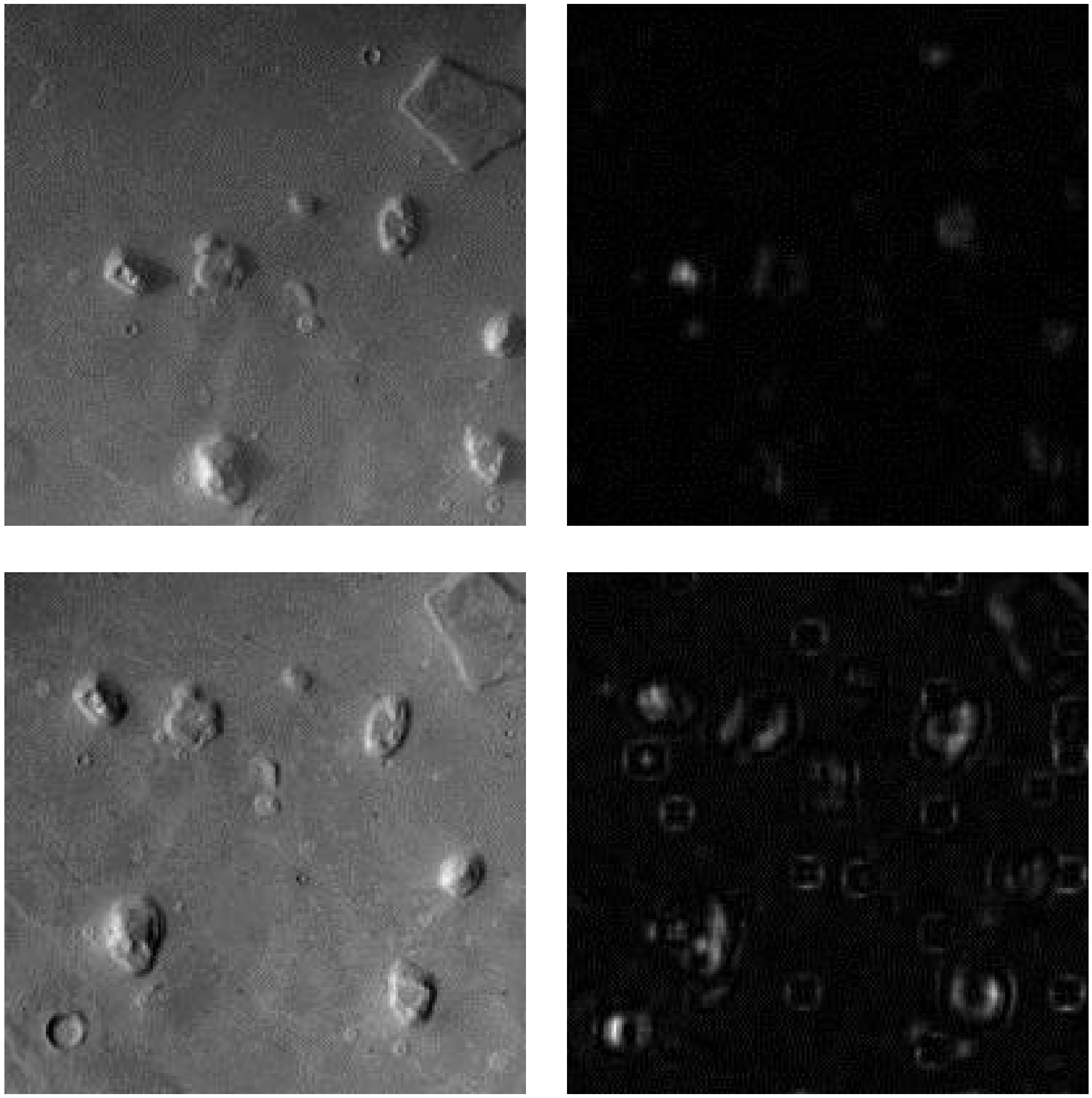


Figure 9 Fractal analysis results for Face and surrounding area. 35A72 and corresponding fractal model-fit image (top). 70A13 and corresponding fractal model-fit image (bottom). Bright areas in model-fit image indicate where structure of the image intensity surface (which is related to the shape of the underlying terrain) does not fit a fractal model and thus is least natural by the fractal criterion.

Similarity Between Face and Rounded Formation in City

The Face and a rounded formation in the City are approximately the same in size, overall shape, and orientation (Figure 10). Both objects also seem to be emplaced on a similar kind of platform. The resemblance between the two suggests the possibility that if the Face is artificial it could have been carved from a similar pre-existing landform.

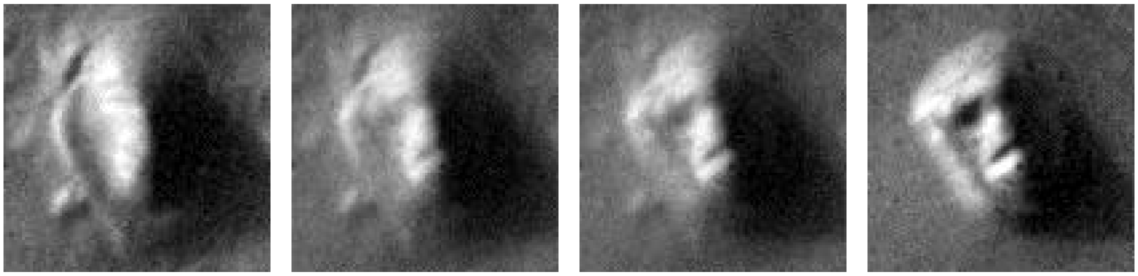


Figure 10 Sequence fading from rounded formation (left) to the Face (right). These images from 35A72 have not been rotated or scaled in size.

Geometrical Shape of the Fortress

The Fortress is a geometrically shaped object in the northeastern portion of the City, closest to the Face. The straight sides and sharp angles of the Fort (Figure 11) are in stark contrast to the sculpted appearance of the Face. Four straight sides or walls are visible in the two available images (70A11 and 35A72) of this object. These walls enclose an inner space; i.e., an area that is lower in height than the surrounding walls.

Subtle Detail in Fortress

Like the Face, the Fortress also contains subtle details that are at or slightly below the resolution of the imagery. In particular, two of the walls appear to contain regularly spaced marks or indentations. These features are visible in both images and thus must be real surface features (Figure 11). As in the Face one would not expect to find the subtle details seen in the Fortress if it was a naturally occurring formation.

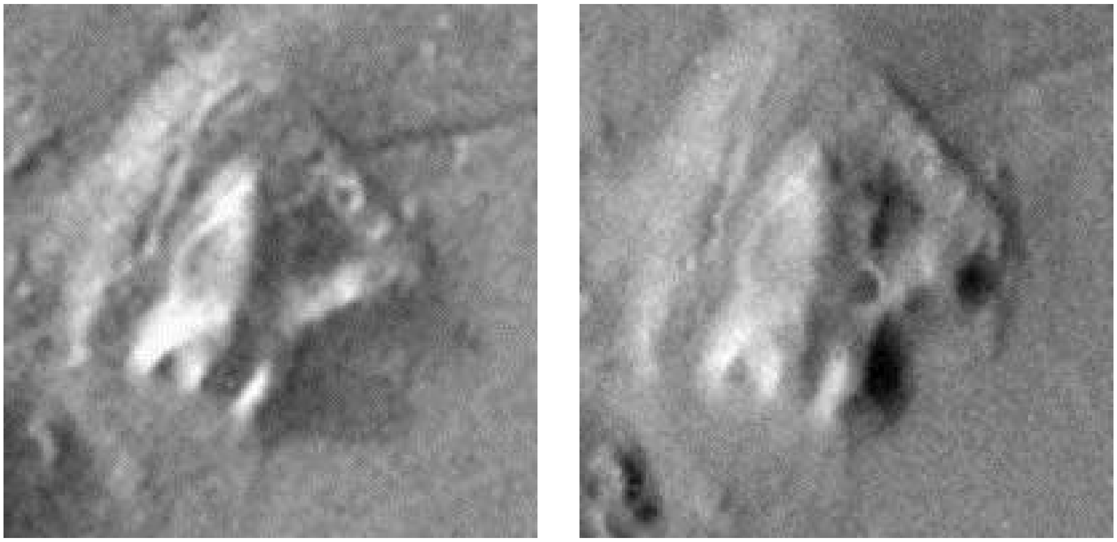


Figure 11 Two images of fortress from 35A72 (left) and 70A11 (right).

Similarity Between Fortress and Adjacent Pyramidal Object

The Fortress and an adjacent pyramidal object are similar in size, overall shape, and orientation (Figure 12). This similarity suggests the possibility that if the Fortress is artificial, it may have been an enclosed pyramidal structure that collapsed inward. This also suggests the possibility that the pyramid next to the Fort may be hollow.

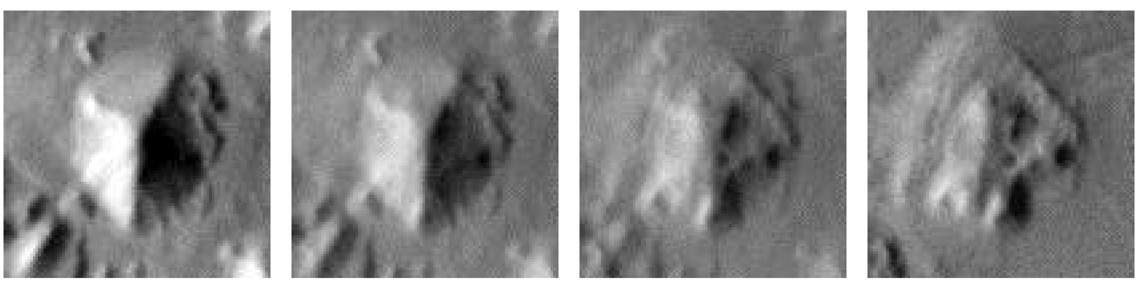


Figure 12 Sequence derived from coregistered images from 70A11 and fade from pyramid (left) to Fortress (right). The images have not been rotated or scaled in size.

Similar Orientation of Fortress, Face, Rounded Formation and Pyramid in City

The Fortress, Face, rounded formation and pyramid in City, though different in shape, are similar in size and orientation (Figure 13). The orientations of the best defined edge on each of these objects are as follows: left edge of Face, 120.9°; right edge of Fortress, 124.5°; left edge of pyramid in City, 120.8°; left edge of rounded formation in City, 120.8. Angles are measured counter-clockwise from east (positive x direction) in images projected to a Mercator coordinate system (Malin 1996). Each of the above values is the average of three separate measurements. The average value (standard deviation) for the four objects is 121.8° (1.6°).

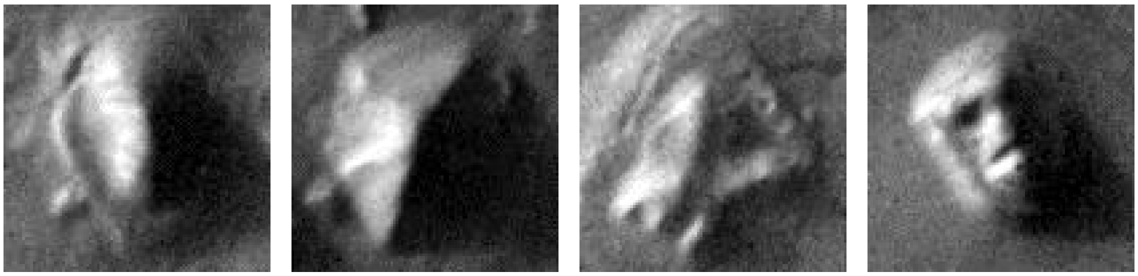


Figure 13 Similarity in orientation and scale of four objects (from 35A72). As in previous figures, these images have not been rotated or scaled in size.

Small Mound-Like Objects in City Arranged in Rectilinear Grid

Within the City, a group of small mound-like objects appears to be arrayed in a grid-like pattern (Figure 2). Hoagland first discovered these objects in the City, noting that one group seemed to lie at the vertices of an equilateral triangle. Recently Crater and McDaniel (1996) analyzed a subset of these mounds and found that they appear to coincide with a rectilinear grid pattern with a long/short side interval ratio of $\sqrt{2}$. Our measurements of the orientations of the lines between mounds PG, EA, DB, EG, and BA were 32.7°, 35.9°, 35°, 123.2°, and 125.5°. As above angles are measured counter-clockwise from the horizontal axis (due east). The average (standard deviation) of the first three measurements is 34.53° (0.91°), and of the fourth and fifth measurements is 124.35° (1.15°). The difference is close to 90° which would seem to indicate the presence of an underlying rectilinear grid pattern.

Similarity in Orientation Between Larger Objects and Mounds

The orientation of the Fortress, Face, rounded formation and pyramid in City (121.8° ± 1.6°) appears to match the orientation of the grid-like pattern of the mounds (124.35° ± 1.15°). The similarity in orientation suggests that the arrangement of these objects may be manifestations of a more subtle underlying regularity or pattern of organization.

D&M Pyramid

The D&M pyramid is a large multi-faceted structure about 20 km south of the City and Face. The southern face is best defined with a straight base, symmetrical sides, and well-defined apex. It also appears to be facing very nearly due south (Figure 14). The left sunlit side appears to contain three well-defined faces. Detail in the right shadowed side is less clear. It has been conjectured that in a hypothetical reconstruction of its shape, certain internal angular relationships in the D&M pyramid are reflected in external relationships between other nearby objects (McDaniel 1992).

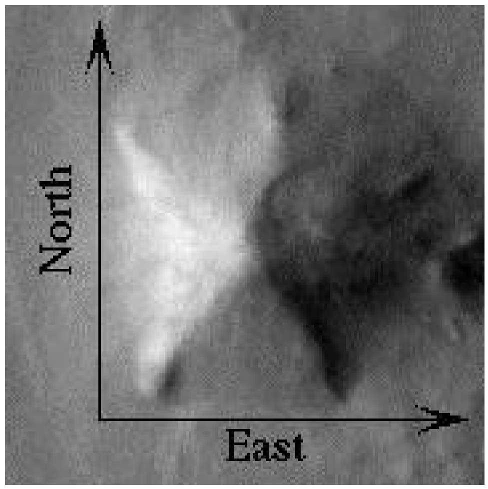


Figure 14 D&M pyramid in 70A13 warped to a Mercator projection.

Tholus

The Tholus is one of several larger mound-like objects southeast of the City and Face. These features remind us of larger volcanic domes on Mars (e.g., Hecates Tholus) but are much smaller and have much smaller slopes. They do not resemble any other landform in this part of Mars. Like the Face and Fortress, the Tholus contains fine scale details. These details which are clearly visible in three images (70A13, 70A15, and 35A74) include two grooves that wind half-way up the feature. One grove appears to lead into a opening in the side of the mound (Figure 15).

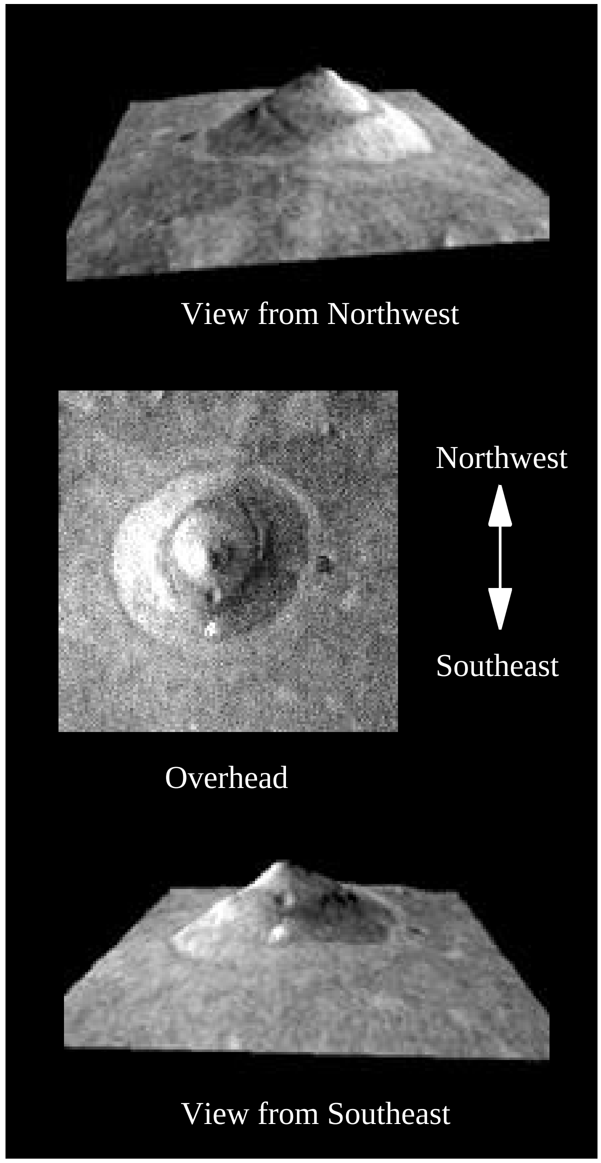


Figure 15 Overhead view of Tholus from 35A74 along with two perspective views generated from the overhead image using shape from shading and image perspective transformation.

Cliff

The Cliff is an elongated mesa topped by a sharp ridge-like feature running down its length (Figure 16). It is similarly oriented and roughly in line with the Face, Fortress, adjacent pyramid and rounded formation in the City. The Cliff is located next to a “Yuty-type” crater, clearly of impact origin. Although it is located within the crater’s surrounding ejecta blanket, there is no evidence of debris flow over or around the Cliff. Also there does not appear to be any evidence of a pre-existing surface removed by differential erosion (Erjavec and Nicks 1997). One possible interpretation of these observations is that the Cliff was formed (or constructed) after the impact occurred.

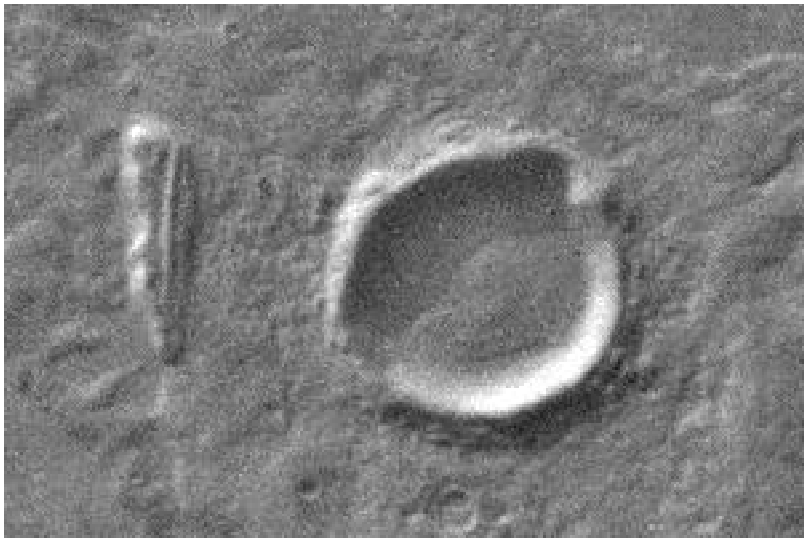


Figure 16 Cliff and adjacent impact crater.

Interpretation

No single piece of evidence has been found that conclusively proves that these objects on the surface of Mars are either natural or artificial. The architectural design, facial proportions, and overall artistic impression suggested the possibility at the outset that the Face might be an artificial object (Pozos 1987). Subsequent tests of this hypothesis involving the enhancement of subtle detail in the Face, shape-from-shading/synthetic image generation to determine if the Face is an optical illusion, and fractal analysis to assess its shape in a quantitative manner have all provided cross-confirming evidence that support the original hypothesis. Other unusual objects have also been found nearby that appear to be related to one another.

The previous section has summarized much of the evidence offered to date in support of the hypothesis that certain objects on Mars are artificial in origin. Not discussed in this paper are the summer solstice alignment (Hoagland 1992), or angular relationships related to tetrahedral geometry discovered by Hoagland and Torun (McDaniel 1994) since they are difficult at present to evaluate. The evidence is of the type that could be used in practice to detect a new archaeological site on earth using aerial or satellite imagery. The question that remains is to what extent can the evidence be assessed collectively and quantitatively?

Bayesian inference is one method of evaluating a set of hypotheses against a body of evidence (Sturrock 1994). It involves using Bayes theorem to determine the posterior probability for the hypothesis H given the evidence $\{E_1 \cdots E_N\}$

$$P[H \mid E_1 \cdots E_N] = \frac{P[E_1 \cdots E_N \mid H]}{P[E_1 \cdots E_N]} P[H] \tag{1}$$

where $P[H]$ is the prior probability that the hypothesis is true, $P[E_1 \cdots E_N \mid H]$ is the probability that a given body of evidence will be observed given the hypothesis is true, and $P[E_1 \cdots E_N]$ is a normalizing constant. The likelihood ratio is

$$L = \frac{P[H \mid E_1 \cdots E_N]}{P[\neg H \mid E_1 \cdots E_N]} = \frac{P[E_1 \cdots E_N \mid H] P[H]}{P[E_1 \cdots E_N \mid \neg H] P[\neg H]} \tag{2}$$

where $P[\neg H]$ is the prior probability that the hypothesis is false and $P[E_1 \cdots E_N \mid \neg H]$ is the probability that a given body of evidence will be observed given the hypothesis is false.

H represents the hypothesis that the objects under consideration are artificial; $\neg H$ is the null hypothesis that they are natural. Taking into account only the prior belief, i.e., without examining any evidence at all, the probability that the hypothesis is true divided by the probability that it is false is called to the prior odds

$$L_0 = \frac{P[H]}{P[\neg H]}. \tag{3}$$

50-50 odds means that the hypothesis is equally likely to be true or false. An extraordinary claim, i.e., a "long shot", might correspond to odds of, say, one in a million. The likelihood ratio after the evidence has been taken into account (post odds) is equal to the weight of the evidence times the prior odds, $L = W' L_0$.

Our goal is to determine the likelihood that the collection of features in question is artificial given a set of evidence. In order to do this we need to estimate the weight of the evidence. For one piece of evidence, the likelihood ratio is

$$\frac{P[H \mid E]}{P[\neg H \mid E]} = \frac{P[E \mid H] P[H]}{P[E \mid \neg H] P[\neg H]} \tag{4}$$

where $W = P[E \mid H] / P[E \mid \neg H]$ is the weight of the evidence. Unfortunately, most of the evidence presented in the previous section is qualitative in nature. For example, is difficult to try to quantify the probability that the Face is artificial given its symmetry, facial proportions, fine scale detail, etc. On the other hand it is possible in principle to determine the weight of the evidence provided by fractal analysis (Carlotto and Stein 1990). In terrestrial imagery, fractal analysis of man-made objects gives a higher fractal model-fit error than that of natural objects. In other words the probability of observing a high value of the fractal model-fit will be greater for man-made objects than for natural objects. Preliminary analysis of terrestrial data give weights between 3 to 5 for fractal analysis (Appendix A).

Ultimately we want to determine the likelihood ratio that the objects are artificial given all of the evidence presented in the previous section. To obtain a rough estimate for the purpose of the present discussion assume that:

1. the sources of evidence are independent,
2. the weight of the evidence for fractal analysis obtained over terrestrial study areas can be extended to Mars, and
3. this value is representative of the weight of the other sources.

The first assumption is reasonable since different methods have been used to examine different aspects of this collection of features and no piece evidence is dependent on another. If we assume that the Face is artificial, it turns out that the performance of the fractal technique in differentiating between the Face and the surrounding background on Mars is comparable to its performance on Earth in differentiating between man-made objects and natural terrain (Appendix A). This provides some justification for the second assumption. The third assumption is made in lieu of specific data concerning the weight of other sources of evidence at this time.

The first assumption allows us to write Equation (2) as a product of N terms:

$$\begin{aligned} L &= \frac{P[H \mid E_1 \cdots E_N]}{P[\neg H \mid E_1 \cdots E_N]} = \frac{P[E_1 \cdots E_N \mid H]P[H]}{P[E_1 \cdots E_N \mid \neg H]P[\neg H]} = \frac{P[H]}{P[\neg H]} \prod_{n=1}^{N} \frac{P[E_n \mid H]}{P[E_n \mid \neg H]} \\ &= L_0 \prod_{n=1}^{N} W_n \end{aligned} \tag{5}$$

If we make the simplifying assumption that weights are the same (all equal to W) then the post odds increases exponentially as the number of sources increases

$$L = L_0 W^N \tag{6}$$

The implication of this is that for a large number of sources, the weight of each individual piece of evidence does not have to be very large for the total evidence to be large (Figure 17). Sixteen pieces of evidence were presented in the previous section. Thus for $N = 16$, $3 < W < 5$, and a prior odds of one in a million, likelihoods between 43 to 1 and 152,600 to 1 in favor of our hypothesis are obtained (Figure 18).

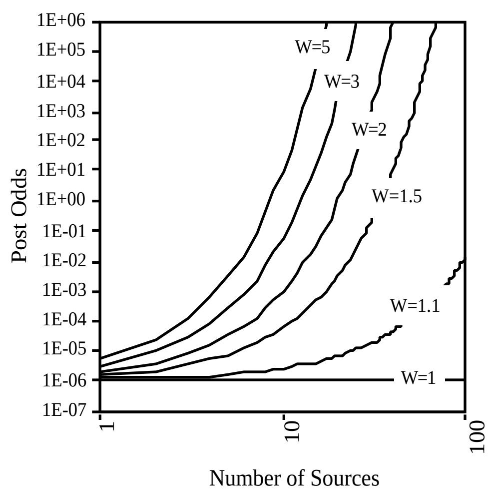


Figure 17 Post-odds increases dramatically as the number of sources increases for weights greater than one.

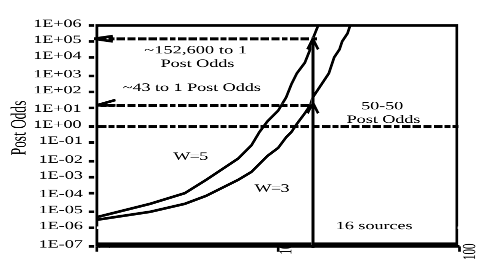


Figure 18 Post odds for N=16 sources with individual source likelihood ratios between 3 and 5.

Discussion

It has been said that extraordinary claims require extraordinary evidence (Sagan 1985). No single piece of evidence has been found that conclusively proves that these objects on the surface of Mars are either natural or artificial (i.e., there is no “smoking gun”). But as noted by Sturrock (1994) weak evidence from multiple independent sources will do just as well. We have demonstrated that it is the quantity and diversity of all of the evidence, rather than any one piece, that makes the evidence in support of our hypothesis so strong. The alternative hypothesis is, of course, that the Face and other nearby objects are simply naturally-occurring geological formations. However no specific geological mechanism(s) have to date been put forth that are capable of explaining the diversity of forms, the patterns of organization, and the subtlety in design exhibited by this collection of objects.

A similar argument has been recently used to justify the claim that a meteorite thought to be from Mars may contain fossilized micro-organisms (McKay et al 1996). These researchers cite only five pieces of evidence to support their claim and state that “although there are alternative explanations for each of these phenomena taken individually, when they are considered collectively, particularly in view of their spatial association, we conclude that they are evidence for primitive life on early Mars.” Surely a similar argument can be used here to justify another extraordinary claim - that there may be large artificial structures on the surface of Mars. A claim that is, in fact, supported by considerably more evidence.

The planetary science community’s reluctance to even consider the possibility of artificial structures on Mars seem to be based on two premises:

1. liquid water was present for too short a period of time for indigenous life to evolve on Mars; thus a native intelligence could not have created these objects, and
2. the possibility that they were built by an a visiting intelligence (from earth or outside the solar system) is considered to be too remote to warrant serious investigation.

Although current models do not favor the Cydonian Hypothesis (Brandenburg et al 1991, Lammer 1996) there is too little data to rule it out at this time. However the second premise is clearly not consistent with on-going SETI projects which assume that there are a sufficient number of technological civilizations in the galaxy to warrant such a search in the first place. To date, SETI has been almost exclusively a radio search program and has produced no convincing evidence for ETs. Alternative SETI proposals have been put forth that involve a search for ET artifacts on planetary surfaces within our solar system (Foster 1972, Carlotto and Stein 1990). Although the same arguments which support radio search also justify a search for ET artifacts, these alternative SETI proposals have not received mainstream support. The reluctance to accept near earth SETI strategies (as well as the possibility of UFOs) is based on the widespread view in the space science community that few if any extraterrestrial intelligences are capable of traveling the great distances between stars. Such a view strongly biases opinion against near-earth SETI programs. This bias is so strong that it appears that very strong evidence is required to even consider the question.

This bias also seems to be compounded by the expectation that ET artifacts on planetary surfaces will be clearly recognizable. For example, in a study performed before the launch of Mariner 9, Sagan and Wallace (1971) concluded that a resolution of 50 meters/pixel or better is required to detect signs of intelligent activity (roads, dams, urban areas) from low earth orbit. Since Viking Orbiter did image the surface of Mars at resolutions exceeding 50 meters/pixel it should have been able to detect similar patterns of activity on Mars. But the expected signs of activity mentioned in Sagan and Wallace's paper were those of an active planetary civilization (our own) and thus do not apply to Mars today. The study did not account for the collapse and deterioration of structures that might have been constructed on Mars long ago. One estimate provides for one ET visitation to our solar system every 10 million years (Foster 1972). If large structures were constructed tens of millions of years ago they have probably become significantly degraded by the Martian environment.

The objects under investigation were imaged at resolutions slightly below 50 meters/pixel. They do not resemble contemporary structures but appear to be sophisticated in design and layout. Is it possible that they are really quite old and have undergone deterioration over time? Perhaps the trained eye and experience of an archaeologist may be just as important, if not more important than that of the planetary scientist in this regard. However the specific question concerning the origin of these objects on Mars is one that can and must be answered through a dedicated effort to re-image these objects in the future.

Appendix A Analysis of Fractal Technique

The model-fit error image $\varepsilon(i,j)$ produced by the fractal analysis technique described by Carlotto and Stein (1990) is a measure of how well an image fits a fractal model on a local basis. Natural terrain is self-similar over a range of scales and thus tends to give low fractal model-fit errors. Manmade objects tend not to be self-similar and thus give higher fractal model-fit errors. If the model-fit error over a region is greater than a given threshold (evidence occurs) the region is classified as artificial. If the model-fit error over a region is less than the threshold (evidence does not occur) the region is classified as natural.

When ground truth data (training set) is available, one can estimate the conditional probability densities of the fractal model-fit error over regions known to contain artificial objects and natural terrain, $P[\varepsilon \mid H]$ and $P[\varepsilon \mid \neg H]$, respectively. The threshold ε^* which satisfies

$$P[\varepsilon^* \mid H]P[H] = P[\varepsilon^* \mid \neg H]P[\neg H] \tag{A-1}$$

is optimal in the sense that it minimizes the probability of misclassification over the training set (Ziemer and Tranter 1976). Since the frequency of occurrence of manmade objects outside the training set is usually unknown, one typically assumes equal priors, $P[H] = P[\neg H]$. The threshold ε^* which satisfies

$$P[\varepsilon^* \mid H] = P[\varepsilon^* \mid \neg H] \tag{A-2}$$

is the point where the two conditional probability density curves cross. The resultant detection and false alarm probabilities are

$$P_D = \int_{\varepsilon^*}^{\infty} P[\varepsilon \mid H]\, d\varepsilon \tag{A-3a}$$

$$P_F = \int_{\varepsilon^*}^{\infty} P[\varepsilon \mid \neg H]\, d\varepsilon \tag{A-3b}$$

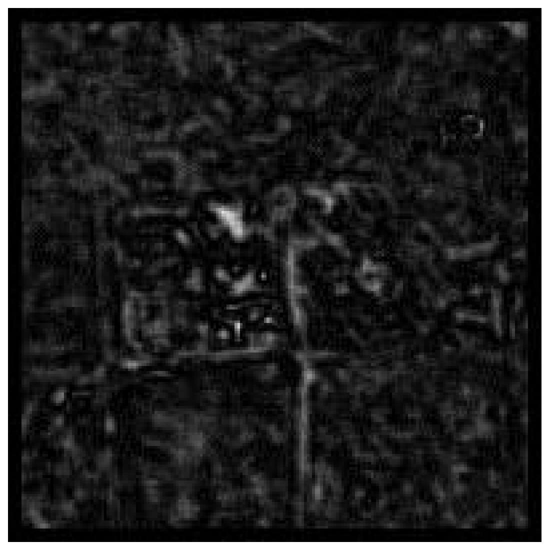
and the weight (4)

$$W = \frac{P[E \mid H]}{P[E \mid \neg H]} = \frac{P_D}{P_F}\,. \tag{A-4}$$

In order to determine typical weight values for fractal analysis a series of experiments were performed using de-classified national intelligence imagery containing a mix of manmade objects embedded in complex natural backgrounds. In these images the manmade objects are about the size (in pixels) of those on Mars and were imaged under similar lighting conditions. Three images were analyzed. The first was over a U.S. military base, Ft. Drum in New York (Figure A-1). The image contained a variety of military hardware arrayed in an open area surrounded by trees. The fractal model fit was computed using 10 scales and a 21 by 21 pixel window (Carlotto and Stein 1990). The conditional density curves intersect at $\varepsilon = 38$ and give $W = P_D / P_F = 3.28$.

Two other images, one containing an SA-2 anti-aircraft site surrounded by brush and tropical vegetation (imaged in August 1962 near Havana, Cuba), the other containing a group of SCUD storage bunkers in the desert (imaged in February 1991 near Quebaysah, Iraq) were analyzed in the same way. The weights computed from these two images were 5.04 for Cuba, and 2.99 for Iraq.

Receiver operating characteristic (ROC) curves are a standard metric used to describe the performance of statistical detection techniques (Ziemer and Tranter 1976). ROC curves plot the probability of detection versus the probability of a false alarm as a function of the detection threshold. Figure A-2a shows the ROC curves computed for the U.S., Cuban, and Iraqi images. The same experiment was performed on the Viking images shown in Figure 9. We assumed that the Face was the only non-natural object in the portion of the images shown. The ROC curves for 35A72 and 70A13 are plotted in Figure A-2b. The performance appears comparable, if not somewhat better, in the Viking images (possibly because the background in the Viking images is less complex than in the three terrestrial images).



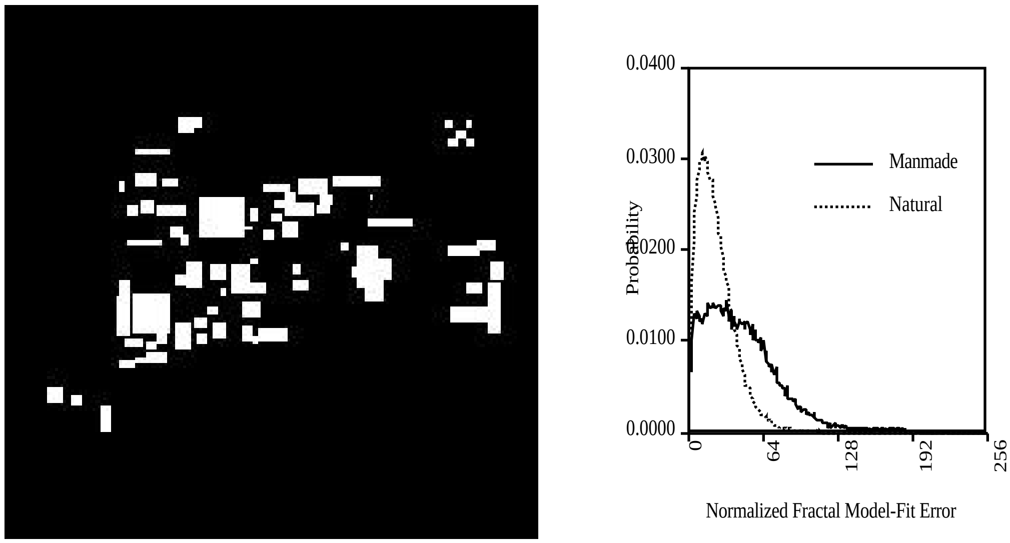


Figure A-1 Image over U.S. military base (top left), fractal model-fit error image (top right), ground truth overlay (bottom left), and conditional density curves (bottom right).

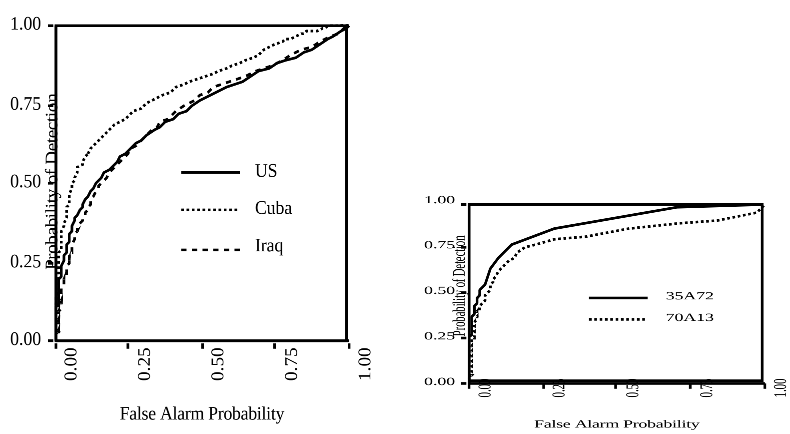


Figure A-2 ROC curves for fractal technique for three terrestrial scenes (left) and two images containing Face on Mars (right).

Based on the results of these experiments we conclude that:

1. weights between 3 and 5 are reasonable for the fractal analysis technique
2. the similarity in performance curves suggests that the fractal technique can be extended and applied to Mars.

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