Observing the planets has been compared to watching a movie with the projector thrown out of focus except for occasional sharp frames thrown in at random.\(^1\) Prior to the application of sophisticated technological solutions to deal with atmospheric turbulence - high-speed digital image acquisition and adaptive optics - expert visual observers recognized that fleeting moments of extreme clarity occurred when the air steadied momentarily, allowing their telescopes to perform at their theoretical diffraction limit. Percival Lowell called these tantalizing glimpses "revelation peeps." Unfortunately, the human eye-brain combination lacks permanent storage capabilities, so detailed drawings were made that inextricably co-mingled the observer's observational skills with his artistic ability, complex psychological aspects of pattern recognition, and, in some cases, the unconscious desire to see things. Yet some of the most remarkable discoveries in lunar and planetary astronomy were made in precisely this way.

Less successful but certainly more dramatic were the renderings of features on Mars during the late 19th and early 20th century, especially the network of "canals" described by Giovanni Schiaparelli, Percival Lowell, and

others. The core argument advanced by the canal advocates, namely that the human eye can perceive in a split second fine detail that no camera can record, remained valid until very recently.

The heated canal controversy was only laid to rest only after the Mariner 9 space probe mapped Mars at high resolution from pole to pole. In the post-Mariner era, the debate about the reality of Martian canals has been replaced by a debate about the visibility of Martian craters.

THE TESTIMONY OF JOHN MELLISH

The Mariner 4 spacecraft flew past Mars in July 1965, snapping 21 high-resolution images of about one percent of the planet’s surface that revealed a bleak, monotonous landscape peppered with eroded impact craters. The June 1966 issue of *Sky & Telescope* a letter by John E. Mellish, an amateur astronomer and telescope maker

The Mariner photographs taken last July reminded me of some observations of Mars that I made with the 40-inch refractor at Yerkes Observatory in 1916. Using a power of 1,100, I saw many small craters and one large one. The latter, estimated to be 200 miles in diameter, was in Martian latitude about –58 degrees; north of it were many bright-rimmed small craters.

My collection of drawings was lost in a fire two years ago, but in 1916 I had distributed some of my Mars pictures to various other observers. Does some *Sky & Telescope* reader know of the whereabouts of any of these drawings?

After seeing the craters, I showed my pictures to E.E. Barnard, who in 1916 was on the staff of Yerkes observatory. He told me: “Now that you have shown me this, I will show you some drawings of Mars with the Lick 36-inch refractor.” Opening an old trunk, he brought out drawings of Mars at opposition in 1892-93; on these some craters appeared as dark circular patches.²

Mellish's letter sparked controversy. Some found his story convincing, but many remained frankly skeptical. Rodger Gordon emerged as the most ardent - some might say strident and dogmatic - advocate of Mellish’s claim. A trio of articles about Mellish written by Gordon launched a protracted debate in the pages of the *Journal of the Association of Lunar and Planetary Observers*, the *Journal of the British Astronomical Society*, and *Sky & Telescope*. After a lapse of more than a decade, interest in the subject has recently been revived by the publication of a booklet authored by Gordon that is devoted entirely to the subject of the visibility of Martian craters, a tract entitled *Observing the Craters of Mars: Part 1*.

From the onset of the debate, skeptics were quick to point out that when Mellish made his observation in November of 1915, Mars presented a tiny disk only 7.7 arc seconds in diameter that displayed an 89% illuminated phase, comparable to the gibbous Moon two and a half days before full phase. At a

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7 J.D. Beish, "Can We See Martian Craters From Earth?"
magnification of 750X, Mars would have appeared as large as the Moon seen through a three-power opera glass, while at 1,100X it would have approached the size of the Moon through five-power binoculars.\(^8\) Since the actual diameter of Mars is about twice that of the Moon, the size of the features visible on Mars would be comparable to those discernible on the Moon with the very modest magnifications of 1.6X and 2.5X.

Gordon assures his readers that “relief features would be easily seen” under these circumstances. But would they? Before space probes obtained close-up views of Mars, most astronomers imagined the planet as a windswept wasteland devoid of any dramatic topographic features. The British astronomer Val Axel Firsoff cautioned that surprises might lie in store:

> When Mars exhibits a gibbous phase, he is so far away that even the Palomar reflector will not bring him much nearer than the Moon seen with the naked eye, on which no mountains can be discerned. Moreover, Mars has a sensible atmosphere, and although this is remarkably transparent, it does intervene, especially at the limb or terminator, where accidents of terrain show best. To sum up, it is perhaps not very significant that no mountains or marked differences in altitude of the ground have been discovered on Mars by direct observation, and our estimates of heights and depressions on its surface must be somewhat problematic.\(^9\)

Firsoff’s arguments about the difficulty of discerning Martian topographic features were driven home in 1966 by New Mexico State University astronomer Thomas Pope. Pope photographed the full and gibbous Moon through an achromatic lens of 7-inches focal length lens stopped down to an aperture of 2.5 millimeters, producing a series of lunar images with the same image scale

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\(^8\) Although Mellish’s accounts refer only to magnifications of 750X and 1,100X, Gordon speculates that he may have employed magnifications as great as 2,500X or even 3,500X. In order to preserve the rationality of the present discussion, the authors will confine their remarks to the values cited by Mellish himself.

and linear resolution as the best photographs of Mars at favorable oppositions (when the apparent diameter of the planet’s disk exceeds 20 arc-seconds) taken by Earl Slipher with the Lowell Observatory’s 24-inch Clark refractor. Pope’s photographs dramatically illustrate the limitations of Earth-based observations of the Red Planet’s topography, for even the prominent lunar crater Copernicus and its extensive ray system were recorded only as a diffuse white patch.\textsuperscript{10}

Jeffrey Beish calculated that in November 1915 a three kilometer-high topographic feature (like the ramparts of a crater) on the Martian terminator would have cast a shadow 2.3 kilometers long, corresponding to an apparent width of only 0.01 arc-second, far beyond the theoretical resolving power of even the mighty Yerkes refractor. Echoing Firsoff’s remarks, Beish added:

Another important aspect must be considered - contrast. Even if we could resolve such topography on Mars, would there be enough contrast between the shadowed or sunlit walls and the crater floor to be recognized by a telescopic observer? Limb darkening, the ever-present dusty haze, and clouds also reduce the contrast of these features considerably. The extension of the atmospheric mass near the planet’s limb will also decrease the contrast of a surface feature.\textsuperscript{11}

In light of Beish’s analysis, it is hardly surprising that Hubble Space Telescope images of Mars at gibbous phases have never recorded craters in shadowed relief along the planet’s terminator, despite the fact that this instrument has more than twice the theoretical resolving power of the Yerkes refractor and operates in the complete absence of atmospheric turbulence.

\textsuperscript{10} Thomas Pope, “Mars and the Moon at Comparable Resolutions” \textit{Sky & Telescope}, February 1967, pp. 119-120.

\textsuperscript{11} J.D. Beish, "Can We See Martian Craters From Earth?" ALPO Mars Section Internet Web Page, August 2000. See: http://www.lpl.arizona.edu/~rhill/alpo/marstuff/articles/MARTIAN/HTM
Gordon uncovered a 1935 letter written by Mellish to the Philadelphia amateur astronomer and optician Walter Leight in which Mellish recounted his 1915 observation. The relevant passage reads:

There is something wonderful about Mars, it is not flat but has many craters and cracks. I saw a lot of craters and mountains one morning with the 40” and could hardly believe my eyes and that was after sun rise and Mars was high in a splendid sky and I used a power of 750 and after seeing all the wonders I went to Barnard and showed him my drawings and told him what I had seen, and he laughed and told me that he would show me drawings made at Lick in 1892-3 and he showed me the most wonderful drawings that were ever made of Mars, the mountain ranges and peaks and craters and other things both dark and light that no one knows what they were, I was thunder struck and asked him why he had never published these and he said no one would believe him and would only make fun of it. Lowell’s oases are crater pits with water in them, and there are hundreds of brilliant mountains shining in the sunlight. Barnard took whole nights to draw Mars and would study an interesting section from early in the evening when it was just coming on the disk until morning when it was leaving and he made drawings four or five inches diameter and it is a shame that those were not published.

Gordon’s omits Mellish’s accounts of “crater pits with water in them” and “hundreds of brilliant mountains shining in the sunlight,” because these remarks describe a Mars that simply doesn’t exist and cast grave doubt on the credibility of Gordon’s cherished notion that Mellish really saw craters.

Mellish’s tale that Barnard kept his drawings a secret for fear of ridicule notwithstanding, they were published. Barnard must have shared them with at least two prominent colleagues, who proceeded to reproduce them with attribution to Barnard in the popular textbooks they wrote - *Elements of Descriptive Astronomy* by Herbert Howe, Director of the University of Colorado’s Chamberlin Observatory\(^\text{12}\) and *A Text-Book of Astronomy* by George

Comstock, Director of the University of Wisconsin’s Washburn Observatory.  

Gordon’s characterization of Barnard as “cynical” is certainly not consistent with the historical record. Barnard was anything but temperamentally timid or averse to controversy, and he emerged as one of the most vocal critics of Percival Lowell’s visions of a canal-cobwebbed Mars and William Henry Pickering’s curious notion that the Galilean satellites of Jupiter were elliptical swarms of dust tumbling end over end. In fact, Barnard shared his telescopic impressions of Mars quite openly. Especially noteworthy in this regard are his frank remarks in the *Monthly Notices of the Royal Astronomical Society* recounting his best views of Mars during fleeting moments of exquisitely steady seeing during the summer of 1894. On several mornings just after sunrise when Mars was on the meridian he was able to distinguish a wealth of detail so intricate and abundant that it defied his best attempts to delineate it:

Though much detail was seen on the bright “continental” regions, the greater amount was visible on the so-called “seas.” Under the best conditions these dark regions, which are always shown with smaller telescopes as of nearly uniform shade, broke up into a vast amount of very fine details. I hardly knew how to describe the appearance of these “seas” under these conditions. To those, however, who have looked down upon a mountainous country from a considerable elevation, perhaps some conception of the appearance of these dark regions may be had. From what I know of the appearance of the country around Mount Hamilton as seen from the observatory, I can imagine that, as viewed from a very great elevation, this region, broken by canyon and slope and ridge, would look just like the surface of these Martian “seas.”

Such, then, were Barnard’s frank impressions of Mars in 1894. He wrote of

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“canyon and slope and ridge,” but made no mention of craters.

THE SOLUTION TO THE MELLISH MYSTERY

In a 1966 letter to Daniel Harris of the University of Arizona’s Lunar and Planetary Laboratory, Mellish wrote: “When I showed Barnard my drawings and he showed me the ones he made of Mars in 1892-3 when Mars was close but he did not see any craters as craters but he did have circular patches which we took to be areas of woods or vegetation of some kind.”

Cornell University planetary scientist James F. Bell, a leading authority on Mars, comments:

While I acknowledge that there can be moments of incredible clarity (some would even say clairvoyance) at the telescope, I have never seen any convincing evidence for the observation of craters on Mars based on their topography. It’s not hard to be skeptical: the elevation differences are quite small and the phase angles are not ever really that large.

However, I find it easy to believe that observers have seen craters on Mars in the past, not based on their topography but instead on their albedo variations. A good example can be seen in the June 26, 2001 F673N HST image.
Looking at that image, which is among the highest resolution images of Mars ever obtained from Earth, one can easily see a number of large and even smallish craters in the Meridiani and Arabia regions. Schiaparelli is of course obvious, but smaller craters like Aram, Crommelin, and even Rutherford, many of order 100 to 200 kilometers diameter and some smaller, are easily resolved. But they are resolved because they are just shallow holes in the ground filled with dark sand, scattered amidst a "sea" of bright dust. The craters in this area (and many others) are natural sinks for coarser-grained and thus darker particles, leading to these large albedo contrasts... Even the keenest observer could mistake the dark inter-crater deposits for shadows, especially for cases where the deposits fortuitously appear biased towards the direction that one might expect for shadows. And these deposits change on decadal (or in a few cases, annual) timescales, so observations of "shadows" that might not be expected to repeat could be ascribed to some kind of special/unique observing circumstances or angles.¹⁵

Using space probe and HST images as the basis of comparison, the most accurate depictions of Mars by visual observers were made by Eugene Antoniadi of Meudon Observatory, Jean-Henri Focas and Audouin Dollfus of the Pic du

Midi Observatory, and the Japanese observers Shiro Ebisawa, and Ichiro Tasaka. They all depict superb seeing the Martian maria break down into intricate mosaics of dusky spots that Antoniadi once compared to a leopard’s skin. Some of these spots are craters, but many are not. In fact, after Mariner 9 imaged Mars at high resolution from pole to pole in 1972, cartographers quickly realized “no correlation between large-scale albedos and topography can be generalized.” Without reference to space probe images, there was simply no way to determine which spots were elevations and which were depressions.

A MULTITUDE OF CRATER “PROPHECIES”

Mellish’s claim that Mars had “many craters and cracks” certainly wasn’t novel, nor is there any reason to believe Gordon’s recurring argument that such claims were withheld by Barnard and other observers so as not to jeopardize their reputations and careers. Quite the contrary - there was a great deal of uninhibited speculation about the possibility that the surface of Mars was studded with craters. In 1892, Harvard astronomer William Henry Pickering had charted dozens of “lakes” on Mars with a 13-inch Clark refractor from a site near the town of Arequipa high in the Peruvian Andes. Located at the points where Schiaparelli’s canals intersected, these features would soon be dubbed “oases” by Percival Lowell. Noting that “the body most resembling the Moon with which we are acquainted is the planet Mars,” in 1904 Pickering suggested that the lakes or oases might be craters rather than bodies of water, while the canals themselves might be shrinkage cracks and fissures exuding carbon dioxide and water vapor that sustain the local growth of vegetation.


Embraced by a number of prominent astronomers including Simon Newcomb, Alfred Russell Wallace, and Clyde Tombaugh, Pickering’s suggestion was often cited in the popular press as a credible alternative to Lowell’s romantic speculations about a colossal irrigation system constructed by a dying Martian race.19

In his influential book *The Face of the Moon*, published in 1949, astrophysicist Ralph Baldwin wrote:

No planet can be seen as well through any telescope as the Moon can be seen with the naked eye. Hence definitive answers cannot be obtained. Nevertheless, Mars has been extensively studied, and certain facts are known. The planet has a rarefied atmosphere, but it would be a fairly good protection against tiny meteorites. Larger bodies would crash to the surface somewhat more easily than they do on Earth... Distributed widely over both the ochre deserts and the green maria are round dark spots, the oases, which conceivably could mark large craters whose sunken floors would trap water vapor and hence permit a local vegetative covering.20

Recounting his views of Mars through the 40-inch Yerkes refractor during a lecture tour of the United States in 1954, the British selenographer Hugh Percival Wilkins wrote that “numerous canals were detected, and they all appeared to be uniform streaks suggesting cracks in the surface, while the oases, several of which were seen, suggested craters, presumably filled up with some dark-coloured matter.”21


Chesley Bonestell was Hollywood's highest paid special effects artist when he supervised the production of the matte artwork for Paramount's 1955 science fiction movie *The Conquest of Space*. Looking uncannily like a view from one of the Viking orbiters, this depiction of a spaceship lifting off the Martian surface made for the film includes shallow impact craters and towering shield volcanoes, a surprising and remarkably prophetic departure from the prevailing wisdom of monotonous dusty plains and tracts of primitive vegetation.

In his books *Life on Mars* (1944) and *Mars Revisited* (1959), Donald Lee Cyr also suggested that the oases of the Lowellian canal network were impact craters. Cyr speculated that the depressed floors of these craters were warm, moist microclimates, while the canals themselves marked the migratory routes of mobile grazing animals whose droppings rendered the soil more fertile, a phenomenon that he observed along the paths of wagon trains and cattle drives in the deserts of the American Southwest.²²

GEORGE HAMILTON AND OLYMPUS MONS

Gordondevotes the fourth and fifth chapters of his book to observations byGeorge H. Hamilton of Nix Olympica, a feature discovered in 1879 by theoutstandingnineteenth century student of Mars, Giovanni Schiaparelli. Using
the 8.6-inch Merz refractor of the Brera Observatory in Milan, Schiaparelli
madeoutatinywhitespot “as bright as the polar snow” that he christened Nix
Olympica (“the Snow of Olympus”) after the mountain abode of the gods in
Greek mythology. The name proved to be singularly apt, evenprophetic.

Schiaparelli’s Nix Olympica is the canopy of cloudsthat often shrouds Olympus
Mons, the largest shield volcano on the Tharsis plateau. Olympus Mons towers
to a height of 24 kilometers - three times the height of Mount Everest - and has
a base 550 kilometers in diameter that is ringed with cliffs several kilometers
high.

When the Tharsis volcanoes are relatively free of clouds, their dark basalt
slopes stand out against the surrounding bright dusty plains. But as local noon
approaches, clouds frequently begin to form over the summits as winds carry warm, moisture-laden air over the peaks. This air expands and cools as it rises, causing water vapor to condense out as ice crystals that often spread over onto the leeward (western) flanks during the afternoon. These orographic clouds appear to hover over the volcanoes as they rotate across the disk, giving them the appearance of tiny tufts of cotton that are often referred to as “domino clouds” by veteran Mars observers.

Two of Hamilton’s drawings of Mars from August 1924, made with the 11-inch Draper refractor at Harvard’s southern observing station at Mandeville, Jamaica, depict Nix Olympica as a dusky spot enclosing a smaller concentric spot about half its diameter. The latter is delineated with a dashed line, the convention used by generations of visual observers to denote bright features like clouds or patches of frost on Mars, white ovals on Jupiter, and eruptive white spots on Saturn. There is certainly no reason to believe that Hamilton was not following this convention, for a number of his other Mars sketches by Gordon unambiguously delineate bright features using dashed lines.
Gordon asserts that the concentric bright spot in Hamilton’s sketches of Nix Olympica represents the caldera or crater formed by the collapse of a magma chamber that is located on the volcano’s summit. However, the proportions of Hamilton’s sketches are utterly inconsistent with this interpretation. While the base of Olympus Mons measures 550 kilometers across, its elliptical summit caldera measures only 60 by 90 kilometers, or about one-sixth of the diameter of the base. Hamilton’s sketches depict a bright feature at least three times this size, far too large to be the caldera, but quite consistent with a mundane orographic cloud.

Although the Tharsis shield volcanoes are huge, in profile they look almost as flat as pancakes. Their very gentle slopes, ranging from 2° to 6°, do not cast appreciable shadows even at the terminator. To illustrate once again just how difficult it is to discern even the most dramatic Martian topography, it is worth noting that Nix Olympica appeared as a large, bright ring in far-encounter images taken by the Mariner 6 and 7 space probes as they approached Mars in the summer of 1969. Although the resolution of these images surpassed the best telescopic views, the bright ring was interpreted as the ramparts of a huge impact crater by the Mariner imaging team, and the feature’s true nature - an enormous elevation rather than a shallow depression - would only be revealed by the Mariner 9 orbiter two years later.

Hellas, a large, circular bright area some 1,300 kilometers across was long regarded as an elevated area because it was a site where clouds frequently developed, and it had often appeared to be frost covered in winter. We now know that it is a low-lying impact basin.
PHOTOGRAPHING THE CRATERS OF MERCURY?

In an attempt to buttress the claim that Mellish was able to detect craters on a tiny Martian disk only 7.7 arc-seconds across, Gordon makes the utterly fantastic claim that craters on the planet Mercury were recorded on photographs more than half a century ago, a feat that somehow managed to escape the notice of even the photographers themselves! The analogy between Mars and Mercury is strained; Mercury exhibits far more pronounced phases than Mars and has no atmosphere to render features along the terminator diffuse. Nevertheless, Gordon cites (but fails to reproduce) a montage of seven photographs of Mercury that appeared in a popular 1977 anthology about the planets. According to Gordon, three of the photographs show “a mottled structure along the terminator,” while in the image at top center “one larger crater is visible along with several smaller ones... Some are so distinct that they resemble lunar craters along the terminator as seen with binoculars.”

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Although Gordon fails to identify the origin of the photographs, they are in fact part of a series taken in 1942 by Bernard Lyot and Henri Camichel with a 15-inch refractor at the Pic du Midi Observatory in the French Pyrenees. Even a cursory inspection reveals that Gordon’s “mottled structures” and “craters” are simply clumps of film grain. No silver halide photograph of Mercury has ever recorded that planet’s craters, and neither do recent CCD images of Mercury obtained with the 0.5-meter Swedish Solar Vacuum Telescope on the island of La Palma in the Canary Islands, a state-of-the-art instrument equipped with adaptive optics that routinely captures diffraction-limited images.


Gordon transcends mere folly and flirts with forgery and fraud when he offers an altered version of a 1998 image of Mercury image taken by Ron Dantowitz and a team of observers from the Boston Museum of Science using the 60-inch Mount Wilson reflector. Dantowitz, who recorded Mercury for 90 minutes on broadcast-quality analog videotape using a high-resolution video camera and painstakingly selected the sharpest frames to obtain the most detailed Earth-based image of Mercury yet achieved, comments:

The image as reproduced in Mr. Gordon's book appears slightly different than my original image published in the *Astronomical Journal*. If one processes my image of Mercury by clipping the lower 30% of the intensity, the result exactly matches the one in Gordon's book. This setting artificially increases the contrast, giving some artifacts and subtle shadings the appearance of sharp, contrasty features on the “terminator.” In fact, the real terminator occurs a significant distance to the east of the one shown in the image in Gordon's book.

Given the signal-to-noise ratio of the image, I would be uncomfortable saying that the features on the terminator of my image are indeed craters. There is a significant amount of statistical noise and turbulence, which one must expect when imaging Mercury during the daytime. It is important to objectively analyze the images with this in mind and not assume that these features on the terminator are indeed “craters.”

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