Images of Some Martian Volcanoes

By: Jeff Beish, Former A.L.P.O. Mars Recorder (May-19-2022)

What may be the first Martian topographic relief feature ever identified from the surface of Earth has been found on a photograph by Don Parker taken on September 03, 1988 at 0523UT. The photograph was exposed on Kodak 2415 film using a 12.5-inch f/6 Newtonian telescope that he made himself and was later digitally processed by astronomer Dr. Steve Larson, (University of Arizona Lunar and Planetary Laboratory). The topographic relief feature is believed to be the volcano Apollinaris Patera (185.6° W, 8.6°S) in the general area of Lucus Planum.

The digital image was used to measure the position of the volcano using WinJUPOS . Using WinJUPOS one can find highly accurate positions of features on Mars.

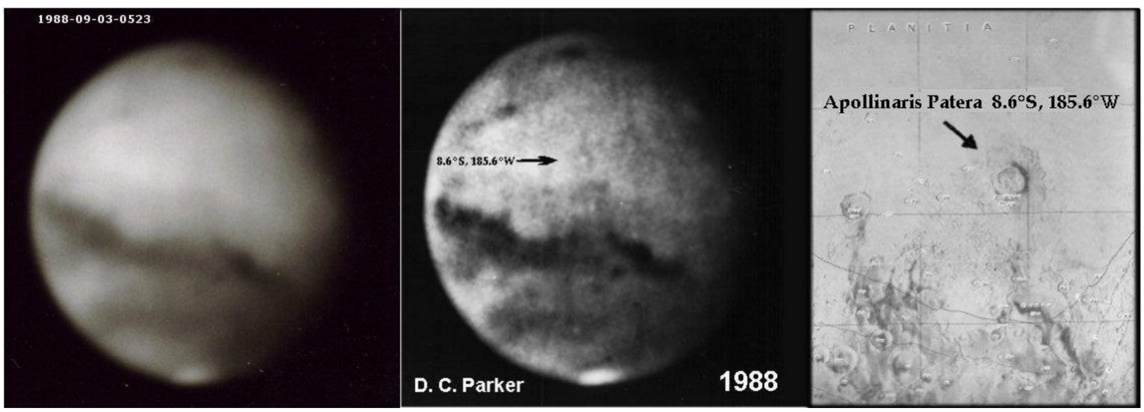


Figure 1. Photograph by Dr. Donald C. Parker, take on September 03, 1988 at 0523 UT, 12.5-inch f/6 Newtonian. LEFT: Original photograph exposed on Kodak 2415 film. CENTER: Digitalized image of Parker's photograph (processed by Dr. Steve Larson). RIGHT: Image of Luicas Planum that may be found on the "On-line Atlas of Mars: The Aeolis Quadrangle of Mars (https://msss.com/mars_images/moc/moc_atlas/mc23.jpg)

Another Martian topographic relief feature identified from near Earth, has been found by Leonard Martin (Lowell Observatory) and Jeff Beish, Former A.L.P.O, Mars Recorder. These may be the first topographic features identified since the Viking Orbiter stopped sending data back to Earth in November 1982. Now, the Hubble Space Telescope has imaged the Red Planet near opposition in February 1995 containing an identifiable topographic feature on Mars (see Figures 2 and 3).

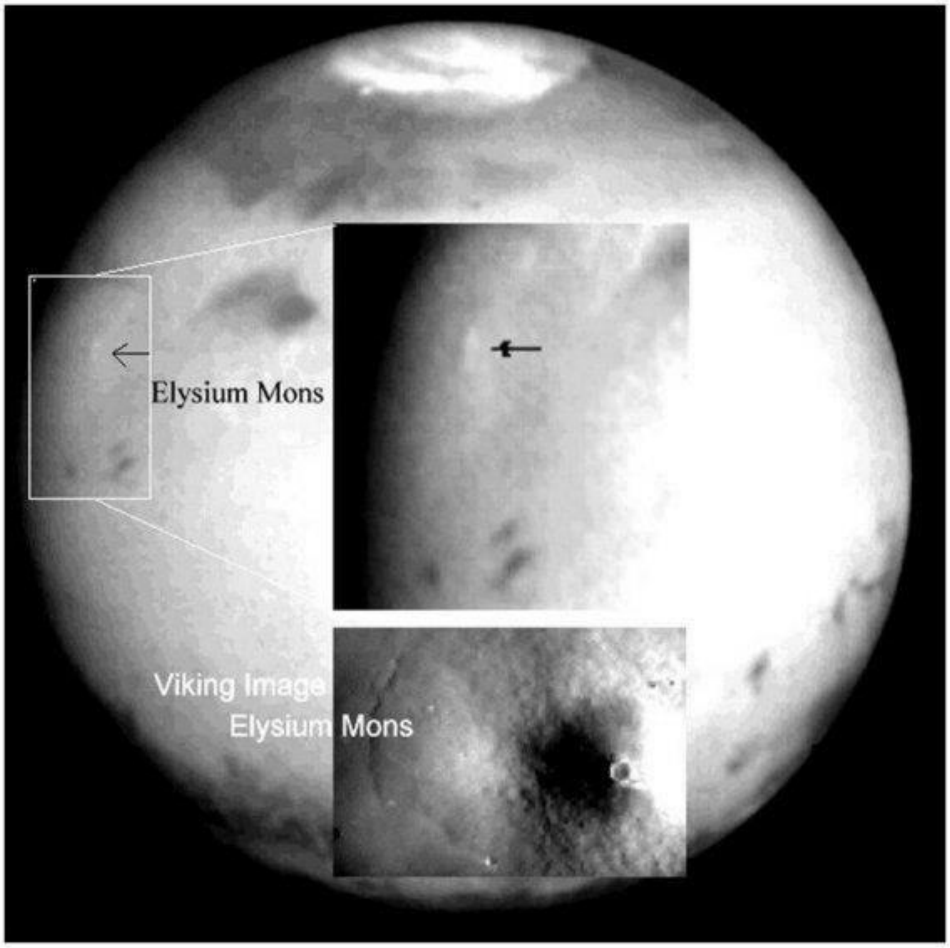


Figure 2. A CCD image of Mars with exploded view inset reveals a topographic relief in the exact position of Elysium. The arrow points to a bright feature of the sunlit slope of the volcano with a shadow to the terminator side of Mars' limb. Image taken from the left-hand image of PR95-17 STOPO HST labeled Tharsis Region 160° Longitude. Bottom inset is an image of Elysium taken by the Viking Orbiter- I spacecraft during the Viking Space to Mars during the period from July 1976 throughout November 1982. Image by NASA.

To illustrate that the HST image of the apparent volcano Elysium Mons Figure 2, bottom inset, reveals the volcano as seen from the U.S. Viking Space Mission to Mars during the period from July 1976 throughout November 1982. Notice the bright escarpment and following shadow towards the terminator of Mars.

To identify a topographic relief on another Solar System body, such as the Moon or Mars, one must be able to see sunlit wall, cliff, slope, escarpment, and/or a corresponding shadow. For instance, a Lunar crater with the right lighting conditions may show a bright Sunlit wall or rim and a shadow on the opposite side of the wall or rim and the reverse on the other side of the crater. A Martian volcano would appear as a triangular slope with a corresponding shadow on the opposite side from the Sun. This would appear similar to a Lunar dome or a steep Lunar mountain, except domes are usually rounder in shape.

The 170-km (106-mi) wide Elysium Mons is located at 213.5W°, 25°N and stands 13.9-km (8.6-mi) high over the Elysium Planitia. This volcano has steeper slopes than the other large volcanoes, such as those found in the Tharsis region of Mars. The very large volcanoes Olympus Mons and Arcia Mons are very flat, appearing like giant cow patties and would not cause much of a shadow or sunlit slope.

Ascraeus Mons and Pavonis Mons have steeper slopes and may be revealed in HST images in the next apparitions of Mars. The 15-km (9.3-mi) high volcano Ascraeus Mons, located at 104.3°W, 11°N, is 400-km (250-mi) wide and is one of the largest volcanoes in the Tharsis region of Mars. The phase terminator appeared to be just right to identify these two volcanoes described above.

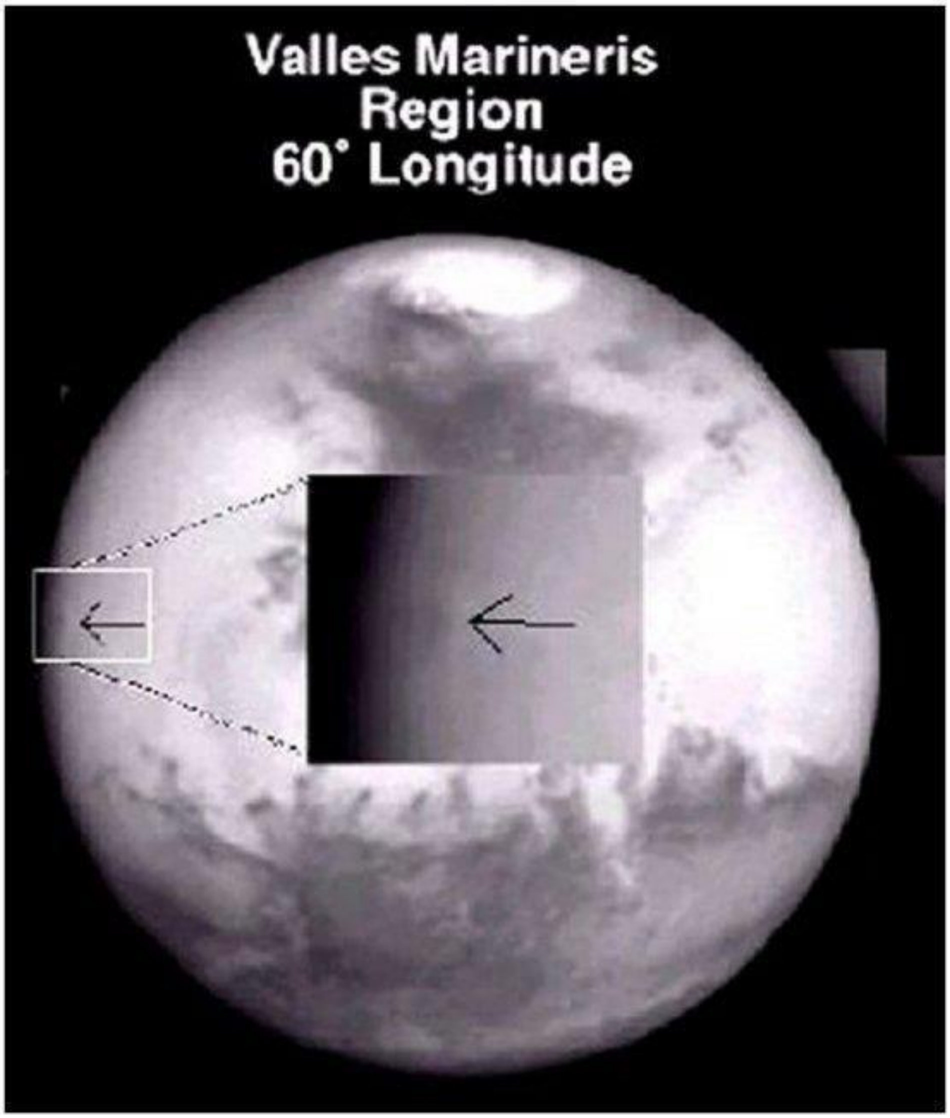


Figure 3. A CCD image of Mars with exploded view inset reveals a topographic relief in the exact position of Ascraeus Mons. The arrow points to a bright feature of what appears to be the sunlit slope of the volcano with a shadow to the terminator side of Mars' limb. However, this is a false assumption because what we see is the top of Ascraeus Mons poking through the cloud. Image taken from the center image of PR95-17 ST Scl OPO HST labeled labeled Valles Marineris Region 60* Longitude.

During the next apparitions of Mars, the planet will be larger and we hope topographic relief of the Red Planet will be identified. The author feels that observing these features on Mars from ground-based telescope is impossible and will not be practical in our life times. The Hubble Space Telescope is the finest astronomical observing instrument ever constructed.

Olympus Mons

How long would the shadow of Olympus Mons (133.4° W, 18.6° N) appear on Mars? Using the 22 kilometer height of Olympus Mons relative to its surrounding area we then can find out how long the shadow would appear near the terminator of Mars. Although the volcano is nearly 22 km high, it is over 20 times wider than it is tall. Thus, most of the volcano has a fairly gentle surface slope.

Remember that Olympus Mons is not like most volcanoes found on earth. The slope angle from the edge of its caldera is only is 2.5 degrees to about 50 miles out and then from there the grade increases to only 5 degrees and continues 162 miles to the very edge or scarp of the volcano. Further shadowing would be seen to cover the slope from the 5-degree slope plane out to miles to the edge of the volcano.

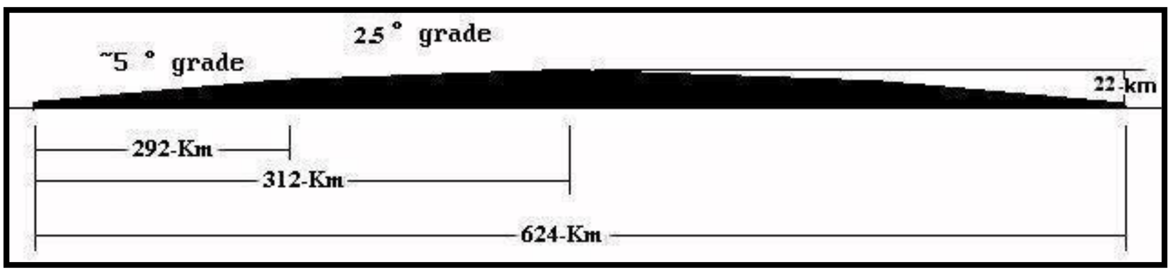


Figure 4. Olympus Mons is classified as a shield volcano that stands 22 kilometers (13.7 miles) above the surrounding plains of the Tharsis region of Mars. It is Olympus (27-Km or 16.8 miles) in altitude, 600 kilometers (373 miles) in diameter and is rimmed by a 6 kilometers (4 miles) high scarp. By comparison the largest volcano on Earth is the 9 kilometer (6 miles) high Mauna Loa that is 120 kilometers (75 miles) across.

New research reveals that this large mountain is not exactly as this author had learned it was in the past. From a paper "SPREADING OF THE OLYMPUS MONS VOLCANIC EDIFICE, MARS, "[***McGovern, et al,*** 2005], it appears that the profile Olympus Mons is irregular and steeper than I was aware of before stumbling upon this paper. Also, another interesting study giving the slope angles of Olympus Mons can be found here.

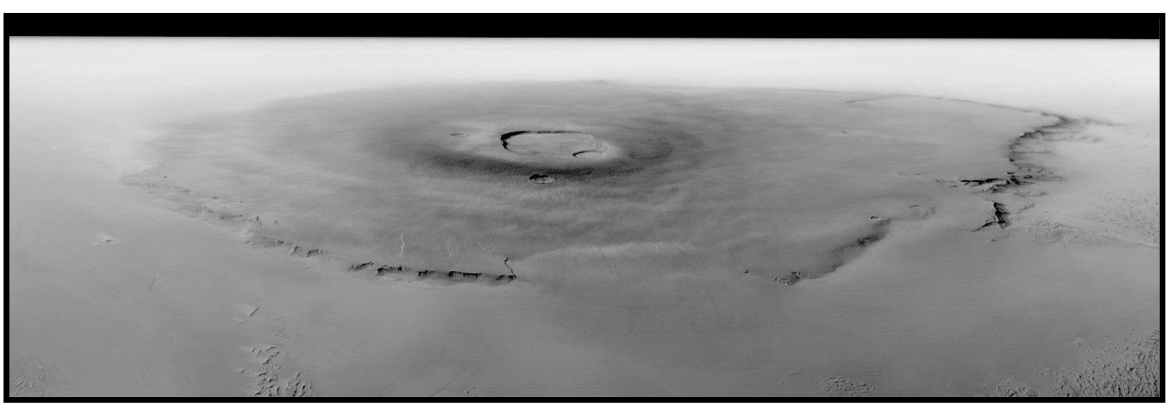


Figure 5. Image of oblique view illustrates the shallow slope and scarp of Olympus Mons. Oblique Olympus, MGS MOC Release No. MOC2-479, 10 September 2003, Malin Space Science Systems.

A good example would be when the phase angle (**i**) of Mars reached 41.1° on September 05, 2005 at 0956UT. The diameter of Mars was 14.6 seconds of arc and a Central Meridian (**CM**) of 147.0°, Ds = -24.6°, Phase Angle (i = 41.1° and elongation = 114.2°W. Ed Grafton's image attached with inset is probably as good as one can capture that cow patty, Olympus Mons, and by my reckoning the image appears to be of a triangular, pointed feature with rills, canons, and a rather blunted and square "shadow" of what appears to me as a sheer straight wall on the evening side of the volcano "image."

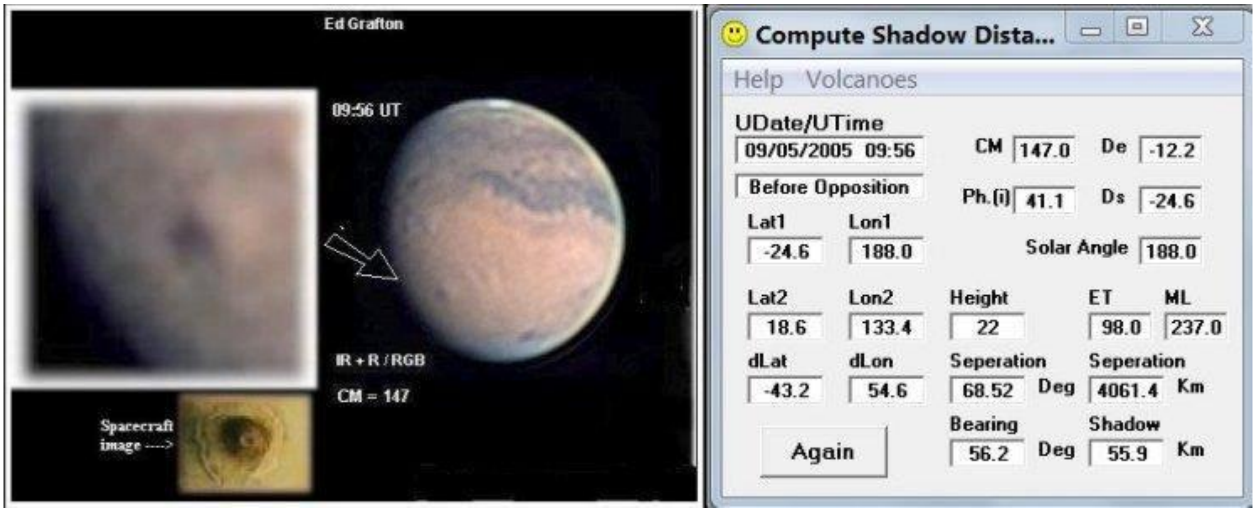
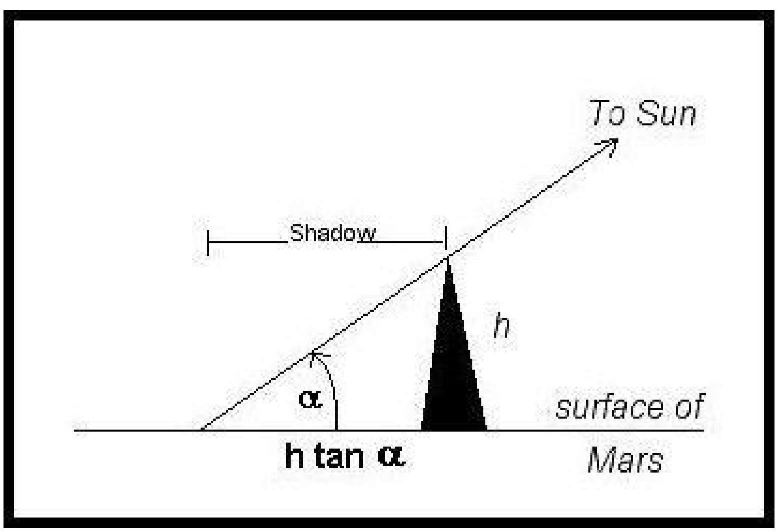


Figure 6. LEFT: Ed Grafton image taken on September 5, 2005 at 0956UT, CM 147°. Olympus Mons with accompanying shadow on the slope of the volcano. RIGHT: Shadow program window

We must first determine at what longitude the sub-Solar point or High Martian Noon is and then determine what angle the Sun is relative to Olympus Mons. The diameter of Mars 6,792-Km, then each degree would represent 6,792/180 = 37.73Km per degree. The shadow length (***S***) using the equation: ***h*** tan α, where ***h*** = height of the object and α = shadow angle between the latitude (λ_1) and longitude (φ_1) of the solar angle (CM + ***i*** = 147.0° + 41.1° = 188.1°) and the latitude (λ_2) and longitude (φ_2) of the object. To find α, the distance between in degrees the solar angle and Olympus Mons, using the Spherical Law of Cosines, where $\varphi_1 = 188.1°$, $\lambda_1 = -24.6°$, $\varphi_2 = 133.4°$, $\lambda_2 = 18.6°$:



$$\cos(\alpha) = \cos(90° - \lambda_1)\cos(90° - \lambda_2) + \sin(90° - \lambda_1)\sin(90° - \lambda_2)\cos(\varphi_1 - \varphi_2)$$

$$= \cos(90° - (-24.6°))\cos(90° - 18.6°) + \sin(90° - (-24.6°))\sin(90° - 18.6°)\cos(188.1° - 133.4°)$$

$$= -0.416281 * 0.318959 + 0.909236 * 0.947768 * 0.577858$$

$$= 0.365189$$

$$\alpha = 68.6°$$

Hence: shadow length (S) = 22 tan 68.6° = 56.1 Km

The 22-km high volcano would produce a shadow of 56.1-Km, a few degrees away from the terminator. Since the average radius of the huge volcano 300 kilometers (186 miles) then most of the terminator side of Olympus Mons will be in a shadow. An hour later when the CM is 161.3° so, the volcano shadow would 125.8-Km shadow, and so on until the shadow is engulfed in the terminator.

Any other shadowing would come from the accumulation of shadows from the hills and valleys of the irregular surface of the volcano slopes. The drop off at the scarp edge, an 8-km high wall, will be seen as a ring like shadow at the parameters of Olympus Mons. So, Olympus Mons is a huge, flat mountain and if I were standing on it the volcano would appear to me as the whole planet from horizon to horizon. One way to look at it, that volcano is shaped like a giant cow patty. Another example show how dark Olympus Mons is when seen under a sunny Martian landscape.

Figure 8. LEFT: Don Parker's image on July 31, 2001 at 0147UT. CENTER: Damian Peach's image on August 11, 2007 at 0405UT. RIGHT: Larry Owen's image of Mars on August 22, 2007 at 1018 UT.

What I am attempting to say is that image processing tends to make features appear not as they are -- but as they are computed. But, why does it appear like a full shadow cast by Olympus Mons when it is near the terminator? If the slope was much steeper than space scientists say it is then it would indeed cast a dark shadow and would begin to be seen shortly after the volcano past through the Noon sky. If the slope of Olympus Mons was more like 5 to 7.2 degrees slope, and not the 2.5 to 5 degrees, as space scientists say it is, then a shadow would be readily seen. We could calculate this further until at some point the shadow would be long and dark enough to be considered observable. At some point the so-called shadow and the slope of Olympus Mons would be in the terminator so it would be impossible to distinguish the shadow from the darkness of the terminator. Remember, Mars falls into complete darkness at the terminator and throughout the night because there is nothing to cast light onto Mars except for the Sun.

Also, the extension of the atmospheric mass near the limb; even in the thin atmosphere of Mars, reduces the contrast at or near the limbs, so in the absence of bright hazes the limbs will appear slightly darker due the optical depth of the atmosphere. Remember too that atmosphere can affect the appearance of volcanoes on Mars. Many times we see orographic clouds that either are centered over the volcanoes or are on the lee side caused by winds. Observers have reported seeing shadows cast by the dense orographic clouds over Olympus Mons and when close to the terminator will add to the cumulative shadowing, atmosphere opacity and the shadowing from the cloud to darken the area even more so.

One of the most spectacular earth-based images of Mars just has to be the one below. Taken a week before opposition Don Parker captured these images illustrating the resolving power of a quality amateur telescope in the hands of an experienced Mars observer. We can conclude that the "donut" shaped feature above the lower limb and near the central meridian of Mars is no doubt Olympus Mons, we should also see the three other huge volcanoes in Tharsis; Ascraeus, Pavonis and Arsia Montes, are barely discernible to the left of Olympus Mons.

While it is true that we can measure this feature and place it at the correct location of Olympus Mons, as we now know the giant volcano to be, would we be able to identify it as a maintain or volcano without prior knowledge? One could conclude the feature would very well be a crater or a large dome similar those observed on our Moon.

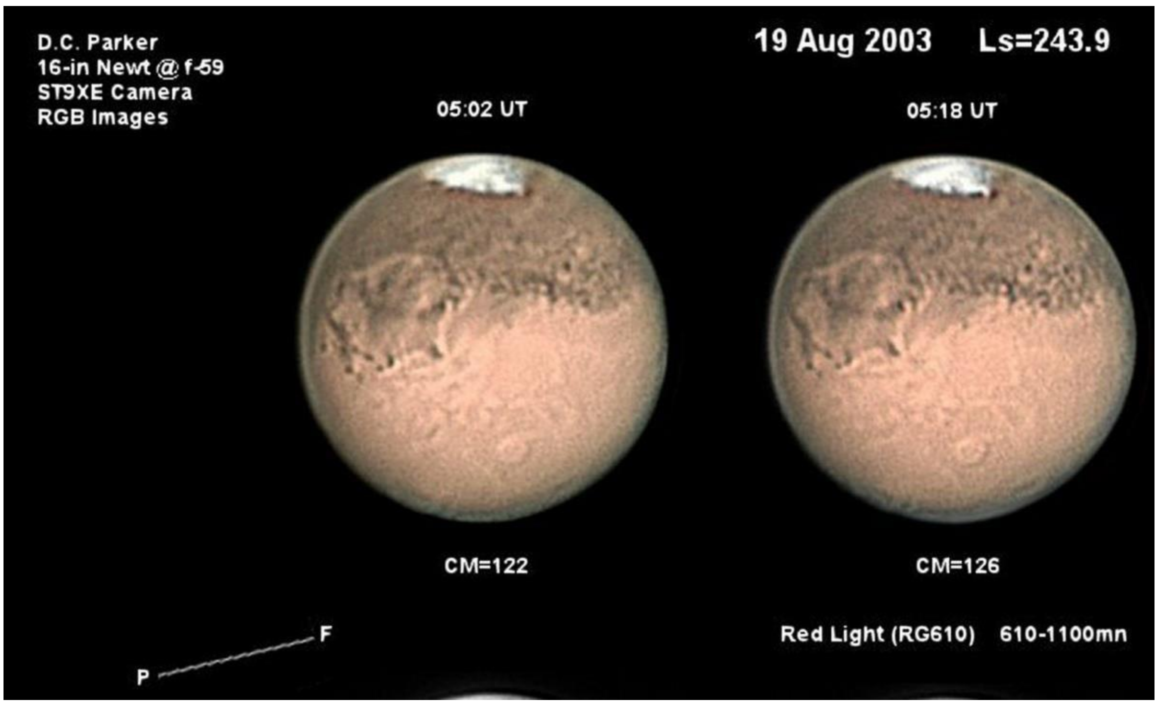
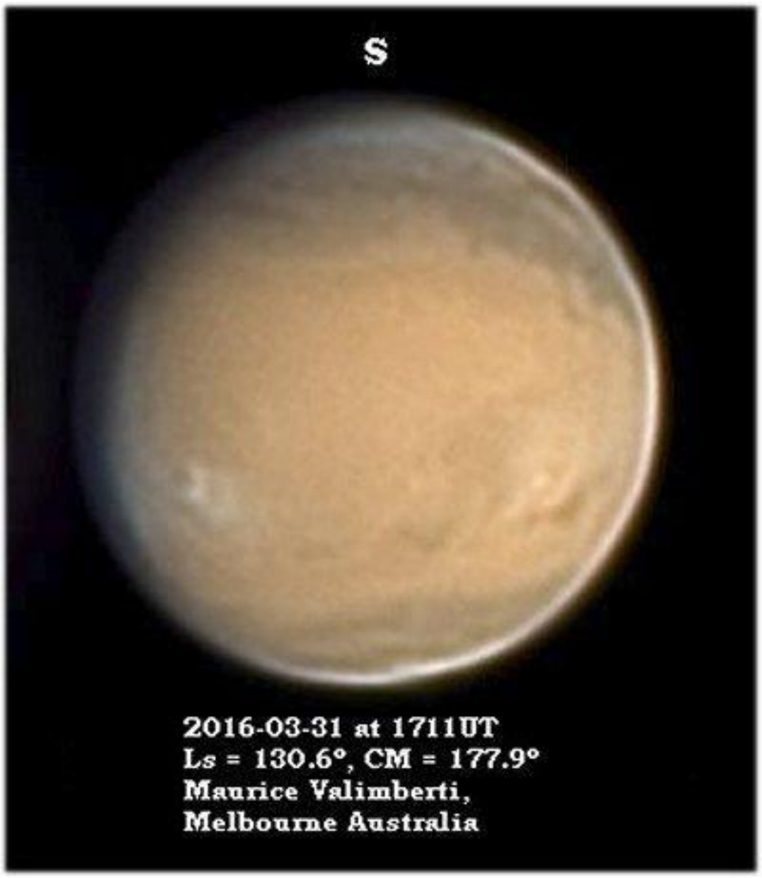


Figure 9. Two spectacular earth-based images of Mars take by Dr. Donald C. Parker a week away from opposition 2003. These images reveal the Tharsis regions of Mars where at least four huge volcanoes can be found.

Another excellent example is the image below taken recently on March 31, 2016 at 1711UT. The diameter of Mars was 11.7 seconds of arc and a Central Meridian (**CM**) of 177.9°, Ds = 18.9°, Phase Angle (i) = 31.4° and elongation = 124.1°W. ***Maurice Valimberti*** of Melbourne Australia and using a 36cm SCT @f/28, ASI 224MC, IR Block filter, captured Olympus Mons with associated orographic clouds being swept westward, or away from the evening limb and terminator, and indicates a shadow being cast by both the volcano and the cloud. The solar angle (CM + ***i*** = 177.9° + 31.4°) = 209.3° in this image. Using the method above, what would be the length of the shadow?

Figure 10. Olympus Mons with orographic cloud combines to cast shadow near terminator in this image of Mars



on 2016-03-31 at 1711UT, Ls = 130.6º, CM = 177.9º); image taken with 36cm SCT @f/28, ASI 224MC, IR Block filter, by Maurice Valimberti, Melbourne Australia.

Recent Image of Olympus Mons with Scarp and Caldera

A excellent example of Olympus Mons was taken by an Australian amateur using a C14 reflector with a phase angle (**i**) of only 13° on April 24, 2013 at 1205UT. The diameter of Mars was 14.9 seconds of arc and a Central Meridian (**CM**) of 116.4°, Ds = 21.4° and elongation = 158.9°W. D P (Mo) Milika's image attached with inset is probably the best one can capture that huge volcano, Olympus Mons, this author has ever seen. Visit their website for images, explanations & tutorials "free": http://www.momilika.net/

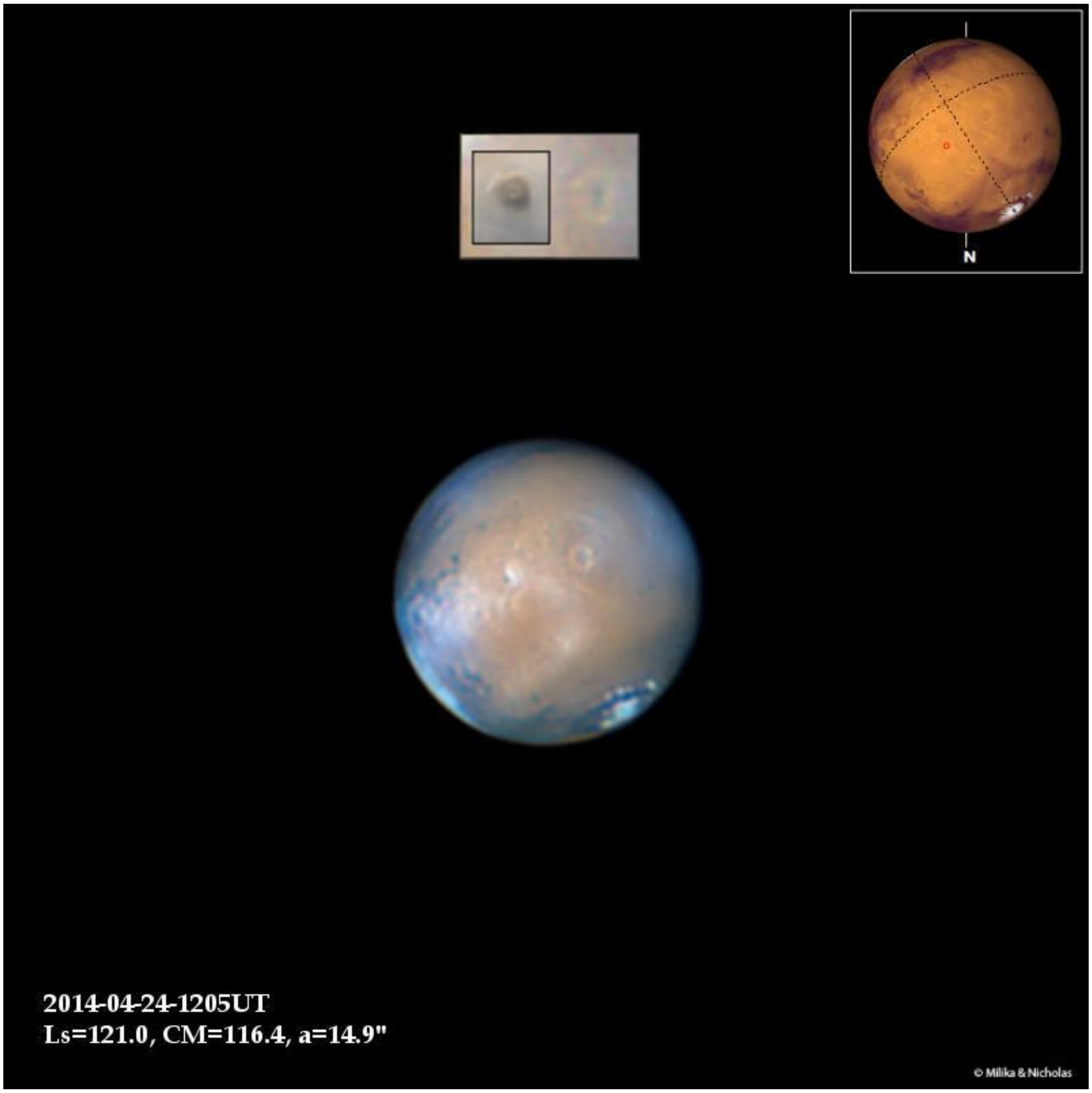


Figure 10a. A spectacular earth-based image of Mars take by D P (Mo) Milika (Australia) with a C14 telescope a month away from opposition 2014. This image reveals the volcano Olympus Mons with great details of the scarp and caldera. Mars on 2014-04-24-1205UT, Ls=121.0, CM=116.4, a=14.9"

What Mars Would Appear Like in the 36-inch Clark Refractor at the Lick Observatory in July and August 1894: Barnard's drawings of Mars

The following drawings were made at Lick Observatory (long. 121ºW 38.3', lat. 37ºN 20.6') in California in the Pacific Standard Times (PST – UT = - 8). The dark spots that appear in E. Barnard's drawings in the illustrations below appear to be two of the Tharsis volcanoes (Arsia Mons and Olympus Mons) [***Misch***, 2003]. At first glance it can be assumed that the apparent "times" penciled in the drawings are UT; however, subtracting 8 hours (time zone for California) from the indicated times does not yield the apparent central meridians indicated on the drawings. By adjusting the time zone difference to 4 hours the drawings and simulated views of the two volcanoes line up much better.

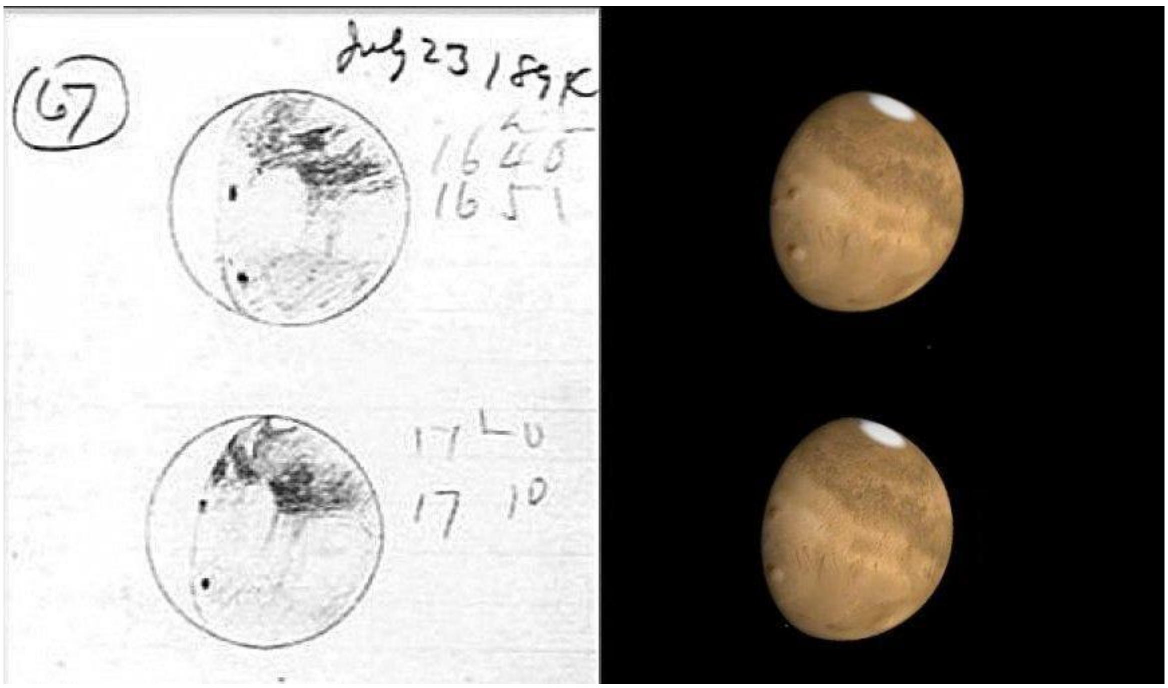


Figure 10. E. Barnard's Drawings of Mars and Simulated Views on July 23, 1894 at 1240 and 1300UT (248º Ls).

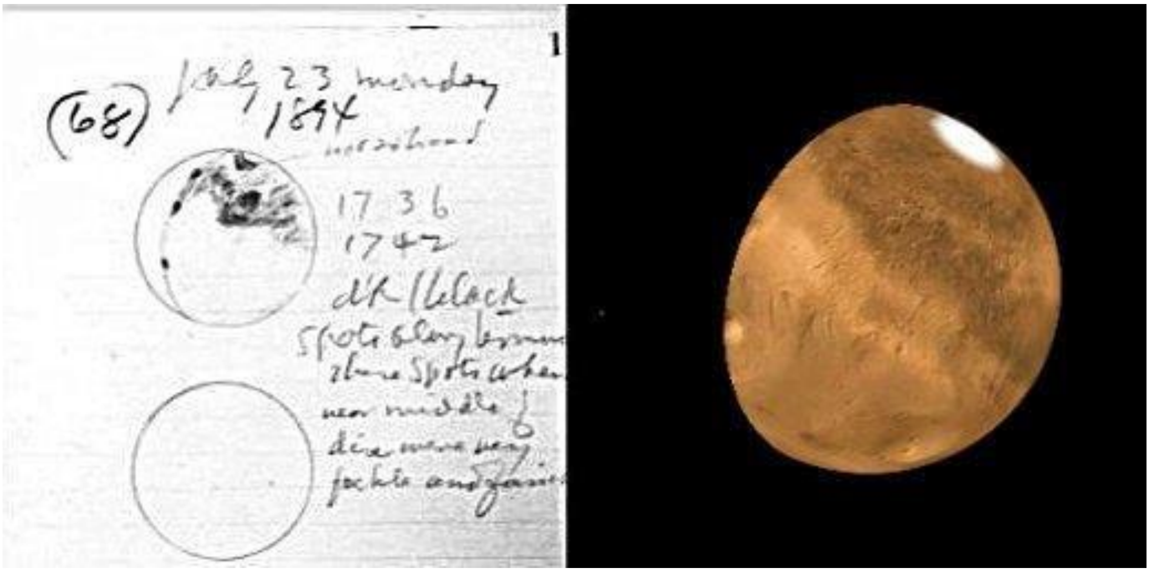


Figure 11. E. Barnard's Drawings of Mars and Simulated Views on July 23, 1894 at 1336 UT (248.3º Ls).

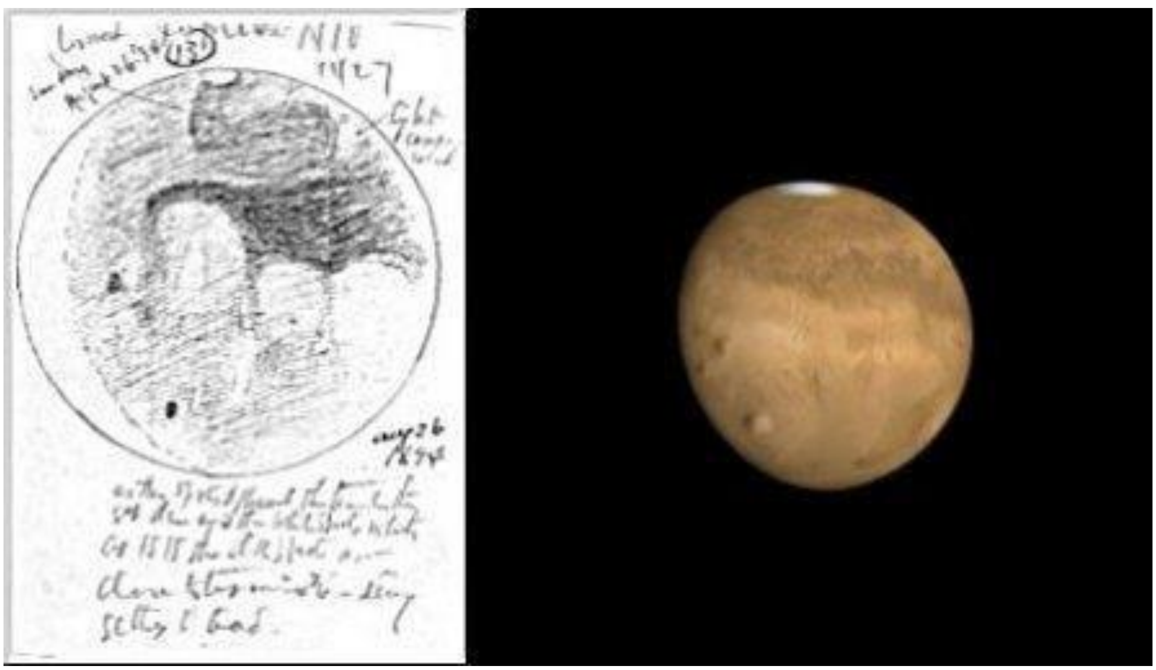


Figure 12. E. Barnard's Drawings of Mars and Simulated Views on August 26, 1894 at 1010 UT (269.8º Ls).

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