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VOLCANIC ACTIVITY ON THE MOON

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by

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• *translated by Edgar Huston* •

ABSTRACT

On November 3, 1958, the author observed ejection of volcanic ash and gases from the central peak of Alphonsus crater. Spectrographic analysis of gas fluorescence induced by hard solar radiation, proved that gases were escaping from the crater floor. It appears that tectonic activity is taking place on the moon. Lack of atmosphere and consequent porosity (caused by rapidly escaping gas) of surface layers have resulted in reduced heat emission; these factors all contributing to the moon's ability to retain internal energy sufficient to initiate tectonic activity. Fissures and dark spots on crater floors indicate endogenic development of the moon's basic surface relief, as opposed to relief development by meteoric impact. --D. D. Fisher.

Study of surface morphology shows convincingly that the relief of the moon developed gradually as a result of repeated uplift and subsidence of its crust. Inclined and semisubmerged craters on the borders of the "seas" show that segments of the crust subsided accompanied by fissure formation and subsequent extrusion of molten material. The famous valley in the lunar Alps is approximately 10 to 15 kilometers (km) wide and more than 100 km long, its sides are steep and similar to one another. This rift furnishes an example of crustal uplift accompanied by considerable stretching; undoubtedly, such tectonic processes are connected with volcanic activity.

Let us visualize the extrusion of molten matter from the inner parts of the moon to its surface. Gases present in this lava in the absence of atmosphere, necessarily would have escaped in a vigorous manner creating a foamy structure. Rocks composing the outer layers of the moon must have become extremely porous, resulting in their extremely low thermal-conductivity coefficient. This probably explains why the thermal-conductivity coefficient for external layers of the moon equals only one-hundredth or one-thousandth of that for external layers of the earth. If extrusion of molten material occurred during different periods on individual sectors of the lunar surface, gases liberated in each of these extrusions could not have created any noticeable atmosphere on the moon. Constant bombardment of the moon surface by solar-corpuscles, micrometeorites, and hard solar radiation must have communicated velocities exceeding the parabolic (approximately 2. 4 km/second) to atmospheric particles; that is, these particles must have blown away and thus have been prevented from accumulating. In the instance of a planet with an extensive atmosphere, the effect of particle penetration into its atmosphere would have been analogous to an explosion at depth. The energy would be communicated to large masses, and low velocities to individual gas particles; this could not lead to dissipation of a planetary atmosphere. Hence, if the moon did not have enough of an atmosphere during this period, it could not have accumulated an atmosphere gradually.

At present, causes of tectonic processes and internal energy within cosmic bodies are not known. It is clear, however, assuming that thermal-conductivity coefficients remain the same, that the capacity of a large body to accumulate and conserve internal energy is greater than of a smaller body. These considerations appear to contradict the possibility that the moon could conserve the necessary capacity to undergo tectonic processes. If we bear in mind, however, the extremely low thermal conductivity of the moon's surface layers, the moon surpasses the earth in the ability to accumulate and conserve internal energy. Accordingly, orogenic processes may be taking place on the moon even more intensively than on the earth, at the present time. To present an interesting and somewhat paradoxical conclusion: the absence of atmosphere, which gives rise to a foamy surface structure, sharply reduces heat emission and implements accumulation of internal energy and development of orogenic processes.

Lunar topography has been carefully studied over a period of 200 years; yet up to the present time we have been unable to verify a single example of change in lunar relief. This does not contradict the conclusion as to possibility, even at the present time, of intensive tectonic activity on the moon. As a matter of fact, aside from planetary processes involved in the activity of water, air, and life, it would be very difficult for an observer on the moon to ascertain reliably the presence of orogenic processes on the earth. Since ancient times, many observers have pointed to possible changes occurring in certain lunar craters. Particularly interesting is a report of occlusion by haze of crater-bottom

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features. Unfortunately, these observations were visual and therefore not convincing; visibility of details on the lunar surface depends to a great extent on the aspect of solar illumination. Other factors, such as atmospheric conditions and quality of photography, may influence the value of an observation.

In October 1956, the first serious and objective basis for a possible haze occlusion of detail on the moon's surface was obtained by the astronomer Dinsmore Olter. Using the 60-inch reflector at the Mt. Wilson Observatory in California, he obtained a series of photographs in blue and infrared light, of Ptolemaeus, Alphonsus, and Arzachel craters. Because earth's atmosphere disperses light, photographs taken in blue light showed much less contrast than those taken in infrared light. Details of the bottom of Alphonsus crater, however, appeared to be very much faded; the investigation published by Olter convinced the author that this effect merited serious attention and, that gas may be escaping from the floor of Alphonsus crater.

The group of three craters mentioned, of which Alphonsus is the central one (fig. 1), is located on a meridian and almost in the center of the lunar disc. The group is of ancient origin; meridional fractures, developed after crater formation, cross the sector in which they occur. An interesting fracture bisects Alphonsus crater; also fissures and dark spots occur on its floor. The crater is approximately 120 km in diameter and its steep central peak is 1,400 meters above the crater floor. Ptolemaeus crater, located north of Alphonsus crater, is a typical large cirque having no central peak. Structure of the bottoms and walls of this crater group confirms a high degree of tectonic activity in this sector of the lunar surface.

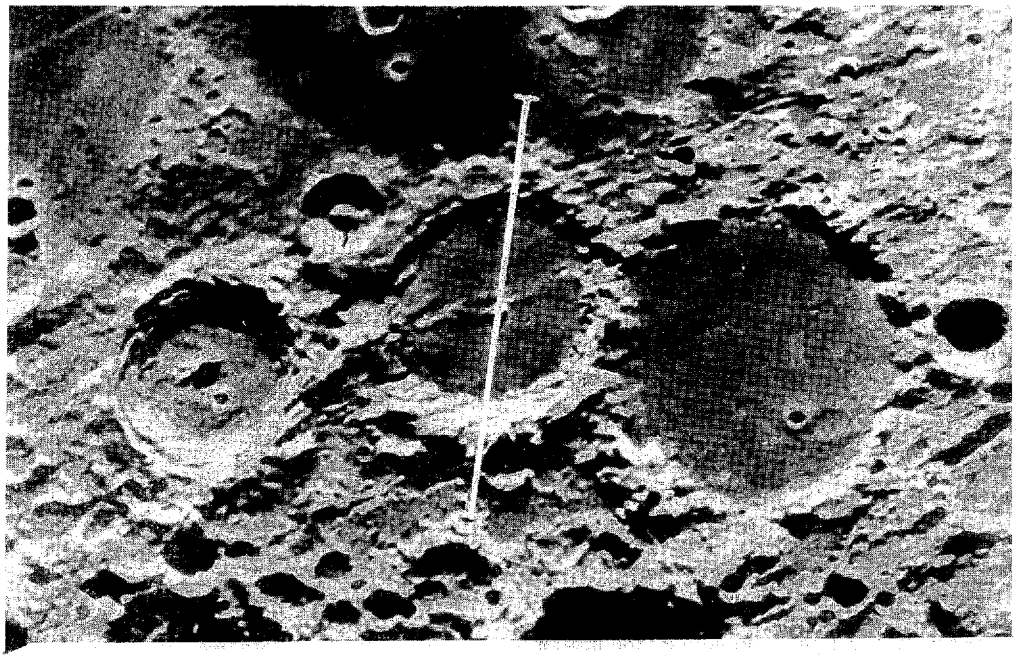

FIGURE 1. Alphonsus (center), Ptolemaeus and Arzachel craters. The white line through the central peak indicates the position of the aperture of the spectrograph.

Let us consider how the faded effect may have been produced by liberation of gases: The faded effect cannot be produced by the light dispersion in these gases; if this were the case, it would be necessary to have a gas column of about 10^{25} molecules per square centimeter (cm^2) of surface; that is, similar to earth's atmosphere. Or, if the gases in question fluoresce when exposed to hard solar radiation, a veil could be created by a gas column capable of absorbing all hard solar radition. The absorption coefficient of hard solar radiation, that is corpuscular, X-ray, and extreme ultraviolet radiation, would have to be very large. We may suppose then, that even a column of gas about 10^{15} molecules, or approximately 10^{-10} of the earth's atmosphere, would create perceptible fluorescence. Development of local atmosphere could be readily possible from the escape of gases in lunar craters. The only question remaining is whether or not the intensity of hard solar radiation is sufficient to create fluorescent radiation in the visible range of the spectrum, perceptible on the solar spectrum background usually reflected by the moon. It should be noted that fluorescence of this type can be produced not only by gases, but by minerals present on the lunar surface as well.

In 1955, the author used the spectral method to compare the Fraunhofer-line contours of solar and reflected-lunar spectra; direct proof of fluorescence in the ray system of Aristarchus crater, was obtained. The maximum intensity of fluorescence in the violet band reached approximately 15 percent of the light usually reflected by the moon. This result indicated the possibility of proving the existence of gas escape at the lunar crater floors by means of spectrum analysis of gas fluorescence.

In October and November 1958, V. I. Yezerky an astronomer at the Kharkov observartory, and the author undertook spectrographic investigation on Mars, using a 50-inch reflector at the U. S. S. R. Academy of Sciences' Crimean observatory. At the same time, the author decided to obtain systematically spectrograms, photometrically standardized, of certain lunar details; particularly those of Alphonsus crater. This was done to investigate further the question of gas escape. During observations, the spectrograph aperture was always placed on a direct ascent. On the photographs, linear dispersion amounted to 23 angstroms (A) per millimeter (mm) close to Hγ, with a scale of detail, about 10 seconds per mm. Normal exposure of Kodak 103 AF plates was from 10 to 30 minutes.

No special features were noted on the Alphonsus spectrogram until the night of November 2-3. On the morning of November 3, we obtained three spectrograms of Alphonsus crater; the spectrograph aperture traversed the crater along its diameter passing through its central peak (fig. 1). In obtaining the first spectrogram (at 0400 hours, Moscow time), the author was surprised, during a traverse of the area under examination, to see in the aperture the highly faded and unusually reddish hue of the central peak. Afterward, in accordance with the program, it was necessary to resume spectrographic investigation of Mars.

The second spectrogram of Alphonsus crater was obtained after an interval from 0600 to 0630 hours. As soon as the central peak of the crater appeared in the aperture, the author noted its unusual brilliance and whiteness. During this traverse, the author did not take his eyes from the telescopic sight, and noticed the sudden drop in the peak's brilliance to normal intensity. The exposure was stopped immediately and started again at 0630 hours, and was continued until 0640 with the aperture in the same position. The author did not attach much importance to visual impression; it was thought that all these special features were connected with changes in the quality of the image. In a somewhat unexpected manner, according to the spectrogram, all changes previously noted in visual observations were verified; they actually had occurred on the central peak of Alphonsus crater.

On the first spectrogram, the central peak was perceptibly weaker by violet illumination, compared to adjacent topographic details of the crater; this sort of thing is not usually observed on a spectrogram. Measurement of the print showed absorption to vary inversely with λ and the calculated total absorption obtained was equal to 15 to 20 percent in the visible spectrum. On the second spectrogram this absorption was not perceptible. Our attention, however, was attracted to the gas emission spectrum, which consists of several wide bands imposed on the normal spectrum of the central peak (fig. 2a). On the third spectrogram, the central peak appeared in its normal state (fig. 2 b). Therefore, gas liberation lasted not more than 2.5, and not less than 0.5 hours.

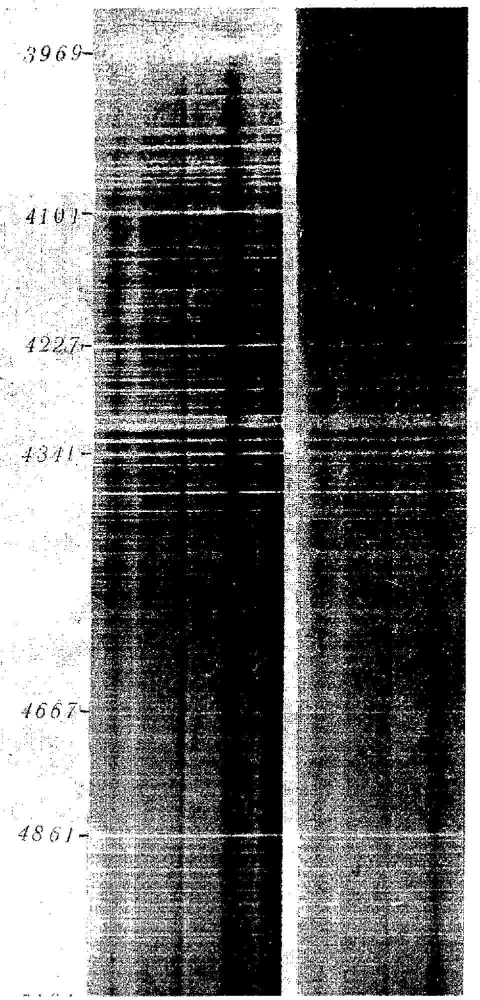

FIGURE 2. Spectrogram of Alphonsus crater left) 0600 to 0630 hours, November 3, 1958; right) 0630 to 0640 hours, November 3, 1958.

On the following night, November 3-4, we obtained two additional spectrograms of Alphonsus crater; the appearance of the crater was normal. By the evening of November 4, the last quarter of the moon had approached, rendering Alphonsus inaccessible to further observation. On the morning of November 3, 1958, Alphonsus crater, specifically the central peak, was the scene of volcanic activity. At first, some dust (volcanic ash) was ejected; then, as usual, gases were liberated. The gases probably escaped from magma rising to the surface; this magma must have contained gases absorbed at depth under high pressure.

The most characteristic feature noted in the emission spectrum of the central peak in Alphonsus, is the group of bands beginning at 4, 754 A and defined comparatively sharply toward the longer wave length region (fig. 2a). The brightness of these bands amounts to 40 percent of the normal brightness of the peak in the corresponding long wavelengths. It is noted that the imposed emission is shifted slightly toward the sun; the shift amounts to approximately 0.7 seconds, or about 1.5 kilometer (km) on the lunar surface. The shift is probably explainable in that hard solar radiation, causing the luminosity, could penetrate only an area of the gaseous column that was emitted from the center of the peak, and on the side exposed to the sun. We must suppose the processes causing gas luminosity to be similar to those of comets. Solar radiation evidently caused dissociation of complex parent molecules into optically active molecular residues (radicals) which created the observed spectrum. It is interesting to compare the surface brightness of the liberated gases to that of comets.

Near the time of full-moon phase, when the incidence of solar radiation is steep, reflectivity of the central Alphonsus peak is 0. 13; that is, almost twice the average reflectivity of the lunar surface. At the moment of observation, the altitude of the sun over the horizon of Alphonsus crater was only 18°. According to data collected by the Kharkov astronomer V. A. Fedorets, the reflectivity of the central peak at this solar altitude, is one-tenth that of the full moon. If we assume brightness of supplementary gas luminosity, taking an average over all wavelengths, to have amounted to 10 percent of the peak's brightness, then surface brightness of the observed gas luminosity is equal to one-fiftieth of the average surface brightness of a full moon. The brightness of the full moon is 5. 5 stellar magnitudes per square minute; that of the luminous gases is approximately 1 stellar magnitude per square minute; for a comet, however, this amounts to approximately 1/9 stellar magnitude per/sq/min.

The observed luminosity of the gases was 10,000 times more intense than that of a comet. This indicates that the quantity of gases liberated was more than sufficient for the absorption of all hard solar radiation. Luminosity of the gases in spite of their brightness, is barely perceptible near full moon when the sun is at a relatively high altitude; illumination would continue to be barely perceptible even if reflecting power of the moon were greater. We should remember that luminosity of volcanic gases may occur only when lunar detail is lit by the sun; therefore, this phenomenon could not be observed at twilight.

To obtain a clear idea of the emission spectrum, one must subtract systematically the brightness of the central peak and the adjacent sectors of the crater floor over the entire spectrum. Measurements of this type require great accuracy and are yet incomplete; nevertheless, certain conclusions can be drawn at this time.

In the bright group of bands beginning at 4,754 A and gradually weakening towards the violet side of the spectrum the Swan band, of the carbon molecule C_2, stands out as the main component. The distinct maximum on wavelength 4, 737 A corresponds to the beginning of the system of vibrating zones for this molecule. The existence of C_2 is confirmed by the presence of other, much weaker groups of the Swan band with maximums of 5,165 and 5,636 A. On this basis, the existence of the C_2 band in the liberated gases can be established. In the areas from Hδ to the line HCa^+ a system of weak bands belonging to the linear molecule C_3, are observed, analogous to those of the Swan band in a spectrum of a comet head. Characteristically different from comet spectra is the complete absence of the ultraviolet band CN 3883 A in spectra of escaping gases. Comparatively bright bands occur in the spectrum at wavelengths from 4, 600 to 4, 250 A; and at other wavelengths, a large number of weak bands. It has not yet been possible to determine the molecule which these bands describe. We should note that all bands of this spectrum are very diffused. The Swan band should be very sharp toward the longer wavelengths, but even these bands were diffused by approximately 5 A. It is most probable that this phenomenon is related to a process of the predissociation type; in general, the bands were observed only at the moment of development of the optically active molecular radicals from the complex parent molecules.

The observed phenomena, as a whole, indicate actual volcanic discharges to have occurred in the central peak of Alphonsus crater. It could not have been a weak gas escape from surface fissures, which was probably the phenomenon observed by Olter. Evidently, this conclusion is confirmed by a communication from the English observers P. Wilkins and F. Brion, that deals with the appearance of a small reddish spot around the south side of the Alphonsus central peak. These spots were observed on November 19, 1958; it was affirmed that they did not exist prior to November 1958.

It is possible that the phenomena described here may not be observed again for a long time; they indicate nevertheless, that the moon still has the internal energy necessary to undergo orogenic processes. The coincidence of the phenomena observed and the position of the central peak cannot be a matter of chance; these indicate the development of basic relief on the moon's surface to be endogenic, not due to meteoric impact.