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LUNAR COLOR PHENOMENA

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United States Air Force
Aeronautical Chart and Information Center
St. Louis, Missouri 63118

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ABSTRACT

The USAF Aeronautical Chart and Information Center (ACIC) is producing a coordinated series of charts of the moon. One phase of this program is to visually observe areas being charted through long focal length refractor telescopes over considerable lengths of time. During the course of this operation at the Lowell Observatory, Flagstaff, Arizona, red coloration appeared in the region of the Aristarchus Crater October 29, 1963 and again November 27. 1963. Opinions as to the cause of the color phenomena have been received from a number of recognized lunar authorities. These opinions are divergent in varying degrees. It is the intent of this paper to record two events of possible scientific significance without hypothesis as to the cause.

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OBSERVED LUNAR COLOR PHENOMENA

On two different occasions, reddish spots near the lunar crater Aristarchus were detected by ACIC members of the Observation Section of the Lunar and Planetary Branch, Lowell Observatory, Flagstaff, Arizona. The initial observations were made by Messrs. James Greenacre and Edward Barr, observers engaged in charting the lunar surface, specifically, the lunar chart identified as "Aristarchus, LAC 39." Greenacre had been making a detailed study of the Aristarchus region over a period of eight months prior to the discovery of the first observed areas of unusual color. Barr had been observing over a three-month period. The second occurrence was also observed and verified by Dr. John Hall, Director of Lowell Observatory; Peter Boyce, Perkins Observatory; and Fred Dungan, ACIC scientific illustrator and observer of the Observation Section. William Cannell, Chief of the Observation Section, was not present for either of the observations. The sequence of events and actions that took place during the sightings are presented as a factual recording of this suspected scientifically significant phenomena.

FIRST OBSERVATION

Early in the evening of October 29, 1963, Messrs. James Greenacre and Edward Barr started their lunar observations on the Lowell 24-inch visual refractor. This telescope is equipped with a zoom lens that has a power range from 400 to 1100. A No. 15 Wratten filter had been inserted at the base of the tube just ahead of a prism system that reflects the image to the eyepiece.

Observations were confined to the western edge of lunar chart LAC 39 (Fig. 1). In particular, they were in the area encompassing the craters Aristarchus and Herodotus and Schröter's Valley. References were made to special drawings that had been prepared of Herodotus and Schröter's Valley and also a proof copy of LAC 39 which included the final drawing for the Aristarchus crater.

When Greenacre started to observe at 1830 MST (0130 Universal Time, October 30, 1963), he concentrated on the Cobra Head of Schröter's Valley. The objective was to refine this area on the chart by additional observation. The morning terminator was at 59°54' West, which gave a high sun over the area, but with a favorable libration it permitted looking into the interior of the features that were of especial interest.

The seeing at first was rated about 2 on a scale of 10. In the next few minutes it improved somewhat with moments of 3 and 4 seeing, at which time the eyepiece was zoomed to about 500 power. At 1850 MST a reddish-orange color was noted over the dome-like structure on the southwest side of the Cobra Head. Almost simultaneously, a small spot of the same color was observed on a hilltop across the valley, (Fig. 2). Within about two minutes, these colors had become quite brilliant and had considerable sparkle with a downward flowing motion toward the north and east.

Figure 1. Location of the observed Lunar Phenomena identified in relation to the Aeronautical Chart and Information Center Lunar Chart, Aristarchus LAC 39.

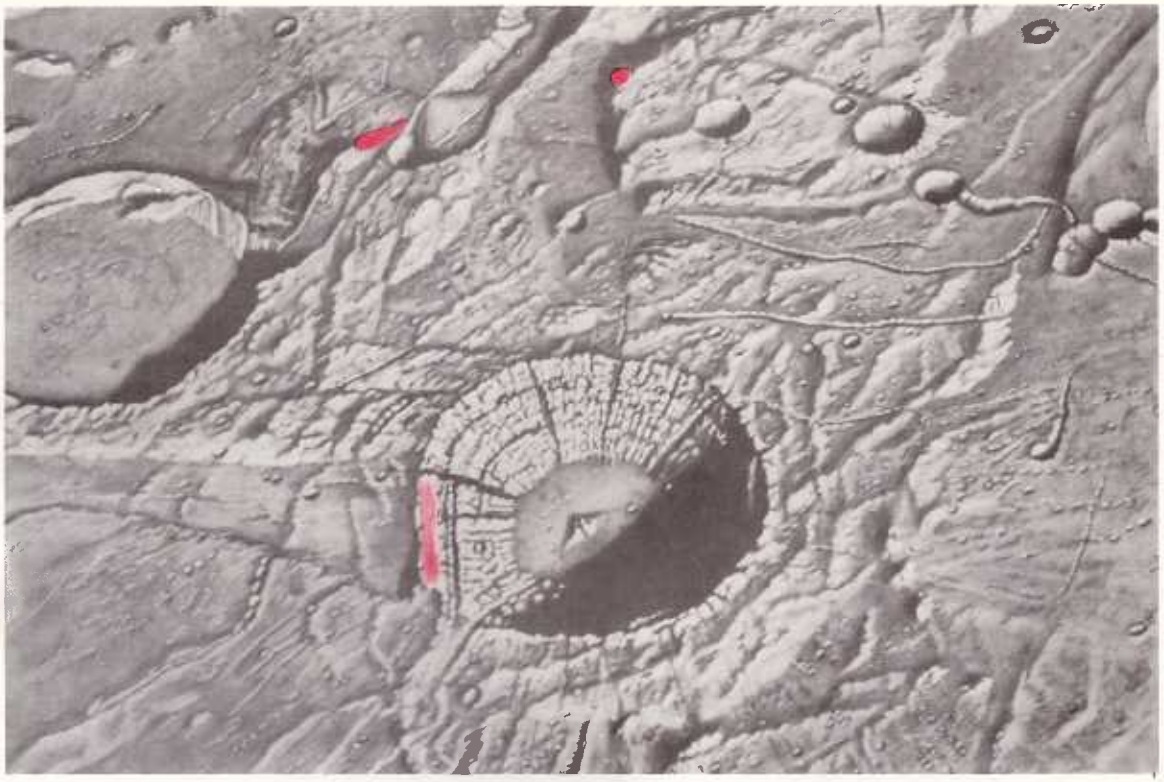

Figure 2. Lunar color phenomena observed October 29, 1963 by James A. Greenacre and Edward Barr. Drawing by Patricia M. Bridges.

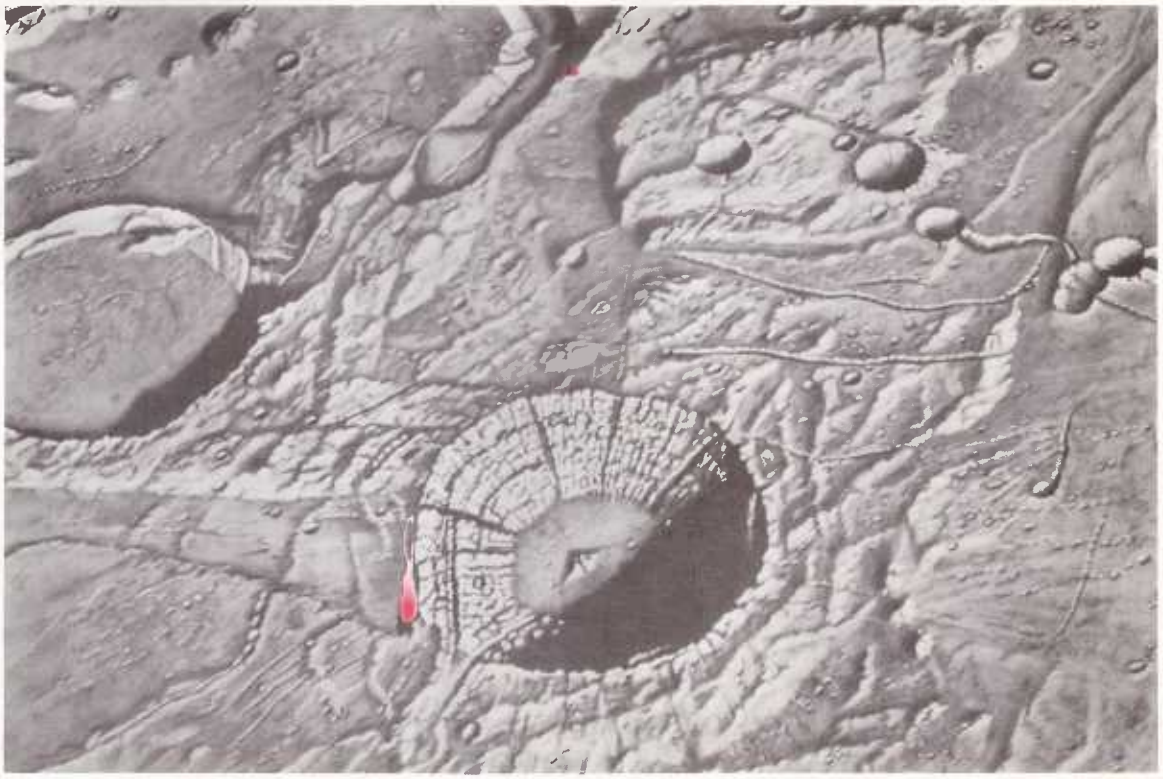

Figure 3. Lunar color phenomena observed November 27, 1963, by James A. Greenacre, Edward Barr, Fred Dungan, and Dr. John S. Hall, director Lowell Observatory. Drawing by Patricia M. Bridges.

Greenacre immediately called Barr to share this observation with him. His first impression of the color was a dark orange. The next step was removal of the No. 15 Wratten filter. Without the filter the color remained the same, but was brighter and had more sparkle. Both observers agreed that at this time the color without the filter was reddish-orange.

Just prior to removing the filter after the first observation, the urgent need to capture the phenomena on film was realized; yet Greenacre was not satisfied that phenomena were occurring. He felt that removal of the filter would indicate to him whether it was causing some unusual effect. The observations without the filter began to confirm in his mind the fact that changes were taking place, but he thought it necessary to scan the entire plateau area.

No other color spots were noted until 1855 MST when an elongated, streaked pink color along the southwest interior rim of Aristarchus was observed. No other color could be seen on the interior or exterior of Aristarchus. Again, observation was made both with and without a filter. The only change seemed to be a somewhat brighter color without the filter. The color along the rim of Aristarchus did not sparkle like the other two observed spots.

The field of view was large enough to have all three of these areas in sight at the same time. At approximately 1900 MST, Greenacre noticed the spots of color at the Cobra Head and on the hill across the valley had changed to a light ruby red, yet their density and sparkle was still sufficient to block out the surface underneath. He had the impression that he was looking into a large polished gem ruby but could not see through it. Barr's impression of the color at this time was that it was a little more dense than Greenacre had described it and it still retained some of the reddish-orange but not as prominently as earlier.

By 1905 MST, it was apparent that the color was fading. The areas in which the phenomena took place were annotated on the drawing of LAC 39. Greenacre was able to observe the color at the Cobra Head and on the hilltop across the valley gradually fade until 1910 MST, when no color could be detected and everything seemed to appear the same as before these observations were noted. The elongated streaks of pinkish color on the southwest rim of Aristarchus were still evident, although fading. He observed these streaks without a filter until they disappeared at 1915 MST and the full brightness of the rim was restored.

The colored region near the Cobra Head appeared to be oval, covering approximately 1.5 x 5 miles. The length of the oval was oriented northwest to southeast. On the gridded sheet E3-a of the Orthographic Lunar Atlas by D. W. G. Arthur and E. A. Whitaker, the center of this area had the coordinates: Xi = -.692, Eta = +.412.

The second colored area on the hilltop across Schröter's Valley was much smaller, about 1.5 miles in diameter, and centered on Xi = -.681, Eta = +.426.

The third area, pink streaks on the rim of Aristarchus, extended about 11 x 1.5 miles, from -.682 to -.684 in Xi and from +.392 to .396 in Eta.

Although the 24-inch refractor is equipped with a 70mm camera, it was out of focus, having been left that way from the previous night. Since several minutes are usually required to focus for a sharp image when the seeing is 5 to 6, Greenacre was extremely reluctant to cease his visual observations and try to focus on the unsteady image. Having never observed such phenomena, he was disappointed to see them fade before he could use all of the facilities at his disposal.

SECOND OBSERVATION

On the evening of November 27, 1963, Barr was again observing the Aristarchus region (LAC 39), using the Lowell 24-inch refracting telescope. Observation was started at 1700 MST. At 1730 a pinkish color streak began to appear on the southwest exterior rim of Aristarchus, (Fig. 3). Within a minute or two the color grew in intensity to a brighter pink or light red.

Using the experience gained from the first sighting on October 29, 1963, Barr immediately started to scan bright areas north and south of Aristarchus. The purpose of this scanning was to determine whether a similar color was noticeable in other places. If he had found this to be so, he would have simply attributed it to atmospheric dispersion. Like the October sighting, this was not the case as no color could be detected anywhere else. Having satisfied himself that there was another probable phenomenon taking place, Barr immediately started calling other observers.

The first to arrive was Fred C. Dungan, a scientific illustrator. Dungan has had a good many hours of telescopic observing and is highly qualified in interpreting color and forms. He is also very familiar with the Aristarchus plateau and its many features. Dungan had no difficulty in seeing the color and agreed with Barr that it was pinkish-red. At 1745 they noticed that a spot of color near the southern extremity of the pinkish-red streak was becoming more intense with a reddish-orange cast. This spot, some two or three miles in diameter, is a high point on the south rim of Aristarchus. The rest of the color remained a pinkish-red streak and extended some 12 miles northwest just along the upper, exterior rim.

James Greenacre arrived at 1730 and was able to observe the color which seemed to still have the same intensity as observed a few minutes earlier by Barr and Dungan. Immediately following verification of the color, Greenacre called Dr. John Hall, Director of Lowell Observatory. Dr. Hall's residence is only a short distance from the 24" dome, so he arrived at the telescope in less than five minutes.

Dr. Hall had no trouble in seeing and verifying the color. As a matter of personal satisfaction and a further check on his observing,

he pinpointed the area on a photograph and on a copy of the LAC 39 chart. The other three observers agreed on the position.

This feature was somewhat larger than that observed on 29 October, being about 12 miles long and one and a half miles wide. The markings coordinates were determined with the aid of the Orthographic Lunar Atlas; it extended from Xi = -.682 to -.685 and from Eta = +.391 to +.398.

Following the visual corroboration, Greenacre started taking black and white pictures at 1806, using the 70mm Hulcher camera. The film used was Panatomic X. The first two bursts were made at slow cine speeds of five frames per second intermixed with short time exposures of one-half and one second. During the time taken for the first two bursts, visual monitoring indicated the color was at its peak intensity.

The second burst was completed at 1809, at which time visual observations were continued. Dr. Hall and Dungan were the first to share the eyepiece. Shortly after 1809, they detected a small reddish-orange spot on a hill on the east side of Schröter's Valley. Greenacre and Barr were unable to make positive identification of this small color spot. Dungan located it on the LAC 39 chart and it proved to be very close to a small spot observed by Greenacre and Barr on 29 October 1963.

During the time that Greenacre was not observing with the 24" refractor, he continued observing with the 12" refractor. As others present left the eyepiece of the 24", they also used the 12". At no time was any color detected using the smaller aperture.

It was evident by 1815 that the color was subsiding in intensity. At 1823 another burst of cine and time photography was taken. The color at this time was clearly observed, but its intensity had dropped some 30 to 50 percent. Visual observations were continued until 1839 when it became evident to all four observers that the color was rapidly fading.

The reddish-orange spot at the southern limit had changed to pink, and the remaining streak was much fainter. Another burst of photography was then taken. Directly after the burst, visual inspection indicated there was little or no color remaining. All four observers took turns observing until 1845 when it was agreed there was no trace of color left. Additional cine and time photography was taken at this time and intermittently until 2110.

A short time after Dr. Hall had made his confirming observation, he telephoned to the nearby Perkins 69" reflector (recently transferred from Delaware, Ohio). He gave Peter Boyce and another observer a description of the color phenomena being observed at Lowell and requested that Boyce try to make a spectroscopic scan of the area. Dr. Hall could not pinpoint the area for Boyce as he did not have a suitable chart or photograph available for positioning.

Unfortunately Boyce had other instruments on the telescope and explained it would take quite some time to remove them. Dr. Hall suggested that he make visual observations of the Aristarchus rim and adjacent areas. Boyce readily agreed to this and within fifteen minutes had called Dr. Hall and confirmed the sighting of the reddish-pink color on the southwest exterior rim of Aristarchus. The following day, 28 November, Boyce located the position of the color he had observed on a LAC 39 chart. It agreed with the position observed and plotted by the observers at Lowell.

All of the film taken was developed on 28 November 1963. Time and temperatures were carefully controlled. Later black and white prints were made using exactly the same exposures and developing times for all frames printed.

A careful study was made of the developed film and prints. No visual evidence of the color could be determined. Densitometer traces made at the Geological Survey's Astrogeological Laboratory also failed to produce any conclusive evidence of the phenomena.

UNPUBLISHED OBSERVATIONS

This portion of the observations has not been published for various reasons, the most important being that there is doubt as to whether they are a part of the phenomena. They do belong in this report as a matter of record and may yet prove to be of scientific value.

After the reddish-pink, reddish-orange, and ruby red colors disappeared in October and November, Barr and Greenacre observed a violet or purple-blue color form on the west side of Aristarchus and gradually spread in a circular pattern around to the north side. On 27 November the color was very deep violet, particularly on the west. A less deep violet was observed in the depressed area at the base of the east side. This color became strong and persistent from 2200 to 2300. At the same time a strong blue color was forming within Aristarchus. The blue within the crater appeared as a haze but not opaque enough to obscure the floor although it dimmed it considerably. The floor appeared quite dark through the blue haze. These colors remained visible until the moon was too low for continued observation. On the night of 27 November the colors appeared brightest from 2200 to 2300, whereas in October they were brightest from 2400 to 0100, but never as vivid as in November. After 2300 the seeing began to deteriorate and it was difficult to judge color intensity because of frequent "washing out" of the image. It is interesting to note that the blue and violet colors sighted on 29 October and 27 November did not appear until about three hours after the reddish colors disappeared.

A blue haze or purple-blue haze has been reported by numerous observers in and around Aristarchus and other craters for many years. It is not uncommon to see a blue haze within Aristarchus, but it is uncommon to see the blue haze on the interior of the crater partially circled by a deep violet haze on the exterior.

OTHER OBSERVATIONS IN THE ARISTARCHUS REGION

The first recorded activity in the Aristarchus region was made by Sir William Herschel in 1783 when he observed the crater and believed it to be an erupting volcano. He again observed in 1787 three bright spots on the earthlit part of the moon. His positioning, however, of these spots 3' 57" from the northern limb may eliminate them as being on Aristarchus.

Since the time of Herschel many observations of flares, bright spots, mists and clouds have been reported. The following observations are some of those made since 1900 in the Aristarchus-Herodotus-Schröter's Valley complex. Some of the comments received at the Lowell Observatory, speculating on the cause of the phenomena are also included.

PICKERING, W. H., (American Astronomer, 1858 - 1938)

At the turn of the century, Pickering reported a phenomenon in the Aristarchus region which he interpreted to be an active volcano. He made a sequence of drawings at various times depicting the apparent vapor column. A later inspection of the drawings revealed that considerable variations had occurred in the outline of the formation. These changes were ascribed to be detectable by anyone during favorable seeing conditions with a six-inch telescope or one of larger diameter.

> NOTE: Pickering does not mention color. Lowell observers have concluded that colors they have observed cannot be seen with a six-inch telescope.

GOODACRE, WALTER, (British Astronomer, 1856 - 1938)

Goodacre has observed and reported in 1931, a bluish glare on the inner E. (W. astronautically) wall of Aristarchus just after sunrise. It was also reported by Molesworth and others. Inasmuch as reflecting telescopes were used for these observations, the observed glare could not be attributed to secondary spectrum.

WILKINS, W. H., (Member of B.A.A.)

In the Journal of the British Astronomical Association, 1945, Wilkins reported observing a "bluish glowing of streaks on floor (Aristarchus crater) and a mountain mass delta."

THORNTON, F. H., (British Observer)

A lunar phenomenon was reported by F. H. Thornton on February 10, 1949. Using an 18-inch reflecting telescope at his home in Norwich, England, he detected a diffused patch of thin smoke or vapor emanating from a point on the east side of Schröter's Valley near the Cobra Head and spreading out onto the adjacent plain. Definition was reported as very good in the entire valley except for that area where the patch occurred; there the detail was indistinct and hazy.

KOZYREV, N. A., (Soviet Astronomer)

In 1955 the Soviet astronomer, N. A. Kozyrev detected through low-dispersion spectrograms emission lines in the central part of Aristarchus. He later identified these emission lines as molecular hydrogen gas and believes the gas must have escaped from the moon. In a letter to Lowell Observatory dated 28 December 1963, Kozyrev says concerning the 29 October 1963 observation, "I have no doubts that the observed phenomena were the out-break of gas which can be identified, most probably, with molecular hydrogen, as its spectrum has many bright bands in the red and orange region."

ALTER, DINSMORE, (Director Emeritus, Griffith Observatory)

Alter, in a letter to ACIC dated 18 November 1963 reported, "The only place on the moon where I ever saw color was within Aristarchus." The following notes were entered in his observing log book on 22 January 1959:

"Visual - Interior of Aristarchus is a light brilliant blue!! Later in night it was white again. The observation was made with the Mt. Wilson 60" and a power near 700. Seeing was only 2. Note about plate: Beautiful plate despite rated low seeing."

Alter commented that a rated seeing of 3 on the Mt. Wilson scale was considered a "good average" night - seeing was seldom rated more than 4 or 5. Time of observation was during a plate exposed on the moon at 10:20 p.m., Pacific Standard Time, on January 22, 1959.

DOHERTY, BERNARD T., (Member of B.A.A. Lunar Section)

In a letter to ACIC at Lowell Observatory dated 5 January 1964, Doherty describes a recently observed coloring in the crater Aristarchus confirmed by a total of four observers. All agreed the color was purple-blue. An accompanying sketch outlined the area in which the purple-blue color was observed.

SWINGS, POL, (Belgian Physicist)

Dr. Harold C. Urey, University of California, forwarded a letter from Pol Swings of the University of Liege, Belgium to Lowell Observatory. Swings wrote about the observed color phenomena, "If this reddish color is real, the brightness cannot be assigned to the Swan bands of C_2 (as in the case of Kozyrev's observation). On the other hand it may possibly be due to NH_2 fluorescence (α - band of Ammonia), as in the comets. The strongest NH_2 band lies near $\lambda 6300$. Liberation of ammonia from the moon would, just as in comets, give rise to NH_2 radicals which would become excited by fluorescence (also in comets). If ammonia really erupts from the moon, it would indeed, as Time Magazine concludes, "present one more difficulty for would-be lunar explorers."

CONCLUSIONS

An evaluation of the reliability of the observers and the thoroughness with which verification was pursued leads to the conclusion that a real phenomenon was observed on two separate occasions.

Periodicity of occurrence is indicated through the fact that both observations were made under similar conditions. Sightings were made less than two days after the Aristarchus region emerged into sunlight under favorable librations and with the moon at a near-earth position, approximately four days before perigee.

Observations will be continued whenever conditions are duplicated in the hope that additional evidence will result. Experiments with color film made by the Observation Section indicate that any future color phenomena can be photographed although there is no evidence that black and white film will respond sufficiently to the color to produce a discernible contrast.

The two observed lunar phenomena have been recorded at Harvard Observatory through telegrams dispatched by the Lowell Observatory on 21 October 1963 and 3 December 1963.

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