MANIFESTATIONS AND POSSIBLE SOURCES OF LUNAR TRANSIENT PHENOMENA (LTP)*

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Abstract. Several different manifestations of lunar transient phenomena (LTP) have been reported. These include: (1) brightenings – both sudden and slow, (2) reddish – both bright and dull, (3) bluish – both bright and dull, (4) fairly abrupt dimmings or darkenings, and (5) obscurations, which may be accompanied by any of the other four manifestations. Approximately 200 lunar features exhibiting such anomalies have been reported at least once, but 80% of all observations are found in less than a dozen sites and 60% are found in about one-half dozen sites.

An observing program is being conducted for the Association of Lunar and Planetary Observers which is designed to monitor the LTP sites, the seismic epicenter sites and non-LTP comparison sites. It addresses the 'brightenings' category of observations and is designed to establish normal brightness of each observed feature for all phases of a lunation. It also seeks to establish a quantified 'seeing' scale. About one-half dozen observers have reported albedo measures (estimated from an albedo scale set up by each observer).

The most extensive new data on albedo versus age (phase of Moon) are for the crater Dawes. Several LTP effects have been discerned in Dawes.

In addition, seeing estimates, based on the behavior of a star's diffraction disk, provided some unexpected results when disk behavior is compared with other subjective estimates of seeing.

1. Introduction

Lunar Transient Phenomena (LTP) are temporary anomalies observed on the Moon by terrestrial observers and reported for the past 400 yr, antedating the invention of the telescope. Most observations have been made during visual telescopic scrutiny of the Moon. However, permanent records including spectra, photographs, photoelectric photometer tracings, and polarization have been obtained. A few observations have been reported from unaided vision!

The phenomena have been manifested in several ways, viz., brightenings, darkenings, color (mostly reddish or bluish, but also involving yellows, oranges, greens coppers and browns), gaseous (where descriptions imply some medium of gas, dust, or gas and dust), and starlike points (which are really one of the brightenings manifestations). The brightenings are of several types; flashes (rise time of $<\frac{1}{4}$ s of time), sudden (rise times of 1–5 s), brighter than normal; and the starlike points that are just there but not usually seen to suddenly appear (Cameron, 1972a).

2. Distribution of LTP Sites

In the catalog being compiled by the author, which will contain >1500 positive and >300 negative (normal) reports, 195 lunar features have been cited as exhibiting

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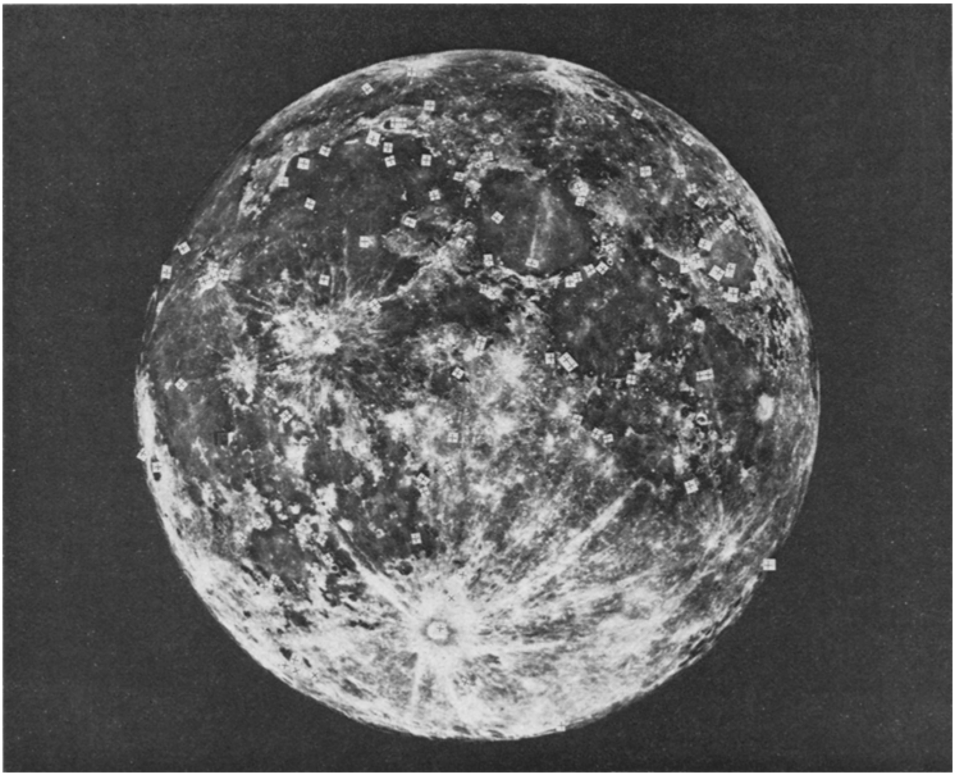


Fig. 1. Mount Wilson full Moon photograph with the Lunar Transient Phenomena (LTP) sites superimposed as crosses. Note the non-random distribution with affinity to the edges of the maria and paucity in the highlands.

anomalies. About 80 of these have been reported in the last five years. Many reports are highly suspect and probably not of real lunar phenomena. If these are neglected, then the number of sites of probable real phenomena is about 100. Of these 100 about 12 contribute 80% of the reports, with about six of these contributing 60%, and one feature (Aristarchus) contributes 33% of all reports. The distribution of these approximately 100 sites is shown in Figure 1. It is rather apparent that their distribution is non-random. In fact, the LTP sites have a strong preference for the edges of the maria (in and outside) and there is a decided paucity of them in the north and south highlands. The distribution is strongly suggestive of a relationship with dark, smooth material – known now to be volcanic. It implies internal activity at the LTP sites. Their distribution (Figure 1) differs from the seismic zone distribution with no coincidences between the most active LTP sites and the 26 seismic sites (Latham *et al.*, 1973) or the later 42 sites (Lammlein, private communication). Comparing the 100 LTP sites and the 42 seismic sites there are only two or three coincidences and these are with minor LTP sites. If dark-haloed craters (Salisbury *et al.*, 1967), sinuous rilles (Lingenfelter *et al.*, 1968), ring dikes (Cameron and Padgett, 1974), domes

(Delano, 1970; Westfall, 1971), and radon emission sites (Gorenstein *et al.*, 1974) distributions were added, all of which show similar marial edge affinities and avoidance of highlands, volcanic implication is overwhelming. The discovery of radon indicates present activity. It appears that many, probably most of the transient phenomena are of internal origin. Since few or no permanent changes have been observed around sites after LTP, the sources are not volumetrically extensive enough to be volcanic in nature, but are more probably a gentle degassing from the Moon. This distribution of the sites suggests that these areas of the maria are the weakest areas, containing many faults, fissures and rilles which could feed or affect the LTP sites and effect release of gas.

Several possible causes of LTP have been suggested: (1) tidal (Green, 1965), (2) low-angle illumination, including two other sunrise effect hypotheses (Blizard, 1969; Sidran, 1968), (3) magnetic tail effects, (a) magnetopause (Speiser, 1967), (b) bow-shock front (Cameron, 1964), and (4) direct solar plasma effects (Kopal, 1966). Cameron (1972a) statistically analyzed $\sim$800 LTP reports with respect to the hypotheses and discussed the implications of the analyses. Surprisingly, results on tidal effects differed from previous analyses (Burley and Middlehurst, 1966), showing no apogee effect and a spread in their perigee peak of $\frac{1}{10}$ of an anomalistic period to $\frac{1}{2}$ a period. Also, when the ratio of Observed to Expected (O/E) was compared the ratio dropped from 1.9 for Burley-Middlehurst's 145 observations to 1.3 for Cameron's 759 observations. Other hypotheses correlated as well or better than the tidal hypothesis, in the order of sunrise, magnetic tail, tidal, and solar.

3. The LTP Observing Program of the ALPO

When the author was appointed Lunar Recorder for LTP for the Association of Lunar and Planetary Observers (ALPO), it afforded an opportunity to conduct a program that would help to obtain data which did not contain the observational biases present in past reports. It is also desirable to try to standardize observing procedures to render the observations more homogeneous, compatible, and comparable with each other. A program (Cameron, 1972b) for observations was devised for observers who, with only a telescope and no auxiliary equipment, could contribute significant data. Specifically, the program addresses mainly the large category of observations called brightenings. This is a relative term for which we do not have any normal or base for comparison. We would like to know if it really was brighter (or conversely, duller) than normal and by what amount.

The objectives of the program are to: (1) monitor the Moon to observe temporary anomalies. (2) establish and quantify normal aspects of features under all illumination conditions – particularly the normal brightness (albedo) at all ages, (3) quantify seeing conditions based on the behavior of the diffraction disks of stars near the Moon, and (4) distribute observations throughout all ages of the Moon.

In order to assure that the 100 or so sites would all be observed, four LTP sites, one non-LTP comparison site and one seismic zone (Latham *et al.*, 1973) were assigned to each observer. Enough observers responded to the call for participants that all features were assigned and a few features could be assigned to more than one person. This might achieve independent confirmation, or at least provide checks and interrelations on observations. For each feature, the observer was to choose several permanent points within or on the feature and one point on the nearby plain north or south of it (so that it would have the same relationship to the terminator as the feature). He might choose the cardinal points on the wall, one or two on the floor, and one on the summit of the central peak.

To standardize observations as to the normal aspects of the features, especially with respect to albedo, the following procedure was instituted to establish an albedo scale. Elger's (1895) albedo scale with examples of features for each half step (0–10) was provided to each observer. He was then to observe at full moon (true albedo), using the eyepiece most frequently to be used for lunar observations, matching each half-step of albedo in Elger's scale with a gray. These grays may be made by pencil shadings, exposed film or paper, photographic wedges, etc. After the scale is set up, then at each observation, he matches each of his points to the nearest half-step (or interpolates) in his scale. The observer should observe his features at least twice a night, separated in time by at least 10 min, preferably about $\frac{1}{2}$ hr. It is anticipated that albedos will change throughout a lunation. If a point is in shadow, it should be of albedo 0, unless there is an anomaly in which case it might be grayish or brownish, etc. At low Sun angles it might be estimated as a lower albedo than at full-Moon, e.g. With enough observations, a table of albedo measures for each day of age (eventually, each degree of colongitude) can be constructed. Thus, we can get a truer picture of what the normal feature is like. A sample chart is shown in Table II and will be discussed later.

It is desirable to quantify the seeing conditions. This has been a very subjective quantity in the past, yet it may be a factor in explaining some of the lunar phenomena. In order to exploit this possibility, the following procedures are suggested for the observer.

(1) Stop the clock drive and set the telescope on a star near the Moon.

(2) Rack the eyepiece (always in the same direction and the same amount; e.g., clockwise, $\frac{1}{8}$ turn).

(3) Set the star's disk at the exit edge of the field of view (FOV). Let the image drift out, timing the disappearance.

(4) Set the star's disk at the opposite edge of the FOV and time the drift across the FOV. These two drift measures can be converted into arc measures for diameters.

(5) With the clock drive turned on, set the star's disk at the edge of the FOV and estimate the amount of excursion of the image perpendicularly inward from the edge, in terms of a fraction of the FOV; e.g., $\frac{1}{20}$.

(6) Time the interval, in seconds, between successive excursions.

(7) Observe the pulsation of the star disk and estimate the ratio of the size of the largest disk to the smallest; e.g., 3:1.

(8) Time the interval between pulsations. The ratio between disks will give a measure

of the amplitude and the interval between blow-ups will give a measure of the wavelength of the disturbing atmospheric waves. The excursions are caused by one layer of air and the pulsations by a different layer. The amount of excursion will give the amplitude and the interval between excursions will give the wavelength of that layer of disturbing air.

LTP DATA SHEET RECORD

Date
Time of observation (UT)
Name, and location within or around, of formation
Selenographic position (IAU – where Mare Crisium is in the east)
Altitude of the Moon
Phase of the Moon
Color – variations
Shape – variations
Motion – variations
Brightness – LTP albedo; normal albedo; nearby plain albedo
Duration
Location of observer
Name of observer
Seeing conditions:
  Star diffraction disk: ratio of largest to smallest diameter
    drift time
    drift time across FOV
    excursion: amount in fraction of FOV
      interval between excursions
  Seeing rated: excellent, very good, good, fair, or poor; or on scale 0–10
  Transparency: faintest magnitude visible to naked eye
  Sky conditions
Telescope: aperture, power, kind,
Others called
Remarks and sketch

Fig. 2. Sample reporting form to be used when reporting on observed LTP.

(9) Estimate the seeing by the observer's old method; e.g., excellent to poor, or 0–10 as on the Antoniadi scale, etc.

(10) Estimate the sky transparency by giving the faintest magnitude stars seen with the unaided eye.

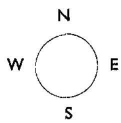
These observations are to be made prior to observing the Moon, but repeated after an LTP has been observed, at the end of the LTP.

Observers are to scatter their observations through all ages of the Moon. If an LTP is observed he should pay minute attention to details. He should note if there are variations; e.g., motions, pulsations, sparkling, etc., and, if so, he should time the variations. He should note if there is color, and if so, closely identify the hue – by color chart preferably. He should note if there is obscuration or not, comparing it with surroundings and particularly with features at the same distance from the terminator. If he has filters he should examine it through them and note its appearance in each. Do the filters eliminate motions (particularly scintillations or sparkling)? The British

Astronomical Association has an LTP program going also with many of the observers using a filter blink technique based on the original Trident Moon Blink (Final report, 1966). Fitton (1973) has devised a technique that determines the nature of the phenomenon (luminescence of surface materials, or gas) if filter effects are reported.

Two reporting forms are provided. One is for LTP and this is to be sent to the author immediately after observation. The other is for normal (negative) observations and these are to be sent in monthly. Examples are shown in Figures 2 and 3 respectively.

Negative (Normal) Observations:

Indey of Points: →


Telescope (kind, aperture, power):
Feature:

Point ↓ / Time→	UT	UT	UT
A			
B			
C			
D			
E			
Nearby Plain			

Diffraction disk FOV drift rate:
Diffraction disk drift rate:
Diffraction disk ratio (largest to smallest):
Excursion fraction (of FOV):
Terminator features:
Field of View (FOV) features:
Altitude of the Moon:
Time interval between blow-ups:
Time interval between excursions:

Fig. 3. Sample reporting form to be used when reporting normal aspects and albedos of permanent, chosen points to monitor.

Active participation in the program has been disappointing with only about ½ dozen observers reporting the desired information. These observers though, over the past two years, have demonstrated the feasibility of the program and that its objectives can be met. Table I lists the most active observers and the number of observations contributed by each.

TABLE I

Albedo observations from the first two years of the ALPO program

Observer	Location	Telescope	No. nights of obs. reported	Total indiv. meas. reported	No. points in each feature
B. Frank	Hopkins, Minn.	6L, 190X	26	531	3
J. Galgocy	Philadelphia, Pa.	2R, 40X	10	387	5
R. Hill	Greensboro, N. Car.	6L, 2R, 10L	19 (1 pos., 18 albedos)	477 (1 pos., 422 abedos)	6
T. Lynch	Pittsburgh, Pa.	6L, 202X	8 (5 albedos)	401 (233 albedos)	8
A. Porter	Narragansett, R. I.	6L, 100, 193X	68 (3 pos., 67 albedos)	3199 (38 pos., 3189 albedos)	6
T. Traub	Warren, Pa.	8L	3	41	4
			134 (4 pos., 129 albedos)	5036 (39 pos., 4803 albedos)	

A. Porter

Crater	Coord. λ	Coord. β	No. indiv. meas.	Remarks
Dawes	26°E,	17°N	725 (715 albedos, 25 positive)	
A16 Seismic Zone	11 E,	6 N	420	(between Ariadaeus and Agrippa)
Godin	10 E,	2 N	453 (10 positive)	
Clavius	12 W,	58 S	660	
Parry	16 W,	7 S	391 (3 positive)	(non-LTP comparison site)
Lansberg	26 W,	1 S	550	

Positive = LTP reported; albedos = albedos reported; L = reflector; R = refractor; X = eyepiece power.

4. Albedo Chart Analysis

The most active observer, Mr Porter, has contributed enough observations that I think we can establish the normal albedo appearance for a complete sunlit lunation for his features. Observers are asked to look for their features in the ashen light also. Table II is the chart constructed that includes all the observations for the crater Dawes. Figure 4 is an Orbiter photograph of the crater. From Table II we can deduce a number of things. These and others' data have been analyzed in terms of the various hypotheses (Cameron, 1974) but will not be discussed here. The albedo measures during one night's observation are separated by commas and different nights or observations are separated by semi-colons. The averages were computed using all measures. The averages designated 'lunation average' are the means of the averages over a lunation for each point. The circled measures are ones I suspect of being abnormal, thus constituting possible anomalies. I arbitrarily consider that a difference of

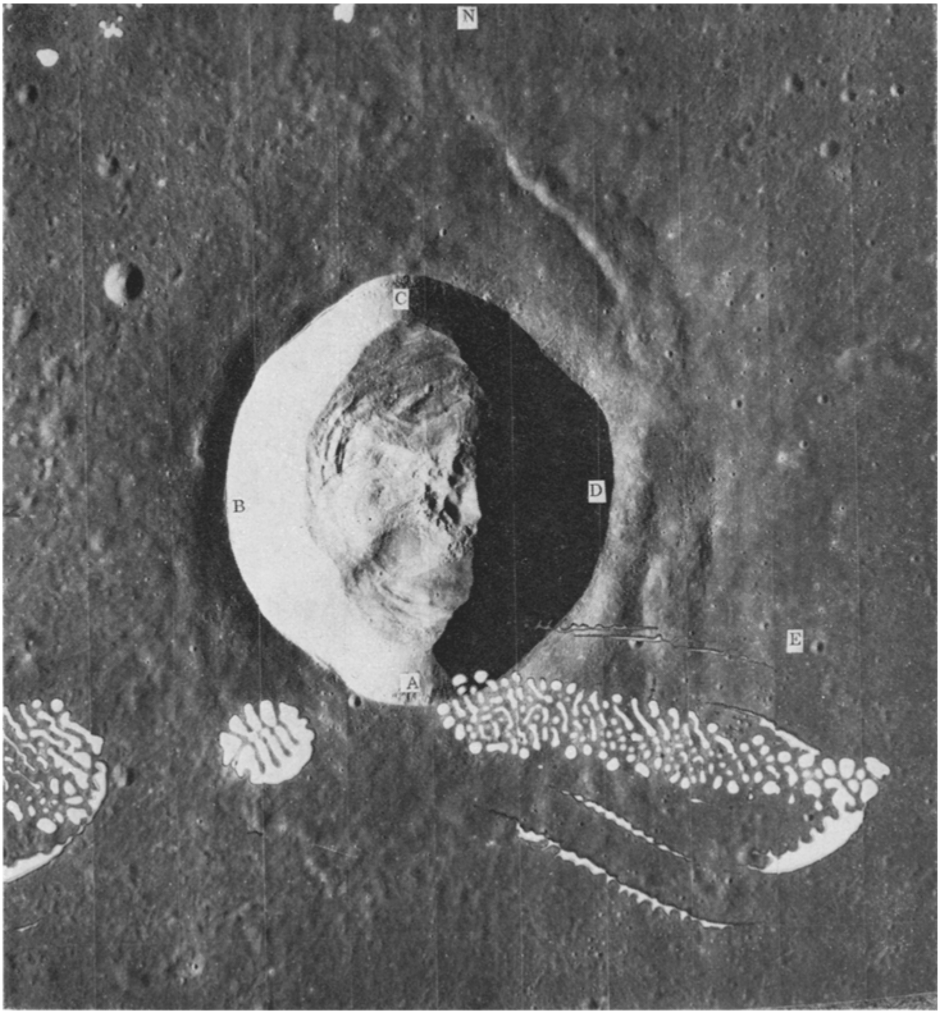


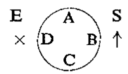
Fig. 4. Lunar Orbiter 5, Frame 70M photograph of the crater Dawes. The permanent points chosen for monitoring are: South Wall (A), West Wall (B), North Wall (C), East Wall (D), and nearby plain (E). North is at the top.

± 2 whole steps in the albedo scale signifies a real change. On that basis, point A (south wall – see sketch at top of Table II) had three possible anomalies in addition to the one reported by the observer (marked by an asterisk). For age 5^d ($5^d.0$–$5^d.9$ age inclusive) there were five nights of observation with 11 individual measures of albedo Of the 11 observations 8 (73%) were 4.5 or higher and all three (all on the same night) were estimated at 2.0. These three measures are 2.5 steps lower than the next lowest measure (or the average) and 3 or more steps below all the other measures. It is my suspicion that that point in Dawes was duller than normal. The observer did not report an anomaly. This was probably owing to at least two factors: (1) all there measures (at different times) were the same so there was no variation during the whole

TABLE II

Albedo chart for Dawes

A. Porter
Narragansett, R. I.
6L 100,193X



Dawes (26° E, 17° N)
Albedo Chart

Sunrise at 334° colongitude ≅ 5d age
Sunset at 154° colongitude ≅ 20d age

Age	Point A (S. wall)	Av.	Point B (W. wall)	Av.	Point C (N. wall)	Av.	Point D (E) wall)	Av.	Point E. (nearby plain)	Av.
d d 0.0–4.9					Dark side sunrise					
5.0–5.9	5,4.5; 5.5,5.5; 2,2,2;5; 6,6,6;	4.5	6.5,6; 5,5; 6.5,6.5,6.5; 6.5; 7,7,7;	6.3	3.4,4; 7,7; 2.5,2.5,2.5; 5.5; 6.5,6.5,6.5;	4.9	4.5,4.5; 5.5,5.5; 5.5,5.5,5.5; 6; 6,6,6;	5.5	2.5,2.5; 3.5,3.5; 2.5,2.5,2.5; 3; 2.5.3.3;	2.8
6.0–6.9	2.5,2; 5,4,4; 3.5,3,3; 4,4; 3,3,3;	3.4	4.5,5; 5.5,6,5.5; 6,6,6; 6,6; 6.5,6.5,6.5;	5.8	5,4.5; 6,5,5; 4,3,3.5; 4,4; 3,3,3;	4.1	2.5; 3; 4.5,4.5,4; 5,4,4; 4.5,4.5; 3.5,3.5,3.5;	3.9	2.5,2.5; 3,3.5; 3,2.5,2.5; 4.5,4.5; 2.5,2.5,2.5;	3.0
7.0–7.9	4,3,3.5; 4,5; 4.5,4; 4,4,4; 5,5; 5,5,5.5; 6,6,6;	4.6	6,5.5,5.5; 6,6.5; 5.5,6.5; 6,6,6; 6,6; 5.5,5.5,6; 6.5,6.5,6.5;	6.0	6,5,6; 5,5.5; 4,4; 5,5,5; 5,5; 5,5,5.5; 6,6,6;	5.2	3.5,3,3.5; 4.5,4; 4.5,4; 4.5,4.5,4.5; 5.5,5.5; 5,5,5; 5.5,5.5;	4.6	2,2.5,2.5; 3.5,3.5; 3,3.5; 3,3,3; 4,4; 4,4,3; 4,3.5,3.5;	3.3
8.0–8.9	4,4,4; 4.5,4.5,4.5;	4.25	5.5,6,6; 6.5,6.5,6.5;	6.2	4,4,4; 4.5,4.5,4.5;	4.25	3.5,3.5,3.5; 5,5,5;	4.25	3,3,3; 2.5,2.5,2.5;	2.75
9.0–9.9	4, 6,6,6,5.5;* 6,6; 5,5; 5.5,5.5,5.5; 4.5,4.5;	5.4	6.5,6.5,6.5,6.5,6.5;* 6.5,6.5; 6,6; 6,6,6; 5.5,5.5;	6.2	4, 6.5,6.5,5,6;* 6,6; 5,5; 5.5,5.5,5.5; 4.5,4.5;	5.4	4, 6,5.5,6,6;* 4.5,4.5; 5,5; 5,5,5; 5,5;	5.1	3,3.5,3.5,3,3;* 3,3; 4,4; 2,2,2; 4,4;	3.1
10.0–10.9	6,6; 5,5,5; 5.5,5.5,5.5; 6,6; 6,6,6;	5.7	6.5,6.5; 6.5,6.5,6.5; 6,6,6; 6,6; 6,6,6;	6.2	6,6; 6,6,6; 5.5,5.5,5.5; 6,6; 6,6,6;	5.9	5.5,5.5; 4,4,4; 6,6,6; 6,6; 5.5,5.5,5.5;	5.3	3.5,3.5; 3,3,3; 2,2,2; 2,2; 4,4,4;	2.9
11.0–11.9	5.5,6.5; 7.5,7.5; 6,6; 6,6.5,6.5; 6,6,6;	6.3	5,5.5; 8,8; 6.5,6.5; 6,6.5,6.5; 6,6;	6.4	5.5,6; 7.5,7.5; 6,6; 6,6.5,6.5; 6,6;	6.3	4.5, 5.5; 8,8; 6,6; 6.5,7.7; 6,6;	6.4	2,2; 2.5,2.5, 2.5,2.5; 3,3,3; 3.5,3.5;	2.7
12.0–12.9	5.5,5; 6.5,6.5; 7,7,6.5; 6.5,6.5;	6.3	5,5.5; 6,6,; 7,7,7; 6,6;	6.2	6,6; 6.5,6.5; 7,7,7; 6,6;	6.4	6,6; 6.5,6.5,7,7,7; 6,6;	6.4	3,3; 3,3; 3,3,3; 3.5,3.5;	3.1
13.0–13.9	5.5,5.5; 6,6; 6.5,6.5; 6,6;	6.0	6,6; 6,6; 6,6; 6,6;	6.0	6,6; 6,6; 6.5,6.5; 6,6;	6.1	7,7; 6.5,6.5; 7,7; 6.5,6.5;	6.75	2.5,2.5; 3,3; 2.5,2.5; 2.5,2.5;	2.6
14.0–14.9	6,5.5; 6,6; 6.5,6.5,6.5; 6,6,6; 6,6;	6.1	5.5,5.5; 5.5,5.5; 6,6,6; 6,6,6; 6,6;	5.8	6,6; 6,6; 6.5,6.5,6.5; 6,6,6; 6,6;	6.1	7,7; 6.5,6.5; 7.5,7.5,7.5; 7,7,7; 6.5,6.5;	7.0	2.5.2.5; 2.5,2.5; 3,3,3; 2,2,2; 3,3;	2.6
15.0–15.9	8,8,8,8,8; 6,5.5; 5.5,5.5,5.5;	6.8	3,4,4,4,4.5; 5.5,5.5; 4.5,4.5,4.5;	4.4	3,3,3,3,3; 6,6; 5.5,5.5,5.5;	4.35	4,4,4,4.5,4.5; 7.5,7.5; 7,7,7;	5.7	3,3,4,2.5,3; 2.5,2; 3,3,3.5;	2.95
16.0–16.9	6,5; 5.5,5,6; 6,6;	5.6	4:,5.5; 4,5,5; 5.5,5.5;	4.9	3.5; ,5.5; 5,5.5,5.5; 6,6 ;	5.3	8.5,8.5; 7,7,7; 7,7;	7.4	2.5,2.5; 3,3,3; 2,2;	2.6
17.0–17.9	3,5,3.5;	3.5	4,4.5;	4.25	4,4;	4.0	8,8.5;	8.25	3,3;	3.0
18.0–18.9	6,6; 6,6,6;	6.0	5,5; 5,5,5;	5.0	5.5,5.5; 4.5,4.5,4.5;	4.9	8,8; 7,7,7;	7.4	2.5,2.5; 3.5,3.5,3.5;	3.1
19.0–19.9	6.5; 5.5,5.5,5.5;	5.75	6; 5,5,5;	5.25	6.5; 5.5,5.5,5.5;	5.75	8.5; 8,8,8;	8.1	2.5; 2,2,2;	2.1
lunation ave. →		5.4		5.7	Sunset	5.3		6.1		2.9
20.0–25.9					Darkside					

: uncertain
* LTP reported
, separates observations within a night
; separates nights of observations

time of observation to arouse the suspicion of the observer; (2) he did not have a chart at hand to note that the albedo was considerably different from his first two nights of observation (for this age). Now sunrise occurs on Dawes' east rim at colongitude 333.3°, at the center (points A and C) at 333.5°, and at the west rim at 333.7° or approximately at age $5^{\mathrm{d}}.0$ (age can range from 4.7 to 5.7 at least). Investigating the colongitudes and ages for the five dates we find 337°, $5^{\mathrm{d}}.2$; 336°, $5^{\mathrm{d}}.0$; 337°, $5^{\mathrm{d}}.6$; 334° (measures in question), $5^{\mathrm{d}}.8$; and 344°, $5^{\mathrm{d}}.7$; respectively. Thus, the crater was 3°, 2°, 3° (measure in question, 10° and 10°, respectively from the terminator. Therefore, the low estimates on this night cannot be ascribed to proximity to the terminator as one night previously, at a time near sunrise (terminator distance of 2°), the estimates were 3.5 steps higher, and another previous night at the same distance from the terminator the estimates were 2.5 and 2 steps higher. Thus, I suspect a true anomaly was observed (though not recognized) here. The fifth night of observations were quite high, possibly anomalously high, but differ from the mean by only 1.5 steps. If the anomalously low measures were not included in computing the average, then the mean would be 5.4 indicating a still stronger anomaly.

The starred measures at age $9^{\mathrm{d}}.0$–$9^{\mathrm{d}}.9$ were reported when a phenomenon was observed. Mr Porter recorded his first estimate as 4.0 then as he was making another estimate he noted that it suddenly brightened. He noted that point B did not vary but points C and D also varied, while point E (nearby plain) did not vary. The measures by themselves corroborate his report of a brightening. However, if one compares the measures with the other four nights of measures one sees that the majority of estimates for the same age were higher steps. It is my opinion that the observer actually observed the end of a dimming phase (he did not report obscuration) and return to normal, rather than a brightening. The age at time of observation was $9^{\mathrm{d}}.6$ when the crater was about 58° from the terminator. Estimates at age $10^{\mathrm{d}}.0$ and $10^{\mathrm{d}}.2$ were all 6.0 and terminator distances were 52.5° (less than the 58° for the LTP) and 65°, respectively. Thus it appears that an albedo of about 6 is normal.

At age $15^{\mathrm{d}}.0$–$15^{\mathrm{d}}.9$ we see a suspected bright anomaly. We have only three nights and 10 individual measures. The other two nights were estimated at 2 or more full albedo steps lower, which are also consistent with the preceding (14^{d}) and following (16^{d}) age measures. Again the observer did not note any variations. This was his first set of measures at this age, so he did not know what its normal albedo was.

Finally, at age $17^{\mathrm{d}}.0$–$17^{\mathrm{d}}.9$, the only measures for this age were estimated at 3.5. Judging from the preceding and following age estimates, which are about 6, I suspect the 3.5 is anomalously low and constitutes a possible LTP. More measures for that age are anxiously awaited. Similar arguments can be made for the other points. Besides the one reported anomaly (age $9^{\mathrm{d}}.0$ to $9^{\mathrm{d}}.9$), there are three other nights when two or more points participated in possible anomalies; viz., at age $5^{\mathrm{d}}.0$–$5^{\mathrm{d}}.9$ points A & C were anomalously low and the others did not vary; age 11^{d} when points B and D were both anomalously high and the other points did not vary; and age 15^{d} when three points were anomalous, point A being brighter than normal while points C and D were anomalously dull. The other possible anomalies seem to involve just one point in the crater at a time, and in two cases just one of the measures during the night's observations. In one of these cases (age 16^d) the observer was not certain of the estimate (marked by a colon). Note that once the nearby plain was possibly anomalously bright, and at a different time than any other anomalies in Dawes.

Thus, out of 58 nights of observation there were seven possible anomalies in Dawes and one reported (1.7%) or 14% incidence of anomalous behavior for the crater Dawes. When individual measures are considered the comparable percentages are 3.5% (reported) and 6.6% (suspected) respectively. The measures for the nearby plain comparison point indicate that one night in 58 showed anomalously high estimates or 1.7% of the time the general surface may vary. Thus, we have some information as to the frequency of occurrence of temporary phenomena on the Moon, at least for one feature. The only other information on frequency of occurrence is found in Bartlett (1967). In this article he reported on observations of the violet glare in Aristarchus. This was the first time that negative observations were reported. Negative (normal aspect) observations are almost as important as positive (phenomena) observations. Bartlett reported 53 negative (violet glare absent) observations and 107 positive for a total of 160 observations. Thus the phenomenon was absent one-third of the time. Formerly, only phenomena were reported although some observers occasionally added that the phenomenon was not seen the night before or after or next lunation, etc.

We can see from the table, particularly in the averages, the behavior of the albedo for each point over a lunation. As might be anticipated, most of the crater gradually brightens, attaining maximum albedo near full-moon, then decreases till sunset. However, point D (east wall) departs from this rule. It gradually brightens, attaining maximum brightness near sunset. This suggests that that part of the wall of Dawes may have some extra specular material (more glass?), or has large, flat, tabular areas that are west-facing, or both situations may obtain. The albedo of the nearby plain point is quite low, about 3. This is consistent with the area surrounding Dawes which is part of the dark annulus between Maria Serenitatis and Tranquillitatis.

Similar treatment can be applied to each of the features for which sufficient data have been reported. Features which may qualify are: Lansberg, Godin, seismic zone (A_{16}) at $\sim$11°E, 6°N, Parry (non-LTP comparison site), Clavius, Calippus, East Mare Crisium seismic zone (A_{19}) at $\sim$67°E, 15°N (relocated at 93°E, 16°N), Eimmart, white spot in Walter, Mersenius, Pontanus (non-LTP comparison site), Messier, Messier A, Pico, Marius, Mare Nubium (A_1) seismic zone, and Lubbock (non-LTP comparison site). Less extensive data are available on Cape Agarum, Wilhelm (non-LTP comparison site), Copernicus, Tycho, Plato, Herschel, Apianus (non-LTP comparison site), Riccioli, Hyginus N, Phiolaus, and Schickard.

The chart for Dawes illustrates the amount and kinds of information that can be extracted with profit. I think it helps to establish standards for terms that are familiar to observers; viz., brightness or albedo, and an observing process that may be performed by any observer once he has set up his albedo scale. One observer can be more easily compared with another on the same feature.

5. Seeing Conditions

The measures for seeing conditions have not yet been analyzed. A cursory examination however suggests some surprising departures from expectation. I would have anticipated that seeing rated excellent (or $\frac{7}{10}$ or $\frac{8}{10}$) would have coincided with small disk diameters and excursions, while the interval between blow-ups and excursions would be long (hence steady). Often the reverse was true. There may be sufficient reported estimates now to set up a table of star disk measures related to subjective seeing estimates. Results thus far show that the program objectives can be obtained. The task now is to get more of the observers to participate.

6. Summary

Analyses of the most comprehensive set of observations of LTP to date (Cameron, 1972a) provided no clear-cut correlations to any suggested causal mechanism. They did reveal that the oft-quoted tidal correlation, found by Burley and Middlehurst (1966) has changed. Their apogee peak disappeared and their perigee peak spread out to one-half an anomalistic period (perigee to apogee) so that there are nearly equal numbers of observations from anomalistic period phase 0.6 to 1.1. When observations were compared with what would be expected if observations were uniformly scattered throughout the anomalistic period or lunar age, the tidal correlation decreased from O/E=1.9 (145 obs.) to 1.3 (759 obs.). The consistently highest O/E correlation was with sunrise followed by the Earth's magnetic tail, then tidal. Solar effects (lunar observations compared with occurrence of magnetic storms on Earth) showed higher than expected ratios, but percentages were still small ($<10\%$) with a couple of exceptions.

A large percentage, perhaps a majority of phenomena are reported as brightenings. These are subjective and have little or no established bases of normality. The author is conducting a program for observations of LTP with procedures for observing addressed to establishing such bases. Estimates of albedos of assigned features are to be made for several permanent points in the feature and one on the nearby plain. The observer should observe at least twice in one night with the observations separated by at least 10 min in time. Albedo estimates are made from a scale set up by the observer as outlined by the author.

Charts of albedos vs. age are made for each feature. Analysis with respect to causal hypotheses was also made, but not discussed here. The feature (Dawes) with the most complete set of albedo measures was analyzed. It shows the behavior of each point for a lunation and suggests that one point (point D) may have different or peculiar properties; e.g., specular material (glass?) and/or flat tabular masses. It also shows several possible anomalies (when reported albedos are $\geqslant 2$ full albedo steps different) that were not noted by the observer and one that was reported. It also suggests that the reported phenomenon (a brightening) was not a brightening, but a return to normal from a dimming phenomenon. We now have a better concept of the normal aspects of the crater Dawes throughout the period of sunlight during lunations. Any other observer may make the same kind of observations on this crater, once he has set up his albedo scale, and his observations can be directly compared with this observer (Porter).

We also have a basis for estimating the frequency of occurrence of phenomena, at least for this feature (and can be extended to all others with like information). Reported frequency was one in 58 *nights* of observing (1.7%) and 14% of nights when possible anomalies are included. Percentages of reported and suggested anomalies by *individual measures* are 3.5% and 6.6% respectively. Similar analyses can be made for perhaps 17 other features.

The results from the ongoing program have shown that the objectives are attainable. The task now is to get all the observers to report their measures and to encourage participation by more observers.

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