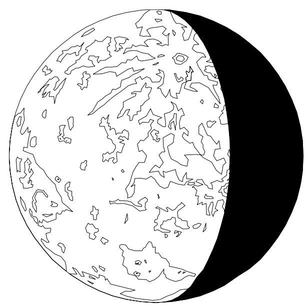
A MANUAL FOR OBSERVING THE MOON: THE A.L.P.O. LUNAR SELECTED AREAS PROGRAM

(*THE LUNAR SAP HANDBOOK*)



5th Revised Edition

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FOREWORD

This observing manual is intended for the serious enthusiast who wants to contribute something useful to lunar science through participation in the specialized efforts of the *A.L.P.O. Lunar Selected Areas Program (SAP)*. In the pages to follow, fundamental methods and techniques for conducting systematic observations of specific types of lunar features (i.e., "selected areas") are outlined and discussed, including remarks on the lasting value of current lunar visual observations by amateur astronomers with Earth-based telescopes. This latest edition of *The Lunar SAP Handbook* also incorporates two previous programs that were originally separate endeavors, the *Dark Haloed Craters Program (DHCP)* and the *Bright and Banded Craters Program (BBCP)*. Both programs are still in need of long-term, systematic observational coverage, and they both fit well within the framework of the existing SAP.

It is the sincere hope of the author that the discerning lunar specialist will find the discussion herein both enlightening and instructive, and perhaps this book will elicit sufficient enthusiasm for increased observational efforts on the part of dedicated students of the Moon. The writer is always delighted to offer comments and suggestions concerning lunar and planetary research programs carried out utilizing the techniques and methods described in the present book.

Current lunar research by the A.L.P.O., as well as observational activities in other disciplines of planetary science, can be found in the *JOURNAL OF THE A.L.P.O.* (formerly *THE STROLLING ASTRONOMER*), published about four times a year. Similar investigations in lunar science abroad can be found in publications such as the *JOURNAL OF THE BRITISH ASTRONOMICAL ASSOCIATION*. The list of references at the end of this book should be consulted for other authoritative information about the Moon. The A. L. P.O. also operates and maintains the following website where detailed lunar observing information, drawing and albedo forms, and recent observational data are provided:

http://www.lpl.arizona.edu/alpo

While it is recognized that any list of acknowledgments is likely to be embarrassingly incomplete, the author would nevertheless like to express his sincere gratitude to a number of individuals who helped make this brief treatise possible. These friends and colleagues include the Director Emeritus of the A.L.P.O., Walter H. Haas, John E. Westfall (also a Lunar Recorder), Winifred S. Cameron, former Lunar Recorder for the Lunar Transient Phenomena (LTP) Patrol. Warmest thanks are also due several past Lunar Recorders, namely: H.W. Kelsey, Kenneth J. Delano, Harry D. Jamieson, Charles L. Ricker, Marvin W. Huddleston, Alain Porter, Christopher Vaucher, Michael Fornarucci, and Roy C. Parrish. Many dedicated observers helped bring about the evolution of the Lunar Selected Areas Program (SAP) to what it is today, although space within these pages is insufficient for a full accounting of all names. A special debt of gratitude extended to my family for their patience and understanding during periods of personal seclusion while developing, revising, and publishing this volume.

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INTRODUCTION

The missions of *Apollo* transformed our nearest celestial neighbor from a virtually unknown and inaccessible object into a relatively familiar world. Including the unprecedented historical events of the first manned lunar landing on July 20, 1969, twelve astronauts from Earth have set foot upon the Moon's surface, collecting and returning to Earth some 380 kg. of rocks and debris from six *Apollo* ventures. Of course, in mentioning any lunar explorations from Earth, one cannot omit the small but no less important 130 gm. of rocks gathered during the unmanned Russian *Luna-16* and *Luna-20* missions.

Apart from the vast collection of photographs supplementing previous data from missions such as *Surveyor* and *Orbiter*, the *Apollo* program enabled equipment to be set up on the lunar surface to monitor moonquakes, meteoric impacts, thermal characteristics of the lunar surface material, and alleged magnetic phenomena. Adding to the wealth of accumulated data that now exists has been the massive collection of photographs of the entire lunar surface made in unprecedented detail in 1994 by the orbiting *Clementine* spacecraft, as well as significant data from remote sensing by *Lunar Prospector* in 1998-99. It will be many years, no doubt, before all of this information will be thoroughly assimilated and carefully refined into a realistic account of the Moon and its cosmic history.

For the amateur astronomer, the Moon has always been a favorite subject for his telescopes, and until the first really energetic space efforts, he mostly dominated the field of selenography. Now, with the impact of a great multitude of photographs taken at close-hand, with precise measurements of the Moon's complex chemical composition, radioactivity, and seismic profile, and following sophisticated petrographic investigations of lunar materials, one might quickly assume that the work of the amateur astronomer has been relegated to redundancy or insignificance from our fixed vantage point in space.

Too many people have gotten the mistaken impression that regular observations of the Moon are pointless and that little awe or mystery remains about our "Queen of the Night." The activities by *Apollo* astronauts on the Moon and close-range photographic surveys by lunar orbiting spacecraft are obviously out of the domain of the amateur astronomer. Yet, it must be emphasized that there are areas of lunar observation that still largely remain the forte of the amateur astronomer, fields that may be pursued without an imminent threat of obsolescence by an onslaught of imposing professional equipment. Unlike the professional specialist, the amateur typically has the freedom to scan at will a chosen lunar feature for extended periods of time in hopes of drawing or capturing photographic, video, or CCD images of low-sun shadows of minor relief features, varying tonal patterns exhibited in lunar environments exposed to a high sun, and other possible long-term or transient events.

Any observing program, for its results to be scientifically useful, requires of its participants a suitable blend of preparation, skill, patience, and tenacity. Because of the large image size and brightness of the Moon, lunar studies are especially suited for amateur astronomers using small to moderate apertures. More importantly, there have been numerous instances when professional astronomers, in trying to resolve some observational query by relying solely on existing spacecraft photographs, have enlisted the services of amateur astronomers. For example, by a fortuitous improper positioning of the spacecraft camera or as a result of unfavorable solar illumination, an optimum view was not afforded of the morphology of a particular lunar crater or other feature. Fortunately, amateur observers were able to provide indispensable assistance by monitoring the specific region of the Moon under the conditions sought by professional astronomers. In a few cases, relevant data already existed in amateur observational archives. Cooperative efforts such as these clearly demonstrate how meaningful amateur observations of the Moon can be and how a vital link to professional research is maintained.

There are many possible areas of lunar research where the imaginative amateur astronomer can find fruitful observational experiences. An example of a very interesting research program is the monitoring of what is known as *Lunar Transient Phenomena (LTP)*. In the very truest sense, LTP represent alleged variations at the lunar surface which are typically of ephemeral or instantaneous nature, usually remaining quite unpredictable. Systematic, simultaneous studies by a team of regular observers using top-quality instrumentation is especially worthwhile, since under optimum conditions LTP events might be glimpsed for only a few seconds to some twenty minutes or so. What is of greatest importance within the scope of such a program is to try to observationally differentiate between LTP reports and bona fide LTP events.

No more than a cursory perusal of the available literature will turn up historical accounts of LTP, and while reports of most activity turn out to be dubious, there are growing numbers of undisputedly authentic LTP phenomena from analytical evaluations of available data. Some events have been observed simultaneously by distant and independent observers, and as investigative procedures have been refined and improved over the years, it has been possible to confirm some LTP events with photographic techniques.

Of the more than 1,500 LTP reports and events catalogued since A.D. 557, perhaps the widely-publicized Alphonsus spectrograms of Kozyrev in 1958, the observations of Greenacre and Barr of Aristarchus in 1962, and the *Moon-Blink* reports of the mid-sixties and early seventies, are the most familiar. Observers are generally more prone to study areas on the lunar surface which are known to have generated LTP reports and events, giving the data sample to date a somewhat lopsided appearance, but it has become evident that LTP events may take place elsewhere on the Moon and not just in the aforementioned "preferential" areas. There are many regions on the lunar surface, indeed, which have been suspected of LTP events, although most of the lesser-known features have been inadequately followed observationally.

Rare and elusive as they may seem, LTP events do appear to fall within rather roughly-defined categories. *Small, temporary reddish or pinkish patches*, presumably due to fluorescence or incandescent gaseous substances, have been noted shortly after lunar sunrise, while *glows* lacking any distinct hue have been noticed, sometimes seen on the night hemisphere of the Moon. Emerging quite instantaneously or lasting for several minutes have been *bright points of light* near the lunar terminator or on the darkened hemisphere of the Moon, while *rapid fluctuations in the brilliance of a specific area* have been occasionally recorded, again most often in the early lunar morning. *Obscurations*, visible directly as "fog" or "mist," or indirectly by concealing or obliterating known surface features, are also curiously associated with times of lunar sunrise, but not always so. Any number of variations may sometimes be reported in Earthshine conditions or in conjunction with partial or total lunar eclipses.

From the analytical information to date, it might be concluded that LTP events are probably of random internal origin and are only weakly attributable to external influences. As noted here, the phenomena seem to be of several kinds and involve possible gas or gas/dust mixtures, luminescence of these gaseous substances, and possible luminescence of surface materials. Perhaps many causative factors operate together to give strong sunrise correlations found in many of the LTP events. Supporting this tentative conclusion of an internal origin of the LTP is the distribution and association of many LTP sites with volcanic maria, dark-haloed craters, sinuous rills, and lunar domes.

Well over a decade ago, the *Lunar Transient Phenomena (LTP) Patrol* was introduced as a new program for the A.L.P.O. Lunar Section, and the major thrust of the endeavor was to visually monitor the supposed transient variations at the lunar surface just discussed. In addition to looking for short-lived events, individuals were asked to supplement their observations with a monitoring of certain selected lunar features suspected or historically known to exhibit "seasonal" or long-term phenomena. For example, a variation in the tone or hue of a given area, which *cannot* be attributed to varying solar illumination and which *does not repeat* systematically from lunation to lunation, can be seen in certain areas. Principally, these tonal changes occur where dark radial bands or dark haloes are seen within or around some craters, or where darker regions or patches exist on the lunar surface in limited environments. Unusual changes in the apparent morphology, pertaining to overall size and shape, have been detected in conjunction with tonal or color fluctuations in many, but not all, cases. Thus, the intensive studies of specific features such as Alphonsus, Aristarchus, Eratosthenes, Herodotus, Kepler, Messier-Pickering, and Plato, have occurred, and as data were accumulated and reports on specific regions published, new areas were then added to the list (e.g., Atlas, Ross D, Hell, Pico, Piton, Colombo, etc.).

By 1971, the Lunar Recorders decided to segregate the study of LTP from the study of long-term or "seasonal" events, forming the *LTP Survey* for strictly transient lunar events and the *Selected Areas Program (SAP)* to deal with long-term variations, each area of concentration headed by a dedicated Recorder. In the years that followed this change, observational data were collected by each program, catalogued, reduced, and published in the *Journal of the A.L.P.O.*, and the results of both programs showed real promise. There were quite a few instances of LTP events and recognized "seasonal" variations apparent in the accumulated data sample.

Indeed, the Selected Areas Program (SAP) and LTP Survey represent meaningful enterprises at the fundamental level of amateur observational astronomy. A major goal of organizations like the A.L.P.O., these are pursuits that are largely concerned with *long-term visual monitoring of variable phenomena at the surface of the Moon*. The scope of such work has definitely not been rendered obsolete by spacecraft gathering such a great wealth of information about our satellite. Persistent, patient observers, participating in the A.L.P.O. LTP Survey and Selected Areas Program (SAP), can successfully supplement the findings of space missions and other ongoing professional research, increasing our overall knowledge about the Moon.

Today, the A.L.P.O. Selected Areas Program (SAP) and LTP Survey persist as active, somewhat separate endeavors, although both programs have achieved greater significance through emerging cooperative ventures of data exchange and comparison in recent years. This trend must continue to insure a steady flow of meaningful, scientific data for the future.

OBSERVATIONAL AND INSTRUMENTAL NOTES

The success of the A.L.P.O. Lunar Selected Areas Program (SAP) is dependent upon long-term systematic observations of specific lunar features not only throughout a given lunation, but also from lunation to lunation for many years. Such regular and careful monitoring will familiarize one with the normal, yet often complex, changes in appearance that many features undergo from lunar sunrise to sunset, and it will be possible for the individual to recognize anomalous phenomena more readily from one lunation to the next, should they occur. Special inherent talents for drawing lunar features, although definitely helpful, are not necessary, nor is exceptional visual acuity. The most fundamental and essential prerequisite for participation in the Selected Areas Program is the willingness to follow the Moon and the chosen feature(s) for many consecutive lunations, year after year.

Scientific objectivity is mandatory, whereby the observer must develop a constant practice of recording precisely what is seen at the eyepiece, not what one might expect to see (as may be derived from one's previous observations or from studies of published reports from other individuals). Should there be any doubt whatsoever about what is perceived, the observer must routinely note such uncertainties. The resulting data will be far more reliable and of lasting value.

While initial efforts to detect rather delicate details on the lunar surface may result in some disappointment, persistent observations will bring about the reward of eventual successful scrutiny (training of the eye) of subtle features at the threshold of vision. The joy of recording phenomena or details hitherto unrecognized is reserved largely for the person who has maintained the perseverance to observe the Moon on numerous occasions.

Although no inflexible minimum size telescope need be specified for active participation in the A.L.P.O. Selected Areas Program (SAP), most experienced observers are in agreement that the largest aperture available, which can be employed with the existing seeing and transparency conditions, should be used. Even so, a good 10.2cm.(4.0in.) refractor or 20.0cm.(8.0in.) reflector will deliver sufficient resolution of lunar detail for full participation in nearly all aspects of the observing program. No attempt here is made to address the various pros and cons of instrument type or design, and the driving factors in choosing a telescope should be the reliability of the manufacturer, optical and mechanical excellence (giving high-contrast, relatively bright, and crisp images), and reasonable portability.

ASTRONOMICAL SEEING AND TRANSPARENCY

The state of the Earth's atmosphere is a critical factor to appraise when one attempts lunar and planetary observations. *Astronomical seeing* is the result of a number of very slight differences in the refractive index of air from one point to another, and such variations are directly related to density differences, normally associated with temperature gradients, from one location to another. The observed effect of such random atmospheric fluctuations is an irregular distortion and motion of the image. At one time, the *seeing* may be evaluated as excellent, whereby no gross image variations are noted over a fairly long interval. At another time, the seeing might be poor, with the image appearing as though it is "boiling" or as if it is being seen through a layer of a moving fluid.

It is important for the individual to estimate as precisely and as objectively as possible the quality of the seeing at the time of observation. When the seeing is poor (when the atmosphere is in a highly turbulent state), it becomes impossible for one to achieve optimum resolution with the given aperture. One is usually forced to await better conditions to do anything useful.

The *Standard A.L.P.O. Seeing Scale* is a numerical sequence ranging from 0.0 (worst possible seeing) to 10.0 (absolutely perfect seeing), from which the observer assigns a numerical value to correctly represent the condition of the atmosphere at the time of observation. The altitude of the Moon should be greater than about 25° above the horizon to avoid adverse low-altitude atmospheric dispersion effects.

Transparency of the atmosphere may be determined on a given night of observation by estimating as accurately as possible (using a good star atlas for reference) the visual magnitude of the faintest star that can be detected by the unaided eye. It will be noted, however, that the Moon contributes sufficient scattered light, more or less due to the phase, to obliterate the dimmest stars. So, the observer is tasked with designating the faintest star that might otherwise be seen on the same night without the influence of the scattered light of the Moon. Estimates of the faintest star can usually be extrapolated by reference to some other attribute of the sky prior to beginning observation, such as twilight blueness, overall clarity of the sky near the Moon prior to and after sunset, etc. Estimates of transparency should always be made in the direction and proximity of the Moon, as should all appraisals of seeing.

Space is provided on the standard observing forms for entering seeing and transparency estimates on the night of observation.

IMAGE BRIGHTNESS AND CONTRAST

Aside from the considerations of evaluating seeing and transparency, attention must be given to factors in lunar observations such as *surface brightness (apparent)* and *contrast perception*.

The *visual geometric albedo,* p_V, of the Moon is the percentage of incident light from the Sun that the Moon reflects in the direction of the observer on Earth at 0^o phase angle. The precise value for p_V can be found in the appropriate literature. The *phase angle, g*, is the angle at the Moon between the Earth and Sun, and it has numerical values ranging from 0° through 180°. When g = 0°, the Moon is fully sunlit (Full Moon); when g = 180°, the hemisphere facing Earth is totally dark (New Moon). A value of g = –90° corresponds to First Quarter, and g = +90° takes place at Last Quarter.

Since the phase angle, *g*, varies throughout the lunar month, the percentage of sunlight reflected in the direction of the observer on Earth changes, too. There will be numerous occasions when practicing observers will encounter the term phase angle, and the computation of this quantitative unit will be most useful when the necessity arises. In reference to the *ASTRONOMICAL ALMANAC*, the observer should look up the value of *B′ the selenographic latitude of the Earth*, and *B″, the selenographic latitude of the Sun*. Also needed are values for *L′ , the selenographic longitude of the Earth*, and *C, the selenographic colongitude of the Sun*. Using these values, the following equation can be employed to compute the *phase angle, g*, at 0^h UT

$$\cos g = \sin B' \sin B'' + \cos B' \cos B'' \sin (C + L').$$

For simplicity, the phase angle, *g*, may also be found using the *fraction of the Moon illuminated by the Sun*, denoted by, *k*, which will be listed in the given ephemeris. The computation is simplified as

$$\cos g = 2k - 1.$$

The value of *g*, calculated by either formula, is the phase angle at 0^h UT on the date in question. Interpolation is necessary to derive this quantity for any other hour of observation (UT).

Regardless of the phase angle, before the light of the Moon reaches the eye of the observer, it will be somewhat diluted by absorption in the atmosphere. It will be further reduced by absorption in the optical system (including any filters employed), and scattered light will be added to the image by both the atmosphere and optics (clean optics will, of course, minimize scattering). Finally, the function of aperture and magnification conspire in a complicated way to determine the final image brightness of the Moon. What we have been discussing here is a resulting factor known as the *apparent image brightness* of the Moon with respect to the lunar phase angle (after all light-reduction parameters have been considered), and a detailed theoretical treatment of just how these cumulative factors affect the image that is being viewed can be found in the appropriate references.

Contrast, or the fractional difference in brightness between two adjacent areas, must be incorporated into any discussion of lunar observations, because contrast inherent in the image will depend in a complex way on image brightness. Suppose that a dark feature on the floor of a lunar crater is being examined, seen against a lighter background. The dark feature, let us assume, is pronounced in appearance in comparison to the surrounding terrain. We would say, therefore, that the dark area reflects less incident sunlight than the surrounding regions, and the conspicuous appearance means that the contrast is excellent. If the brightness differences are not significant between two adjacent areas, then the contrast may be correspondingly poor, and subtle intensity differences may not be apparent. Where very delicate contrasts are involved, as is frequently the case in lunar studies, image brightness becomes a critical factor in determining whether or not certain regions will be distinguishable from one another. For the majority of lunar observations, particularly those areas far from the terminator or at Full Moon, extraneous light is always a problem, and contrast will suffer in such circumstances.

Although albedo estimates should be made with no filters (in *integrated light*), irradiation may be reduced at times of Full Moon and at other phases (with an increase in contrast) by employing *Wratten filters #15 (deep yellow), #21 (orange), #23A (reddish-orange), #58 (yellow-green), #25 (red), #38A (blue), and #47 (violet)*. *Polarizing filters* are also extremely useful in improving image quality by reducing glare.

Our goal, therefore, in considering contrast and image brightness is to find a magnification for a given aperture which will together provide sufficient image brightness and optimum contrast. Perception of delicate contrasts depends on the right relationship between magnification and lunar phase angle.

Experience has shown that magnifications for lunar studies in the range of *25D* through *50D*, where *D* is the aperture expressed in inches, are the most useful. For example, this corresponds to 100X to 200X on a 10.2cm. (4.0in.) aperture under average seeing and transparency conditions. When conditions are exceptionally good, it may even be possible to push these limits to as much as *60D* (or 240X in our example). For the A.L.P.O. Selected Areas Program (SAP), although the inclination may be to use very high magnifications, one should choose powers that adhere to the parameters just discussed in this section to collectively optimize image brightness, contrast, and image crispness.

LUNAR ORIENTATION AND COORDINATES

Two different *lunar orientation systems* have been in use over the past several decades. One is the *classical system*, which is analogous to the directions in the sky or celestial sphere. For example, if the observer is using no optical assistance (unaided eye) located in the northern hemisphere of the Earth, and if the Moon is Full ($g = 0°$) and being observed at midnight (it will then be approximately on the celestial meridian), North (N) will be up, South (S) will be down, East (E) to left, and West (W) to the right. A quick reference to the cardinal points when facing the Moon will show that the directions just noted are those in the sky on the celestial sphere. Employing a conventional telescope, without any star diagonal or other prismatic right-angle device, an inverted, reversed image will be produced, and the orientation may be described using the classical system, as indicated in *Figure 1*. In the eyepiece of the telescope, the crater *Tycho* would be toward the classical South, while *Mare Crisium* would be toward the classical West.

The other orientation system is the *IAU system*, officially adopted by the International Astronomical Union (IAU) in 1961, indicated also in *Figure 1*. With the unaided eye again, let's duplicate our previous observation at Full Moon at midnight in the northern hemisphere of the Earth. North (N) will be up and South (S) will be down, just as was the case in the classical system, but West (W) will be true West on the lunar surface, toward the left. East (E) will likewise denote true East on the Moon, toward the right. Thus, *Mare Crisium* will be near the East lunar limb, while *Tycho* remains to the South. In the eyepiece of our astronomical telescope, the inverted and reversed image will show South toward the top of the field, North will be at the bottom. East will now be to the left, and West is to the right. It will be helpful to remember where certain craters are with respect to the IAU system so that one does not become confused.

The A.L.P.O. Lunar Selected Areas Program (SAP) has adopted the practice of always using the IAU system of orientation when discussing and recording observations. Observers, therefore, are required to adhere to this convenient system at all times. Complications in the interpretation of directions will be encountered when one employs star diagonals or other prismatic devices, and the best way to avoid trouble is to observe the Moon as a conventional inverted and reversed image. For those who have telescopes with built-in prismatic devices, care must be taken at the outset to be absolutely sure of one's image orientation and which way N, S, E, and W is with respect to the lunar feature being observed. Records of observations should always, without exception, list whether or not star diagonals and other devices are being employed, along with orientation notes. Charts and blanks issued by the Selected Areas Program will always conform to the IAU system.

Sign conventions for lunar directions in the IAU system are such that North and South are positive (+) and negative (–), respectively; East and West are also denoted as positive (+) and negative (–), respectively. It is best to avoid errors by using N, S, E, and W rather than sign directions of + or – when denoting selenographic latitude and longitude.

On the surface of the Moon, *selenographic longitude* is measured from the *lunar meridian* that passes through the mean central point of the visible disc, positive toward Mare Crisium (East in the IAU sense). *Selenographic latitude* is reckoned positive toward the North limb (i.e., positive in the hemisphere containing *Mare Serenitatis*). The *mean central point of the disc* is defined as the point at which a straight line between the centers of the Earth and Moon would intersect the lunar surface, if the Moon were at mean ascending node when the node coincided with either the mean perigee or mean apogee.

Lastly, it should be emphasized that, since the axis of the Moon is not precisely parallel to that of the Earth, lunar North will not usually be in exactly the same direction as celestial North. The difference between the two directions is tabulated in the *ASTRONOMICAL ALMANAC* as *"Position Angle of Axis."*

CHANGING SOLAR ILLUMINATION, COLONGITUDE, AND LIBRATION

Observational studies of the Moon will reveal that the appearance of a lunar feature will be almost completely transformed by the varying solar illumination throughout any given lunation. It is essential to specify solar lighting conditions at the time of observation for the feature being studied.

The overall lighting conditions for the Moon will be defined in terms of the *selenographic latitude and longitude of the Sun*. The selenographic coordinates of the point on the lunar surface where the Sun is at the *selenocentric zenith* are the selenographic latitude and longitude of the Sun. Subtracting the selenographic longitude of the Sun from 90° or 450° gives the *selenographic colongitude of the Sun*, which is never greater than 360° or negative (-). As an approximation, *colongitude, C*, is often thought of as the *longitude of the sunrise terminator* (the great circle on the lunar globe along which the Sun is either rising or setting). Numerically, colongitude is the East selenographic longitude of the morning terminator, and is therefore approximately 270° at New Moon, 0° at First Quarter, 90° at Full Moon, and 180° at Last Quarter. The longitude of the evening terminator differs by 180° from that of the morning terminator.

The *ASTRONOMICAL ALMANAC* gives the *colongitude, C*, for each day of the year at 0^h UT. Interpolation must take place to derive the colongitude at the time of the actual observation, which is done by taking the colongitude at 0^h UT for the date in question and adding to it the appropriate colongitude change for the time of the observation. Colongitude always increases with time by an average amount of 12°.19 per day, and for values greater than 360°, one must subtract 360°. *Table 1* gives the mean colongitude change throughout the day for hours and minutes.

It is perhaps worthwhile, at this point, to take a give a few examples of computation of *colongitude, C*, for hypothetical observing sessions:

> *Example 1*. Compute *C* for 1983 March 01^d 05^h 15^m UT.
>
> From the *1983 ASTRONOMICAL ALMANAC* the value of *C* is 107°.03 at 0^h UT on 1983 March 01^d. The *change in colongitude,ΔC*, from *Table 1* for 05^h is 2°.54 and for 15^m is 0°.13. Adding these values to 107°.03 results in *C* = 109°.70 for the observing date of 1983 March 01^d 05^h 15^m UT. This value is entered in the space provided on the observing form being used.
>
> *Example 2*. Compute the UT during March 1983 for a lunation when the desired value of C is precisely 305°.00.
>
> Since the desired value of *C* = 305°.00, the *ASTRONOMICAL ALMANAC* is consulted for a date in March when there is a value for *C* close to this figure at 0^h UT. It is found that on 1983 March 17^d *C* = 301°.98, which means that a *change in colongitude, ΔC*, of only 3°.02 exists between the desired value and the *ASTRONOMICAL ALMANAC* value at 0^h UT on March 17 (305°.00 – 301°.98 = 3°.02).
>
> Looking up this value for *ΔC* in *Table 1*, the closest matching time difference is 05^h, which has a known value for *ΔC* = 2°.54. The variance between the two *ΔC* values now amounts to only 0°.48 (3°.02 – 2°.54 = 0°.48). Further examination of *Table 1* shows that a time interval of 57^m corresponds to 0°.48, and combining the values derived above, we find that a value of *C* = 305°.00 exists on 1983 March 17^d 05^h 57^m UT. We can then plan our observation for that date and time.

TABLE 1. CHANGE IN MEAN COLONGITUDE (*ΔC*)

I. *ΔC* (Hours):

h	***ΔC***	**h**	***ΔC***	**h**	***ΔC***
01^h	0°.51	09^h	4°.57	17^h	8°.64
02	1 .02	10	5 .08	18	9 .14
03	1 .52	11	5 .59	19	9 .65
04	2 .03	12	6 .10	20	10 .16
05	2 .54	13	6 .60	21	10 .67
06	3 .05	14	7 .11	22	11 .18
07	3 .56	15	7 .62	23	11 .68
08	4 .06	16	8 .13	24	12 .19

II. *ΔC* (Minutes):

	00^m	**10^m**	**20^m**	**30^m**	**40^m**	**50^m**
0^m	0°.00	0°.08	0°.17	0°.25	0°.34	0°.42
1	0 .01	0 .09	0 .18	0 .26	0 .35	0 .43
2	0 .02	0 .10	0 .19	0 .27	0 .36	0 .44
3	0 .03	0 .11	0 .19	0 .28	0 .36	0 .45
4	0 .03	0 .12	0 .20	0 .29	0 .37	0 .46
5	0 .04	0 .13	0 .21	0 .30	0 .38	0 .47
6	0 .05	0 .14	0 .22	0 .30	0 .39	0 .47
7	0 .06	0 .14	0 .23	0 .31	0 .40	0 .48
8	0 .07	0 .15	0 .24	0 .32	0 .41	0 .49
9	0 .08	0 .16	0. 25	0 .33	0 .41	0 .50

NOTE: The values given above assume a mean rate of colongitude change, *ΔC*, of 12°.19 per day. For greater accuracy, take *ΔC* to be the tabulated change in colongitude during the entire day of observation and correct the values above by multiplying by the factor *ΔC*/12°.19. The difference can amount to ±0°.07 in extreme cases.

It is of great value for individuals to know how to compute the Sunrise, Local Noon, and Sunset colongitudes of each feature that will be observed, and the following facts will be useful in planning observations:

1. *Features with W selenographic longitude:*

   Sunrise *C* = W longitude of the feature
   Local Noon *C* = W longitude of the feature + 90°
   Sunset *C* = W longitude of the feature + 180°

2. *Features with E selenographic longitude:*

   Sunrise *C* = 360° - E longitude of feature
   Local Noon *C* = Sunset colongitude - 90°
   Sunset *C* = Sunrise colongitude - 180°

Because colongitude varies through 360° during the course of a lunation, while the selenographic latitude of the Sun can change only between the limits of ±1°.6, colongitude is by far the more significant parameter in solar lighting. Nevertheless, for a precise description of illumination conditions, solar latitude must be considered (particularly in cases of low illumination near the lunar polar regions).

Careful telescopic examination of the Moon will reveal that our satellite does not present exactly the same face toward Earth at all times. Although it is true that at any given instant we can see only 50% of the lunar surface, it has been possible to map 59% of the total area of the Moon by observations from Earth alone. The slight alteration in the portion of the Moon we see, which permit these determinations from Earth, are termed *librations*, and they arise from three dynamic effects:

1. *Libration in latitude (N-S libration)* arises from the fact that the Moon's rotational axis is inclined to the perpendicular of its orbital plane by 6°.5, and we see alternating polar regions not continuously visible from Earth.

2. *Libration in longitude (E-W libration)* arises from the fact that the Moon rotates uniformly, but because of its elliptical orbit, the speed in the orbit changes in agreement with *Kepler's Law of Areas* from perigee to apogee, and vice versa. Hence, the rotation occasionally gets ahead of or behind the revolution, exposing portions of the surface behind the E or W limbs.

3. *Diurnal libration* arises from the fact that the Earth has finite size, so when the Moon is rising we see slightly more of one hemisphere, and when it is setting, we see a little more of the other.

The combined effects of all these factors is that the orientation of the Moon varies in a complex fashion within the limits of ±8°.0 in longitude and ±7°.0 in latitude.

The effect of libratory motions is to bring about variations in the apparent position and shape of lunar features. Of course, these phenomena are more pronounced near the limbs, reaching their maximum in the *libratory sector or zone*, where a feature may be visible or not, depending on libration. A positive (+) libration in longitude exposes the E (IAU) limb, while a negative (–) libration in longitude reveals more of the W (IAU) limb. In the same manner, a positive libration in latitude exhibits more of the N pole of the Moon, and a negative one yields more of the S pole. In combination, both librations bring into and out of our view, through time, more or less of the NE, NW, SE, or SW limb areas.

In the event that a lunar feature that is being studied is near one of the lunar limbs, observations should be planned to coincide with favorable libration effects. Unfortunately, the combination of optimum libration and suitable lighting conditions is rare. No opportunity to view a feature under the best circumstances should be missed!

OBSERVING SELECTED LUNAR FEATURES

The percentage of sunlight reflected by the surface of the Moon, as we have seen, varies as the *phase angle, g*, changes throughout the lunar month. Taken a step further, observers are well aware that one area of the Moon reflects more light (e.g., a crater rim or central peak) than another region (e.g., the maria), regardless of the phase angle, and these areas in turn vary in appearance as the illumination changes. These differences in *tone* are generally more conspicuous at Full Moon ($g = 0°$), and the investigation of light and dark areas of the Moon is an interesting observational endeavor.

While there is a definite requirement to know how various lunar features change their normal appearance throughout a lunation in response to variations in phase angle, even more intriguing are those lunar features that behave in an unusual, sometimes unpredictable, and non-repeating manner as solar illumination changes. The A.L.P.O. Lunar Selected Areas Program (SAP) is chiefly concerned with systematically monitoring regular and cyclical long-term variations during many lunations of specifically designated, or *"selected,"* areas on the Moon. In general, the SAP is designed to intensively study and document for each of these features the *normal* albedo changes in response to conditions of varying solar illumination. The program is equally concerned with the following possible *anomalous* phenomena:

1. *Tonal and/or Color Variations*. These are variations in tone or color, or in the size and shape of a region of tone or color, that is not related to changing illumination (i.e., the phenomenon does not exactly repeat from lunation to lunation). Areas in lunar features most subject to suchanomalous behavior are *radial bands, dark patches, and nimbi or haloes*.

2. *Shape and Size Changes*. These are variations in the appearance and morphology of a feature that cannot be traced to changing solar illumination or libration.

3. *Shadow Anomalies*. These are deviations of lunar shadows away from the theoretical normal absolute black condition, or a shadow with an anomalous shape or hue, in most cases not attributable to changing phase angle.

4. *Appearance or Disappearance of Features*. Although exceedingly improbable and controversial, these are features that seem to be present now, but appear to be absent on earlier maps or photographs; or, features that are no longer visible today but which are clearly indicated on earlier maps or photographs.

5. *Features Exposed to Earthshine*. These are any anomalous tonal or albedo phenomena (any of the categories listed here) that occur under the conditions of Earthshine.

6. *Eclipse-Induced Phenomena*. These are features which exhibit anomalous characteristics (categories 1 through 4 above) during and after an eclipse, compared with previous eclipses when the same areas were monitored.

Most of the phenomena listed above are related to anomalous variations in morphology, tone (albedo), or color, which cannot be attributed to changing solar angle (phase angle) or libration, and which clearly *do not* repeat systematically from lunation to lunation. As stated earlier, however, it is essential in our program *to establish a record of both the normal and abnormal behavior of suspect lunar areas* under all conditions of illumination.

Generally, the SAP has incorporated some of the methods pioneered years ago by past Lunar Recorders, but a few significant changes have been necessary as the SAP evolved with time. Several areas had been selected in the past for inclusion in the SAP, and while massive files exist on many of these regions, there has been no reason to simply abandon study of these areas. A few published reports appeared in the *JOURNAL OF THE A.L.P.O.*, and some very interesting data resulted, but further investigations are needed to establish a long-term record of normal and any abnormal albedo variances.

Following considerable research, and through consultation with various other colleagues involved in lunar studies, it has been decided that the lunar features that will become an *official* part of the SAP will be those listed in *Table*

2. All of these areas were chosen because of their ease of location and observation, and due to the fact that they historically have shown numerous instances of suspected anomalies in the past. Complete outline charts and observing forms have been prepared by the A.L.P.O. Lunar Section for each of the features noted in *Table 2*, and these blanks are available from the SAP Recorder.

TABLE 2. STANDARD SAP FEATURES

Feature	**Selenographic Lat.**	**Long.**	**Sunrise *C°***	**Local Noon *C°***	**Sunset *C°***
Alphonsus	4° W	13°S	4°	94°	184°
Aristarchus	47 W	23 N	47	137	227
Atlas	43 E	46 N	317	47	137
Copernicus	20 W	9 N	20	110	200
Plato	9 W	51 N	9	99	189
Theophilus	26 E	11 S	334	64	154
Tycho	11 W	42 S	11	101	191

(the nearby *Herodotus* is also considered a part of the program with its environs)

The standard SAP procedure is to visually monitor as many of the selected lunar features as possible throughout successive lunations, employing established systematic, objective methods of observation. It has already been stressed earlier in our discussions how important the quality of the instrument being used is, and individuals should be familiar with their telescopes and accessories, how to recognize scattered or reflected light, irradiation, as well as aberrations caused by the eye, the instrument, and the atmosphere.

The standardized observing procedures of the SAP are as follows:

1. Concentrate on one or two features only throughout any given lunation. Each observation should always be placed on the forms provided by the SAP.

2. Observations should be carried out using the same magnification(s), telescope, and accessories throughout any given lunation (and for a succession of lunations, if possible).

3. Careful records should be maintained of the date and time (UT) of the observation, the colongitude (*C*), the field orientation (IAU) of the view in the eyepiece, the seeing and transparency conditions, etc. Space is provided on the SAP forms for this kind of information, and all information requested should be provided as accurately as possible.

4. Observations should be attempted only when the Moon is at least at an altitude of 25° or more above the horizon to avoid the adverse effects of atmospheric dispersion and poor seeing near the horizon.

5. For each standard SAP lunar feature, *Reference Outline Charts* has been provided with the observing forms with several *index points* chosen to help standardize the observations. Points chosen are indicated by letters to refer to the following for each selected area when assigning albedo values:

A. A letter has been given to each cardinal point (N,S,E, and W) in the IAU sense on the *inner walls of craters or on the exterior sides of a lunar mountain or dome*.

B. A letter has been assigned to the *summit of any central peak or peaks* that may exist (or *summit of a specific mountain*).

C. Several points have been selected on the *floors of craters* and in some cases on *surrounding terrain*.

It is exceedingly important for individuals to recognize that these pre-defined features must be consistently utilized when assigning albedo values during the lunation in question, as well as always from lunation to lunation. Care must be taken to insure that the location of the intended index point being estimated is established from using the *Reference Outline Chart*. Also, any additional points of interest, chosen by the observer and assigned to the specific feature, should be carefully denoted in the record to prevent confusion with the standard points.

In *Table 4*, *Elger's Albedo Scale* is presented with examples at Full Moon (g = 0°). Observers must initially familiarize themselves (at Full Moon) with as many of the steps and examples in Elger's scale as possible and establish a *Permanent Reference Gray Scale*. This can be done quite easily by using graded exposed black & white film or prints, graded pencil shadings, or a reliable commercial gray scale wedge, to match each step (in integrated light) in Elger's scale. It is essential for one to employ the same telescope, magnification(s), and accessories when setting up the scale as will be used for routine observations. Once established, the scale is used exclusively as a reference standard for albedo estimates, and the observed albedo of every index point chosen for the feature under scrutiny (plus those picked by the observer) is matched to this scale.

During the normal course of a lunation, the assigned N and S points (IAU) of a feature should exhibit albedos of nearly the same value throughout a lunation, possibly brighter at Full Moon or at local noon for the site (both points would be quite similar to one another in behavior).For E and W (IAU) points, mirror-image behavior between the two should be encountered. For example, the E wall of a crater should be dull at sunrise, increase progressively in brightness or albedo, reaching a maximum near sunset. The W wall of the same crater would be most prominent at sunrise, go through a diminution in brightness, and be dullest at sunset. The albedo may, indeed, be greatest at local noon or Full Moon. Behavior of crater floors should follow tonal (brightness) variations that are "normal" for the feature, established after numerous observations through many lunations (a major part of the program). Dark areas periodically brighten at the times of local noon and at Full Moon, but some may darken under a high Sun.

6. There is also a *Drawing Outline Chart* provided as an observing form along with the *Reference Outline Charts* to be utilized for any "photographic" drawings or sketches that are executed. To perform such drawings will help train the eye to recognize even finer details and will add much to the value of the data. While artistic drawings are pleasing to the eye, accuracy is the main objective when trying to depict the form, position, shape, and tone of the lunar feature with respect to solar illumination. A separate *Albedo and Supporting Data Form* has also been provided to accompany the *Drawing Outline Chart* and *Reference Outline Charts* on which to record albedo data and supporting information for each observation. The *Albedo and Supporting Data Form* and *Drawing Outline Chart* should be sent to the A.L.P.O. Lunar Section following each lunation. Samples of these charts appear at the end of this book.

7. Observations should be carried out employing high-quality red, blue, and green filters to monitor features for possible brightness differences in various wavelengths. Filters should always have precisely-known wavelength transmissions, and the following *Wratten* filters (or their equivalent) are suggested for regular use in the SAP:

W23A or W25 (red) *W38A or W47 (blue)* *W58 (green)*

Dense filters, such as *W25* or *W47*, should be avoided for the smallest apertures.

8. Descriptive notes should accompany each observation, and they should include information that might not be apparent in examining the drawing or albedo chart. Things worth mentioning are features that are obvious only under low or high solar angles, the nature and extent of bright rays and/or bands visible in the proximity of the feature, and the general morphological appearance of the region and its environment. In particular, any anomalous or unusual aspects should be carefully noted and referenced.

9. Although the program is chiefly concerned with long-term phenomena, any transient events (LTP) that might be noticed in the course of an observation should be carefully recorded. Individuals might evaluate any occurring LTP with respect to time and duration, whether they represent brightenings or darkenings (suddenly), short-term anomalous fluctuations in hue, shadow anomalies, obscurations, etc. In any case, LTP events should be immediately brought to the attention of the Lunar SAP Recorder.

10. Observations should always be kept in duplicate, the originals being sent to the Lunar SAP Recorder at the end of any given lunation.

In recent years, our observers have expressed a strong desire to have greater freedom of choice among features to follow as part of the Selected Areas Program. In compliance with this request, the A.L.P.O. Lunar Section has developed special observing forms for this purpose, whereby the identity of the feature being studied is entered at the top of the sheet in the blank provided. These forms are similar to the standardized ones. In this instance, however, the observer must draw his own outline chart on the form (in the space provided) using an appropriate lunar atlas for reference and then assign index points analogous to the locations of those set on the pre-drawn outlines for standard features. The same outlines and index points should always be used for all observations of the lunar feature in question. Other than this requirement, the observing methods and techniques remain the essentially the same.

As an aid to observers who wish to choose their own features to monitor, *Table 3* lists lunar areas in which or near which one or more of the aforementioned anomalous phenomena have been suspected. Readers wishing to receive further details on a specific area are requested to contact the A.L.P.O. Lunar Section. This compilation is not complete because many unusual sightings have never been published. Some regions on the Moon have been traditionally watched more frequently than others, but in the last decade or so, observational coverage has been lacking for nearly all of the areas listed in the table. Persons interested in choosing their own lunar features to monitor should contact the A.L.P.O. Lunar Section for assistance, if necessary.

TABLE 3. SOME LUNAR REGIONS WITH HISTORICALLY SUSPECTED ANOMALIES

Feature	Feature	Feature	Feature	Feature	Feature	Feature
Agarum, Prom.	*Agrippa*	*Albategnius*	*Alhazen*	*Aliacensis*	*Alpetragius*	*Arago*
Alphonsus	*Archimedes*	*Aristarchus*	*Aristillus*	*Aristoteles*	*Arzachel*	*Atlas*
Mare Australe	*Bartlett*	*Beer*	*Bessarion*	*Billy*	*Boscovich*	*Mt. Blanc*
Bullialdus	*Bürg*	*Carlini*	*Cassini*	*Cavendish*	*Cleomedes A*	*Cichus*
Cleostratus	*"Cobra Head"*	*Colombo*	*Conon*	*Copernicus*	*M. Crisium*	*Crüger*
Darwin	*Dawes*	*Dörfel Mts.*	*Eimmart*	*Endymion*	*Eratosthenes*	*Eudoxus*
Feuillee	*M. Foecunditatis*	*Fourier*	*Mare Frigoris*	*Furnerium*	*Gassendi*	*Grimaldi*
Gutenberg	*Mt. Hadley*	*Halley*	*Hansteen*	*Helicon*	*Hell*	*Hercules*
Herodotus	*Hevelius*	*Mare Humorium*	*Hyginus*	*M. Imbrium*	*Sinus Iridium*	*Kant*
Julius Caesar	*Kepler*	*La Hire*	*Lambert*	*Langrenus*	*Lebnitz Mts.*	*Linne´*
Le Verrier	*Lichtenberg*	*Macrobius*	*Mädler*	*Manilius*	*Sinus Medii*	*Marth*
Menelaus	*Mercenius*	*Messier*	*M. Nectaris*	*M. Nubium*	*Pallas*	*Peirce A*
Mt. Percy	*Petavius*	*Philoaus*	*Phocydides*	*Picard*	*Piccolomini*	*Pico*
Pickering	*Piton*	*Plato*	*Plinius*	*Posidonius*	*Oceanus Proc.*	*Proclus*
Ptolemaeus	*Pythagoras*	*Reiner*	*Riccioli*	*Rocca*	*Sinus Roris*	*Ross D*
Schiaparelli	*Schickard*	*Schröter's Valley*	*M. Serenitatis*	*M. Smythii*	*Palus Somnii*	*Snellius*
Stadius	*Stevinus*	*Theaetetus*	*Theophilus*	*Thales*	*Tycho*	*Timocharis*
Torricelli	*M. Tranquillitatis*	*Triesnecker*	*M.Undarium*	*M. Vaporum*	*Lacus Somniorum*	
Vitello						

TABLE 4. ELGER'S ALBEDO SCALE

Numerical Value	Lunar Features as Examples
0.0	*Black Shadows*
1.0	*Darkest parts of Grimaldi, Riccioli*
1.5	*Interiors of Billy, Boscovich, Zupus*
2.0	*Floors of Endymion, LeMonnier, Julius Caesar, Cruger, Fournier*
2.5	*Interiors of Azout, Vitruvius, Pitatus, Hippalus, Marius*
3.0	*Interiors of Taruntius, Plinius, Theophilus, Parrot, Flamsteed, Mercator*
3.5	*Interiors of Hansen, Archimedes, Mersenius*
4.0	*Interiors of Manilius, Ptolemaeus, Guericke*
4.5	*Surface around Aristillus and Sinus Medii*
5.0	*Walls of Arago, Lansberg, Bullialdus; surfaces around Kepler and Aristarchus*
5.5	*Walls of Picard and Timocharis; rays of Copernicus*
6.0	*Walls of Macrobius, Kant, Bessel, Mösting, Flamsteed*
6.5	*Walls of Langrenus, Thaetetus, and LaHire*
7.0	*Theon, Ariadeus, Bode B, Kepler, Wichmann*
7.5	*Ukert, Hortensius, Euclides*
8.0	*Walls of Godin, Bode, Copernicus*
8.5	*Walls of Proclus, Bode A, Hipparchus C*
9.0	*Censorinus, Dionysius, Mösting A, Mersenius B and C*
9.5	*Interior of Aristarchus and LaPyrouse*
10.0	*Central peak of Aristarchus*

DRAWING LUNAR FEATURES

Sketches or drawings of lunar features fall into three rather distinct categories:

1. *Notational sketches* are rather incomplete drawings which are accompanied by detailed notes and numerals actually entered onto the face of the sketch.

2. *Line drawings* are executed with pencils or with special drawing ink, and they are used only to record topographic features, and possibly shadows, without reference to tonal differences. Both of these types of drawings are deceptively troublesome to do accurately, and the more common representation of lunar features is by the "photographic" or artistic drawing.

3. *"Photographic" or artistic drawings* are employed to depict lunar features precisely as they appear with espect to time, and the drawing should show as realistically as possible everything that the eye can perceive with respect to the area in question at the existing phase angle. Features recorded in this way usually exhibit details which are not readily apparent on actual photographs taken with the same instrument. This is because the eye can take advantage of moments of good seeing to record delicate contrasts and details at the threshold of vision that cannot be easily registered on a photograph. These drawings are performed entirely in pencil, with the possible exception of using drawing ink to represent shadows or white paint to depict exceptionally brilliant objects (e.g., the central peak of Aristarchus at Full Moon).

Outline forms are provided for specific lunar features which are part of the SAP, and all such "photographic" drawings should be carried out using the blanks prepared by the Recorder. Lunar features are shown on the blanks to scale, with topographic features outlined precisely for a suitable drawing reference. Errors in proportion are consequently reduced or eliminated when making drawings at the telescope.

Before the drawing is begun, and prior to coming to the telescope, it is wise to give some thought to what materials will be needed during the observing session. It is assumed that "photographic" drawings will be the regular practice of observers participating in the SAP, aside from albedo estimates, and line or notational sketches will be utilized only very rarely. A few of the essential items that will be needed in executing drawings are:

1. A complete set of observing forms, with a clipboard (equipped with a plastic, dew-preventive coversheet).

2. Pencils of varying softness and sharpness, with a razor to scrape graphite shavings onto the drawing blank.

3. A solid roll of soft blotting paper, known as an *artist's stump*, for blending and shading delicate changes in tone.

4. Erasers (some blunt and some sharp), with a brush to remove debris after erasure.

5. A small flashlight with a red filter; some observers use a headlamp similar to a "miner's headlamp" with a red filter, freeing up both hands for drawing.

6. Accurate watch, calibrated to WWV or CHU time signals, to set starting and ending times of the drawing (from which colongitudes will be calculated).

Detailed "photographic" drawings of lunar features are accomplished by either of two methods:

1. The *shading-erasure technique* involves preparing the drawing blank by sprinkling graphite shaving onto the form, then shading over the entire area using a soft tissue or rag to establish an overall grey tone of relative uniformity. The surface of the paper represents the apparent monotone of the lunar surface devoid of detail. Lighter regions of the feature in question are correctly represented by subsequently erasing to the desired tone, while dark areas are depicted by rubbing with the artist's

stump, adding more graphite where needed to gain depth. Very bright regions are noted by complete erasure or by white paint, and darkest areas are shown properly by using pencils or by drawing ink (for true shadows).

2. The *sketching method*, more commonly employed than the above technique, is executed by making pencil outlines of features seen, working from the largest to the smallest features. After most of the outline work is complete (this stage should not be necessary for features of the SAP which have outline charts), the areas are shaded in with the proper relative tones, leaving the brightest areas unshaded. Again, the use of drawing ink or white paint to emphasize extreme tonal impressions is recommended.

Both of the described methods have specific advantages and disadvantages. For example, with the shading-erasure technique, delicate maria shadings are often troublesome to get just right. In the use of either procedure, every effort must be made to employ the entire tonal range available; the brightest features should be left white (or emphasized with white paint), and the darkest features should be very dark grey, with shadows definitely black (assuming no anomalies). In any case, all drawings should depict features on the Moon that are definitely and accurately perceived. One must make clear through the medium of the drawing exactly what is intended.

Realistic "photographic" drawings of lunar features are achieved with constant practice, and a three-dimensional impression should be conveyed by the final product. For example, depressions and elevations on the Moon should look like what they are intended to be. A mountain, lunar dome, hill, or crater rim should look, in relation to the environment, like a relief feature. Practicing with high-quality photographs of the lunar feature in question will provide useful experience in executing the techniques discussed here.

Since the observer has an outline of each feature to follow in making drawings as part of the SAP, there should be no difficulty in generating a final product in which the positions, shapes, and relative sizes of objects are essentially correct. In any case, extreme care must be exercised to insure that errors in proportion do not occur, particularly when drawings are made of areas not normally part of the routine SAP endeavor. Throughout the drawing procedure, one must check and re-check for erroneous impressions, eliminating them whenever possible.

The greatest emphasis in completing drawings for the SAP is to establish the correct tonal representations which convey accurate relative albedos. In this instance, reference will continuously need to be made to the albedo outline onto which estimates have been noted with regard to all index points (and those chosen by the observer).

Upon completion of the drawing, final checks should be made to be certain that everything important has been included (i.e., the drawing should look like the object being observed as much as possible). No more than about 30 to 45 minutes should elapse between start and completion of the drawing, since longer time spans may well alter the appearance of certain aspects of features as solar illumination gradually changes. Also, the entire drawing should be finished at the telescope, not later. All details, including starting and ending times (UT), telescope and magnifications used, colongitude, seeing, transparency, etc., should be recorded on the forms provided by the Lunar Recorder.

SPECIAL SELECTED AREAS PROGRAMS

After considerable discussion with several past A.L.P.O. Lunar Recorders, and as a result of a number of appeals by observers, it was decided during early 1996 to resurrect two important lunar observational programs, the *Bright and Banded Craters Program* and the *Dark Haloed Craters Program*. Because of inherent similarities in observing methodology and technique, both programs have been merged with the A.L.P.O. Selected Areas Program.

1. DARK HALOED CRATERS

The *Dark Haloed Craters Program* (abbreviated *DHCP*), as the name implies, focuses on systematic observations of lunar craters which have dark haloes surrounding them. The most familiar examples of dark haloed craters (abbreviated *DHCs*) are the small craterlets girdled by very dark material situated on the floor of Alphonsus and which are especially prominent at Full Moon. Other DHCs are found near the crater Copernicus.

Many theorists believe that the majority of DHCs are endogenic volcanic features that are morphologically and dimensionally analogous to *maars* found on Earth. Terrestrial maars are produced by explosive, usually singular, events that create craters surrounded by dust and debris rather than lava. Maar-type DHCs have interiors that are at least as dark as their haloes. Some DHCs, however, appear to be exogenic (i.e., meteoric) in origin, as evidenced by outer slopes that are upwardly concave like typical impact craters. Meteoric DHCs have interiors that are characteristically light, yet have dark ejecta surrounding them. Good examples of what seem to be meteoric DHCs are found near Copernicus.

During 1968, it had been suggested in the literature that, after a detailed examination of high-resolution Earth-based lunar photographs, there are probably no less than 100 definite DHCs, with another 300 or so suspected DHCs that remain unconfirmed. DHCs, including some that are too small to be resolved from Earth, were revealed on photographs taken by spacecraft such as *Orbiter*, *Apollo*, and *Clementine*.

The original DHCP was initiated during August of 1971 with the following objectives:

1. Confirm the existence of dark haloed craters (abbreviated as *DHCs*).

2. Discover new DHCs.

3. Determine how the visibility of DHCs changes with varying solar illumination throughout a lunation and from one lunation to the next.

4. Document the existence of any dark rays associated with DHCs.

5. Define and understand the distribution pattern of DHCs on the lunar surface.

6. Define and understand the association of DHCs with rills, lunar domes, and Lunar Transient Phenomena (LTP).

7. Catalog all observationally confirmed DHCs with respect to location on the lunar surface and record details on their morphological and dimensional characteristics.

Unfortunately, due to inconsistent observer participation, the DHCP was terminated in 1976 after cataloging some 83 DHCs. Clearly, an enormous amount of observational and analytical work still needed to be done. Even so, the DHCP was successful in generating some interesting and valuable data. The following are some of the more important gleanings from the five-year observational effort, with notes added as appropriate suggesting where there exists a need for further study in a subsequent observational program:

1. As noted above, 83 confirmed DHCs were cataloged by 1972, and charts were made by the A.L.P.O. that plotted all confirmed and unconfirmed DHCs in the catalog. [NOTE: Further checking needs to be performed to insure the accuracy of positional data.]

2. Based on studies of albedo vs. changing solar illumination for about 20 DHCs throughout several lunations, it was found that no real variation patterns could be established. Thus, the tentative conclusion was be that most DHCs remained rather stable in albedo. Some DHCs, however, exhibited definite intensity variations in response to changing solar angle. [NOTE: More thorough, long-term albedo studies are needed, ideally for all confirmed and cataloged DHCs.]

3. Nearly two-thirds of the confirmed 83 DHCs were distributed on the *maria* (found most often along the edges of the maria), and about a fourth of the DHCs were located on the dark floors of larger craters (e.g., Alphonsus). [NOTE: As more DHCs are observed and confirmed, their distribution patterns need to be given further scrutiny.]

4. About 61% of the 83 cataloged DHCs were situated in clusters or pairs, with only 39% appearing singular. Some DHCs are so close together in clusters that their dark haloes overlap. [NOTE: With the addition of additional confirmed DHCs, it would be interesting to see if these statistics change.]

5. Nearly 80% of the 83 DHCs were located at or near the center of their dark haloes (i.e., radially symmetrical with respect to the central crater); with regard to peripheral boundaries, it was found that 78% of the dark haloes were circular, 12% were elliptical, and 10% were irregular. [NOTE: As more DHCs are confirmed, it would be useful to reassess these statistics.]

6. Among the 83 DHCs, only 2 had dark rays emanating from them, suggesting that there may be poor correlation between DHCs and craters exhibiting prominent bright rays. [NOTE: As cataloged DHCs grow in number, it would be meaningful to see if the relative abundance of dark rays associated with DHCs changes.]

7. Efforts to understand any relationship of DHCs with Lunar Transient Phenomena (LTP) resulted in limited success. For example, DHCs in the crater Alphonsus have produced sporadic LTP events over many years, but few systematic observations of DHCs in relation to LTP were carried out during the DHCP from 1971 - 1976. An internal origin of LTP is supported by the distribution and association of many LTP sites with volcanic maria, dark-haloed craters, sinuous rills, and lunar domes. [NOTE: Consistent monitoring DHCs for LTP as part of a systematic program needs to continue.]

8. Studies of DHCs and how they relate to features like sinuous rills and lunar domes gave limited results. A few DHCs were found in the environs of sinuous rills, as well as atop lunar domes. Because lunar domes are most probably endogenic and sinuous rills are collapsed lava tubes, the idea that dark haloed craters have an internal origin is given more credence. [NOTE: The location of DHCs in the proximity of sinuous rills and lunar domes needs further study.]

It should be pointed out that some lunar craters fortuitously occur within localized dark spots or regions on the Moon. By an earlier classification scheme adopted by the DHCP, these are not considered bona fide DHCs. This convention means that craters located within dark regions that are *more than 10 times greater than the diameter of the crater itself* would not be considered a DHC. We will maintain this criterion. A complication arises, however, when two or more DHCs are clustered near one another with overlapping dark haloes. For example, dark haloes merging together when two DHCs are in close proximity to each other would take on the appearance of a elongated dark region engulfing the two craters. Thus, our criterion would be applied to the *width* of the merging haloes rather than to their combined length. An example of this scenario can be seen on the floor of Alphonsus adjacent to the West (IAU) wall.

Photographs taken from Earth or from spacecraft have not typically shown DHCs to real advantage, mainly because of the unique exposure requirements needed to enhance the contrast of the DHCs with respect to surrounding lunar terrain. It is also quite unlikely that the Moon will remain under enough rigorous photographic surveillance (via spacecraft or large Earth-based telescopes), especially under optimum contrast conditions, to spoil the dedicated efforts of DHCP observers for years to come. The amateur observer who wants to contribute something useful to our knowledge about the Moon can definitely do so.

By now, it may be quite obvious that observations of DHCs have a strong correlation with other studies of the Moon. As we have seen above, some DHCs are LTP sites, and several DHCs are located within craters that are already monitored by the Selected Areas Program (e.g., Atlas and Alphonsus). Thus, including the detection, observation, and cataloging of DHCs into the overall Selected Areas Program is justified.

The objectives of the initial DHCP have been revised as follows:

1. Using the existing DHC catalog, further confirm the existence and location of known DHCs. Survey the Moon for additional DHCs, and enter their precise location in the existing DHC catalog. A systematic, standardized approach would be to limit scans of the lunar surface to a small region at a time (e.g., 15° of selenographic longitude x 15° of selenographic latitude) when searching for new DHCs to include in the catalog.

2. Monitor each DHC throughout a lunation, and from lunation to lunation, to determine the normal albedo profile for the feature as a function of changing solar illumination. Because of the small size of most DHCs, the number of albedo reference indices used by the Selected Areas Program will need to be adjusted accordingly.

3. Further confirm or establish the morphological and dimensional characteristics of DHCs, including their overall symmetry with respect to craters vs. surrounding dark haloes, the occurrence of any associated dark rays, as well as the distribution of DHCs on the Moon.

4. Determine how soon after lunar sunrise a particular DHC is first noticed, establish the *colongitude, C,* when the DHC becomes most prominent, and ascertain how close to lunar sunset the DHC can still be seen.

5. Further confirm or establish the occurrence of clusters of DHCs vs. singular DHCs.

6. Further confirm or establish the occurrence of DHCs in association with features such as sinuous rills, lunar domes, etc.

7. Monitor DHCs for LTP events (data would subsequently be passed on the Lunar Recorder in charge of the Lunar Transient Phenomena Patrol).

8. Use extensive drawings, photographs, CCD images, and video tape to help support and achieve the objectives of the DHCP.

With only slight modification, individuals would use the same observational procedures, methods, and techniques normally employed by the Selected Areas Program when observing DHCs. For the convenience of the observer, a *DHC Observing Form* has been developed for use in recording DHCs. In most cases, observing DHCs is easy and less time consuming that regular SAP observations. In terms of their visibility, the relative sizes of DHCs range from diminutive craterlets near the threshold of resolution of larger instruments to the crater Picard, which is fairly conspicuous. So, the majority of DHCs are within reach of a 10.2 cm. (4.0 in.) to 15.2 cm. (6.0 in.) aperture, but instruments in excess of 20.0 cm. (8.0 in.) are recommended for more detailed work. In the final analysis, the main factor that affects visibility of DHCs, aside from atmospheric seeing and transparency, is varying illumination by the Sun. Observers will soon discover that there is a particular phase of the Moon when a specific DHC will be most prominent in contrast with its environment. Yet, even though optimum observing times need to be established for each DHC, it is just as important to know what the overall pattern of visibility for each DHC is throughout a lunation.

Although filling out the *DHC Observing Form* is fairly straightforward, the following tips may be worth considering:

1. Use only one form for each DHC observed.

2. Lunar maps and atlases of differing vintage exist among observers. Positional data for DHCs may be expressed using *xi* and *eta* coordinates, as well as *Selenographic Longitude* and *Selenographic Latitude*. Either or both coordinates are useful. Enter descriptive data about the "Environs" in which the DHC is located [e.g., "DHC located on floor near W (IAU) wall of Alphonsus"] should always be included. Always enter the *colongitude, C,* for the date and time of the observation.

One of the easiest ways to determine the position of a newly confirmed DHC, or to check the positional accuracy of an existing DHC, is to make a copy of the region containing the DHC from a lunar atlas depicting coordinates. Using the copy, sketch in the position of the DHC, paying attention to the relative size of the crater and dark halo, and measure the coordinates of the feature later. Some observers actually make drawings on copies of lunar maps, attaching them to the observing forms.

3. Using lunar features of known dimensions, estimate the diameter of DHCs in kilometers whenever possible (careful use of kilometer scales on lunar maps will improve accuracy).

4. Estimates of albedo (intensity) should be made by reference to *Elger's Albedo Scale*, and albedo data should be linked to specific indices on the DHC (in most cases, there will be an index for the crater itself, another for the dark halo, and one for the surrounding terrain). Utilization of the *Albedo and Supporting Data* form is essential for recording intensity data, and it should be attached to the *DHC Observing Form*. Information that is duplicated on the two forms need not be entered twice.

5. Drawings of DHCs should be made on the *DHC Observing Form*. Make certain that the direction of North (N) is clearly indicated on the drawing (attention should be given to the proper field orientation of the eyepiece). Also, supplement drawings with good photographic, CCD, or video images of DHCs in an effort to capture their overall characteristics during different solar illumination conditions. It would be useful to record the appearance of DHCs in different color filters and variable-density polarizers, too.

6. In the "Descriptive Notes" section of the *DHC Observing Form*, include information that may not be immediately apparent on the rest of the form or drawing. Notes should be made about the symmetry of the DHC with respect to the surrounding dark halo, whether the crater and/or dark halo is circular or elongated, etc. If the crater and/or dark halo is non-circular, notes describing the orientation of the major axis of the feature should be included. A sample *DHC Observing Form* appears at the end of the book.

7. Submit observations at the end of a given lunation along with any photographs, video tapes, or CCD images to the A.L.P.O. Lunar Section.

The A.L.P.O. Catalog of Dark Haloed Craters, which includes all 83 DHCs confirmed by August 1976, is presented in *Appendix A*. It is also worthwhile to know how groups of DHCs are separated from one another. In *Appendix B* appear the separation distances in kilometers of the 51DHCs that appear in groups from the 1976 DHCP catalog.

2. BRIGHT AND BANDED CRATERS

The *Bright and Banded Craters Program*, abbreviated *BBCP*, is concerned with systematic observations of lunar craters that appear extremely brilliant when the Sun is overhead (i.e., near Full Moon), as well as craters that exhibit dark or light radial bands within their walls. A particular crater may be both bright and banded, or it may just be bright with no bands; also, a crater may not be particularly brilliant, but it may exhibit dark or bright bands. So, there may be several categories of features covered by the BBCP. Earlier efforts to observe, categorize, and catalog these features generated useful data, but program participants were too few in number to provide adequate coverage. Considerable work, therefore, remains to be done.

Some of the objectives of the BBCP may be listed as follows:

1. Limiting systematic scans of the lunar surface to a small region at a time (e.g., 15° of selenographic longitude x 15° of selenographic latitude), detect and catalog craters that are especially brilliant (have high albedos) at or near local noon at the site. Record the albedo for each crater, using indices in the

same manner as for other SAP features, as applicable. Like other SAP features, it is worthwhile to examine these bright craters under all illumination conditions throughout a lunation and from one lunation to the next to establish normal albedo profiles.

2. Determine whether or not there is a relationship between crater brightness at local noon and the visibility of dark or light bands, central peaks, or both.

3. Limiting systematic scans of the lunar surface to a small region at a time (e.g., 15° of selenographic longitude x 15° of selenographic latitude), detect and catalog craters that exhibit dark or bright bands, or both, under various lighting conditions throughout a given lunation and from one lunation to another.

4. For craters exhibiting banding, determine the relative positions, orientation, and intensities (albedos) of the bands throughout a lunation and from one lunation to another.

5. Investigate what correlations may or may not exist between crater size, the presence of central peaks, and the occurrence of light and/or dark bands.

6. Monitor the visibility and morphology of bright and/or banded craters during umbral and penumbral lunar eclipses.

7. Use extensive drawings, photographs, CCD images, and video tape to help support and achieve the above goals.

Observational data should always be recorded on the *BBCP Observing Form* (a sample copy is presented at the end of this book). Like filling out the *DHC Observing Form* discussed earlier, employing the *BBCP Observing Form* is also relatively simple. Consider the following tips when completing the forms:

1. Use only one form for each bright and/or banded crater observed.

2. A number of lunar maps and atlases of differing vintage exist. Positional data for bright and/or banded craters may be expressed using *xi* and *eta* coordinates, as well as *Selenographic Longitude* and *Selenographic Latitude*. Either or both coordinates are useful. Enter descriptive data about the "Environs" in which the feature is located [e.g., "crater is located approximately 4 km E (IAU) of Gassendi"] should always be included. Always enter the *colongitude, C,* for the date and time of the observation.

One of the easiest ways to determine the position of a newly confirmed bright and/or banded crater, or to check the positional accuracy of an existing feature, is to make a copy of the region containing the crater from a lunar atlas depicting coordinates. Using the copy, sketch in the position of the crater, paying attention to its correct relative dimensions, and measure the coordinates of the feature later. Some observers draw features directly on copies of lunar maps, attaching them to the observing forms.

3. Using lunar features of known dimensions, estimate the diameter of crater, as well as the length and width of bands, in kilometers whenever possible (careful use of kilometer scales on lunar maps will add precision to this process).

4. Estimates of albedo (intensity) should be made by reference to *Elger's Albedo Scale*, and albedo data should be linked to specific indices on the crater (set up in the same manner as for other SAP features). Utilization of the *Albedo and Supporting Data* form is essential for recording intensity data, and it should be attached to the *BBCP Observing Form*. Data that is duplicated on the two forms need not be entered twice.

5. Drawings of craters should be made on the *BBCP Observing Form*. Make certain that the direction of North (N) is clearly indicated on the drawing (attention should be given to the proper field orientation of the eyepiece). Also, supplement drawings with good photographic, CCD, or video images of bright and/or banded craters in an effort to capture their overall characteristics during different solar

illumination conditions. It would be useful to record the appearance of craters in different color filters, as well as with variable-density polarizers.

6. In the "Descriptive Notes" section of the *BBCP Observing Form*, include information that may not be immediately apparent on the rest of the form or drawing. Notes should be made about the morphology of the feature (e.g., visibility of dark or light bands, central peaks, or both; relative positions, orientation, and albedos of bright and/or dark bands; correlations that may or may not exist between crater size, the presence of central peaks, and the occurrence of light and/or dark bands).

7. Submit observational data, along with photographs, CCD images, or video tapes, to the A.L.P.O. Lunar Section at the end of a given lunation.

OTHER SPECIAL OBSERVING PROJECTS

In addition to the aforementioned activities, several additional programs might be initiated by the imaginative observer, all of which fit into the overall framework of the Selected Areas Program. Some of these endeavors are:

1. Observing and cataloging *lunar domes*, and monitoring their visibility and changes in albedo with varying solar illumination throughout a given lunation, as well as from one lunation to another. The *Lunar Dome Survey* (abbreviated *LDS*) conducted by the A.L.P.O. years ago sought to catalog all lunar domes visible with Earth-based telescopes, and considerable success was achieved. The LDS is still an active program, and interested observers are invited to participate.

2. Observe and record albedo changes of *bright rays* during a lunation and from one lunation to the next. Monitor albedo changes associated with lunar rays during penumbral and umbral eclipses.

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APPENDIX A.

The 1976 A.L.P.O. Catalog of Dark Haloed Craters

DHC xi eta	Selenographic Longitude	Selenographic Latitude	Location	Diameter of Crater	Diameter of Halo	Shape of Halo	DHC within 15 km. of Rill?
+838–355	+63° 38′	–20° 48′	–	8 km.	15 km.	C	N
+821–122	+55 15	–06 47	M	2	6 x 8	E	N
+790+251	+54 33	+14 32	M, P	25	37	C	Y
+774+227	+52 40	+13 10	M, P	14*	27 x 32	E	N
+760+313	+53 24	+18 15	M, P	18*	32 x 60	I	N
+757+331	+53 30	+19 22	M, P	10	15 x 20	E	N
+690–029	+43 50	–01 40	M, P	1.5*	14	C	N
+671–053	+02 02	–03 00	M, P	4	11	C	N
+556–317	+32 10	–18 32	M	5	10	C	N
+514–045	+29 08	–02 35	M	6	14	C	N
+500–196	+30 42	–11 18	M	2	6	C	N
+490+717	+44 35	+46 20	C, P	5.5 x 4	15	C	Y
+490–239	+30 20	–14 13	M, G	1*	4	C	N
+486–248	+30 04	–14 22	M, G	5*	15	I	N
+484+034	+28 55	+02 00	M	5*	20	I	N
+481–237	+29 40	–13 42	M, G	2	8	C	N
+480+814			C, G	1	4	C	N
+476+735	+44 35	+47 25	C, P	1.5 x 3	15	C	Y
+476+815			C, G	1.5 x 2.5	5	C	N
+473+816			C, G	1.5 x 3.5	5	C	N
+473+670	+39 40	+42 02	–	4	12	C	N
+412+709	+35 45	+45 07	M, G	4*	10	E	N
+407+708	+35 10	+45 05	M, G	2*	10	E	N
+392+707	+33 40	+45 02	M, G	4	15	I	Y
+353+017	+20 38	+01 00	M	3	10	C	N
+271+301	+16 37	+17 38	M, P	3*	5 x 8	E	Y
+256+306	+15 50	+17 50	M, P	2*	7	C	Y
+222+294	+13 21	+17 02	–	7	20	C	N
+172+229	+10 10	+13 16	M	2	7	C	N
+127+248	+07 32	+14 22	M, P	1.5	6	C	N
+125+259	+07 27	+15 02	M, P	2	5	C	N
+107+500	+07 08	+30 03	M, G	2	5	C	N
+087+513	+05 50	+30 53	M, G	3	12	C	N
+081+517	+05 25	+31 10	M, G	3	8 x 12	E	N
+073+510	+04 49	+30 42	M, G	4	14	C	Y
+066+553	+04 33	+33 37	M	5	11	C	N
+050+071	+02 54	+04 08	M, G	1	7	C	N
+041+069	+02 32	+03 52	M, G	0.5	3.5	C	N
+037+073	+02 13	+04 03	M, G	0.5	4	C	N
+037+078	+02 04	+04 28	M, G	0.5	2	C	N
+034+082	+01 52	+04 38	M, G	1	3	C	N
+033+076	+01 52	+04 20	M, G	2	4	C	N
–013+565	–01 55	+34 28	M	3	12	C	N
–025–235	–02 41	–13 18	C, G	1	8	C	Y
–027–223	–01 37	–12 52	C, G	3	10	C	Y
–028–217	–01 42	–13 14	C, G	2	7	C	Y
–032–248	–01 50	–14 22	C, G	3.5	11	C	Y
–033–216	–01 55	–12 33	C, G	2	7	C	Y
–057–238	–03 21	–12 47	C, G	1	5	C	Y
–069–235	–04 03	–13 40	C, G	2	8	C	N
–070–234	–04 07	–13 38	C, G	1	6	C	N

−071−237	−04 11	−13 43	C, G	2	8	C	N
−112−538	−07 32	−32 38	C	2*	6.5 x 5.5	C	N
−127+192	−08 05	+11 09	M	2	6	C	N
−137+314	−08 20	+18 20	M, G	7	16	C	N
−143+320	−08 40	+18 42	M, G	6	16	C	N
−150+335	−08 58	+19 30	M, G	1.5	3	C	N
−156-353	−09 33	−20 42	M	4	15	C	Y
−166+306	−10 05	+17 55	M, G	0.5	1.5	C	N
−180+299	−10 52	+17 30	M, G	4	7	C	Y
−180+308	−10 52	+18 00	M, G	4	8	C	Y
−186+146	−10 50	+08 22	M	2.5	7	C	N
−205+290	−12 25	+16 58	M, G	6	9	C	Y
−231+142	−12 28	+18 12	M	2	6	C	N
−231+199	−12 38	+11 33	C, P	1.5*	6	C	N
−237+199	−13 59	+11 30	C, P	2*	7 x 11	E	N
−261+421	−16 45	+25 06	M	2	4.5	C	N
−264+311	−16 03	+18 13	M	1.5	6	C	Y
−265+140	−16 01	+07 53	M	1.5	2 x 5	C	Y
−293+219	−17 32	+12 41	–	1*	6	C	Y
−312+120	−18 15	+06 53	–	4.5	15	C	Y
−348+218	−20 28	+12 28	–	2.5	10	E	N
−348+233	−23 38	+13 35	–	4	15	C	N
−398+083	−23 38	+01 45	M	1	4.5	C	N
−409+052	−24 33	+02 59	M	2*	10	E	N
−447+103	−26 41	+04 55	M	7	16	I	N
−457+078	−27 39	+04 30	M	2.5	7	C	N
−466+124	−28 01	+07 08	M	1.5*	9	C	N
−488−744	−46 48	−48 02	–	9	21	I	N
−500−726	−46 32	−46 27	–	3.5*	7	C	N
−575−695	−53 05	−44 00	C, G	4	11	I	N
−578−696	−53 39	−44 07	C, G	4	11	I	N
−659−700	−66 00	−44 00	–	5	14	C	N

NOTES:

The above table lists positional data of each DHC in terms of *xi* and *eta*, plus *selenographic longitude* and *selenographic latitude* (columns 1, 2, and 3). Note that xi and selenographic longitude is positive (+) toward the East, such at East (in the IAU sense) on the Moon is the hemisphere including Mare Crisium; eta and selenographic latitude are positive to the North. In column 4, the letter "M" designates that the DHC is located in one of the lunar maria, "C" indicates that the DHC is situated inside of a dark-floored crater, "G" signifies that the DHC is part of a local group of DHCs, and "P" means that the DHC is one of a pair of DHCs. Columns 5 and 6 list the diameter of the DHC in kilometers, but when a particular DHC is not located in the center of its surrounding halo, an asterisk (*) appears in Column 5 along with the dimension. In column 7, the letter "C" indicates that the perimeter of the halo is circular, "E" denotes an elliptical halo, and "I" refers to an irregular one. The last column uses "Y" or "N" to indicate whether the DHC is located in close proximity of a rill (less than 15 km. away).

APPENDIX B.

Kilometer Separations of Groups of Dark Haloed Craters

No. of DHCs in Group	DHC Group	Separation
2	+774+227 and +790+251	45 km.
2	+760+313 and +757+331	35 km.
2	+690-029 and +671-053	35 km.
2	+490+717 and +476+735 (in *Atlas*)	30 km.
3	+490–239, +486-248, and +481–237	10 and 20 km.
3	+480+814, +476+815, and +473+816	7 and 7 km.
3	+412+709, +407+708, and +392+707	12 and 40 km.
2	+127+249 and +125+259	20 km.
4	+107+500, +087+513, +081+517, and +073+510	10, 15, and 25 km.
6	+050+071, +041+069, +037+073, +037+078, +034+072, and +033+076	7 to 15 km.
7	–137+314, –143+320, –150+335, –166+306, –180+308, –205+290, and –180+299	15 to 50 km.
2	–231+199 and –237+199	8 km.
2	–575–695 and –578–696	10 km.
2	+256+306 and +271+301	36 km.
9	–025–235, –027–223, –028–218, –032–248, –033–216, –057–238, –069–235, –070–234, and –071–237 (all within *Alphonsus*)	10 to 50 km.

Association of Lunar and Planetary Observers: The Lunar Selected Areas Program

***Visual Observations of Selected Lunar Features:* ____________________**

(indicate chosen feature)

S

N

Blank for Albedo Indices *Drawing Blank*

Date (UT):____________________________ Start Time (UT):____________________ End Time (UT):______________________

Colongitude (Start):___________________° Colongitude (End):___________________° Altitude of Moon:__________________°

Seeing:______________ Transparency:______________ Instrument:____

Magnification(s):________X________X________X________X Filter(s): 1._________2._________3._________4. _________

Observer:____ Location:____

Index Point	Albedo: Filter 1	Albedo: Filter 2	Albedo: Filter 3	Albedo: FIlter 4	Index Point	Albedo: Filter 1	Albedo: Filter 2	Albedo: Filter 3	Albedo: Filter 4
A					K				
B					L				
C					M				
D					N				
E					O				
F					P				
G					Q				
H					R				
I					S				
J									

Observational Notes:

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A.L.P.O. Lunar Section: Selected Areas Program

Bright and Banded Craters Observing Form

Crater Observed : ___________________________________

(identify by name, *xi* and *eta* designation, or *selenographic longitude* and *selenographic latitude*)

Observer: ___________________________________ Observing Station: ___________________________

Mailing Address: ____
street city state zip

Telescope: ____
instrument type aperture (cm.) focal ratio

Magnification(s): __________X ___________X ___________X Filter(s): F1 ___________ F2 ___________
Seeing: _______________________________________ [A.L.P.O. Scale = 0.0 (worst) to 10.0 (perfect)]
Transparency: _________________________________ [Faintest star visible to unaided eye]

Date (UT): ____________________________ Time (UT): ____
year month day start end

Colongitude: _______________________° ________________________°
start end

Position of Crater:

xi	*eta*	Selen. Long.	Selen. Lat.	Environs

Lunar Atlas Used as Reference: ____

DRAWING

Show detailed morphology, position, orientation, and other characteristics of the crater, including any bands that are definite or suspected, in the drawing blank below. Use the *Albedo and Supporting Data* form for albedo estimates of assigned indices for the crater and for any bands observed (attach to this form). Indicate correct direction of N (IAU) on the drawing.

DESCRIPTIVE NOTES:

scale
|--|

A.L.P.O. Lunar Section: Selected Areas Program

Dark Haloed Craters Observing Form

Dark Haloed Crater Observed : ______________________________
(identify by *xi* and *eta* designation or *selenographic longitude* and *selenographic latitude*)

Observer: ______________________________ Observing Station: ______________________________

Mailing Address: ____
street city state zip

Telescope: ____
instrument type aperture (cm.) focal ratio

Magnification(s): __________X __________X __________X Filter(s): F1 _________ F2 _________
Seeing: ______________________________________ [A.L.P.O. Scale = 0.0 (worst) to 10.0 (perfect)]
Transparency: ______________________________ [Faintest star visible to unaided eye]

Date (UT): ___________________________________ Time (UT): ______________________________
Year month day start end

Colongitude: _______________________° _______________________°
start end

Position of DHC:

xi	*eta*	Selen. Long.	Selen. Lat.	Environs

Lunar Atlas Used as Reference: ____

Dark Haloed Crater (visibility):
[ ] definitely visible
[ ] strongly suspected
[ ] vaguely suspected
[ ] not visible
[ ] centered [ ] off center

Relative Intensity (crater) ______
Crater Diameter ______ km

Surrounding Dark Halo (visibility):
[ ] definitely visible
[ ] strongly suspected
[ ] vaguely suspected
[ ] not visible
[ ] circular [ ] elliptical
[ ] other ________________________

Relative Intensity (halo) ______
Halo Diameter ______ km

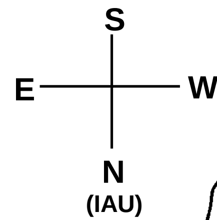
DRAWING

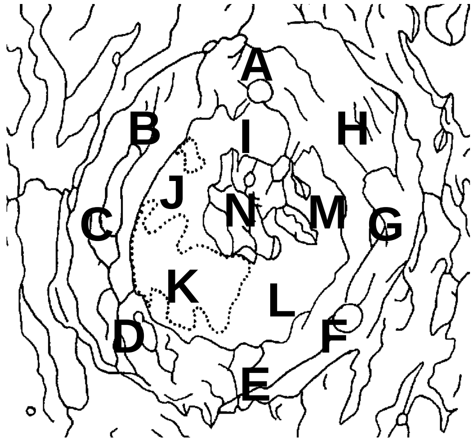
scale
|--------------------------------------|

NOTES:

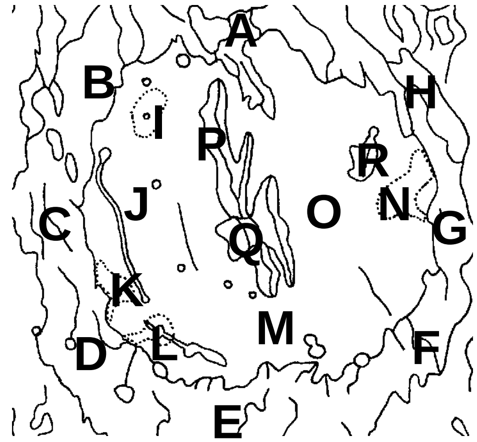
A.L.P.O. Lunar Selected Areas Program

Assigned Albedo Index Points

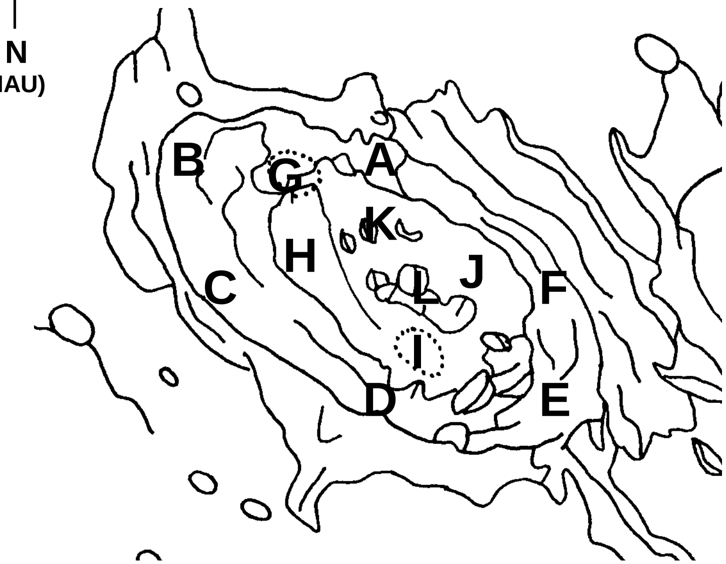




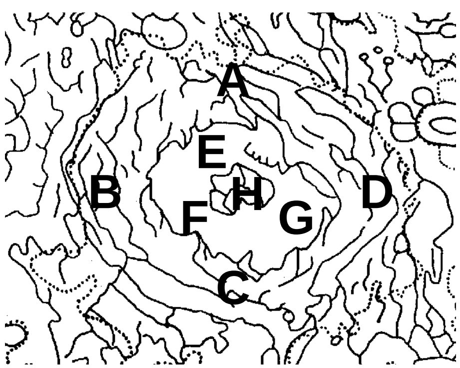
Theophilus



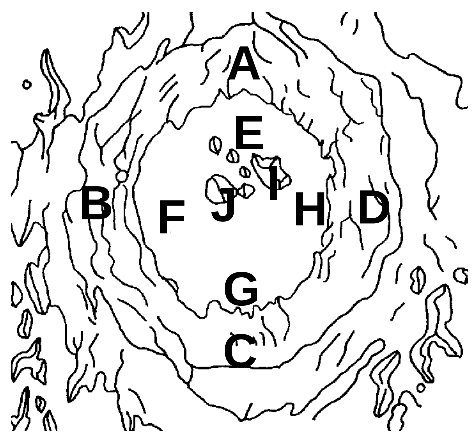
Alphonsus



Atlas



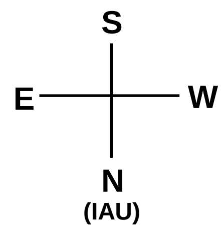
Tycho



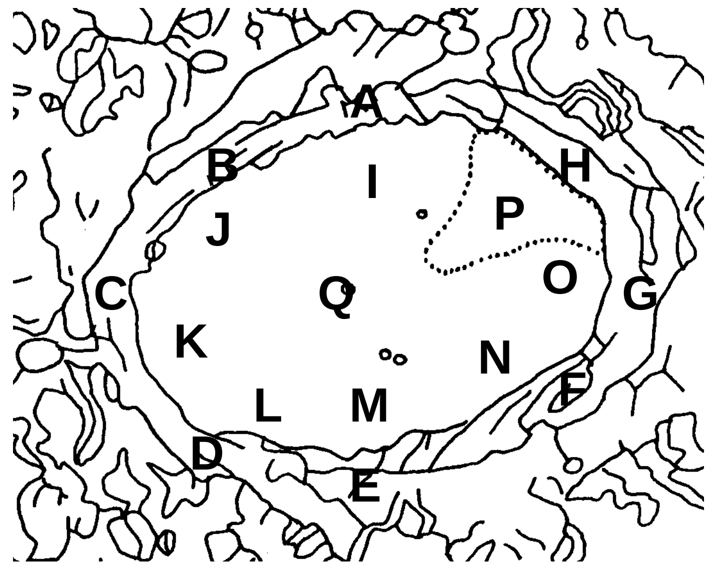
Copernicus

A.L.P.O. Lunar Selected Areas Program

Assigned Albedo Index Points



Aristarchus



Plato