A Lunar Isotonal Map*

ROBERT J. HACKMAN,
U. S. Geological Survey,
Washington, D. C.

ABSTRACT: *An isotonal map of the Lansberg region of the Moon has been prepared at a scale of 1:2,000,000 as part of a program of geologic investigations of the lunar surface. Tone values were determined by densitometer measurements on a high-contrast positive transparency of a full-moon photograph. The relative densities obtained from 32 traverses and 600 spot measurements were reduced to standard density units. Lines connecting points of equal film density were drawn on the photograph and then transferred to a base map.*

Comparison of the isotonal map with the photograph shows that the unaided eye cannot unambiguously recognize the same tones at different places, particularly dark tones surrounded by varying darker backgrounds. Tone values measured on the lunar maria are not correlated with recognizable topography and presumably indicate changes in texture or composition. The measurements made in this study could be correlated only approximately with normal albedo measurements.

INTRODUCTION

THE lunar maria, where not covered with ray material, generally display subtle differences in brightness, which may be related to local differences in texture and composition. Theoretically, the most precise way of investigating these differences is to measure normal albedo (absolute brightness) at individual points on the lunar surface. A few such measurements have been made, more on bright areas than on the dark maria. To be useful in geologic mapping, albedo measurements would have to be made at a great number of points covering the surface of the moon; the technical difficulty of the measurements precludes this.

Tone values obtained by measurement of density of photographs provide a less precise measure of brightness than to direct telescopic measurements of normal albedo. However, photographic measurements of relative density can be made at all points on a lunar photograph independent of changes in atmospheric transmission or solar illumination. In this study an isotonal map was prepared by outlining areas of equal density on a photograph.

The Lansberg region of the Moon (Figures 1 and 2) is located in the center of the western half of the lunar disk. It covers forty degrees of latitude and thirty degrees of longitude, and includes an area of about 400,000 square miles. A full-moon photograph,[1] in which no shadows are present (Figure 2), was chosen for the density measurements.

Densitometer traverses were made across high-medium- and low-contrast full-moon positive transparencies to determine the most suitable contrast for enhancement of the darker tone values on the maria. The transparencies (1/8,000,000 scale), were printed on masking film from a glass plate negative (1/20,000,000 scale). The different contrasts were produced by varying the exposure time during the printing process.

Figure 3 shows the densitometer curves for the three traverses across the Lansberg region of the Moon. The location of the traverse line is shown as *XY* in Figure 2. The curves demonstrate that the high-contrast film was exposed so as to enhance tone contrast in the darker parts (the maria) of the photographs. As a consequence, tone differences in the brighter parts (highlands and rays) of the photograph are diminished. The dark tones are shifted from the shoulder of the gamma curve to the straight-line portion and exhibit more

[1] Mt. Wilson Observatory photograph, H. Wright series, no. 198, July 11, 1938.

* Publication authorized by the Director, U. S. Geological Survey.

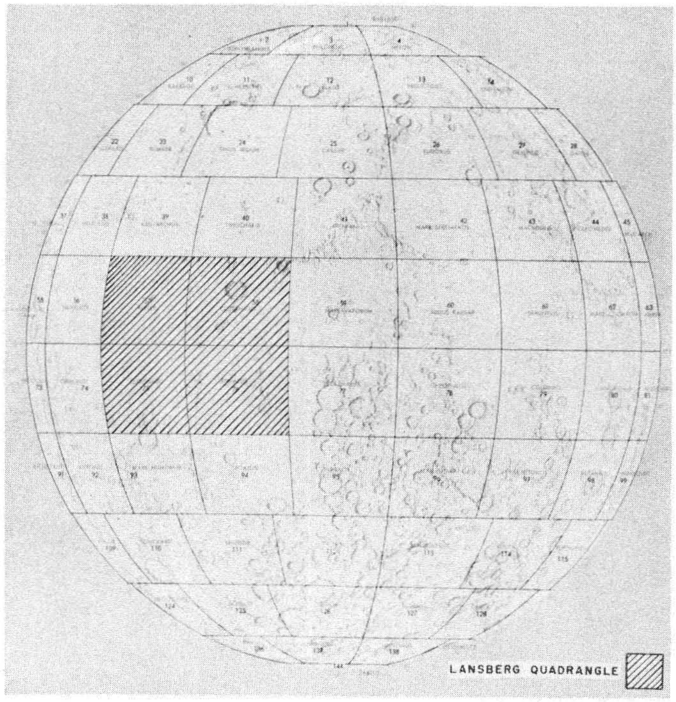

FIG. 1. Index map showing location of Lansberg region of the Moon.

contrast. The brighter tones are shifted to the toe of the curve and exhibit less contrast. A similar high-contrast film transparency from the same negative, but at a larger scale, was selected for the study.

PROCEDURE

Film density was measured with a MacBeth Ansco densitometer (see Figure 4), using a circular aperture of one millimeter. A positive transparency at a scale of 1/4,250,000 is

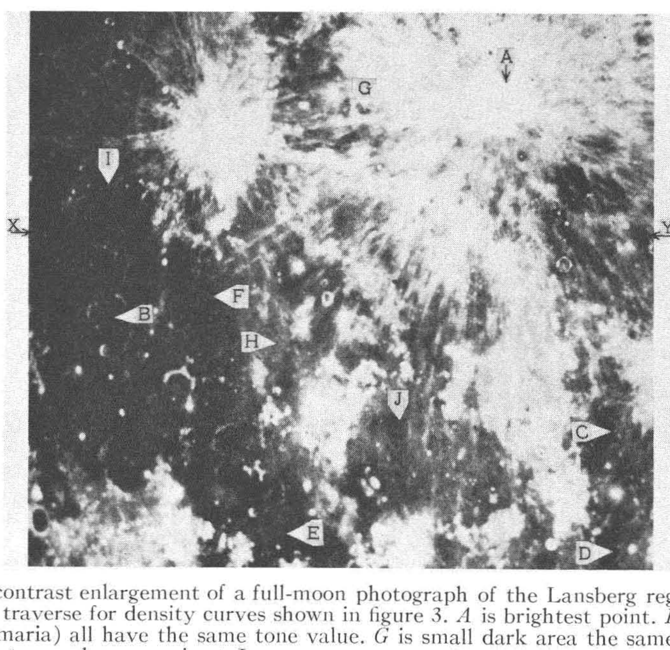

FIG. 2. A high-contrast enlargement of a full-moon photograph of the Lansberg region of the Moon. *XY* is location of traverse for density curves shown in figure 3. *A* is brightest point. *B* is darkest point. *C*, *D*, *E*, and *F* (maria) all have the same tone value. *G* is small dark area the same tone value as *H*. Ray at *I* has same tone value as maria at *J*.

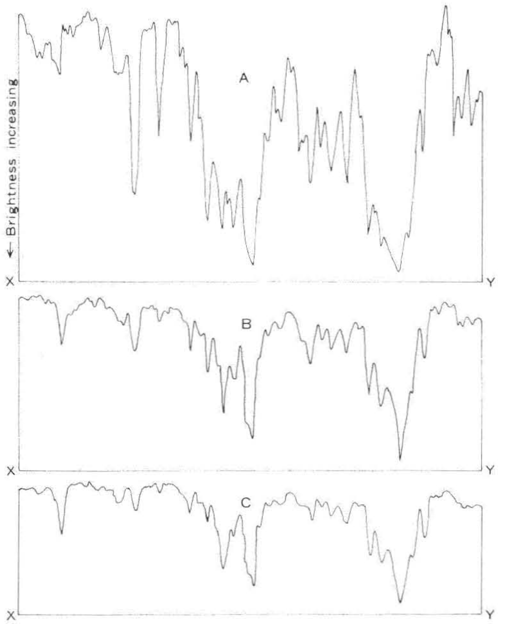

FIG. 3. Densitometer curves for traverse across Lansberg region on (A) high-contrast film. (B) medium-contrast film and (C) low-contrast film.

placed at position *A* on the densitometer, and a stable-base positive print at the same scale is placed at *B*. The two photographs are secured to a power-driven movable stage, and all lines of traverse are followed across both. The densitometer curve for each traverse is simultaneously plotted on graph paper by the recorder at *C*.

A control traverse was run over a standard density wedge to provide a relative scale of density increments preceding and following a set of 32 traverses. Six hundred spot measurements of density were also made.

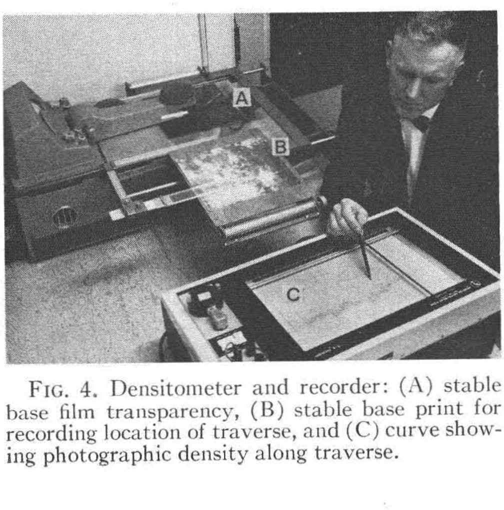

FIG. 4. Densitometer and recorder: (A) stable base film transparency, (B) stable base print for recording location of traverse, and (C) curve showing photographic density along traverse.

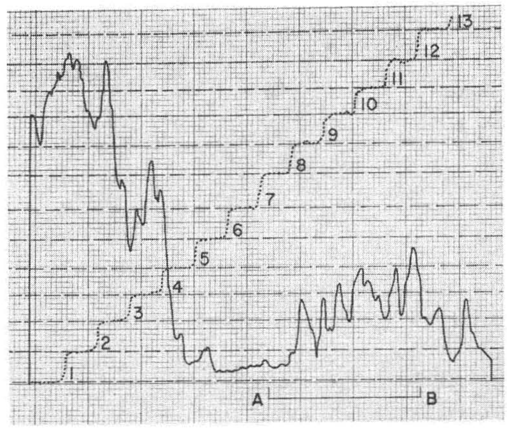

FIG. 5. Diagram shows relationship of density curve to stepped curve of density wedge. Curve AB shown in figure 6 at larger scale.

Figure 5 shows how each traverse curve was related to the stepped curve of the density wedge. With the stepped curve as a guide, parallel lines were drawn, separating the traverse curve into density units. An enlarged portion of the curve (Figure 6) shows how values and widths of density units were projected and plotted on a line representing the traverse.

Traverse lines, point locations, and density values were projected from the transparency on to a high-contrast stable-base positive print enlarged to 1/2,000,000. The graphic records determined from the density curves were enlarged to the same scale and plotted along their traverses. With the spot and traverse measurements as control, and tonal patterns on the photograph as visual aids for interpretation, isotonal lines connecting points of equal density were drawn on the photograph.

Coordinate intercepts of latitude and longitude (from Kuiper, 1961) along with recognizable features on the full-moon photograph, were used as control in transferring the isotonal lines to the Mercator projection of the U. S. Air Force lunar topographic chart. The transfer was done with a Zeiss Sketchmaster, modified with a supplemental lens providing gradational distortion in one direction only. (Figure 7 shows the configuration of isotonal lines on the map; figure 8 shows a portion of the isotonal map (Hackman, 1963) superimposed on the Air Force topographic chart.

Isotonal lines delimiting certain features such as small bright craters on the lunar maria probably do not reflect properly the abrupt change associated with the margins of such features. This is due in part to the diminution

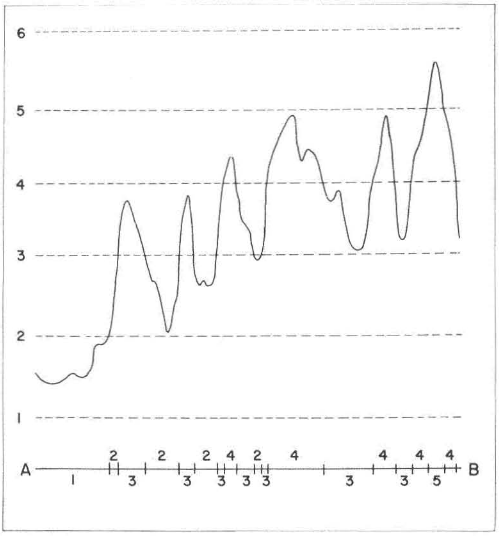

FIG. 6. Enlargement of part of curve shown in figure 5. Density values determined from curve are projected to line AB for transfer to compilation photograph.

of edge sharpness by the photographic process and in part to the use of a 1.0-millimeter aperture on the densitometer (corresponding to a resolution of 2.65 miles on the lunar surface), which is larger than some of the small bright features on the photograph. As a result some small features may be shown with a tone value somewhat higher or lower than their true value.

Morris (1963) attempted to correlate the relative tone measurements with normal albedo measurements that have been made by other investigators. Figure 9 shows a comparison of these albedo measurements with relative tone values measured in this study. A bar is used instead of a point for the albedo measurement because of the difficulty in properly locating them on the isotonal map, and also because the tone values may represent an integrated measurement of a specific albedo measurement integrated by the relatively large size of the densitometer aperture. There is a correlation between the darker tone measurements and the corresponding lower albedo measurements. However, as mentioned above, because of the restricted density range introduced by high-contrast development, which has shifted the brighter tone values to the toe of the gamma curve, tone differences among the brighter areas are compressed, and all albedo measurements above 0.085 are restricted to the first two density units.

INTERPRETATIONS AND CONCLUSIONS

With due consideration to other criteria,

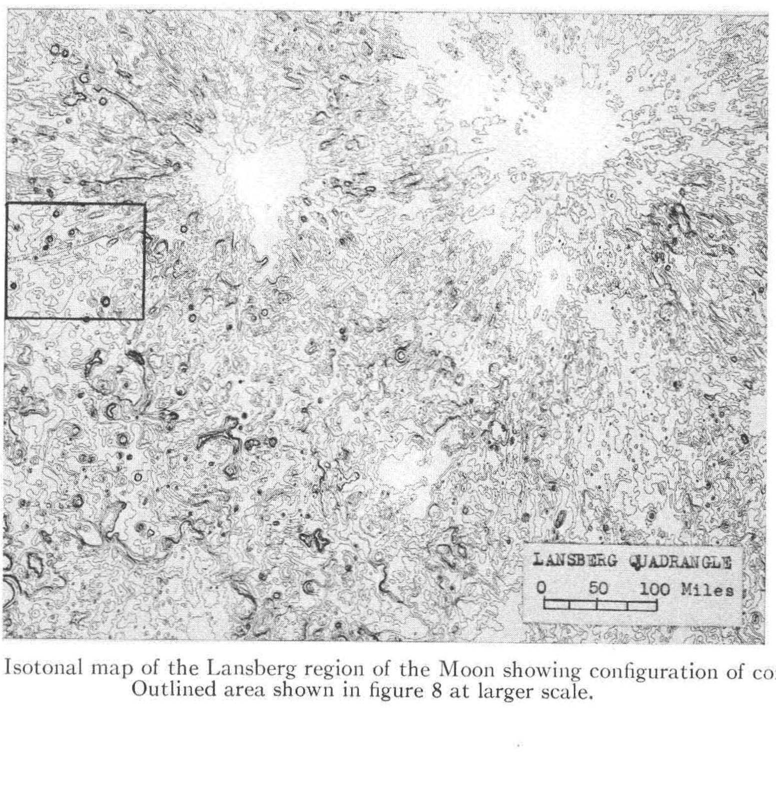

FIG. 7. Isotonal map of the Lansberg region of the Moon showing configuration of contours. Outlined area shown in figure 8 at larger scale.

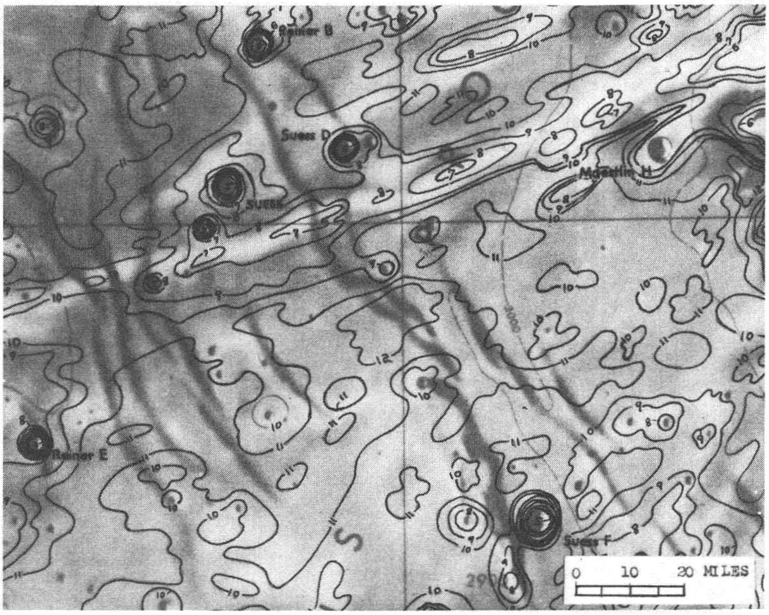

FIG. 8. Part of isotonal map of Lansberg region (Fig. 7) superimposed on U. S. Air Force chart.

tone values are an important key in interpreting the geologic data on lunar and terrestrial photographs. Similar tone values of widely distributed rock outcrops are often a clue to the correlation of such units. An isotonal map, such as the one compiled in this study, depicts small-tone variations that would escape the unaided eye, designates the brightest- and darkest-toned areas, and also correlates tones with a far greater precision than could be done visually. For example: In Figure 2, *A* is the brightest tone measured, and *B* is the darkest. *C*, *D*, *E*, and *F* are mare surfaces that all have the same tone value and may be areas of similar texture and chemical composition.

The dark area at *G* has the same tone value as what appears to be a lighter-tone mare area at *H*. The brighter tones surrounding *G* enhance its darkness and cause it to appear darker than *H*. The unaided eye cannot unambiguously recognize the same tone at different places on the photograph.

Although maria material is generally dark on lunar photographs, some is light enough to be confused with light-toned ray material. The ray west of Kepler (see Figure 2 at *I*) stands out quite clearly in contrast to the darker maria. A ray of the same tone value would not be visible at location *J* since the mare surface in this area has the same general tone value as the ray. Only rays of a lighter tone value show up in this area. Thus, ray material, although usually conspicuous where it overlays mare material, has probably gone unrecognized in some smaller areas and is probably more extensive than has been supposed.

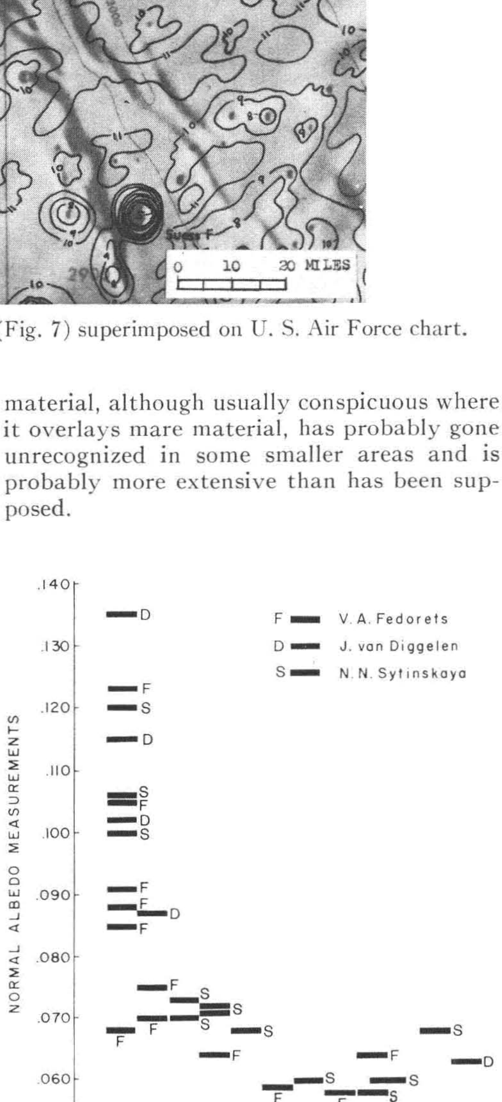

FIG. 9. Comparison of 29 albedo measurements with tone measurements made on the high-contrast film positive of the Lansberg region.

Tone variations on the lunar maria are not related to recognizable topography. This is readily apparent in Figure 8, where isotonal lines of the darker mare material not obscured by rays, cross the low mare ridges indiscriminately. This relationship suggests that these tone variations were present before the formation of the maria ridges. These variations are most likely the result of textural and compositional differences, and may be related to the age and genesis of the material. Although conclusive evidence is not available as to the exact nature of this material, a popular theory suggests an extrusive origin. The tone variations observed on the mare surfaces are not dissimilar to tone differences observed on terrestrial flows of basalt or welded tuff (Smith, 1960 and van Bandat, 1962, p. 57).

References Cited

Hackman, R. J., 1963, "Isotonal map (Lansberg region of the Moon): *in* Astrogeologic Studies, Annual Progress Report, August 25, 1961 to August 24, 1962, Part A, U. S. Geol. Survey Open-File Report, p. 58–59, (map in pocket).

Kuiper, G. P., ed., 1961, "Lunar Atlas, v. II, Selenographic coordinates on photographic plates," compiled by D. W. G. Arthur and E. A. Whitaker: U. S. Air Force, Aeronautical Chart and Information Center, St. Louis.

Morris, E. C., 1963, "Albedo measurements in the Lansberg region of the Moon:" *in* Astrogeologic Studies, Annual Progress Report, August 25, 1961 to August 24, 1962, Part A, U. S. Geol. Survey Open-File Report, p. 60–63.

Smith, R. L., 1960, "Zones and zonal variations in welded ash flows:" U. S. Geol. Survey Prof. Paper 354-F, p. 149–159.

Van Bandat, H. F., 1962, Aerogeology: Houston, Gulf Publishing Company, 350 p.

*A Freon-Cooled Film Viewer**

BERNT THULE, DAVID WEINSTEIN, HELEN GUSTAFSON,
Nuclear Research Instruments,
A Division of Houston Fearless Corp.
2800 7th St. Berkeley, Calif.

Abstract: *NRI is developing a system to solve a particular film analysis problem where large quantities of photographic records must be viewed and measured. The film is in reels of several widths, up to 9½ inches, and in lengths up to 1,000 feet. Much of the imagery is very dark with a high average density. In order to identify the picture detail the operator must see the projected picture with an average luminance suitable for the best operating range of the human eye. Therefore the energy of visible light incident on the dark field must be many times greater than the necessary transmitted energy for the projected picture. This calls for a very high intensity light source.*

In order to prevent film damage, a large amount of heat must be removed from the system. A technique used in printing photographs has been adapted for this application. The film which is in the illuminated platen area passes between two glass plates and is surrounded on either side by flowing Freon. The liquid used is Freon 113 which is a liquid at room temperature, has a high enough specific heat to carry off the absorbed energy from the film, and has an index of refraction very close to that of film.

The instrument described in this paper is a rear-projection viewer which permits high intensity illumination and projection of a wide variety of films. It was developed in response to a photointerpretation problem—that of viewing many different kinds of imagery and sizes of film with enough intensity control to present the image at the optimum viewing condition, without damaging film. The major problem is keeping the film cool while passing high intensity light through it. The photographs that are under study may vary in density from almost clear film to an average density of 3 over the viewing region.

* Presented at 30th Annual Meeting of the Society, Hotel Shoreham, Washington, D. C., March 17–20, 1964.