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COVER SHEET FOR TECHNICAL MEMORANDUM

TITLE- Apollo 12 Multispectral Photography Experiment

TM- 70-2015-1

DATE- February 20, 1970

FILING CASE NO(S)- 340

AUTHOR(S)- A. F. H. Goetz

FILING SUBJECT(S) (ASSIGNED BY AUTHOR(S))- Apollo 12 Photography

ABSTRACT

The Lunar Multispectral Photography Experiment, S-158, was successfully carried out on Apollo 12. A number of photographs were returned in the blue, green, red and infrared portions of the optical spectrum. Preliminary data analysis shows no color boundaries in the frame containing the Fra Mauro formation and the Apollo 13 landing site. Color differences were found in the frame containing Lalande η, establishing the existence of small-scale color differences on the lunar surface.

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TECHNICAL MEMORANDUM

I. PURPOSE OF THE EXPERIMENT

The goal of the Lunar Multispectral Photography Experiment (S-158) was to obtain vertical strip photography in three portions of the optical spectrum, blue, red and infrared, at one to two orders of magnitude higher resolution than obtainable from earth. A fourth camera, having a green filter was added to the array for operational purposes. However, for the sake of the following discussion it will be considered part of S-158.

The further objectives of this experiment were to:

1. Photograph future Apollo landing sites so that ground truth information provided by the returned samples may be extrapolated to other points on the lunar surface.

2. Produce photometrically accurate, two and three color images by photographic as well as computer processing methods which will accurately delineate lunar color boundaries and their magnitudes.

II LUNAR COLOR MEASUREMENT

Lunar color and its variation across the surface has interested planetary astronomers for many years. This interest has heightened with the growing weight of evidence, obtained from accurate earth-based photoelectric photometry, which points toward a positive correlation between color and compositional differences(1). Once we have obtained ground truth samples at several sites of differing color, it may be possible to extrapolate compositional color information to large areas of the moon which will not be sampled in-situ.

In the present context color differences mean relative differences in spectral reflectivity between points on the surface. The general spectral reflectivity curve of the moon shows a near linear increase in reflectivity from 400 nanometers (nm) to 800 nm[2]. Areas designated red or blue reflect more energy in their respective wavelength regions than a standard lunar area. In most cases the greater the separation in wavelength, the greater the color difference obtained. The differences between 400 nm and 800 nm, among points on the lunar surface, average 4-8%[1].

Photographic[3] and photoelectric[1] methods have been used in the past for the measurement of lunar color variations. The best known photographic method used to date is Whitaker's[3] sandwich printing tehhnique in which a negative UV and positive IR plate were sandwiched together and printed. Color differences then show up as varying shades in grey. The disadvantages of this method are that it is not quantitative and that albedo changes can masquerade as color differences if the D log E curves of the two plates are not extremely well matched. The advantage of the method lies in the image form of data display.

Recent advances in photoelectric instrumentation allow ground-based relative color measurements to be made to ±0.1% accuracy[4]. However, point-by-point measurement is a time consuming process and not suited for image display. Work now in progress with electronic imaging systems will incorporate the advantages of both methods.

Computer image processing[5] of photographs combines the advantages of photographic image display and provides quantitative color information for the entire picture, albeit at accuracies less than obtainable from photoelectric photometry.

III EQUIPMENT AND OPERATION

The S-158 array consisted of four 70mm Hasselblad cameras with 80mm lenses. The filter — black and white film combinations were: blue, 47B/3401; green, 58/3401; red, 29+0.6ND/3401; IR, 87C/SO246. Type 3401 is a plus-X, aerial-film and SO246 is 5424 infrared aerographic film coated on a 4 mil base. The center wavelength of each filter-film combination is: blue, 430 nm; green, 540nm; red, 660 nm; IR, 860 nm.

An intervalometer tripped all shutters simultaneously at 20 second intervals. For operational purposes the shutter speed on all four cameras was fixed at 1/60 second. Focus settings were fixed at 44 feet for the IR camera and ∞ for the other three. In order to facilitate f-stop changes, the vertical strip photography was broken into three segments. During rev 27 the blue, green and IR cameras were set at f-5.6 and the red camera at f-4.0. Photography was taken between longitudes 120°E and 90°E and between 54°E and 15°W. The minimum sun angle was approximately 25°. The remainder of the vertical photography was carried out on rev 28 at f-8/5.6. The off-vertical targets of opportunity were exposed at f-5.6/4.0 for Theophilus and Descartes and f-2.8/2.8 for Fra Mauro. Figures 1 and 2 show the photography ground track.

IV FILM CALIBRATION AND PROCESSING

All flight film calibration and processing was carried out by the MSC Photo-Technology Laboratory (PTL). Pre-flight calibration was accomplished by applying a 21-step gray wedge to the film in a 1-B sensitometer. For S-158 a special step tablet was constructed to provide 4 21-step wedges arranged to fit in a 60 x 60mm format to facilitate film scanning procedures. In addition, a pre-flight standard wedge and a post-flight special tablet were applied to the leader of the film.

Pre-flight process controls were established to develop the films to the following gammas: blue, 1.7; green, 1.65; red, 1.6; IR, 1.5. The different gammas were chosen to compensate for the increasing transmission of the standard wedge toward longer wavelengths. In other words, the absolute gamma should be 1.7 for each film. The relatively high gammas were chosen to give the maximum exposure differentiation commensurate with the required dynamic range on the film. The gammas obtained were: blue-1.68, green-1.48, red-1.42, IR-1.44. The reasons for the discrepancy among control and flight film gammas are not completely understood but, most likely, they can be attributed to radiation fogging and latent image decay. PTL is investigating this effect.

V FILM RETURN

Each of the blue, green and red cameras returned 142 frames while the IR camera in which the film had been rationed, returned 105 frames.

The resolution in the 3401 returned film is about 30 meters. This limit is approximately the motion resulting from the shutter speed of 1/60 second. The densities on all frames fell within the approximate straight line portion of the respective D log E curves shown in Figure 3. This was a necessary requirement for data reduction by photographic methods. For reasons not understood at this time all IR frames have a 4mm wide underexposed stripe at the leading and trailing edges of each frame. The IR frames are not in focus and will not be usable for color difference analysis.

VI DATA REDUCTION AND ANALYSIS

The color or spectral reflectivity differences sought in this study are not detectable by eye or on normal color film. The eye is very sensitive to small color variations under controlled laboratory conditions, in particular when the objects have the same brightness and are juxtaposed. However, the eye is incapable of reliably detecting small differences in spectral reflectivity in conjunction with brightness differences such as in a lunar surface scene. Normal color additive techniques using color separation photographs also fail to show up differences even at high saturation.

The two methods mentioned in Section II, the photographic sandwich and computer image processing techniques, are basically techniques for ratioing two pictures. Ratioing is necessary to remove the brightness variations due to general albedo and slope differences. Because the film density is a function of the log of the exposure, ratios are formed by taking differences in densities between two pictures. Such difference pictures for two colors have been produced by photographic[3] and computer methods[5]. Data reduction for S-158 will be carried out in three colors using extensions of both methods. Details of these procedures will be the subject of later publications.

Figure 4 shows frame 8438, a view of the Fra Mauro Formation and the Apollo 13 landing site, taken with the blue, green, and red filtered cameras. The dark corner in each picture is due to obscuration by the edge of the hatch window. No noticeable density variations, other than an overall brightness difference, are visible.

A two color computer difference picture was constructed from the center portion of the frame, including the Apollo 13 landing site. A blue and a red frame were digitized and, through use of the calibration wedges, each point in the picture was converted into the log exposure domain. A total of approximately two million points were measured in each picture. The pictures were registered, subtracted from another point for point, and contrast stretched. An arbitrary location was chosen to be gray. Preliminary data reduction shows no significant color variations within the frame, suggesting that the area is uniform in composition.

A two color difference picture of frame 8392, Figure 5, covering a portion of Mare Nubium and Lalande η was constructed. Figure 6 is a contrast stretched red minus blue print of 8392 in which dark areas are bluer and light areas are redder than an arbitrary point which was chosen to be gray.

Distinct color differences are evident particularly between Lalande η and the surrounding mare and between what appears to be secondary impact ejecta rays and the surrounding mare. Although the frames have not been calibrated for camera vignetting or adjusted to a lunar standard by earth-based photometry, there is now clear evidence for local, small scale color variations on the lunar surface. Further discussion of this result must await the analysis of other frames.

VII SUMMARY

The Lunar Multispectral Photography Experiment has yielded a large number of black and white photographs in the four colors. Preliminary inspection has shown evidence of a wide variety of surface features which may or may not exhibit color differences. Two existing image data reduction methods are being expanded to produce images which display greatly enhanced three color contrast. Two color difference pictures have been produced, one of which establishes the existence of small scale color differences on the lunar surface.

ACKNOWLEDGMENTS

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A. F. H. Goetz

2015-AFHG-gmr

Attachments
References
Figures 1-4

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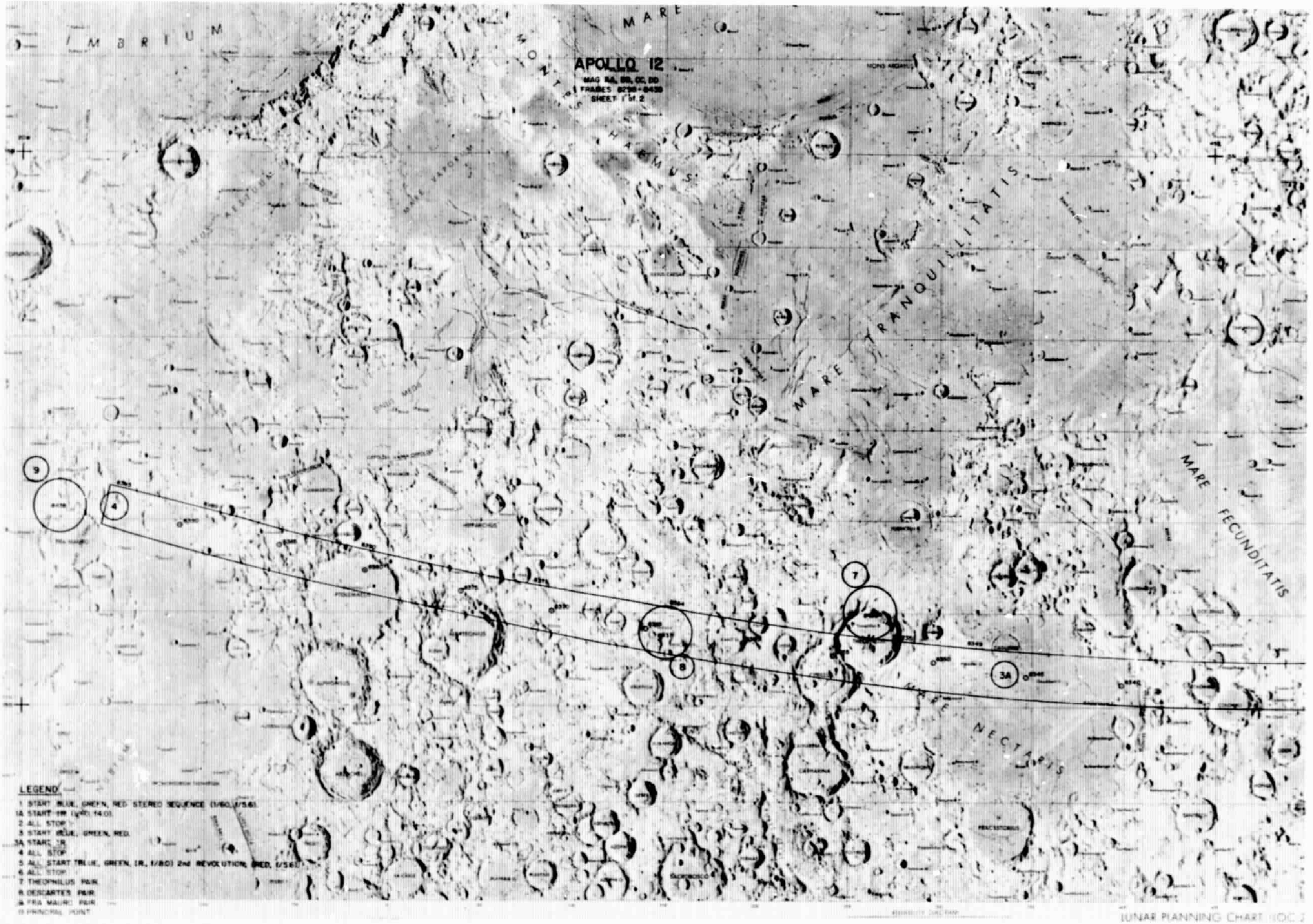

MARE IMBRIUM
MONTES HAEMUS
APOLLO 12
MAG RA, BB, CC, DD
FRAMES 8298-8439
SHEET 1 of 2
MARE TRANQUILLITATIS
MARE FECUNDITATIS
MARE NECTARIS
LEGEND
1 START BLUE, GREEN, RED STEREO SEQUENCE (1/60, 1/56)
1A START IR
2 ALL STOP
3 START BLUE, GREEN, RED
3A START IR
4 ALL STOP
5 ALL START (BLUE, GREEN, IR, 1/80) 2nd REVOLUTION (RED, 1/56)
6 ALL STOP
7 THEOPHILUS PAIR
8 DESCARTES PAIR
8A FRA MAURO PAIR
9 PRINCIPAL POINT
LUNAR PLANNING CHART (LOC-2)

FIGURE 1

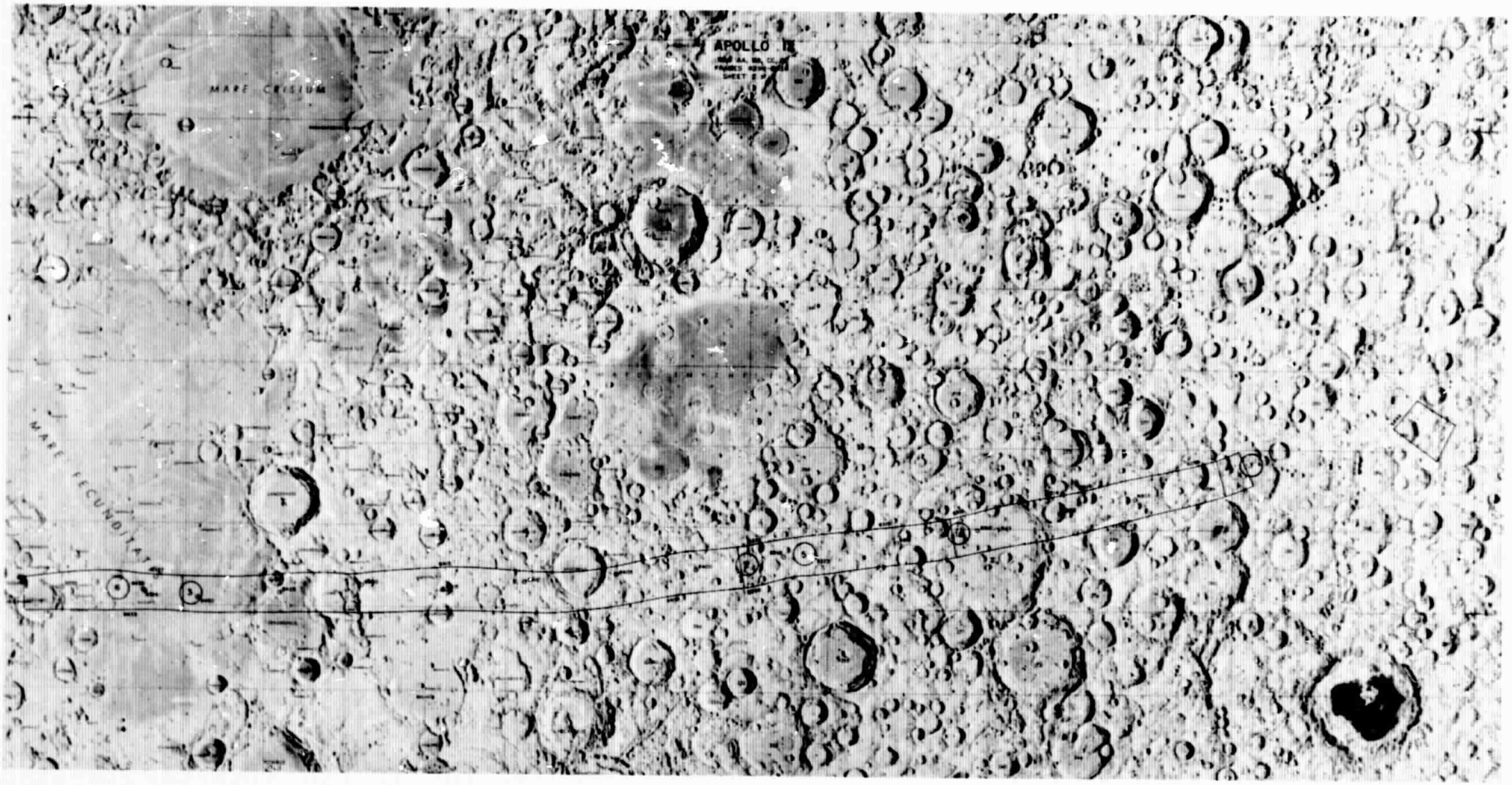
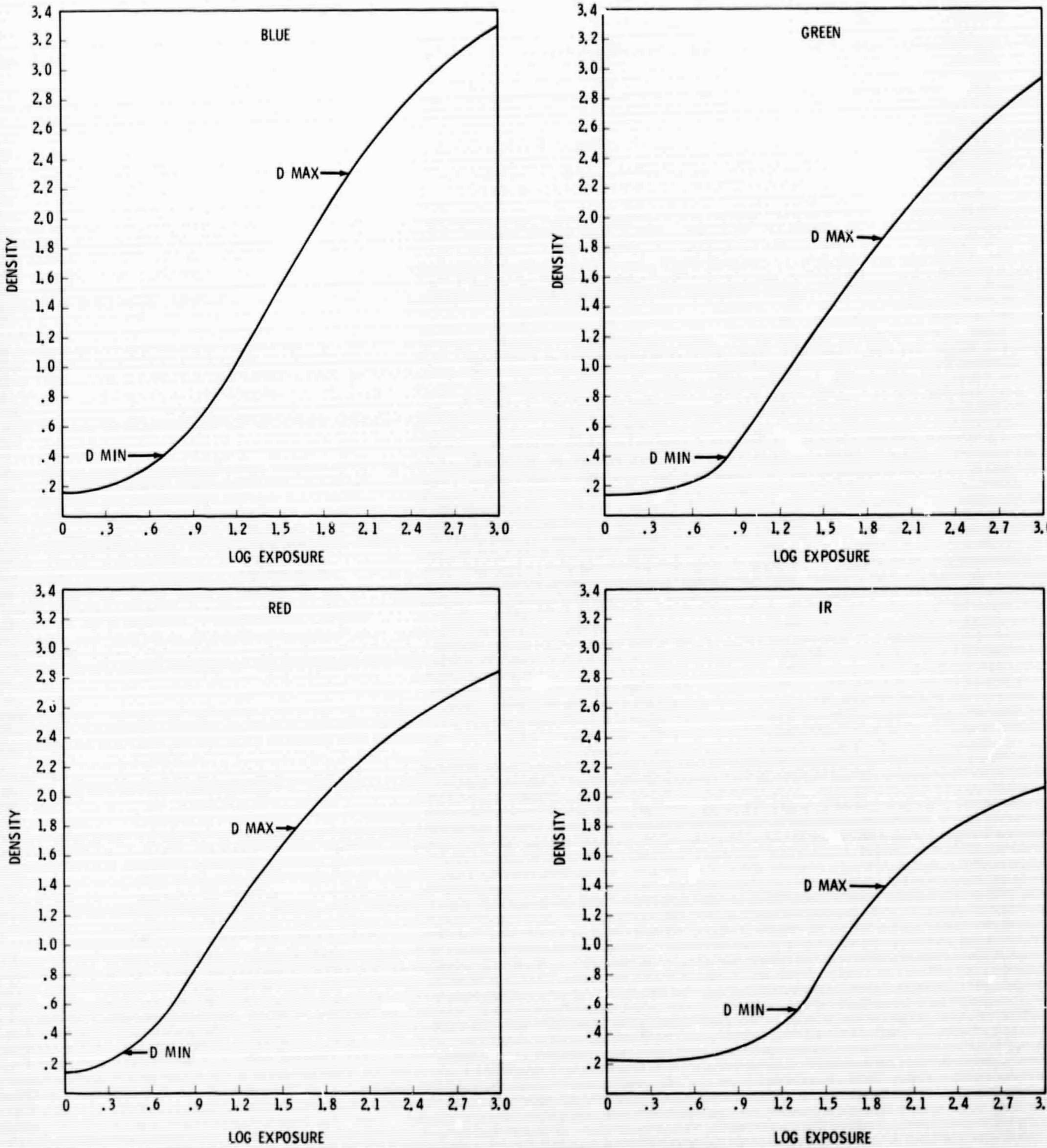
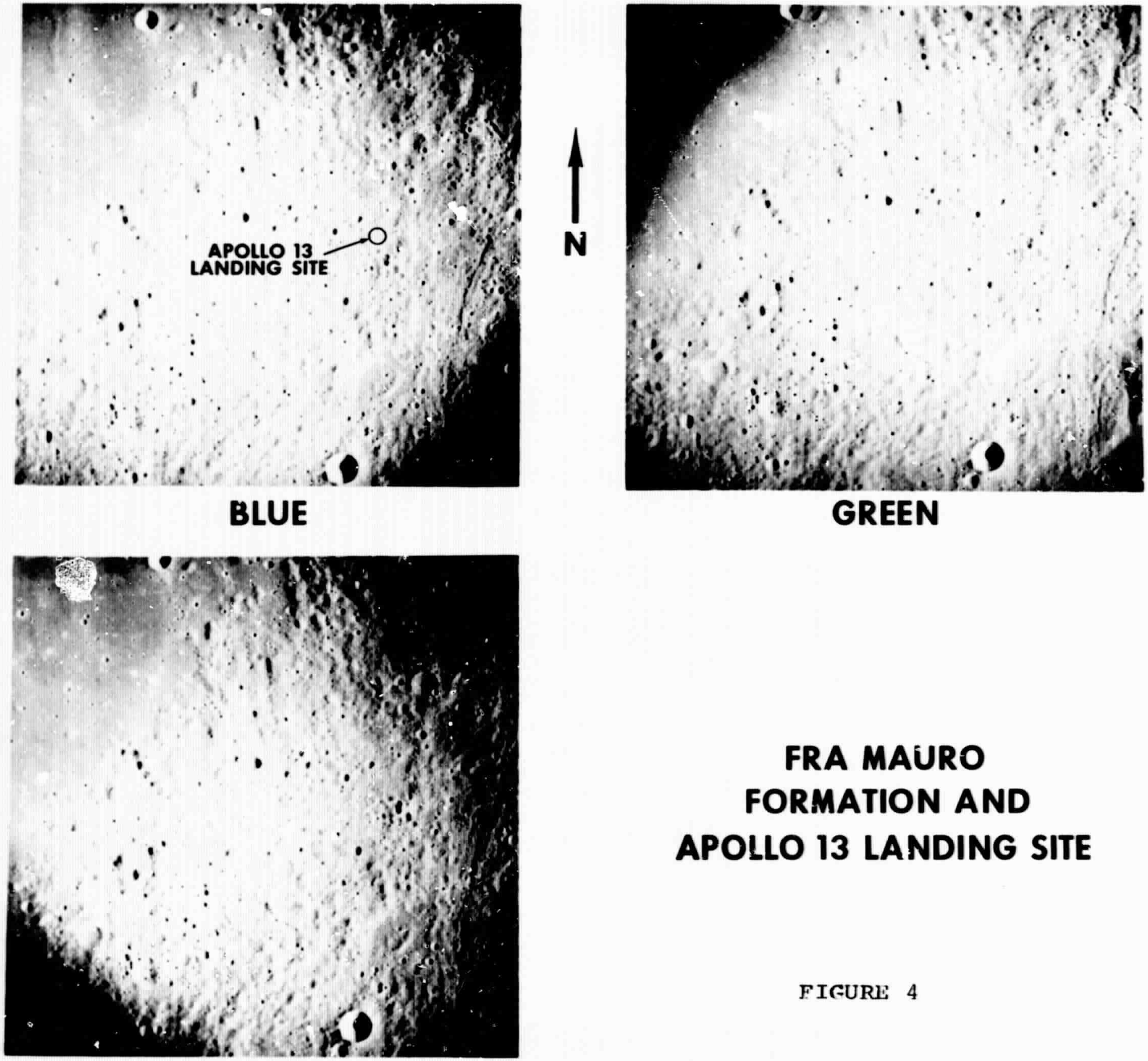


FIGURE 2



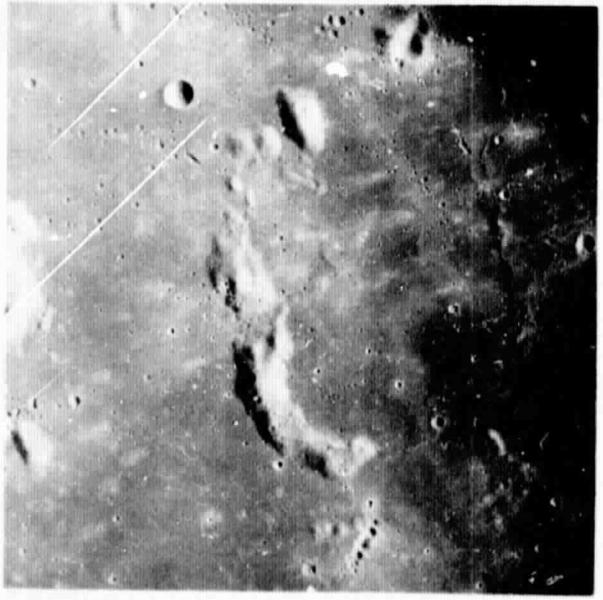
PROCESSING CURVES OBTAINED FROM PRE-EXPOSED STANDARD WEDGE

FIGURE 3



**FRA MAURO
FORMATION AND
APOLLO 13 LANDING SITE**

FIGURE 4



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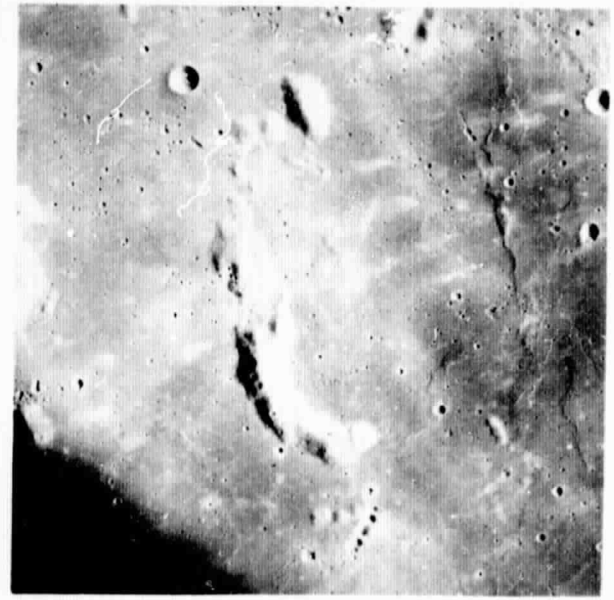

BLUE

GREEN

AREA CENTERED
ON LALANDE η

FIGURE 5

Figure 6. Contrast stretched, red minus blue difference picture of the center portion of frame 8392. Dark areas are bluer and light areas are redder than an arbitrary point taken as neutral gray. The light vertical banding is an artifact introduced in the scanning process. Slight misregistration of the red and blue frames enhances crater boundaries. In addition, color information cannot be obtained from deep shadow areas and hence those areas will appear anomalously colored.

AP-8392 RED STRETCH LOG E
STRETCH
AP-8392 RED - BLUE
DIFFPIC
AP-8392 RED - BLUE STRETCH 35 130
STRETCH

FIGUPE 6

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