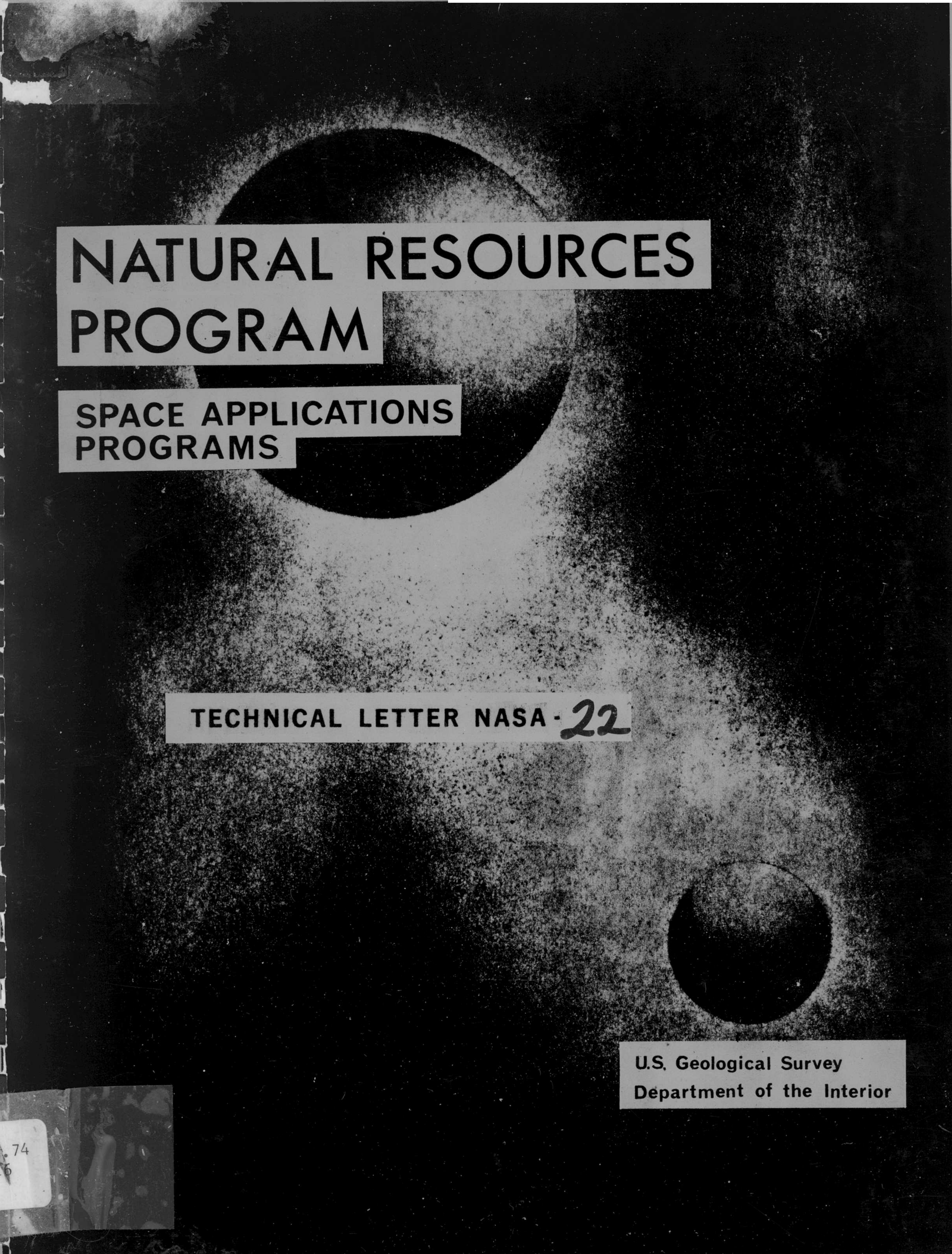

NATURAL RESOURCES PROGRAM

SPACE APPLICATIONS PROGRAMS

TECHNICAL LETTER NASA-22

U.S. Geological Survey
Department of the Interior

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON, D.C. 20242

Technical Letter
NASA - 22
May 1966

Dr. Peter C. Badgley
Chief, Natural Resources Program
Office of Space Science and Applications
Code SAR, NASA Headquarters
Washington, D.C. 20546

Dear Peter:

Transmitted herewith are 3 copies of:

TECHNICAL LETTER NASA-22

TIME, SHADOWS, TERRAIN AND PHOTOINTERPRETATION*

by

R. J. Hackman

Sincerely yours,

William A. Fischer
Research Coordinator for
USGS/NASA Natural Resources Program

*Work performed under NASA Contract No. R-09-020-013

UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

TECHNICAL LETTER NASA-22

TIME, SHADOWS, TERRAIN AND PHOTOINTERPRETATION*

by

R. J. Hackman

May 1966

These data are preliminary and should not be quoted without permission

Prepared by the Geological Survey for the National Aeronautics and Space Administration (NASA)

*Work performed under NASA Contract No. R-09-020-013
**U.S. Geological Survey, Washington, D.C.

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Time, Shadows, Terrain, and Photointerpretation

By

Robert J. Hackman

ABSTRACT

Recent lunar studies have suggested that greater enhancement of the terrain is apparent on photographs taken at very low sun angle. To illustrate the effect of sun angle in the photointerpretation of aerial photographs, a plaster terrain model was photographed at 10 degree increments of illumination, ranging from 70 degrees to horizontal. The resulting photographs show that as the angle of illumination is decreased, tone differences become less apparent. In contrast, the enhancement, by shadow effect, of the topography, especially the micro relief (texture), becomes more apparent. These effects are further illustrated by a set of photographs of the Kilauea Crater, Hawaii, taken with a solar angle of 21 degrees and 53 degrees, and also by a set of Gemini V photographs of a part of Iran, taken with a solar angle of 15½ degrees and 30 degrees. Although most photographs presently used in photointerpretation studies are taken with high-angle illumination, this study suggests that photographs of the terrain at both high and low sun altitude would provide the greatest amount of terrain intelligence for the photointerpreter, and that if only one picture can be taken, one with the sun angle at approximate 30 degrees would be the most satisfactory in showing both tone difference and relief enhancement owing to shadows.

Time, Shadows, Terrain, and Photointerpretation

By Robert J. Hackman

Introduction

Are we taking aerial photographs at the right time of day in order to make proper use of shadows in photointerpretation of terrain? According to the Manual of Photographic Interpretation (1960, p. 102-103), shadows may help the interpreter by providing him with profile representation of objects of interest. Shadows are particularly helpful if objects are very small or lack tonal contrast with their surroundings. Under these conditions the contrasting dark tone of shadows may enable the interpreter to identify objects that are otherwise beneath the "threshold" of recognition. Although photographs taken under low angles of illumination have been used in some military, agricultural, and archaeological studies, virtually all photography used in the interpretation of earth terrain (mainly geological and geomorphological studies) is taken with the sun at high angle.

Most work that has been published concerning the effects of angle of illumination has been with regard to recognizing features on the lunar surface (Baldwin, 1949, Kuiper, 1959, Hackman, 1961 and others). In fact, many of geologic studies of the lunar surface are made from photographs taken at times of very low sun angle. In comparing the full moon and quarter moon photographs (fig. 1), it is quite apparent that more topographic forms are visible near the terminator (sunset zone) on the quarter moon photograph than in the same area on the full moon photograph. In contrast, however, it should be pointed out that differences in tone values, visible on the full moon photograph, become less apparent as the angle of illumination is decreased, and many are undiscernible near the terminator (Hackman, 1961.)

To further illustrate the desirability of using photographs taken with the sun at various angular altitudes, the author undertook a controlled experiment, utilizing a terrain model that could be viewed and photographed at various angles of illumination.

Experiment design and procedure

The model (figure 2) used in this study is a plaster cast of part of the U. S. Army Map Service plastic relief map of the Harrisburg, Pennsylvania quadrangle (NK18-10) (vertical scale exaggerated 3X with respect to horizontal scale.) This cast was modified by adding some minor topographic and textural details (fig. 2). A tilting platform (fig. 3) was constructed that enabled the model to be photographed at different angles of illumination. To provide near parallel light, (hence, sharply defined shadows) sunlight passing through a small window into an into an otherwise darkened room, was used as a source of illumination.

The model was photographed at angular increments of 10 degrees from the horizontal to 70 degrees with light coming first from the right and then the left. Because the shadow of the camera partly obscured the model at high angles of illumination, photographs were not taken at angles greater than 70 degrees. A press camera and panchromatic film were used to take the model photographs. Prints were made on high contrast paper.

Enhancement and tone contrast

Figure 4 shows eight of the sixteen photographs taken of the model. They are all illuminated by light coming from the same direction but at decreasing angles of illumination. It is readily apparent that except where obscured by shadow, the photograph with the illumination angle taken 10 degrees from the horizontal shows the greatest detail of relief, especially detail of micro-relief (texture). Figure 5 is an enlargement of this photograph and figure 6 is an enlargement of the photograph taken at the highest angle of illumination (70 degrees). In comparing the two photographs, note that most of the fine structure has been enhanced by the shadows and that the edges of the shadows exaggerate the profile shape of features, thus, providing data on their ruggedness. The angular sharpness of the surface of the crushed glass material is certainly apparent from the shadow effect.

The orientation of features, however, strongly affects their appearance on photographs taken at low angles of illumination; for example, the raised ridge, C, near the right side of figure 2 is so oriented that it casts no shadow and is therefore, less apparent than the three similar ridges also labeled C to the left of it which are oriented near-normal to the direction of illumination, and, thus, cast strong shadows.

Although, only photographs illuminated by light coming from the same direction are shown in the illustrations, photographs of the model under opposite lighting, as would be expected, show similar enhancement.

The crushed glass material is darker in tone than the surrounding white plaster material on photographs taken with relatively high angles of illumination; i.e., 70 degrees (fig. 6) and 30 degrees (fig. 2), but with low angles of illumination; i.e., 10 degrees (fig. 5), no difference is detectable. This loss of tone contrast at low angles of illumination is in agreement with similar effects observed on lunar photographs.

Terrestrial aerial photographs taken at different times of day are not readily available. However, some were produced in conjunction with recent infrared studies of Kilauea Volcano, Hawaii (Fischer et al, 1964.) These photographs taken at a scale: 1:10,000, (figs. 7 and 8) are of an area adjacent to the rim of Kilauea crater on the island of Hawaii. Figure 7 was taken at 08:00 AM, solar altitude 21 degrees, and figure 8 at 11:59 AM, solar altitude 53 degrees. These two photographs demonstrate the value of photographs taken at times of low sun angle. In figure 7 the minor relief and textural patterns are more easily discernible than in figure 8. Tone differences, however, are more noticeable in figure 8 than in figure 7.

By viewing these photographs stereoscopically the difference in the information content within them can be easily seen. Stereoscopic viewing of photographs taken at different sun angles has been very helpful in lunar studies (Hackman, 1961.)

A comparison of figure 7 to the topographic map of the area (fig. 9), shows much of the micro-relief is not defined by the 20 foot topographic contours; for example, relief difference of the rugged appearing lava flow seen at A in figure 7 must be in inches and feet but less than 20 feet, as the topographic map shows this as a relatively smooth surface.

Figure 10, A and B, are two Gemini V photographs taken over southern Iran. These photographs although taken as part of a synoptic terrain photographic study (Lowman, 1966), fortuitously, demonstrate shadow enhancement resulting from different angles of illumination. Figure 10 was taken at approximately 6:00 AM (local time in Iran), August 26, 1965 - solar altitude $15\frac{1}{2}$ degrees, while figure 11 was taken at approximately 8:30 AM, August 22, 1965 - solar altitude 30 degrees. It is readily apparent that the lower sun altitude of figure 10 results in greater shadow enhancement in delineating the complexly folded structure of the Cenozoic sedimentary rocks present in the area.

Summary and conclusion

Most vertical aerial photographs presently used in photointerpretation studies are taken with high-angle sun illumination. These investigations indicate that:

1. Photographs of areas taken with the sun, 10 degrees or less above the horizon, will show subtle differences in relief and textural pattern that would otherwise be unrecognizable. These photographic subtleties are helpful in many photointerpretation studies. The use of such photography would of course be controlled in most cases by the amount of large scale relief. This photography is commonly more useful in areas of low relief than in areas of high relief, because of the long shadows by the large topographic elements.

2. As a result of loss of tone values accompaning increase shadow enhancement of micro-relief on low sun angle photographs the interpreter should use two photographs of the same area; one taken at high angles of illumination and one at low angle. These photographs are especially helpful if combinations of high-angle and low-angle photographs are studied stereoscopically.

3. If only one set of photographs can be taken, those taken with a sun angle of 20 to 30 degrees are thought to be the most satisfactory.

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Figures

Figure 1. Photograph of the full moon and quarter moon. On the full moon photograph the ray patterns are distinct whereas topographic detail is obscure. On the quarter moon photograph, topographic detail is conspicuous, especially along the terminator (sunset zone), whereas many of the ray patterns are not readily distinguishable.

2. The model is a plaster cast of part of the U. S. Army Map Service plastic relief map of the Harrisburg, Pennsylvania quadrangle, NK18-10 (vertical exaggeration 3X). It is shown here under 30 degrees angle of illumination. Letters A through F indicate some sculptural and textural detail added to the plaster cast: A, circular depressions; B, cross hatched and linear grooves; C, small ridges; D, smooth flat area; E, coarse fragments of plaster; and F, patch of dark colored, crushed-glass beads. The fine-lined lineations from right to left are brush marks.

3. Camera and model holding frame. The model can be tilted and photographed under different angles of illumination: A, sunlight normal (90 degrees) to plane of model; B, sunlight 45 degrees to plane of model; and C, sunlight parallel (0 degrees) to plane of model.

Figure 4. Photographs of the model under angles of illumination from 70 to 0 degrees. Arrow indicates direction of light. In this series the greatest detail of topographic relief (where not covered by shadow) is recognizable when angle of illumination is 10 degrees.

5. Photograph of model under 10 degrees angle of illumination.

6. Photograph of model under 70 degrees angle of illumination.

7. Area adjacent to rim of Kilauea crater, Island of Hawaii, photographed with sun angle of 21 degrees from the horizon. A, indicates area of 1921 lava flow.

8. Same area as figure 7 photographed with sun angle of 53 degrees from the horizon.

9. Topographic map (20 foot contour interval) of area covered by figures 7 and 8.

10. Area in Iran covered by two different Gemini V photographs, each taken under different angles of illumination. Photograph A, was taken August 26, 1965, solar altitude 15½ degrees. Photograph B, was taken August 22, 1965, solar altitude 30 degrees. (Photography courtesy of the U. S. National Aeronautics and Space Administration nos. S-65-45345 and 45480.)

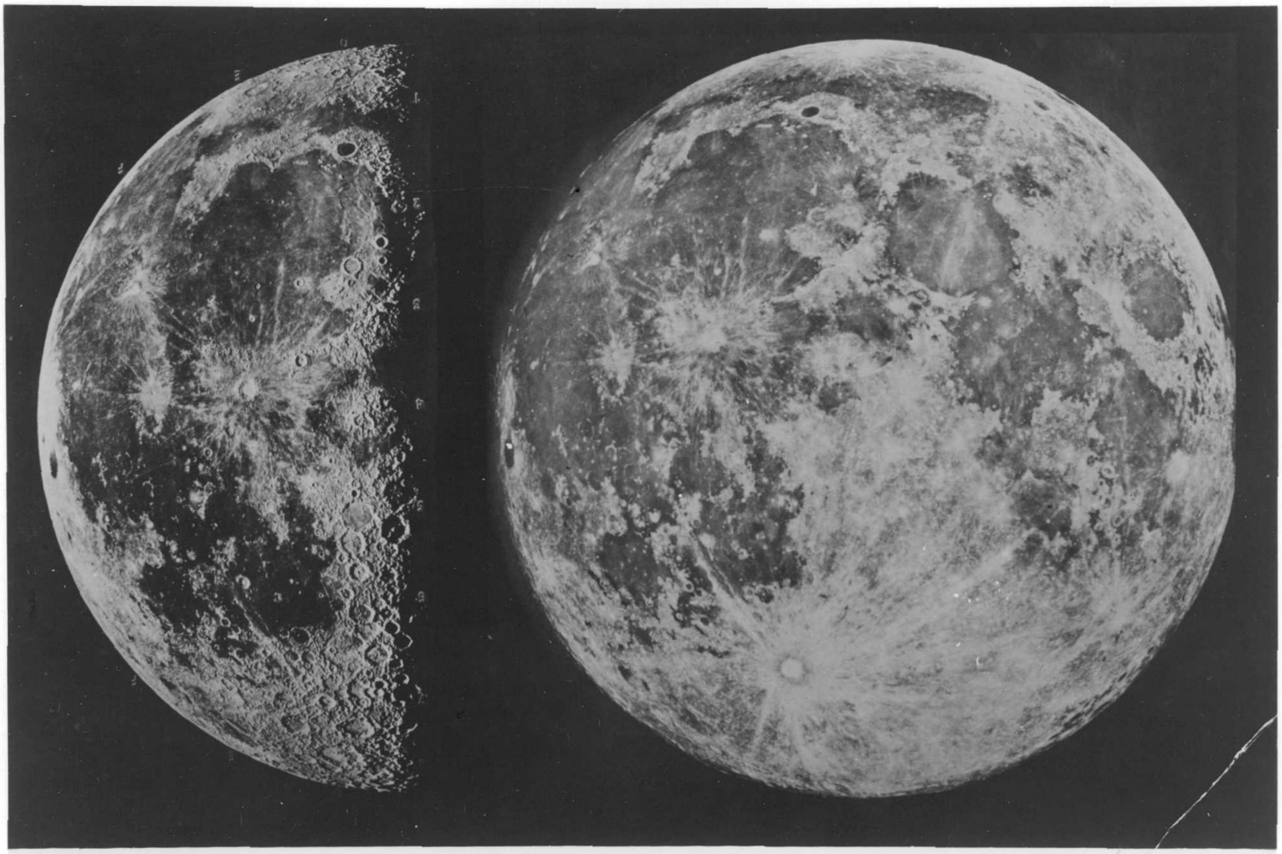


Figure 1. Photograph of the full moon and quarter moon. On the full moon photograph the ray patterns are distinct whereas topographic detail is obscure. On the quarter moon photograph topographic detail is conspicuous, especially along the terminator (sunset zone), whereas many of the ray patterns are only poorly seen.

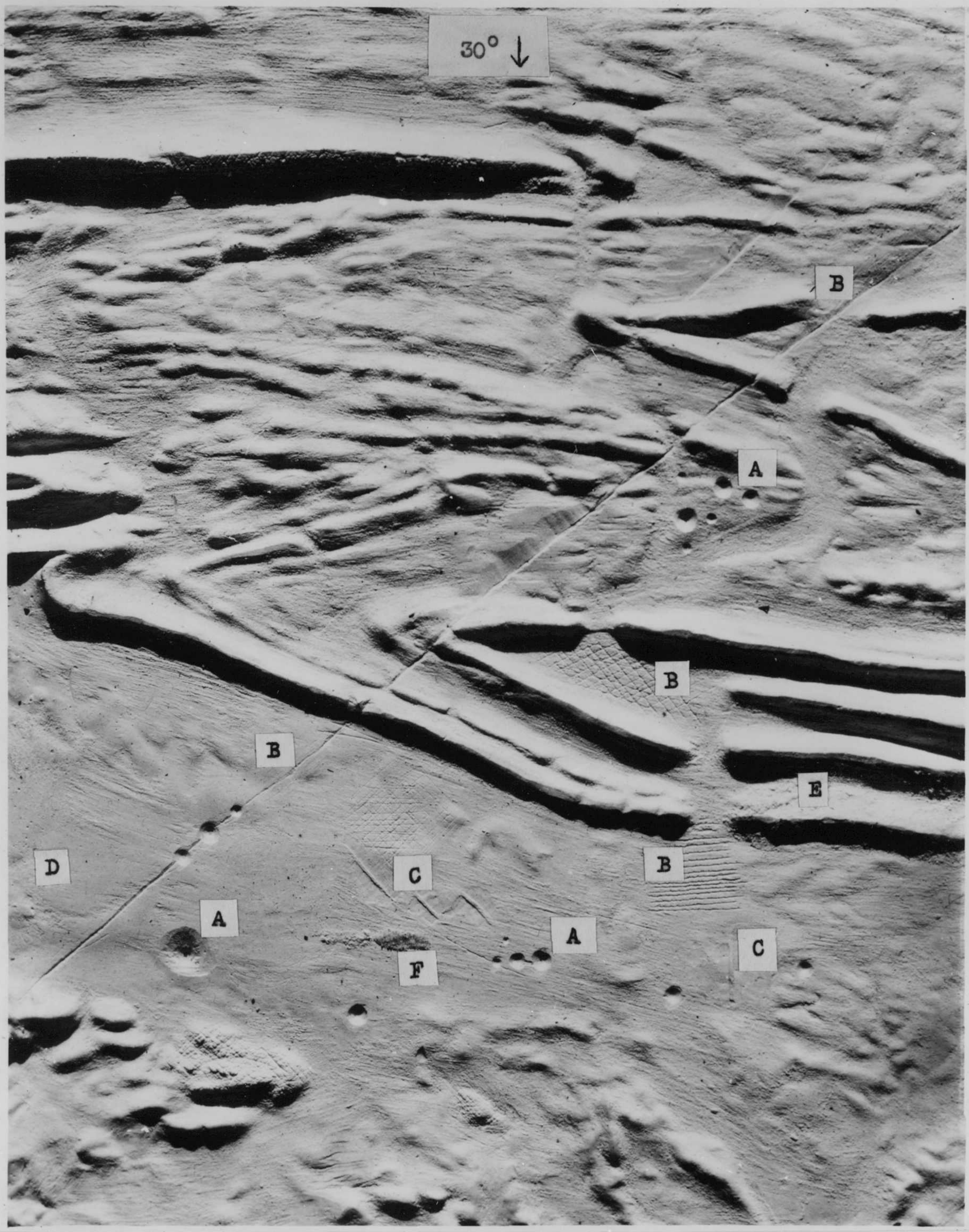


Figure 2. The model is a plaster cast of part of the U.S. Army Map Service plastic relief map of the Harrisburg, Pennsylvania quadrangle, NK18-10 (vertical exaggeration 3X). It is shown here under 30 degrees angle of illumination. Letters A through F indicate some sculptured and textural detail added to the plaster cast: A, circular depressions; B, crosshatched and linear grooves; C, small ridges; D, smooth flat area; E, coarse fragments of plaster; and F, patch of dark colored, crushed glass beads. The fine-lined lineations from right to left are brush marks.

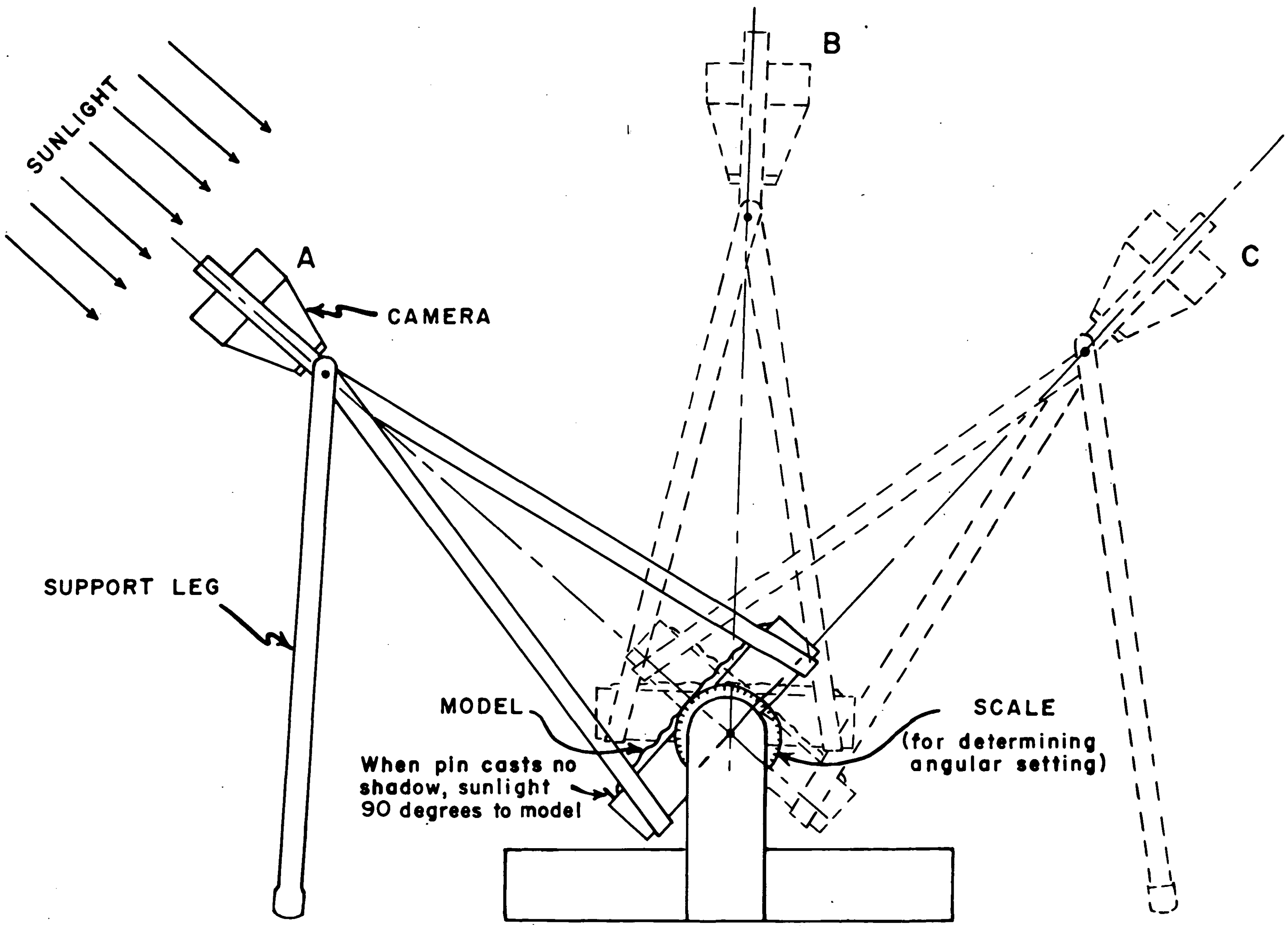


Figure 3. Camera and model holding frame. The model can be tilted and photographed under different angles of illumination: A, Sunlight normal (90 degrees) to plane of model; B, sunlight 45 degrees to plane of model;and C, sunlight parallel (0 degrees) to plane of model.

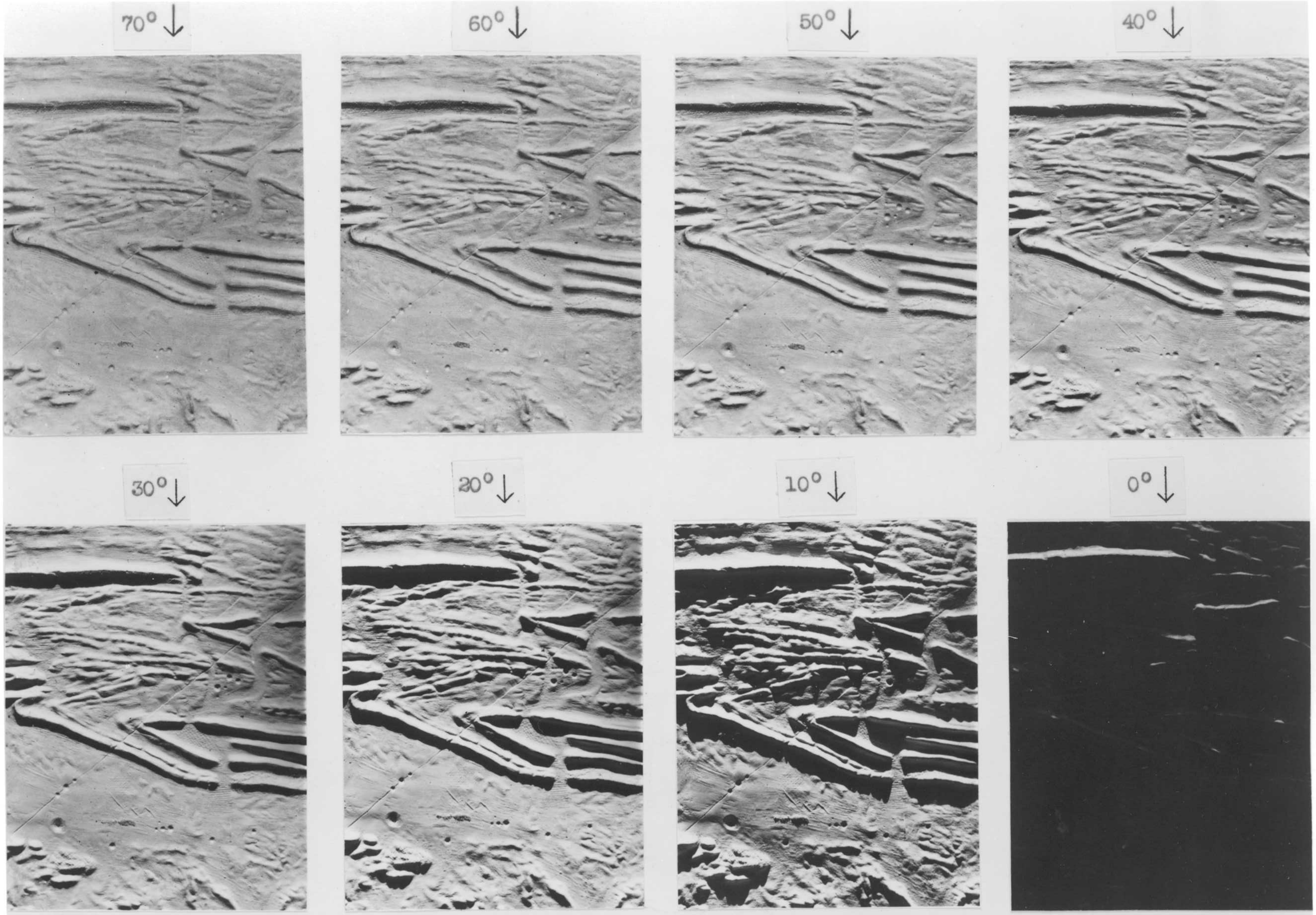


Figure 4. Photographs of the model under angles of illumination from 70 degrees to 0 degrees. Arrow indicates direction of light. In this series the greatest detail of topographic relief (where not covered by shadow) is recognizable when angle of illumination is 10 degrees.

Figure 5. Photograph of model under 10 degrees angle of illumination.

Figure 6. Photograph of model under 70 degrees angle of illumination.

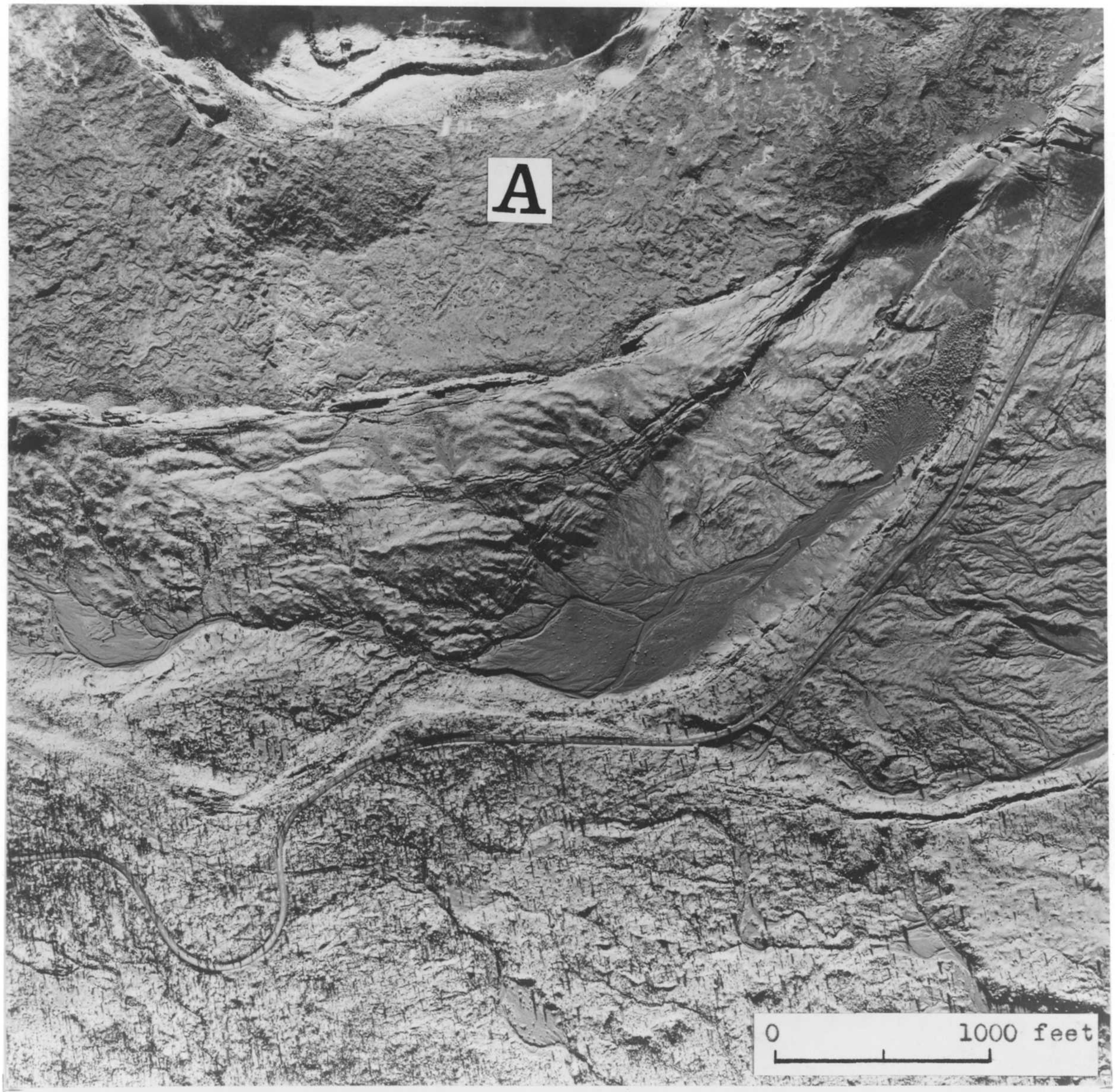


Figure 7. Shows the same area as figure 8, but with the sun angle 21 degrees. A, indicates area of 1921 lava flow.

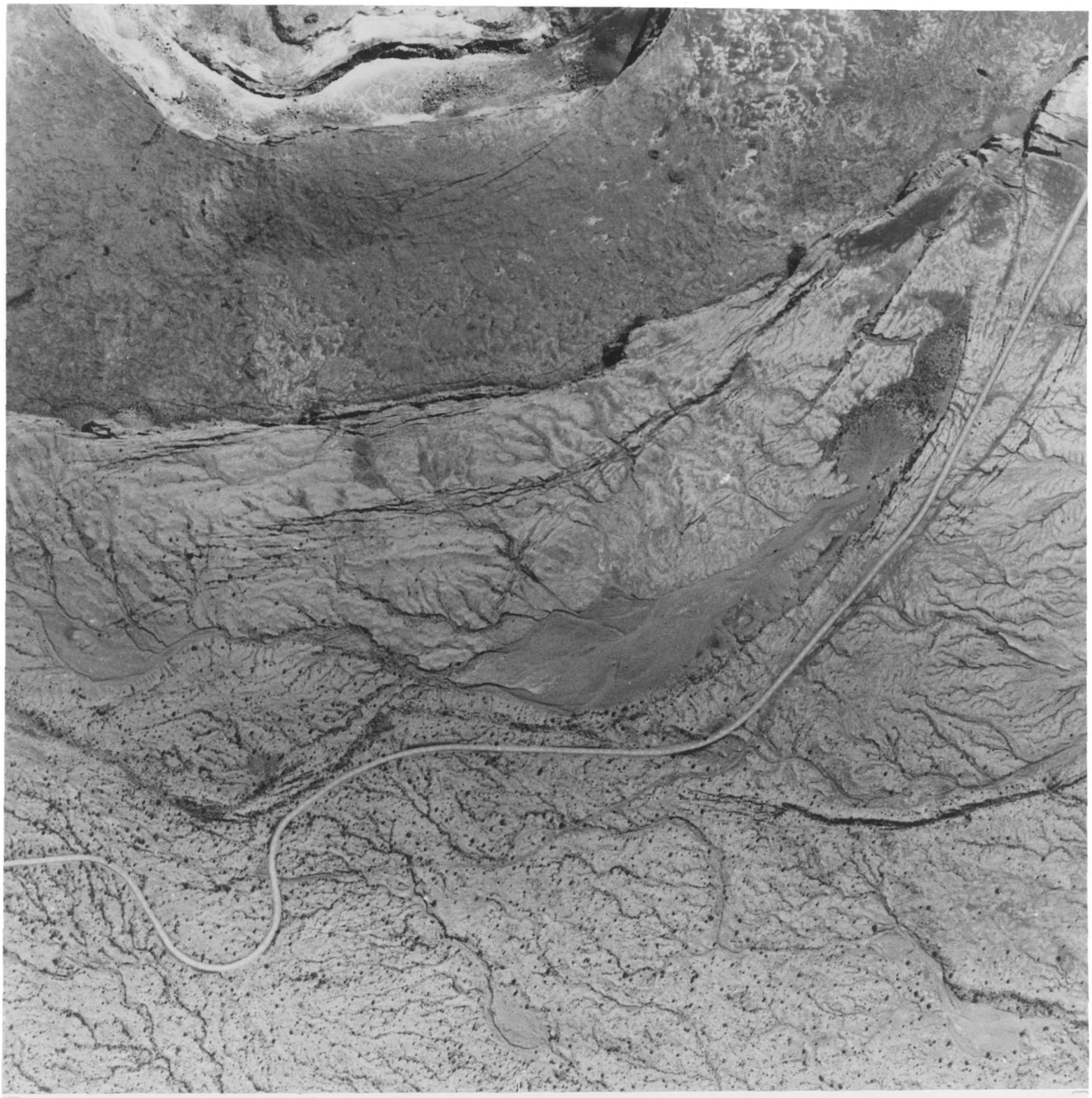
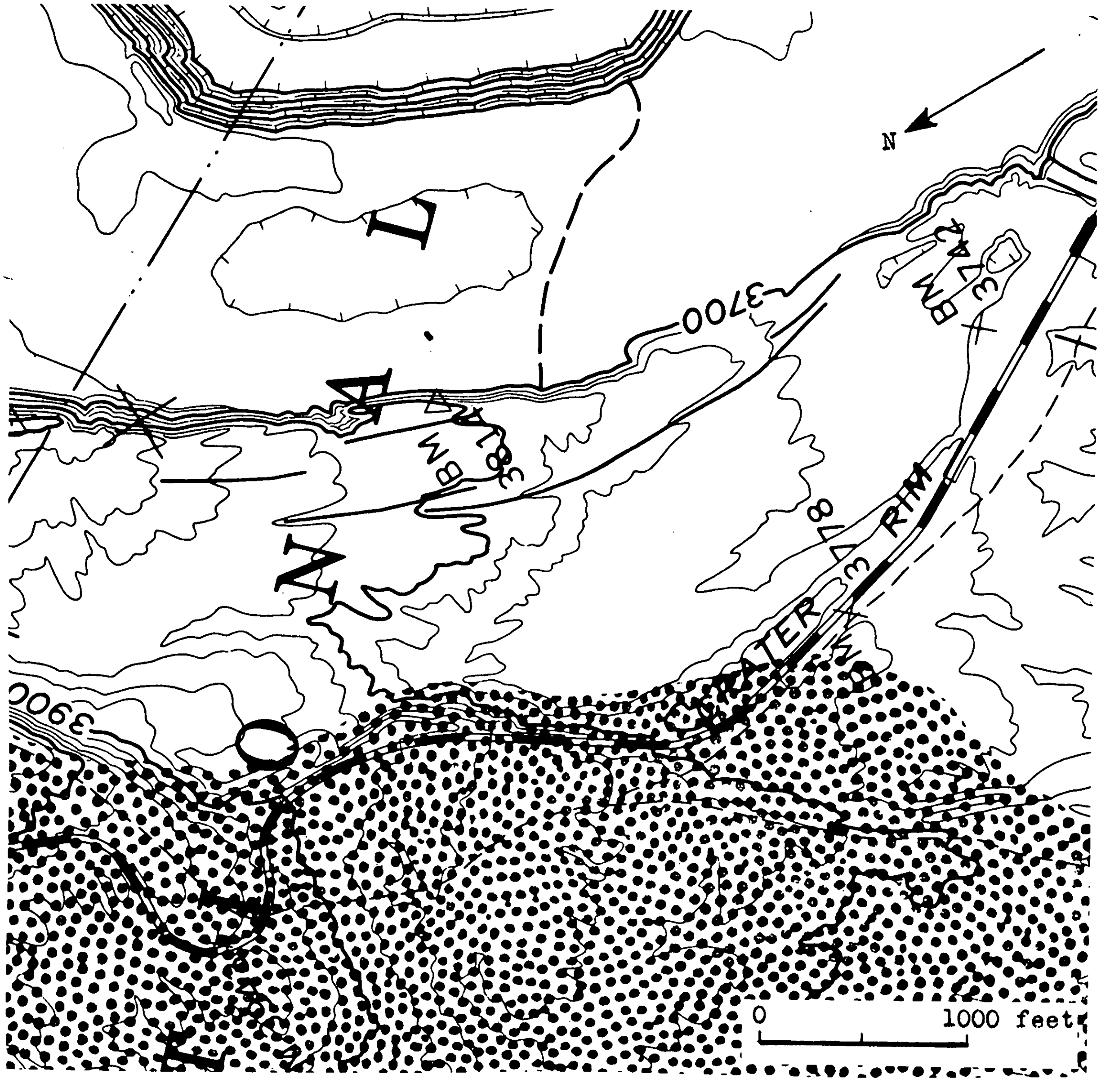
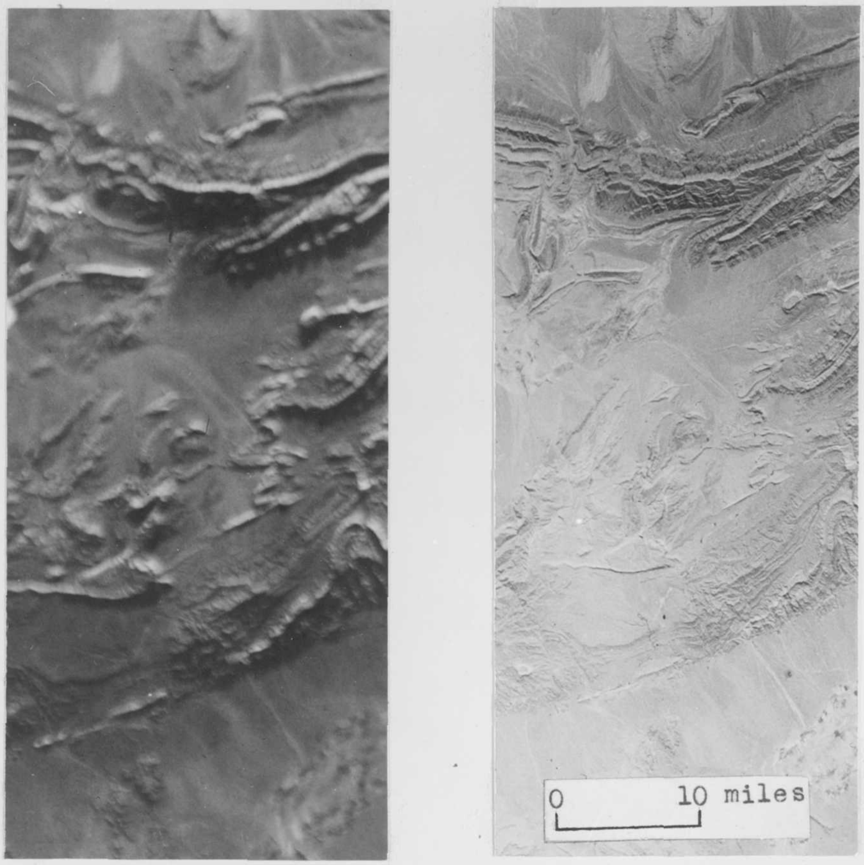


Figure 8. Shows area adjacent to rim of Kilauea Crater, Island of Hawaii, with the sun angle 53 degrees with horizon.



<u>Figure 9.</u> Shows topographic map (20'contours) of area covered by figures 7 and 8.



A B

Figure 10. An area in southern Iran covered by two different Gemini V photographs each taken under different angles of illumination. Photograph A was taken August 26, 1965, solar altitude $15\frac{1}{2}$ degrees. Photograph B was taken August 22, 1965, solar altitude 30 degrees. (Photographs courtesy of the U.S. National Aeronautics and Space Administration, nos. S-65-45345 and 45480).