FRONTISPIECE. Pisgah Crater, California.

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Pisgah Crater Terrain Analysis

A rough volcanic feature near Los Angeles, Calif., served both as a lunar model and also as a validation site for automated contouring

(*Abstract on page 812*)

INTRODUCTION

EARTH-BASED RESEARCH with simulated lunar terrain can be used to great advantage prior to actual detailed studies of the lunar surface. For this reason a large amount of data concerning terrain features of the Pisgah Crater, California area has been compiled for analysis by a digital computer. This paper describes the rational of terrain selection and suggests various uses for the data.

For terrain analysis on the scale of lunar vehicle wheels or landing pads, 25 centimeter contour-interval topographic maps of four terrain areas were prepared from controlled aerial photographs. Numerical data (x, y, z-coordinates) were compiled at one-meter intervals from each area and are now available for computer studies which require a simulated lunar terrain.

PISGAH CRATER TERRAIN SELECTION

In 1960, geologists of S & ID's* Space Sciences Laboratory selected and surveyed four test areas in the vicinity of Pisgah Crater near Barstow, California (Figures 1 and 2). Each of the areas was selected on the basis of varying degrees of topographic complexity, as well as resemblance to various hypothesized lunar surface textures (Frontispiece and Figure 3). Each test area is 305 meters (1,000 feet) square, with nine datum control points. Eight of these control points are located around the

* Space and Information System's.

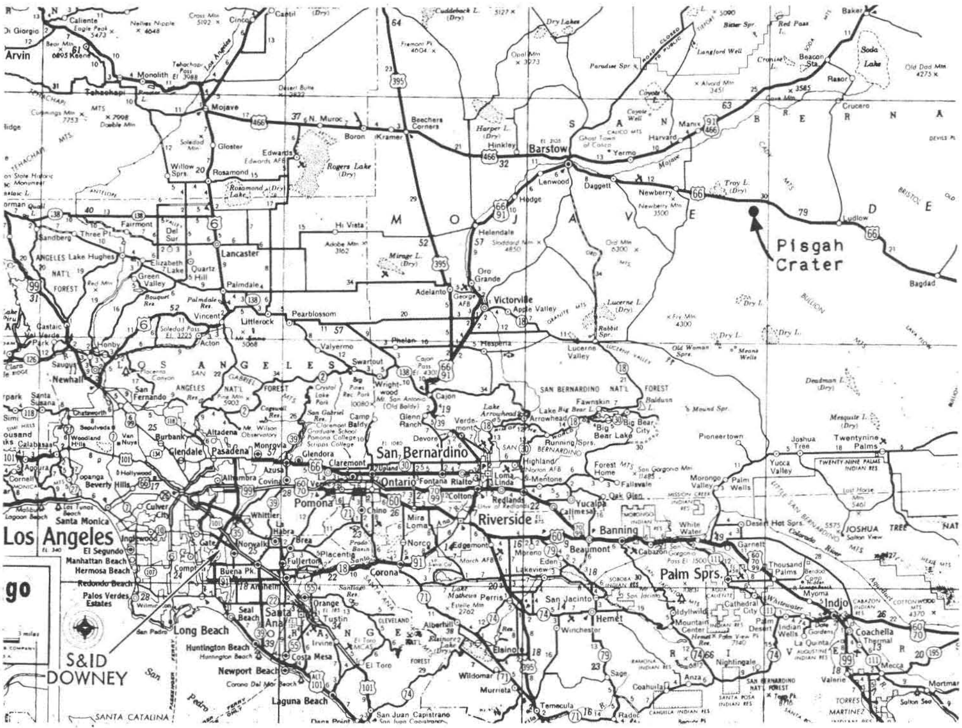

FIG. 1. Location of Pisgah Crater area.

perimeter at 152-meter (500-foot) intervals, with the ninth point located at the center of the square. After completion of the ground survey, aerial photographs were taken by Aero Service Corporation from altitudes of approximately 808 meters (2,650 feet) and 2,360 meters (7,750 feet) above ground level. Modified Air Force resolution patterns were placed at the center of each square to calculate actual ground resolution. Good resolution was obtained for objects greater than 7.6 centimeters (3 inches) in diameter. Stereographic pairs and conventional photogrammetric methods were used to contour the test areas, using a 25-cm. contour interval (approximately 10 inches). The contour elevation for each test square is relative to its center control station, and each test square is individually contoured, assuming zero elevation for the center station.

After the original surveying and contouring was performed, approximate elevations were obtained at the center of each square using a Model M-2 micro-surveying altimeter. This was accomplished by obtaining a primary altimeter setting at the Lavic Station surveying bench mark (T7N R6E Section 2) which was then used as a base station. The Lavic Station base was read four times in $4\frac{1}{2}$ hours to correct for barometric diurnal changes. A standard laboratory thermometer was used to obtain temperature correction values. In this manner, elevations at the center of each test square were obtained and are correct to ± 1.5 meters (± 5 feet). For greater accuracy, a transit chain survey may be conducted from Lavic Station to the center and corners of each test square.

A detailed description of the basaltic terrain comprising each of the four test squares appears below.

AREA A (FIGURE 4)

Area A was selected because of its resemblance to a meteorite impacted lunar maria region. This test area occurs in the terminal area of a unit flow composed of variably vericular basalt and contains a number of "sinks" resembling impact craters. These sinks were formed by subflow erosion of unconsolidated lake bed sediments and consequent collapse of portions of the thin lava flow. Relatively large tensional slump fractures parallel and outline the sinks. The detailed topographic maps do not show many of these narrow fractures. Some of the lightcolored material which now occupies the depressions is dust blown in from the adjacent playa area. The lava surface is relatively flat, except in the immediate vicinity of the sinks. The flows of this area are probably younger or contemporaneous with the evolution of Pisgah Crater which is of recent age.

AREA B (FIGURE 5)

Area B was selected because it is representative of the transition from pahoehoe to aa lava; that is, a transition from relatively smooth terrain to one with an extremely rough fabric, with the pahoehoe smoother and closer to the flow origin. This relationship is true in all volcanic areas, and the transition from pahoehoe to aa lava is unknown. This area will be used for checking the averaging effects of a known quantity of rough terrain with a known quantity of smooth terrain. A considerable amount of volcanic ash less than 1 meter thick is present over 15 per cent of this area. A similar relationship may be present on the moon as is indicated by Ranger photographs. Lava tubes (Figure 3) are abundant. A collapsed lava tube six meters wide is shown encircled in this area (Figure 5).

AREA C (FIGURE 6)

Area C was selected because of its extremely smooth, dusty character and excellent trafficability. Within the test square protrude three relatively small lava remnants which are used for contrast. In general, the square is covered with playa clay, with the exception of the three contrasting lava areas. Parts of the area are also covered with basaltic outwash debris imbedded in the dust. The debris consists of widely scattered lava fragments averaging about 3 centimeters in diameter and ranging from 0.1 to 10 cm. fragments.

AREA D (FIGURE 7)

Area D was selected because it represents the roughest lunar surface terrain expected in the vicinity of recently formed rills and caldera terraces. This area consists of aa and blocky basaltic lava, with broad steep-walled fractures and numerous small fractures. Trafficability, other than by foot, is almost impossible and straight line traverses are very difficult. Sharp, blocky, vesicular lava is dominant. Extreme roughness, from the microscopic to the macroscopic level, is the general character. These flows post-date the formation of Pisgah Crater with the complex rifting being due to subsurface intumescence of magma accompanied by surface lava flows. The tension fractures may be similar to those in the lunar crater Alphonsus photographed by Ranger 9.

This test square, in conjunction with the others listed above, covers the complete spectrum of anticipated lunar surface fabrics.

ABSTRACT: *Four areas closely approximating hypothesized lunar surface detail were chosen from volcanic terrain adjoining the Pisgah Crater, California. The areas were surveyed and mapped using high precision photogrammetric methods. A contour interval of 25 centimeters was utilized to preserve details in each of the square areas which measure 305 meters (1,000 feet) on a side. Terrain data were digitized for computer utilization by recording surface elevations at 1 meter intervals throughout each area. A digital computer contouring technique was then employed to generate contour maps from the digitized terrain data. The numerical maps show excellent agreement with the photogrammetrically reduced maps, thus demonstrating the validity of the numerical data and the machine contouring technique. Computer simulation studies suggested by the availability of digitized terrain are discussed.*

TABLE 1

PISGAH TERRAIN DATA-TAPE PARAMETERS

Area	*No. Rows*	*No. Columns*	*Total Points*	*Grid Size (Meters)*
A	306	305	93,330	1
B	306	306	93,636	1
C	153	152	23,256	2
D	306	305	93,330	1

DIGITIZED TERRAIN DATA

Using conventional photogrammetric methods, Aero Service Corporation prepared topographic maps of each of the four areas (Figures 8a, 9a, 10a, and 11a). A contour interval of 25 cm. was chosen to preserve sufficient topographic detail relative to the dimensions

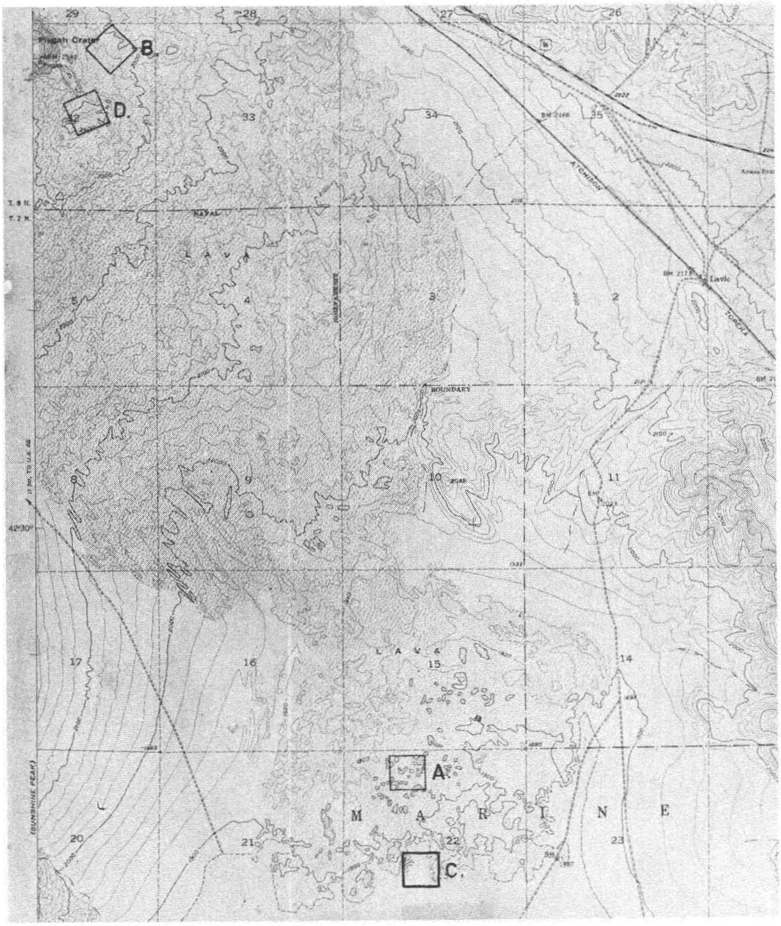

FIG. 2. Relation of the Pisgah test squares to local terrain.

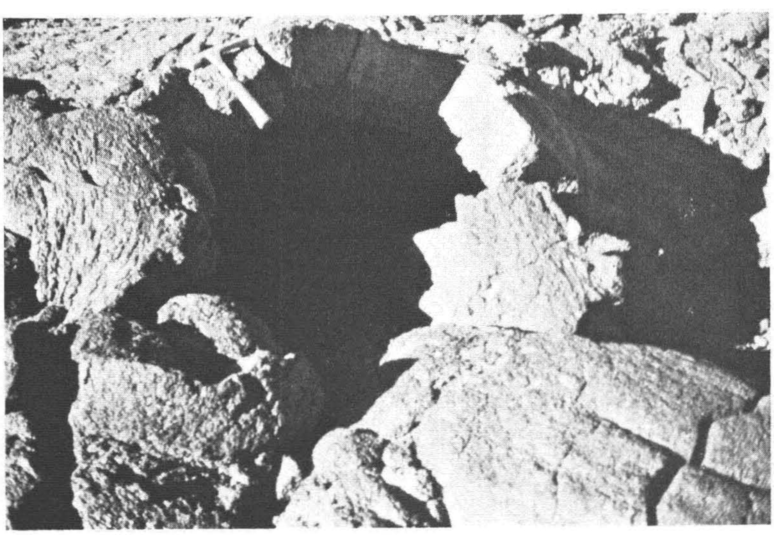

FIG. 3. Detail of Pisgah lava tube.

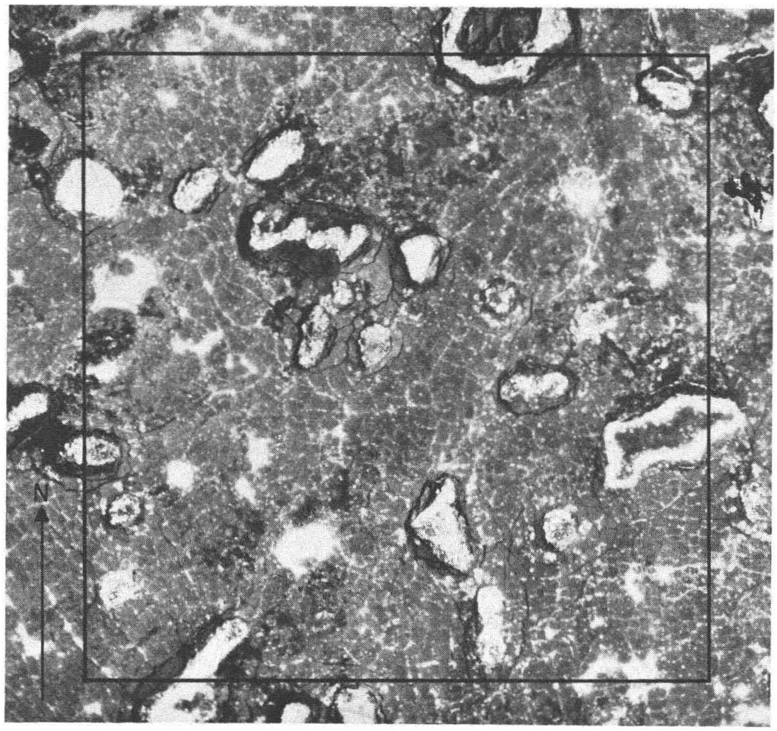

FIG. 4. Area A—Pisgah Crater lava sink area (simulated lunar impact area). The square is 305 meters on a side.

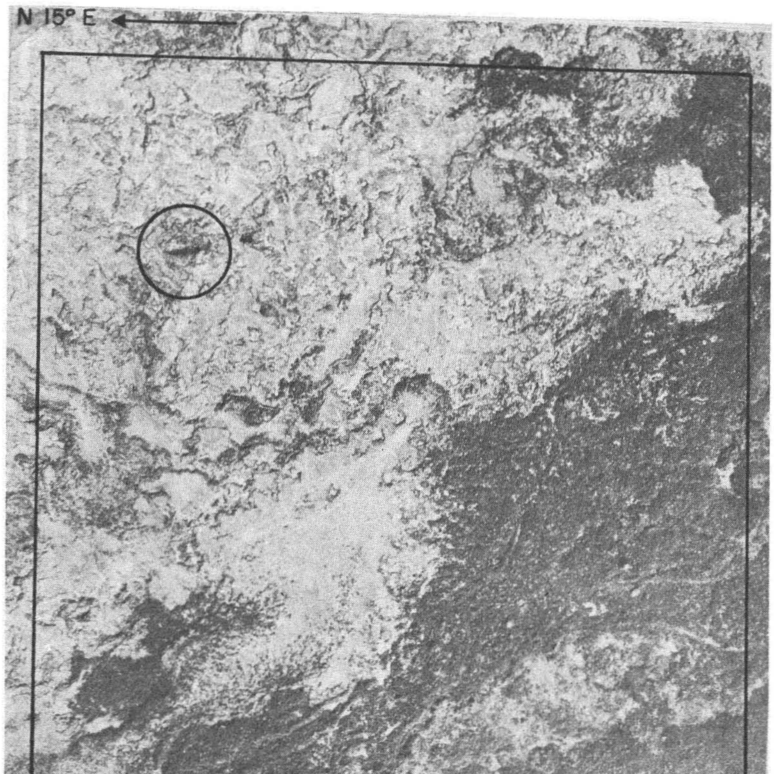

FIG. 5. Area B—Pisgah Crater lava flows (simulated lunar lava flow area). The square is 305 meters on a side. Circle encloses a collapsed lava tube roof.

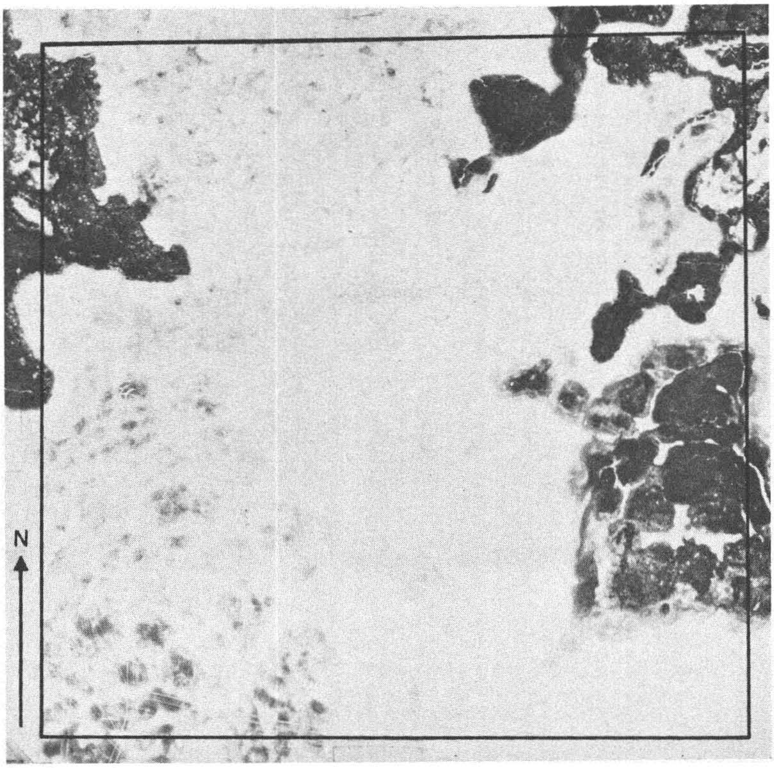

FIG. 6. Area C—Pisgah Crater Lavic Lake area (simulated lunar dust plain). The square is 305 meters on a side.

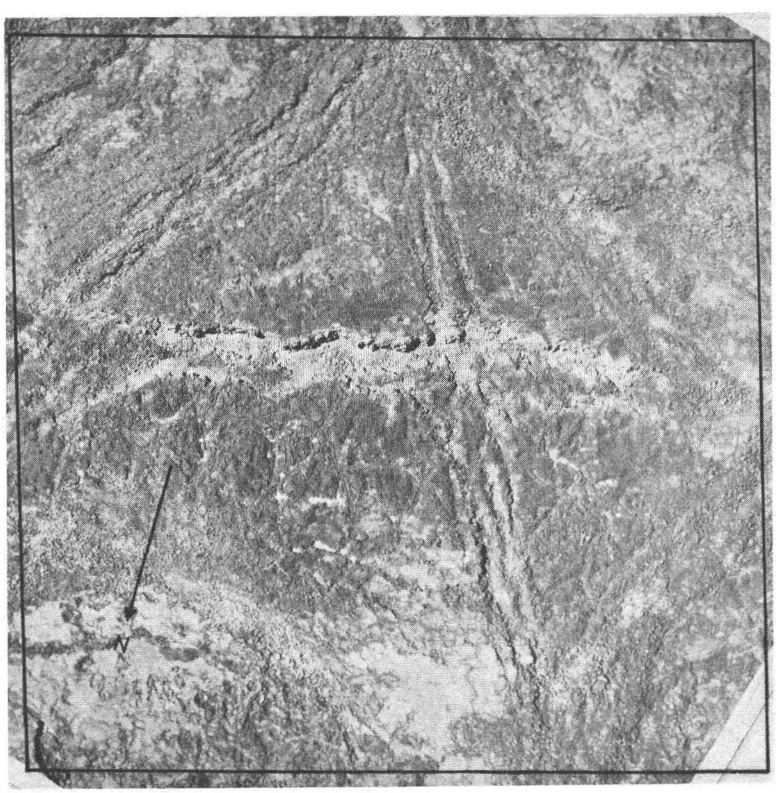

FIG. 7. Area D—Pisgah Crater Fracture Zone (simulated lunar rift area). The square is 305 meters on a side.

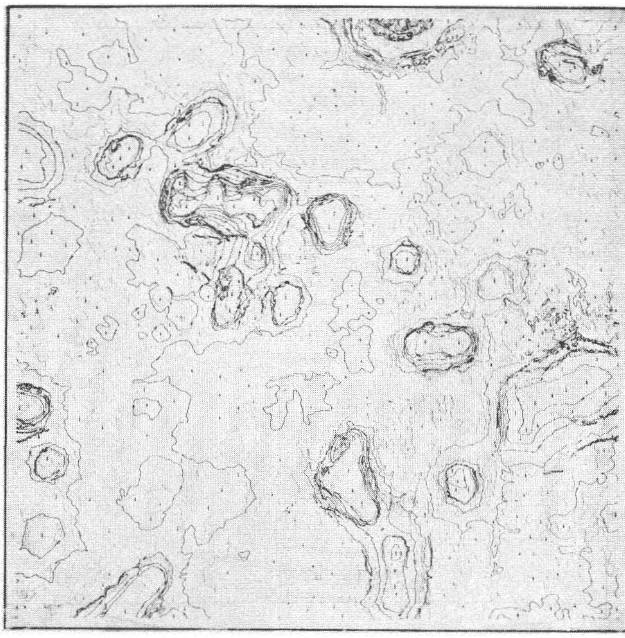

Fig. 8a

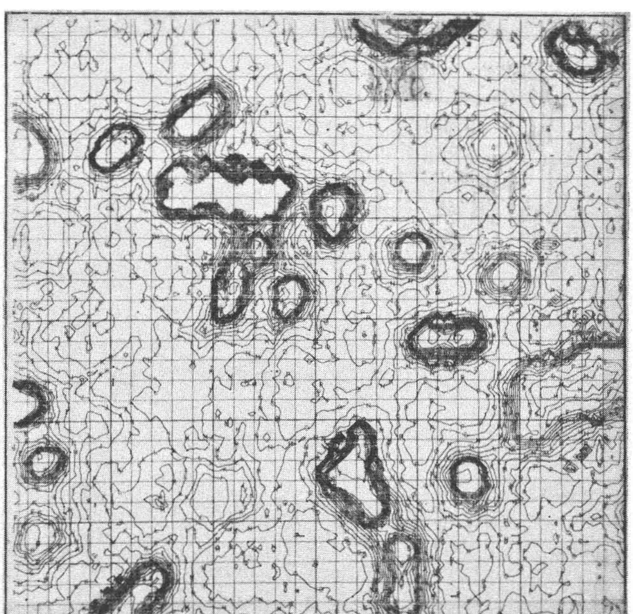

Fig. 8b

Fig. 8. Comparison of computer generated (bottom) and photogrammetrically compiled (top) contour maps, Area A.

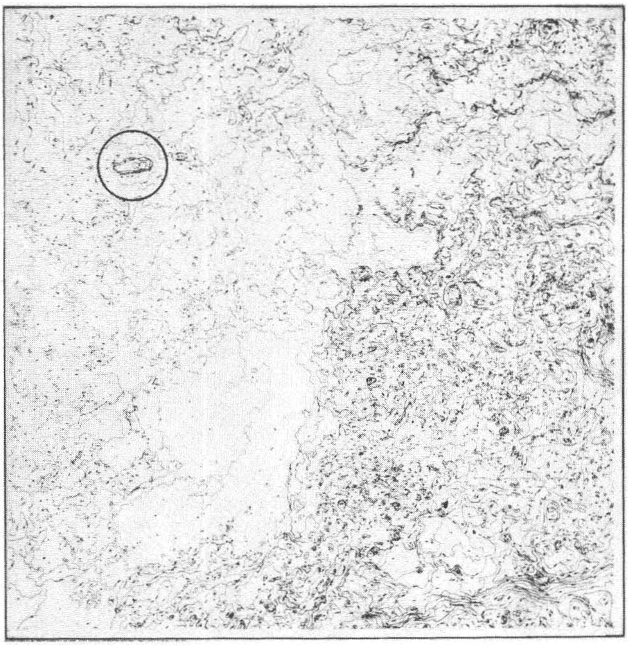

FIG. 9a

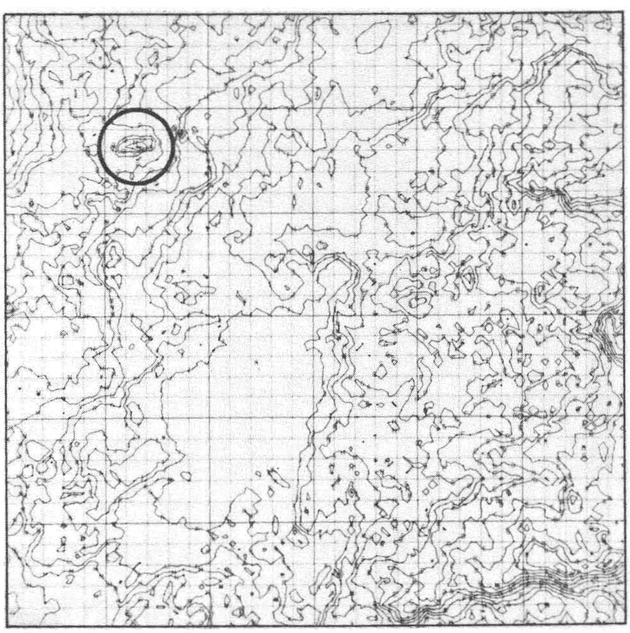

FIG. 9b

FIG. 9. Comparison of computer generated (bottom) and photogrammetrically compiled (top) contour maps, Area B.

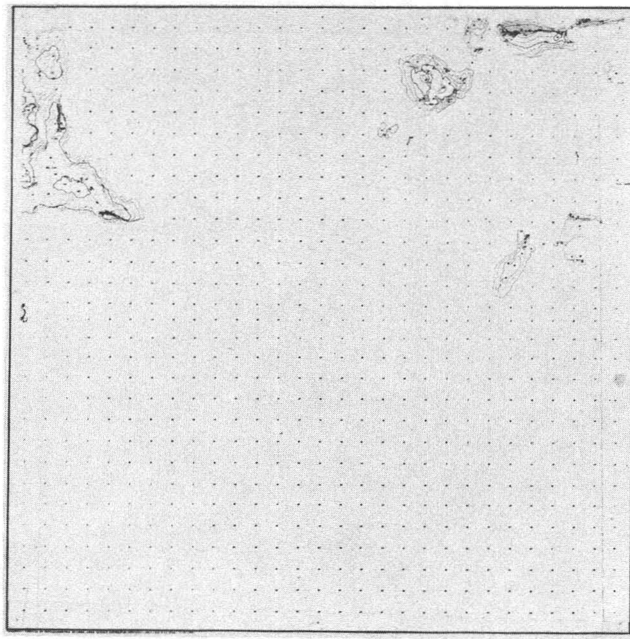

FIG. 10a

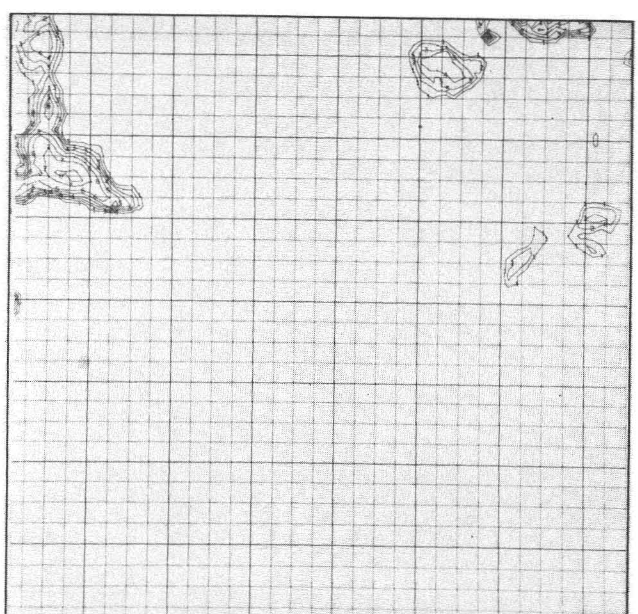

FIG. 10b

FIG. 10. Comparison of computer generated (bottom) and photogrammetrically compiled (top) contour maps, Area C.

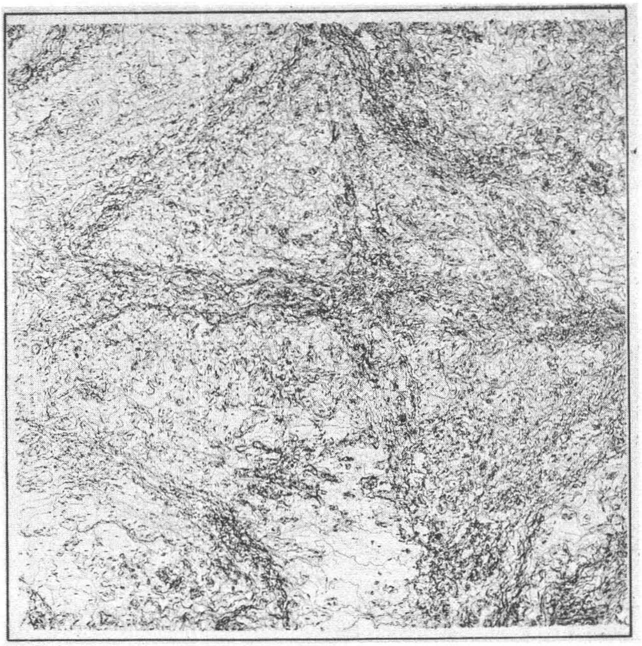

FIG. 11a

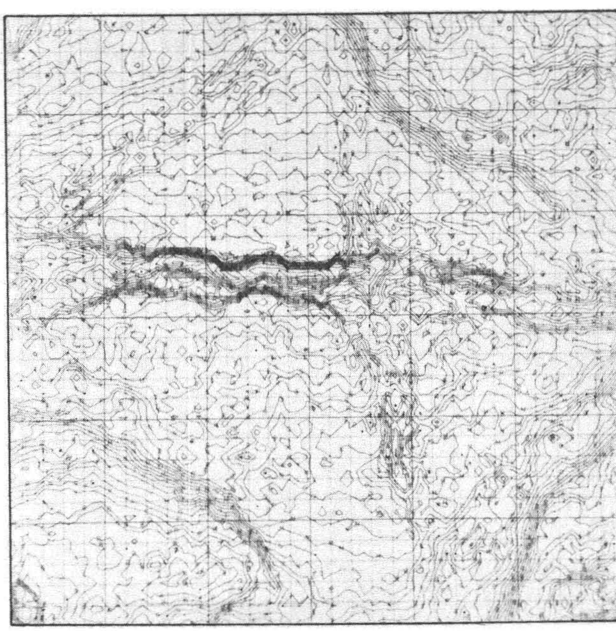

FIG. 11b

FIG. 11. Comparison of computer generated (bottom) and photogrammetrically compiled (top) contour maps, Area D.

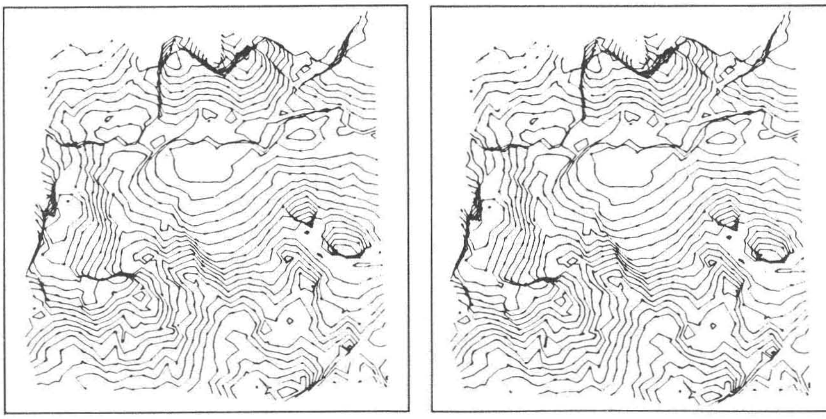

FIG. 12. Computer generated perspective views of Pisgah Crater terrain.

of probable landing pads. Aero Service Corporation also prepared punched cards containing the x, y, z-coordinates of points located in a square grid at one meter intervals (two meters for Area C). These data have now been sorted, corrected, and compiled into four Fortran IV binary tapes which are being used at Space and Information System Division, North American Aviation, Inc. Pertinent items concerning each data tape are summarized in Table 1.

VERIFICATION OF DIGITAL TERRAIN DATA

An IBM 7094 computer program (References 1, 2, 3, and 4) was utilized to produce contour maps directly from the x, y, z terrain data. As a result, a number of errors in the data were easily discovered and eliminated by comparison with the original photogrammetrically generated contour maps. The digital computer generated contour maps (Figures 8b, 9b, 10b, 11b) show excellent agreement with the conventional maps (note that larger contour intervals were used for some of the computer generated maps). Detailed study of the two different kinds of maps confirmed the accuracy of the numerical data stored upon each of the four tapes.

It is interesting to note the accuracy with which the original contour maps may be reconstituted from the x, y, z-data. The plotting accuracy of the computer has been proven by the generation of perspective views of contour lines which have been properly displaced in three dimensions (Figure 12). A "3D" presentation is immediately obtained if two properly constructed perspective contour maps are viewed using a stereoscope (References 3 and 4).

Of further interest is the fact that only about 30 seconds of IBM 7094 computer time was required to generate each of the maps appearing in Figs. 8–11. A similar amount of time was required to plot the data using an off-line SC4020 CRT plotter.

APPLICATIONS OF DIGITAL TERRAIN DATA

A number of relatively inexpensive computer simulation studies involving lunar landing, exploration, and mapping systems are immediately suggested by the availability of the Pisgah terrain tapes. Several such uses are noted below.

Statistical Lunar Landing Study. A vehicle with given landing gear configuration may be randomly positioned upon any of the four Pisgah areas to determine the possibility of successful landing as a function of terrain roughness and landing gear parameters.

Simulated Traverse Study. A hypothetical lunar exploration vehicle configuration having given wheel size and coefficient of friction may be randomly placed upon the digital terrain, and its ability to move in a given direction may then be calculated. Probable limiting vehicle characteristics for successful traverse of any of the four terrain types then may be computed.

Radar Correlation Study. The ability of a radar sensor to determine the roughness and textural features of particular kinds of terrain may be evaluated using the Pisgah data. Correlation with computer studies may be achieved by actually flying a radar sensor over the test squares.

Conclusion

The selection and mapping of terrain simulating hypothetical lunar conditions has been completed. Terrain data is available on Fortran IV binary tapes which have been verified by digital computer contouring techniques. As a result, a large amount of accurate, realistic digital data is available for use in computer simulation studies involving proposed lunar landing, exploration and mapping vehicles.

Acknowledgements

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