PHOTOGEOLOGIC INSTRUMENTS USED BY THE U. S. GEOLOGICAL SURVEY*

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PHOTOGRAMMETRY serves geology in three basic ways: 1) in the preparation of geologic base maps, 2) in the transfer of geologic data mapped on aerial photographs to existing base maps, and 3) in the measurement and interpretation of geologic features.

All the instruments and techniques utilized in these three basic functions cannot be discussed here. Therefore, the first two are covered in summary only.

In most respects, the ideal base maps for the compilation of geologic data are topographic maps, such as the standard topographic maps of the United States Geological Survey. However, they must at times be supplemented by maps and photographic materials of larger scale. In areas for which no standard topographic maps exist, preliminary base maps or map substitutes must be made. In some work a planimetric map will suffice. It is desirable that these preliminary maps have sufficient relative accuracy to permit later map-to-map transfer. Low-cost maps of constant scale and sufficient accuracy for preliminary geologic compilation can be produced by using the stereotemplet developed by Marvin Scher of the Geological Survey. This is a mechanical device for expanding control. Orthographic photographs, rectified photographs having orthographic or map-like characteristics, are now becoming available in the Geological Survey. When these photographs are mosaiced, they may be used as a substitute for planimetric maps.

In transferring geologic data from air photographs to an existing base map, more advanced stereoplotting equipment such as the Kelsh plotter and Multiplex, as well as the KEK and Mahan paper-print plotters, have been used. Also the Kail radial planimetric plotter is widely used in transfering geologic data to base maps. Many geologists like to work on enlargements of the aerial photographs in the field. To accommodate these enlargements special Kail plotters have been made that will hold photographs as large as 12 inches × 12 inches. Although this instrument does not permit correction for tip and tilt, its accuracy is sufficient for most geologic transfer work. All the above instruments are essentially office machines.

Recent experiments were conducted in which a grid, usually 1 centimeter square, was superimposed on an air photograph and this same grid plotted orthographically on the base map. This was done before the geologist entered the field, thus permitting him to plot accurately by eye merely by moving from square to square, checkerboard style. This method may be used even in the absence of a map. The orthophotograph, in addition to its use as a base map substitute, may solve the problem of accurate transfer of geologic data from aerial photograph to base map.

In the interpretation and measurement of geologic features the basic instrument is the stereoscope. Many types and varieties of stereoscopes have been tested and used by the photogeologists and by field geologists in the Geological Survey. In photogeologic interpretation the instrument most often used is a mirror-binocular stereoscope that is mounted from the rear on a long extension arm so as to give complete freedom beneath the instrument for annotation (Figure 1). This instrument is so designed that the user must look vertically down at

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* Presented at semi-Annual Meeting of the Society, in Philadelphia, Pa., Sept. 16, 1954. Published by permission of the Director, U. S. Geological Survey.

the photographs, a feature which it is believed helps the average interpreter to visualize a horizontal plane. Choice of magnification permits close inspection of detail or an over-all view of the model area. This instrument is uncomfortable to use over long periods of time if the binoculars are being used. For this reason this instrument is supplemented with other stereoscopes for general study of the photographs. Three stereoscopes commonly used by photogeologists of the Geological Survey for this purpose are:

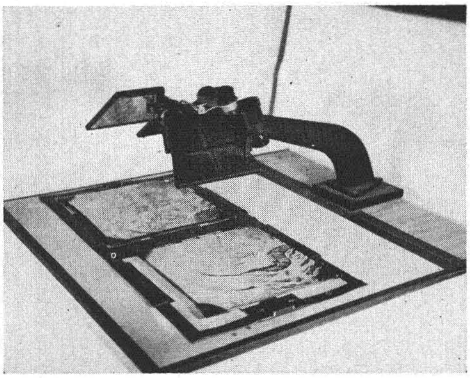

FIG. 1.—The Ryker mirror stereoscope mounted on special supporting arm.

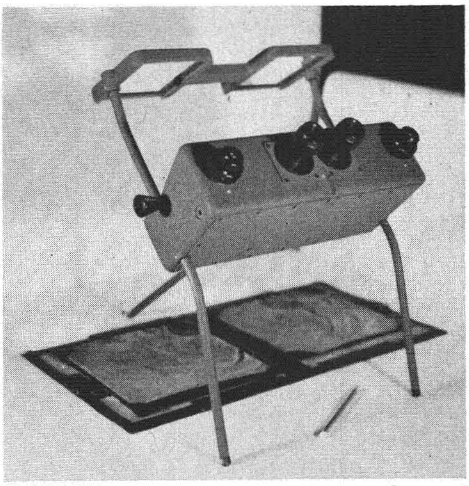

FIG. 2.—The Old Delft scanning stereoscope.

(1) The Old Delft Scanning Stereoscope (Figure 2), a mirror prism scanning stereoscope with magnification selective at 1.5× or 4.5×. Movement of prisms within the optical train of this instrument enables the operator to scan the entire model area without moving the stereoscope or the photographs. This instrument is so designed that two of them placed back to back permit two operators to view the same model area. This feature provides an excellent means of training new photogeologists.

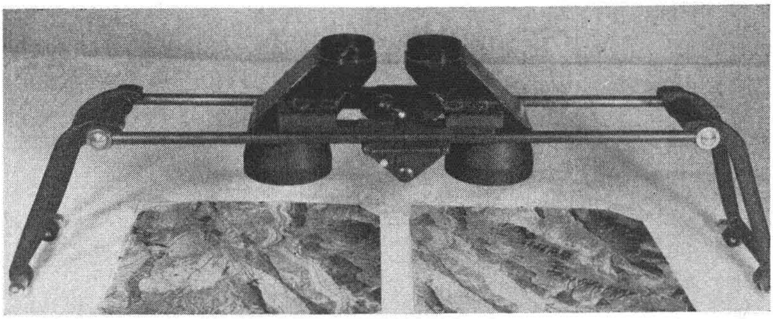

FIG. 3.—The Schneider stereoscope.

(2) The Schneider stereoscope (Figure 3), is designed in such a way that a series of photographs fastened to the table or some similar flat surface may be viewed in three dimensions without moving or curling the photographs. The optical qualities are good, magnification is approximately 2×.

(3) The Abrams two power-four power lens stereoscope (Figure 4), a regular lens stereoscope with supplemental lenses that may be quickly placed in the optical train to increase magnification.

Geologists using aerial photographs under field conditions normally use one of two types of stereoscope depending on the need for magnification. If magnification is desired, a lens stereoscope mounted on a piece of hardboard approximately 10 inches by 12 inches is used. When magnification is not needed a single prism type stereoscope is used. This consists of two pieces of hardboard approximately 10 inches by 10 inches, hinged so that they open slightly more than 90 degrees. One photograph is then viewed directly with one eye; the other eye views the inclined photograph through a small single prism. This gives a stereoscopic view of approximately all of the model area. Both these stereoscopes fold for easy portability.

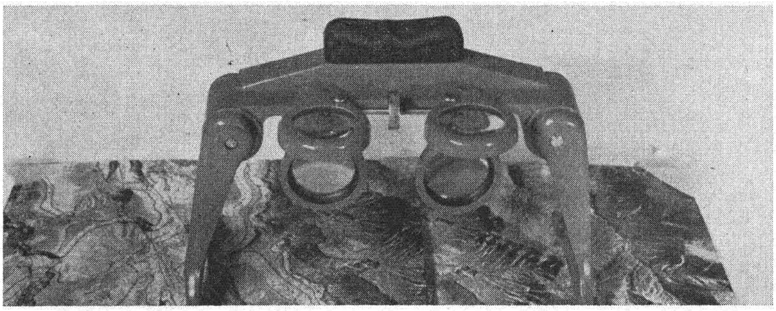

FIG. 4.—The Abrams 2×-4× lens stereoscope.

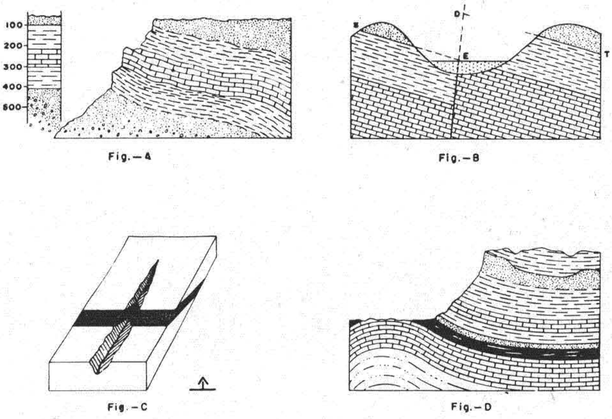

FIG. 5.—Geologic features commonly measured by geologists. (A. thickness of beds; B. vertical movement along fault; C., D. strike and dip.)

The accuracy requirements for geologic measurements are extremely variable. There is, therefore, need for many instruments so that the most economical procedure may be followed. Figure 5 illustrates not only some of the basic accuracy limitations of the science of geology but also three measurements often made by geologists. Note that in some of these drawings the contacts between various units and the thicknesses of various units have been drawn irregularly, as of course many are in nature. Such basic variables limit the accuracy required of various measuring procedures or instruments. The three measurements illustrated are:

(1) The composite thickness of a series of rock units (Figure 5A);

(2) The relative vertical movement along a fault and the inclination of the fault plane (Figure 5B);

(3) The strike and dip of beds (Figure 5C, D). If altitudes are determined at three places in triangular arrangement on a bedding surface, a line connecting points of equal elevation—the strike—and the amount of slope in the direction normal to the strike—the dip—may be determined. In nature, bedding surfaces are normally not planar surfaces but are actually warped or curved as shown in Figure 5D. Thus, dip-and-strike measurements are usually approximations.

Measurements of the type shown in these illustrations are normally not related to a common datum, and as they involve measurement of vertical intervals between features which are usually close together in plan position—such as the top and bottom of a near vertical cliff—tilt can be ignored. Therefore, measurements of this type are normally made with simple stereometer type instruments. Five instruments of this type commonly used now by the Geological Survey are shown in Figure 6. Of these instruments the stereo elevation meter is of particular interest in that readings are made directly in feet. Settings for flying height and photo base are made at the base of the instrument.

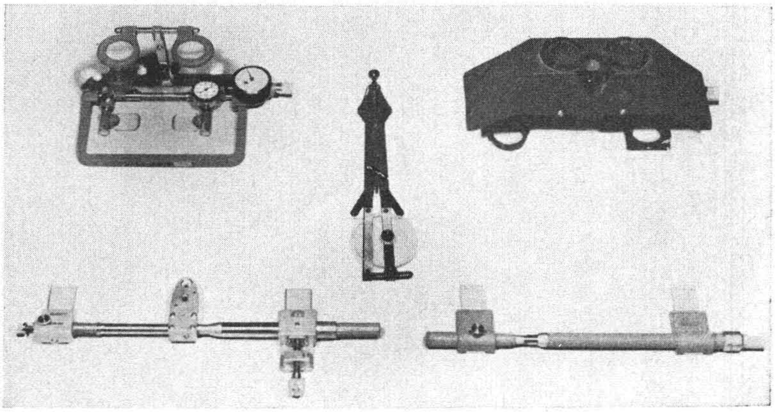

FIG. 6.—Instruments used by photogeologists of the U. S. Geological Survey for measuring relative altitudes. A. Abrams contour finder; B. Stereo elevation meter; C. Fairchild stereocomparagraph; D. Zeiss stereometer; E. Wild stereometer.

Some geologic problems demand greater precision—an example of this is in the study and mapping of variations of thickness of a formation or rock unit usually over large areas. To achieve the degree of accuracy required in this work a measuring instrument of high precision, such as the Kelsh Plotter is required. In addition, there must be a method of maintaining constant scale. The stereotemplet has been successfully used for this purpose.

Another common geologic mapping procedure is structure contouring; that is, the contouring of a selected surface within the bedrock sequence. In this procedure all vertical measurements must be referred to an arbitrary but common datum. Altitudes are obtained on or referred to the selected surface within the bedrock, and a contour map of the surface is then prepared from these.

Figure 7 shows a typical structure-contour map. This map was developed by purely photogrammetric means. The closure of this particular structure, that is, the structural relief above the lowest closing contour is approximately 1,000 feet, and an error of 25 to 50 feet here would be insignificant. However, in areas of very gentle folding an error in vertical measurement of 50 feet could remove an otherwise promising area from further consideration, and alter the whole course of a petroleum exploration program.

A great proportion of our work so far has been in areas where field control was not available in sufficient density to permit the use of the Kelsh or Multiplex plotters directly. Therefore, supplemental control had to be established by photogrammetric means. The photoalidade has been used for this purpose. It is an instrument for measuring horizontal and vertical angles on oblique photographs, thus establishing positions and altitudes of features. These positions and altitudes determined from the oblique photographs are then used as control for the orientation of models of the vertical photographs in the Kelsh and/or Multiplex plotters.

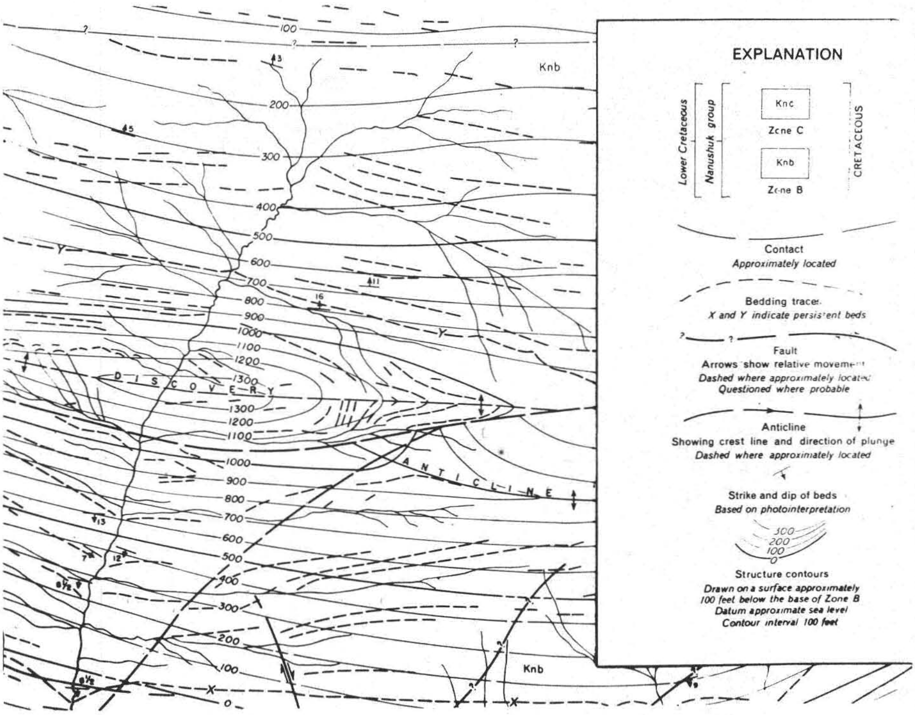

FIG. 7.—Structure-contour map of a part of Discovery anticline, Alaska. Contour interval 100 feet.

Angles of slopes, that is, strikes and dips, inclination of fault planes, etc., are measurements important in almost all geologic studies. These can be calculated from horizontal and vertical measurements, but a geologist's work would be greatly implemented if these slopes could be read directly on a stereoscopic model. This problem is complicated by the exaggeration of the vertical scale of a stereoscopic model when viewed through a stereoscope. The effect of this exaggeration is shown in Figure 8. Several devices have been and are being developed for reading slope angles on the stereoscopic model. One that the Geological Survey is presently developing and testing is a dip and strike finder developed by R. J. Hackman of the Geological Survey. Figure 9 shows a device that employs two identical targets which, when fused stereoscopically along with the stereoscopic image of the aerial photographs, can be raised or lowered within or upon the stereoscopic image, by an adjustment of the separation of the targets. The targets are then swung and tilted until they agree in orientation with the surface to be measured. Preliminary experiments indicate that the target itself takes on in large part those distortions and exaggerations caused by: (1) the type stereoscope used, (2) the position of the slope in the model, and (3) variations in image separation. Thus the reading so obtained is affected chiefly by the base height ratio of the original photograph, which may be easily computed or determined empirically by comparison with known slopes. As the targets are actually tilted in space, and do not rely on an apparent slope created beneath a stereoscope by parallactic divergence, the instrument may be used to measure slopes oriented in any direction in the stereoscopic model. Further, as the targets are interchangeable, they can be selected so that the size of target will nearly coincide with the size of the slope to be measured; this procedure, it is believed, increases the accuracy of the reading.

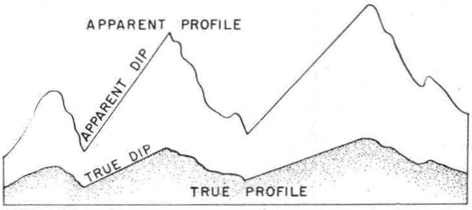

FIG. 8.—Diagram showing generalized relation of true dip to exaggerated dip as seen in a stereoscopic model.

Oblique photographs have tremendous application to geologic mapping as

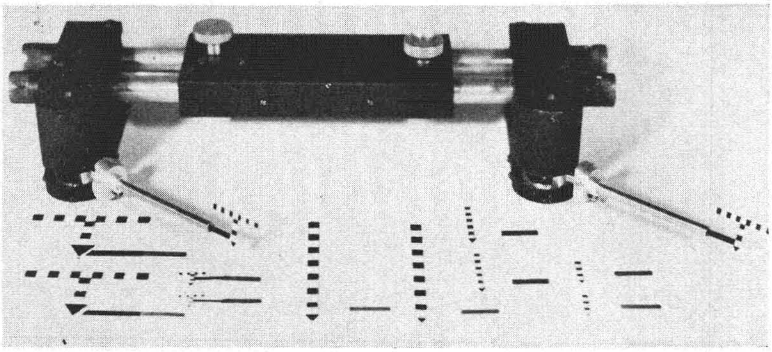

FIG. 9.—The "Super Duper Dipper," a device for measuring slope angles in a stereoscopic model.

many geologic studies involve measurement and study of features exposed in near vertical faces—river and road cuts are typical examples. Satisfactory oblique photographs may be made either from the ground or from low-flying aircraft. The Geological Survey, in its investigations of the Naval Petroleum Reserve No. 4 in northern Alaska, made extensive use of high-angle oblique photographs taken from aircraft flying at altitudes of from 50 to 200 feet. The photographs were taken at the maximum scale permitted by the terrain and the hyperfocal distance of the camera lens. Photographs were made of most of the outcrops along the courses of the major rivers in the area. Field parties followed identifying and marking features on the photographs for later measurement. The orientation of the cameras in space at the time of exposure was unknown;

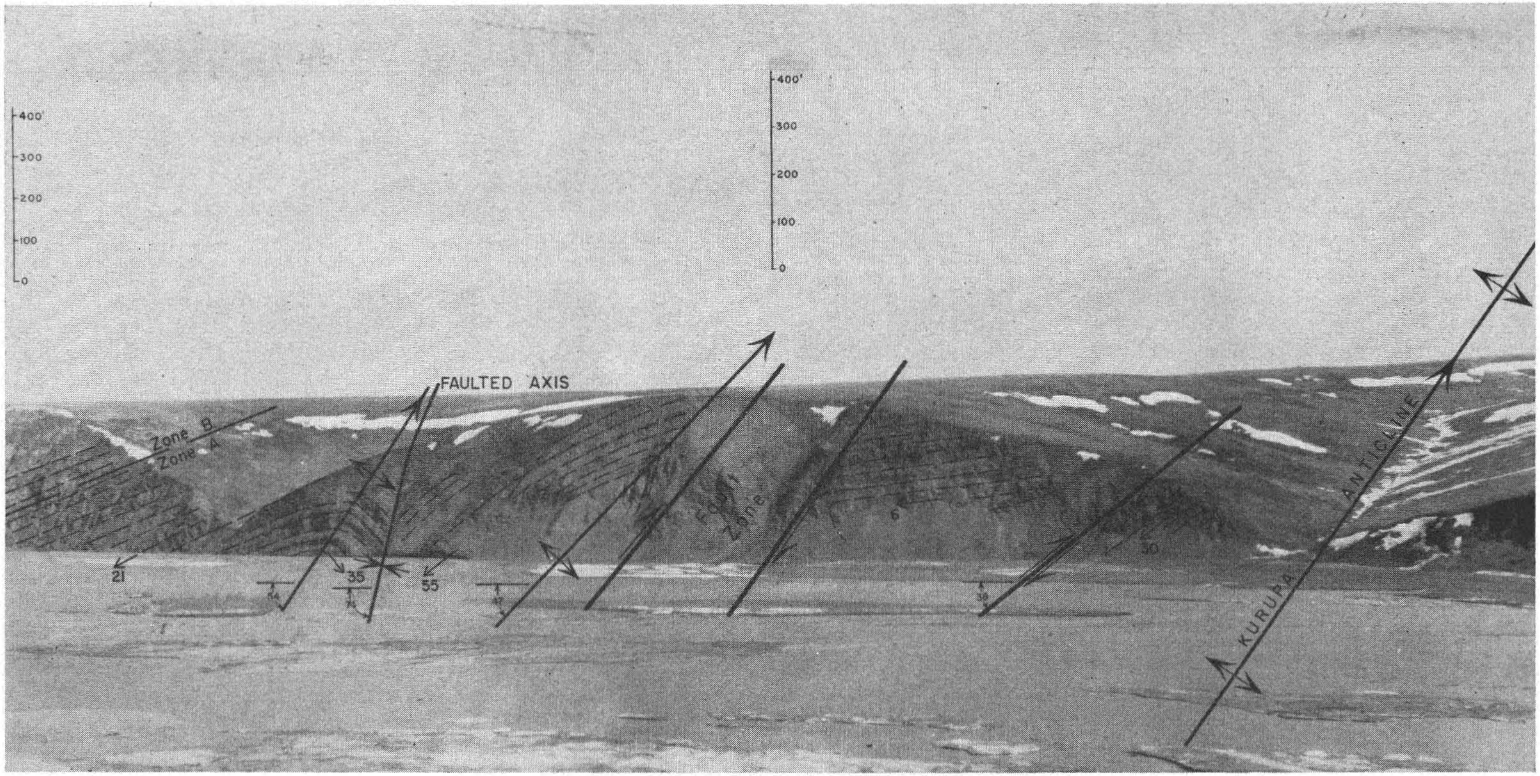

FIG. 10.—An oblique photograph showing a cross section view of the Kurupa anticline, Alaska.

and control available in the area was inadequate; furthermore, the studies were of a general reconnaissance nature. After considering these factors it was decided to determine the vertical scale of the oblique photographs by measuring the bluff height on the vertical photographs with a stereometer. As the face of the bluff or cut was not always parallel to the flight direction of the plane, at least two measurements of the bluff height were made within the field of each oblique (Figure 10). This general procedure worked well in this particular project as the project was large enough to justify the use of specially equipped aircraft. For smaller projects, however, and for projects requiring a higher degree of precision, other procedures must be developed. The most promising involves terrestrial photogrammetry. There is a definite need for a light portable camera having stable metric characteristics. This camera should be designed to permit attachment to a very light theodolite or telescopic alidade or to be used independently.

Geology is an earth science. Its very nature precludes its being divorced wholly from field investigation. However, some geologic problems, such as structure contouring in well-exposed areas, lend themselves in large part to solution by photogrammetric and photointerpretation methods. The photogrammetric instruments now available are adequate for solution of such problems. Other geologic studies such as those associated with intensive geologic investigation of mineralized areas must be performed, in large part, by field methods. Parts of such investigations, however, may be expedited by the use of photogrammetry. The use of photogrammetry under such conditions can be increased by designing equipment which can be used under field conditions and which can be successfully operated by men with little photogrammetric training. Such instruments will hasten the full acceptance of photogrammetry as a valuable tool in the study of geology.

NEW ASPECTS OF MONO-PHOTOGRAMMETRY*

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INTRODUCTION

HAVING chosen the subject Mono-Photogrammetry for today's discussion I do not wish to give the impression that I am discussing something basically new. If we look through the early photogrammetric literature before the first World War, we find that several authors have concerned themselves with the theory and some practical applications of Mono-Photogrammetry. The Austrian Professor Zaar has given the theory in one of the volumes of the *International Archives of Photogrammetry*. Since then little has been heard of this subject which in the quoted literature was named "Mirror photogrammetry." In more recent text books[1] we find remarks on the possibility of using mirror images for photogrammetric measurements.

In view of the advancement of our science during the last 40 years, and particularly in view of the achievements in the optical and mechanical fields, it seems appropriate that we review the subject of Mono-Photogrammetry and try to visualize what the advanced technology has to offer to this field of endeav-

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* Presented at Semi-Annual Meeting of the Society, in Philadelphia, Pa., Sept. 16, 1954.

[1] O. Lacmann: Die Photogrammetrie in ihrer Anwendung auf nichttopographischen Gebieten.