GEOPHOTOMETRIC MAPPING*

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I FEEL honored in being invited to present a paper to your society. The main reason is because photogrammetry isn't exactly my field; I am a geophysicist. However, in my attempts to develop a better method of surveying to be used in connection with geophysical prospecting, it seems that I have inadvertently stepped over into the field of photogrammetry. After learning of the extremely complex instruments and theory that have been developed in connection with the science of photogrammetry, I consider it an honor indeed to have my amateurish efforts somewhat recognized by a society composed of men who are experts in this highly specialized field.

This new surveying method, to which I refer, is a photographic method of surveying to which I have given the name of Geophotometric Mapping. The instrument which I invented to obtain the field data I call the Topographic Camera. This instrument uses certain principles of terrestrial photogrammetry for obtaining the distances, directions, and elevation differences needed for the construction of topographic maps. We have been using this instrument now for quite some time on all of Republic Exploration's gravity crews and with very satisfactory results.

Figure 1 shows the Topographic Camera in its present state of development. It consists of a 35 mm. camera with telephoto lens and reflex housing, all rigidly mounted on a standard transit head. It is mounted in such a way that no vertical angles can be turned by the objective lens. A sensitive level bubble is mounted on the right side of the reflex housing, and the instrument line-of-sight is adjusted parallel with this level bubble. This adjustment is accomplished by means of the eyepiece mounted on the back of the camera box which permits viewing the image brought in by the objective lens and focused in the plane of the mil scale lines which are located in the plane of the film. By sighting on a Philadelphia rod, the instrument is adjusted by the standard two-peg method as used in adjusting a transit or other conventional surveying instrument. After adjustment, the eyepiece is covered and not used again in regular field work except to check the adjustment.

In field operation, the instrument is level for all shots but the lens takes in a field of view of 10 degrees vertical angle range, thereby permitting operation over relatively rough topography with the same ease and facility as operation in level country. Since the instrument is level for all shots, the plane of the film is then parallel to the plane of the rod which results in true elevation differences and map distances, regardless of the vertical angle involved in the field work, without the need for secondary corrections of any kind.

Perhaps the outstanding feature of the Topographic Camera is the complete elimination of all instrumental readings in the field by the instrument-man. The instrument-man simply levels his instrument, sights on the rod, and snaps the picture. Compared with transit operations, this means the elimination of (1) stadia-reading for distance, (2) rod-reading, (3) vertical angle-reading for elevation difference, and (4) horizontal angle-reading for direction. This means four chances for error on every back-sight and fore-sight are eliminated in the field.

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The only note-keeping the instrument-man does in the field is to record the station number and the shot number, and to check whether the shot is a back-sight or fore-sight.

An auxiliary lens and prism system mounted on the left side of the reflex housing brings an image of a portion of the azimuth compass card on to the film incorporating these data on to the same frame with the rod. Thus, on each exposure is recorded all of the information that is needed to determine the distance, direction and elevation difference between the instrument and the rod.

The rod is a fixed-target type as sown in Figure 2. The target interval being fixed serves to calibrate the scale of the resulting picture at the particular distance the rod is held from the instrument, thereby permitting vertical scaling from the level reference line to the datum target in terms of feet of elevation difference per millimeter of film interval.

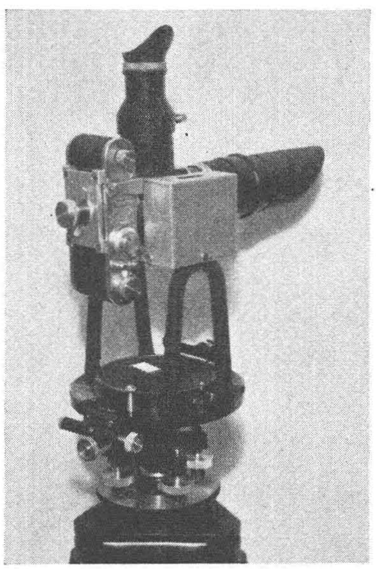

FIG. 1. The Topographic Camera.

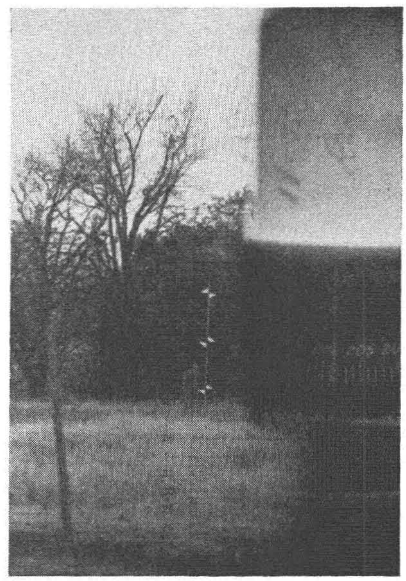

FIG. 2. A field shot taken by the Topographic Camera.

This target material is chosen for certain desirable photographic properties which are necessary for the successful operation of this method. It is a translucent material that produces good results regardless of field lighting conditions.

The accuracy of vertical closures needed for satisfactory results in gravity work is given by the formula $\pm .20\sqrt{\text{miles of traverse}}$. Actually, we get better closures than this with the Topographic Camera because we are approaching 3rd order leveling very closely. Our experience has shown that there are just three simple requirements for obtaining the above accuracy with the camera. First, the instrument must be in good adjustment; second, the instrument must be level at the instant the picture is taken, and third, the rodmen must be absolutely certain of *exact* take-off and tie-in points within each traverse run. This third requirement is sometimes the most difficult to achieve because the average rodman is not too concerned over exact points; anywhere within a radius on a road intersection, is in his opinion close enough.

The length of shot for accurate results with present lens should not be over one-fourth mile. Half-mile shots can be taken but the accuracy drops considerably on such long shots. Distances may be read on the film to an accuracy of about 5 feet per 1,000 feet. The directions, using magnetic azimuth, are read to the nearest 15 minutes of horizontal angle which is accurate enough for plotting the horizontal control for gravity surveys. More accuracy could be obtained by using a vernier scale instead of the simple index line but such accuracy is not warranted in our type of work.

The speed of operation of the field instrument is such that one instrumentman and two rodmen, each with a car, can do the work that normally requires two transit men, each with rodman and car. Not only is the volume of work increased but the accuracy of the results is also increased. The camera can be operated under certain field conditions where a conventional surveying instrument could not be operated. For instance, heat wave effects cannot be detected on the film, partly because of the short exposure time as compared to the low frequency heat-wave effects, and partly because the film possesses a certain selective sensitivity to certain portions of the visible spectrum.

Also in late evening, when the light intensity was too weak for any kind of visual operations, time exposures were taken that gave very good results. No amount of increase in observation time would have yielded a sharper image to the eye in direct visual readings.

A further increase in speed is effected by the virtual elimination of re-runs in the field, because the film can be re-run in the office at any time without the costly procedure of sending men and equipment back to the field when a mis-tie occurs in a line.

The training time needed to teach a man to operate the instrument within the required degree of accuracy is reduced from approximately one year to about one week. In a week's time we have actually trained men on the Topographic Camera who have had no previous surveying experience, and the results they were able to obtain at the end of that time were as accurate as any that the best surveyor would be able to obtain and with practically the same speed of operation.

The results of a field shot are shown in Figure 2 which shows the fixed-target stadia rod, the horizontal reference lines which are numbered in series of two's starting from 16 at the bottom of the frame to 84 at the top, and the azimuth scale on the right side of the frame just below the identification tab. This identification tab serves for the notation of the date, roll number, party number, etc., on each frame.

Three targets are used on the rod, any two of which must be visible for distance determinations except on very short shots, in which case only one target is needed for usable results. Quite frequently, the lower target may be obscured by the crest of a hill or by brush, in which case a half-interval is read and calculations made accordingly in the office. The horizontal reference line numbered 50 is the HI or level-line to which the instrument is adjusted. The top target is usually the datum target from which all measurements are made. In computing the results, the interval between the top and bottom targets is very accurately measured. Then the interval from the 50 line to the top target is measured and divided by the target interval as measured on the film. The quotient is then multiplied by the fixed-target interval in feet which converts the elevation differences into feet. The distance is a function of the target interval and lens focal length.

In addition to engineering information, the film provides a visual check on the geological outcrops in connection with studies of surface geology and also shows the need for terrain corrections in connection with gravity meter surveys.

All readings and measurements are made in the office directly from the film negatives, using a specially designed reading device as shown in Figure 3. The film is loaded into the projector which is shown to be located just below the screen and inside of the main instrument case. The image is projected behind the screen by means of double reflection from front surfaced mirrors. The projector and one mirror move as a unit by means of the small crank shown located

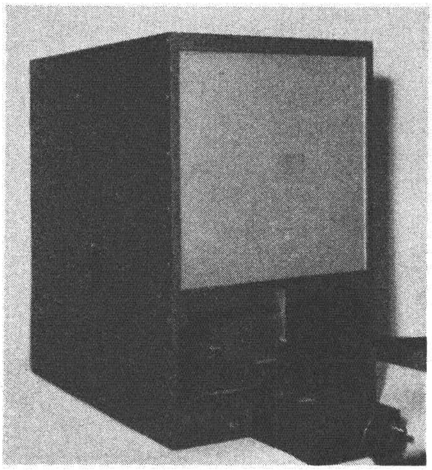

FIG. 3. Special film reading device for computing engineering data.

on the lower right hand side of the case. Reference lines are drawn on the screen, the top line being numbered zero, the remainder of the lines being used to measure the target interval directly for short shots from about 100 feet up to 800 feet. For longer distances, the readings are taken from a horizontal graduated dial contained in the housing to which the small crank is attached. In operation, the frame under study is positioned in the projector so that the top target is very near the zero line on the screen. The screen itself is then moved up or down slightly by means of the cam-actuated handle located in the center of the frame just below the screen until the zero line splits the top target. The small crank is then turned, moving the projector in such a manner that the image travels up the screen until the zero line intercepts the first mil scale line below the top target. This interval is then read on the lower window of the dial. The projector is moved still further in the same direction, until the zero line splits the bottom target, then the conversion factor and distance are both read in the upper window of the horizontal dial. These readings permit vertical angle measurements to within 6 seconds of arc. The azimuth scale is read directly to the nearest 15 minutes of horizontal angle.

Although we are able at present time to make these instruments fast enough for our own use, there has been so much interest shown by the oil industry in general in obtaining the instrument as soon as it is available, that we plan on going into mass production within a short time. We seem to have all of the "bugs" pretty well ironed out now, although there are a few changes that we would like to make before placing the instrument on the market. One such change would be a camera that will hold a day's supply of film. Also a little longer focal length lens, and, at the same time, an increase in the frame length to take in about a 12 degree vertical angle range would be desirable in mountainous country. Several people have suggested putting the image of the level bubble on the picture to be sure the instrument is level. This of course could be done with a little more added weight. We have tried to keep the instrument as light in weight as possible, and at present it weighs about the same as the average transit.

There are a great many uses to which the instrument could be put besides our own use in geophysics for which the instrument was primarily designed. The simplicity of operation enables junior engineering personnel to easily handle the field work and permits easy supervision of each step of the work by senior engineers from a central office location.