# *Terrestrial Photography for Establishing Supplemental Control**

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ABSTRACT: *Terrestial photography has been used by the U.S.G.S., Topographic Division, for several years to establish supplemental control in mountainous areas. Terrestrial photographs are taken in the field from points of known elevation and position. Later, in the office, picture points are cross identified between the terrestrials and the verticals. Vertical angles are measured to the picture points on the terrestrial photo. With this vertical angle and a photogrammetric distance between the picture point and the camera station, the difference in elevation and, in turn, the elevation of the picture point can be established.*

*The expected accuracy of the elevations so established is given and the practices in the field and the office are thoroughly covered.*

## PRINCIPLES INVOLVED IN THE USE OF TERRESTRIAL PHOTOGRAPHY

SUPPLEMENTAL, control for photogrammetric mapping operations is one of the most costly operational phases in current mapping programs. Bridging by aerial triangulation, in one form or another, is accepted for horizontal positioning; but obtaining vertical control is still largely a field operation.

The importance of establishing supplemental control from terrestrial photographs lies not so much in the cost, which is slightly lower than for conventional methods, but in the ability to shorten the required field time in areas where bad weather and rugged terrain are major obstacles. The field work necessary to obtain primary and supplemental control in one operation is approximately half that of the two done separately. Many more supplemental control points can be obtained by this method than it is economically feasible to obtain in the same time by field methods. Following the taking of the photographs, point identification, reading vertical angles, and computing elevations can be carried out free from weather uncertainties. For this reason, terrestrial photography occupies a place of great importance in the field of photogrammetry.

Until the advent of the airplane, terrestrial photography was, with few exceptions, the only kind of photography used in photogrammetry. The use of such photography by the U. S. Geological Survey was started in 1904. It was first used by two Staff members, C. W. and F. E. Wright; they improvised a panoramic camera from a commercial camera by adding level bubbles and internal scales. In 1907, C. W. Wright had a camera constructed expressly for use as a surveying camera. Later, J. W. Bagley, another member of the Survey Staff, re-designed and improved the camera for reconnaissance mapping in Alaska.

Mr. Bagley designed the first photoalidade with which it was possible to abstract certain information from panoramic pictures taken from known points in the field. Later, R. M. Wilson re-designed the photoalidade to accommodate aerial photography and developed the resection method for orienting the instrument.

The early photoalidade made possible measuring vertical angles on the photograph. Distances were established by the intersection of rays drawn to image points on the photograph. Having the vertical angle and the distance, it was easy to determine differences in elevation between

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the camera station and other identifiable points.

Using oblique aerial photographs the Wilson photoalidade was used by the Survey's Topographic Division in Alaskan mapping work for a number of years. During World War II, the instrument was an important part of the trimetrogon method and was used extensively in preparing aeronautical charts. More recently, an improved model has been used by the Special Maps Branch for special-purpose maps in order to establish vertical control in rugged areas. The Pacific Region has reported successful results in controlling quadrangles to satisfy National Map-accuracy Standards.

In either case, it was possible to develop intersections for distance and, with the vertical angles, determine the difference in elevation.

Intensive use of terrestrial photographs has been made by the Rocky Mountain Region of the Geological Survey's Topographic Division. Since its establishment in 1946, the Region's engineers have faced the problem of establishing control in areas of terrain such as shown in Figure 1. The topography is extremely rugged and there are few, if any, access roads or trails. The control problem was similar to that faced by old-time mappers in Alaska.

The problem of obtaining differences in elevation is simplified when a distance obtained photogrammetrically can be used with a vertical angle measured on a terrestrial photograph. With this in mind, the Region's engineers decided to investigate phototheodolites. The Wild instrument appeared to offer a solution. The engineers were thoroughly familiar with the Wild T-1 and T-2, and furthermore, the Wild phototheodolite appeared to be of more simple design and more rugged construction than others. Simplicity in the camera was important, particularly as most Geological Survey engineers were not trained photographers. The difficult areas over which the instrument had to be transported made ruggedness important.

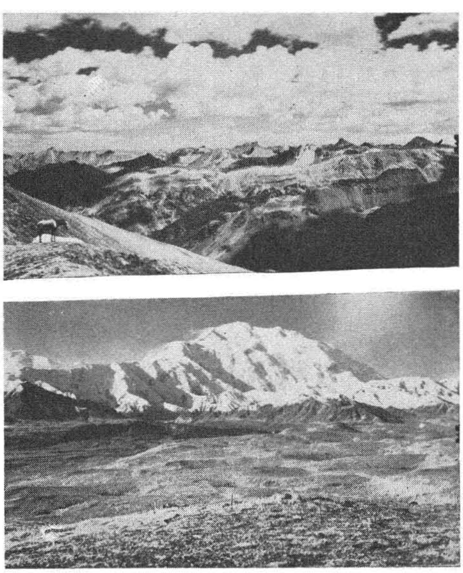


FIG. 1. Typical areas of rugged terrain.

Today, the Rocky Mountain Region uses terrestrial photography, where feasible, to establish vertical and horizontal supplemental control for multiplex mapping.

## DESCRIPTION OF THE PHOTOTHEODOLITE

The Wild phototheodolite is, essentially, a Wild T-2 combined with a camera. The details of its construction are shown in Figures 2 and 3. A casting has been added to the theodolite between the normal horizontal motion and the leveling screws. This casting is free to turn on an axis coincident with the vertical axis of the theodolite. Trunnions are provided on the sides of the camera which fit into "V"-shaped bearings attached to the above mentioned casting. This permits rotating the camera about a horizontal axis. This motion is controlled by a yoke attached to the camera near the lens. The yoke contains a series of cylindrical spacers which fit over an extension of the supporting casting and is held in place by a spring clip. Each spacer represents a fixed inclination of the camera axis measured in grads.

The camera itself is of very simple design. The aperture is fixed. As there is no shutter, exposure is controlled by removing the lens cap for the required time. The camera is designed to use glass plates preloaded in plate holders. A device on the back of the camera permits numbering the photos from 001 to 999.

A very good list of laboratory tests appears in the *Text Book on Photogrammetry* by Professor Dr. Max Zeller. This includes testing the camera levels, the theodolite vertical axis and camera vertical axis, focusing screw, collimating marks of the camera, telescope axis and camera

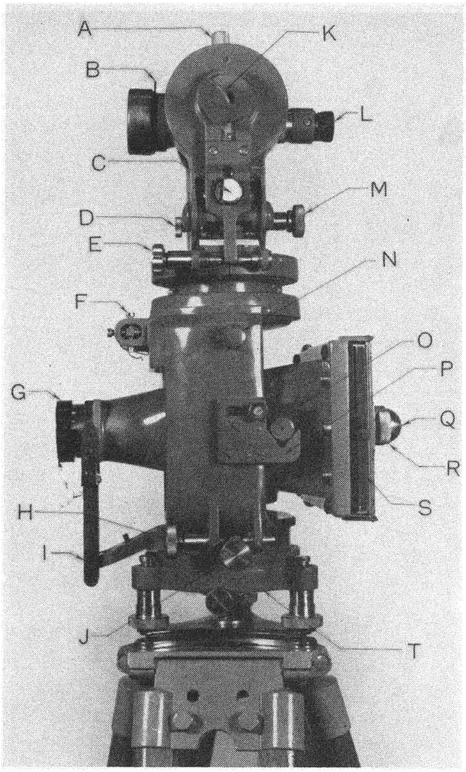



FIG. 2. Details of instruction of Wild T-2 combined with a camera.

A Clamping screw for vertical circle
B Front telescope sight
C Prism for viewing vertical bubble
D Inverter knob
E Leveling knob for vertical bubble
F Adjusting screw for horizontal bubble
G Lens cap
H Tangent screw for lower motion
I Camera supporting yoke
J Lock screw for lower motion
K Illuminating mirror for vertical circle
L Eye piece of telescope
M Tangent screw for altitude
N Illuminating prism for horizontal circle
O Camera trunnion bearing cap
Q Pressure knob
R Knob for locking pressure door
S Plate holder
T Leveling head

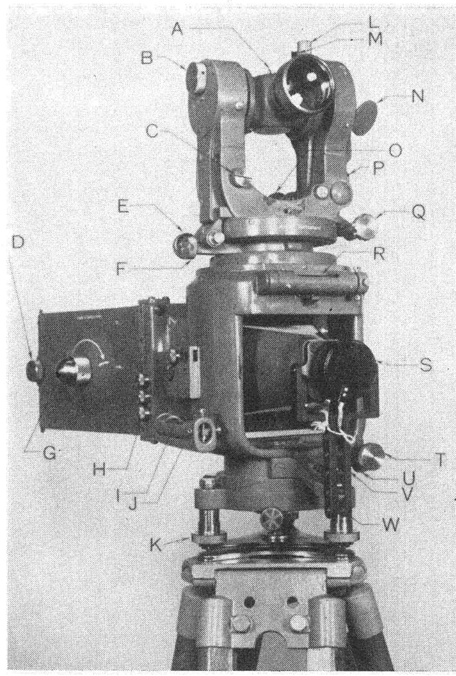



FIG. 3. Details of construction of Wild T-2 combined with a camera.

A Rear sight for telescope
B Knob for coincidence setting
C Inverter knob
D Opening knob for pressure door
E Tangent screw for upper circle
F Clamping screw, upper circle
G Pressure knob
H Numbering device for photos
I Horizontal level
J Bubble adjusting screws
K One of three leveling screws
L Clamping screw for vertical circle
M Front sight for telescope
N Illuminating mirror for vertical circle
O Tangent screw for altitude
P Split bubble prism for vertical circle
Q Leveling knob for vertical bubble
R Horizontal level
S Lens cap
T Lower motion tangent screw
U Lower motion lock screw
V Camera supporting yoke
W Steps for inclining camera

axis, focal-plane frame of the camera, and determination of tilting values. Although Dr. Zeller recommends sending the instrument to the factory for adjustments, it has been found that many adjustments can be made at the Survey's instrument repair shop. Each instrument must be thoroughly checked before use.

Experience has established that Eastman Spectroscopic IV-N is well suited for this purpose. The fine-grained emulsion is essentially panchromatic in its sensitivity to color and, in addition, has a long extension into the infra-red zone.

## OPERATIONS AT THE PRIMARY STATION

The normal observation routine at a station includes measuring angles for triangulation and taking photographs. To reduce the effects of refraction, horizontal angles are measured early or late in the day. It is advisable to read vertical angles and to take photographs between 10 A.M. and 2 P.M.

One of the first photographic operations in the field is determining exposure time, through the use of an exposure meter. The emulsion speed of the photographic plates used is so slow that present-day meters will not give a value for exposure directly. A special table must be prepared for the light values read from the meter.

An exposure meter is not a fully automatic instrument for reading exposure time. It indicates an average reading for a limited area, with perhaps a slightly greater sensitivity to the areas reflecting the greatest light. This means that shadowed areas may be under-exposed. This can be compensated by making a reading, with the back to the sun, on the area lying halfway between the horizon and the camera station. The Region's table of light values is designed to give the minimum time for a fully illuminated subject. This, in combination with the latitude of the emulsion, requires doubling the time to get detail where shadows exist. Considerable experience in using the exposure meter is valuable to the operator.

The following check list of the observing and photographic procedures has been found of great assistance to engineers not especially trained in photography:

1. Record plate holder number
2. Set plate number in camera and record
3. Record initial station sighted
4. Set horizontal circle at pre-determined value
5. Record angle from initial station
6. Read exposure meter
7. Compute exposure
8. Set inclination of camera
9. Pull dark slide out
10. Check plate pressure
11. Check level bubbles
12. Check pointing
13. Make exposure
14. Release pressure plate
15. Replace dark slide
16. Remove plate holder

Admittedly this list is simple, but with its aid, any instrument man can secure an acceptable set of pictures.

Before exposing any plates, it is recommended that vertical angles be turned to check points on one picture in the set. Points used are generally horizontal points one on either side of a given photograph. As the photograph has 43-degree coverage, points 20 degrees to the right and left of the sighting direction will suffice. Points on a skyline with a rounded profile should be chosen. As the initial pointing is made at a triangulation station whose altitude is known, it is recommended that these check points be selected on the initial picture.

To provide the office engineer with adequate information to compute the needed supplemental control, it is necessary to "close the horizon" from a series of camera stations with a set of photographs from each station. Since each photo covers 43 degrees, a set of nine pictures is required to close the horizon. On the horizontal circle, one reads the difference in direction between the telescope and the camera.

Before any exposure is made, all bubbles on the phototheodolite should be checked to be certain that the instrument is level. The horizontal circle is set to the predetermined value. This fixes the horizontal angular relationship between the camera and the sighting telescope. The theodolite is pointed at the initial triangulation station from which all horizontal angles are to be measured. This pointing is made with the lower motion of the instrument, thereby leaving the relationship of the theodolite and the camera undisturbed. The lower motion is locked and a plate holder placed in the camera. The items in the check list are checked off as operations are completed.

After the first picture has been exposed and a new plate holder placed in the camera, the theodolite is turned to the left with the upper motion, and the angle reading in the microscope is set at 320°00′00″. The upper motion is clamped, after which the original pointing is recovered with the theodolite. This leaves exactly 40°00′00″ between the direction of the principal ray of the camera and the direction of the telescope.

The procedure for exposing the picture, reducing the plate reading by an additional 40°00′00″ after each exposure, and repointing on the initial station is repeated for a total of nine times. This closes the horizon photographically, with approximately one and one-half degrees overlap between successive photographs. Hence, the exact direction for the principal ray of each photograph can be determined and, in turn, the direction to any photo image.

### Side Stations

To facilitate cross identification between the vertical and terrestrial photographs, stereo coverage is obtained by taking additional photographs from side (or eccentric) stations. Providing stereo coverage of the entire horizon enables the operator to make two independent readings of the vertical angle to any selected point, and to check the elevation determined. The location of the side stations, with respect to the primary station, will be controlled by the topography. For ideal relationships, the limiting factors are: The difference of the direction to the side stations should be as nearly 90 degrees as is possible. The distance should be approximately 150 feet; it can be extended to as much as 1,500 feet but should never be less than 30 feet.

So far as concerns stereoscopic viewing of the photographs, an elevation difference between primary and side station is not a critical factor. If possible, side stations should be selected at the same elevation as the primary; however, a difference of as much as 100 feet is acceptable if it results in a longer base in the correct direction and does not introduce obstructions into the field of view. The difference in elevation can be determined by a checked vertical angle and stadia distance.

The engineer must keep in mind that each photograph from the primary station must have a companion photograph from a side station. The directions of companion photographs should agree, although they need not be exactly parallel.

As shown in Figure 4, a schematic plan should be prepared in the field, at such a scale as 1 inch = 100 feet. It is relatively simple, from a brief study of this plan, to determine which photographs should be taken from each side station to maintain the most favorable stereoscopic base.

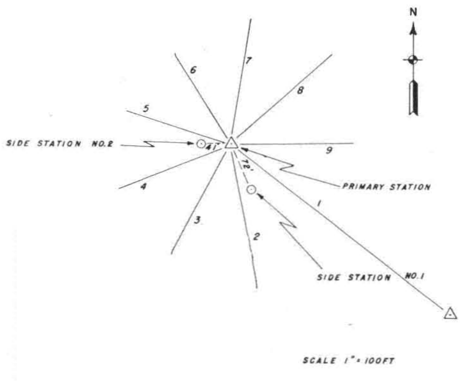



Fig. 4. Schematic plan.

### Photographic Problems

Several tests are extremely important at the beginning of the season when there may be doubt that the photos have been exposed properly. It may be advisable to develop an occasional extra test plate while in the field, or by shipping to the office. In addition, one must guard against the following:

1. Inadvertent exposure of plate while loading holder;
2. Facing of emulsion in proper direction;
3. Separation of exposed and un-exposed plates;
4. Dust or dirt in plate holders.

### Indexing Pictures

Accurate indexes should be made for all photographs. One good type is shown in Figure 5. The directions of primary photographs are shown with dashed lines. This index should be made on a tracing of a plane-table sheet of the area, at a scale of 1:125,000. The directions of the photographs should be shown accurately, as they facilitate cross identification between the aerial and terrestrial photographs. The distances between primary camera stations and side stations should be printed on the index. Experience has proved it best to disregard scale as far as distances to side stations are concerned. It is recommended that this sketch be made in the field by the observer. In short, the field man must furnish an index showing the interrelationship of various photos.

In addition to being a sample index, Figure 5 gives an excellent picture of the amount of camera stations needed to establish supplemental control for a 15-minute quadrangle. In this case, eight triangulation stations were established and pictures were taken from each one. The supplemental control developed from these photos was sufficient to stereo-compile a standard-accuracy, 40-foot-contour-interval map. Generally, if an area has been covered by third-order triangulation, the supplemental control can be established by taking pictures from each triangulation station. Anyone planning phototheodolite work should be alert to the occasional need for establishing secondary stations to assure full coverage.

With the exception of test photos, negatives are developed at Region headquarters and a glossy contact print is made of each. These prints are later used in planning.

### Calibration Range

As soon as the camera is returned to headquarters, it is checked to be certain that calibration has been maintained. As a cross check on laboratory calibration, it is necessary to set up a range in the field. It is important that sharp, readily identifiable image-points appear in each of the nine critical areas in the photograph. See Figure 6 for the position of the critical areas. Setting targets is much more satisfactory than trying to select natural objects of appropriate size. Targets should be made with a black cross on a white ground. Figure 7 is a typical target. As the distance to the targets increases, the width of the cross must be increased to maintain an angular width of one minute.

The best calibration range can be established where a canyon lies between the camera and the targets. This provides better vertical range for testing. Figure 8 pictures a highly satisfactory calibration range.

Regular checks on the calibration should be made. Whether Zeller's laboratory tests, a calibration-range test, or a combination of the two shall be used depends upon the facilities available. If checks are made, in both Spring and Fall, it can be determined whether the calibration of the instrument changed during the field season and how much.

### Determination of Principal Distance

The principal distance of the camera can be established in the following manner: Referring to Figure 9, it can be shown mathematically that the following relationship exists:

$$f^2 - \frac{(r+s)f}{\tan\theta} - rs = 0\cdot$$

From a solution of this equation, a value for the principal distance can be determined. With an accurate value for the angle $\theta$, the accuracy of the principal distance depends entirely upon the accuracy of the values $r$ and $s$. These distances must be measured to the nearest .01 mm.

Using the photograph of the calibration range and the field angles measured, a principal distance can be established.

### Cross Identification of Picture Points

Accuracy is paramount in cross identifying picture points between the aerial and terrestrial photographs. Any point improperly cross identified will lead to the determination of an incorrect elevation.

Cross identification of picture points is done on glossy-paper prints of the terrestrial photographs. Pairs are viewed with a stereoscope as an aid to identification.

Small areas can be bridged photogrammetrically so the inability to establish control in every corner of each model need not be cause for concern.

It is desirable to have each vertical picture point identified on terrestrial photos from more than one primary camera station. If this cannot be done, however, the final elevation can still be considered to be a checked elevation, as it will be established from the angles measured on two terrestrial photographs—the photograph from the primary camera station and the photograph from the side camera station.

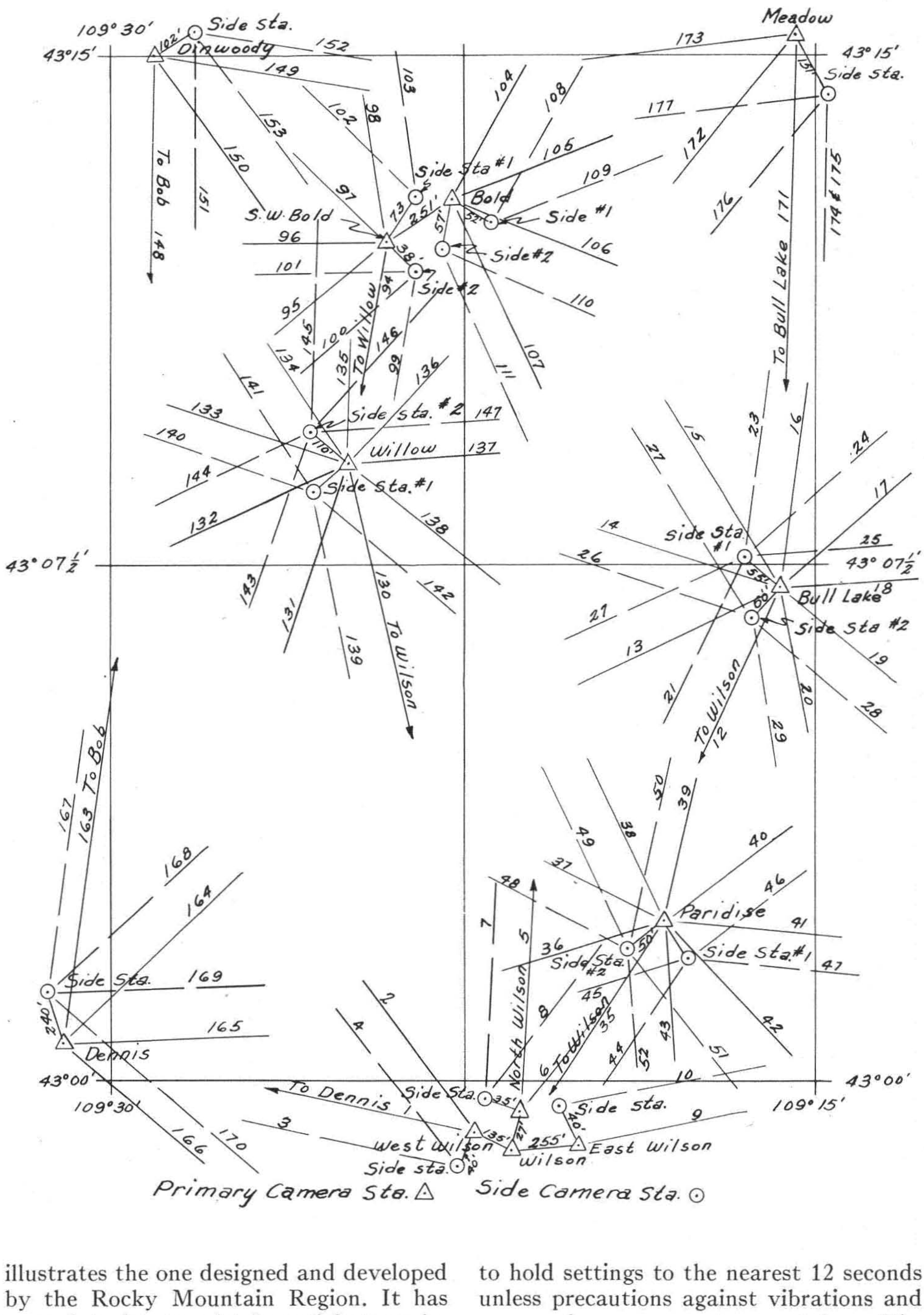
When positive cross identification is made, the point is circled on the vertical photograph designated. A short description is written on the back of the vertical photograph for each point. This point is circled on the terrestrial photograph and its designation marked above it.

During this phase of the work, it should be remembered that vertical angles to triangulation stations appearing on the terrestrial photographs have been recorded. If these angles are reduced to ground elevation, they can be used to check angles measured on the terrestrial photograph. For this reason, triangulation stations should be marked on the terrestrial photograph and angles measured to these stations.

### Photogoniometer Method of Measuring Angles

Angles are always measured on glass positives made from the original negatives. This measurement can be made in two ways; with a goniometer, or by measuring linear distances on the photograph with a comparator.

The photogoniometer method of measuring angles on a terrestrial photograph involves the use of an instrument especially designed for this purpose. Figure 10




illustrates the one designed and developed by the Rocky Mountain Region. It has proved to be completely satisfactory for the work. This photogoniometer was built by modifying a grinding machine, and has all the necessary adjusting motions. As the photograph shows the photogoniometer has been mounted on a slate table to maintain rigidity. It is extremely difficult to hold settings to the nearest 12 seconds unless precautions against vibrations and any undue movements are taken. The photogoniometer is equipped with a Wild T-1 theodolite which is capable of being read to 0.1 minute by interpolation.

In adjusting the photogoniometer, one must strive for the same tolerance that would be used in adjusting the theodolite.

| CAMERA STATION | Initial Triangulation Station | Distance from Primary Δ Sta. | Direction from Primary Δ Sta. | Diff in elev. from Primary Δ Sta. | Dist. from Primary Camera Sta. | Direction from prim. Camera Sta. | Diff. in elev. from prim. Camera Sta. | H.I. of Camera |
|---|---|---|---|---|---|---|---|---|
| W. Wilson | Dennis | 135′ | 13° 41′ | -50′ | | | | 4.0′ |
| W. Wilson (side) | Dennis | | | | 40′ | 291° 10′ | -2.2′ | 4.0′ |
| N. Wilson | Dennis | 27′ | 88° 40′ | -11′ | | | | 4.4′ |
| N. Wilson (side) | Dennis | | | | 35′ | 08° 50′ | -22′ | 4.5′ |
| E. Wilson | Dennis | 255′ | 162° 23′ | -41.0′ | | | | 3.9′ |
| E. Wilson (side) | Dennis | | | | 40′ | 53° 05′ | +21.0′ | 5.0′ |
| Paridise | Wilson | Camera centered over station mark | | | | | | 4.6′ |
| Paridise (side #1) | Wilson | | | | 40′ | 292° 31′ | 0.0′ | 4.1′ |
| Paridise (side #2) | Wilson | | | | 50′ | 18° 04′ | -14.3′ | 4.2′ |
| Bull Lake | Wilson | Camera centered over station mark | | | | | | 5.2′ |
| Bull Lake (side #1) | Wilson | | | | 60′ | 18° 24′ | -21.0′ | 3.6′ |
| Bull Lake (side #2) | Wilson | | | | 55′ | 104° 00′ | -11.0′ | 4.2′ |
| Bold | Willow | Camera centered over station mark | | | | | | 4.6′ |
| Bold (side #1) | Willow | | | | 52 | 269° 31′ | -31.0′ | 4.3′ |
| Bold (side #2) | Willow | | | | 57′ | 350° 46′ | -10.0′ | 3.6′ |
| SW. Bold | Willow | 251′ | 35° 10′ | -3.8′ | | | | 4.0′ |
| SW. Bold (side #1) | Willow | | | | 73′ | 205° 20′ | +6.0′ | 3.9′ |
| SW. Bold (side #2) | Willow | | | | 38′ | 304° 05′ | -3.4′ | 3.0′ |
| Willow | Wilson | Camera centered over station mark | | | | | | 4.1′ |
| Willow (side #1) | Wilson | | | | 170′ | 64° 00′ | -10.0′ | 4.0′ |
| Willow (side #2) | Wilson | | | | 110′ | 147° 28′ | -20.0 | 4.2′ |
| Dennis | Bob | Camera centered over station mark | | | | | | 4.5′ |
| Dennis (side) | Bob | | | | 240′ | 332° 30′ | -7.7′ | 4.3′ |
| Dinwoody | Bob | Camera centered over station mark | | | | | | 4.6′ |
| Dinwoody (side) | Bob | | | | 102′ | 240° 10′ | -51.0′ | 3.5′ |
| Meadow | Bull Lake | Camera centered over station mark | | | | | | 4.7′ |
| Meadow (side) | Bull Lake | | | | 151′ | 229° 41′ | 0.0′ | 4.3′ |
| | | | | | | | | |

FIG. 5. Lenore 15′ Wyo. Photographic index "Terrestrial," Scale 1:126,720.

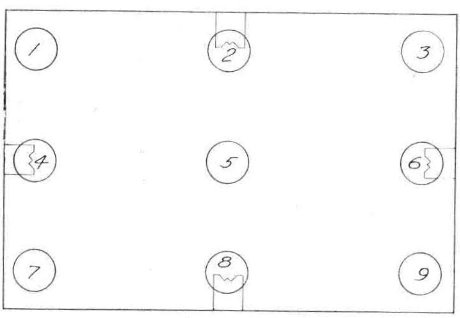



FIG. 6. Position of the critical areas.

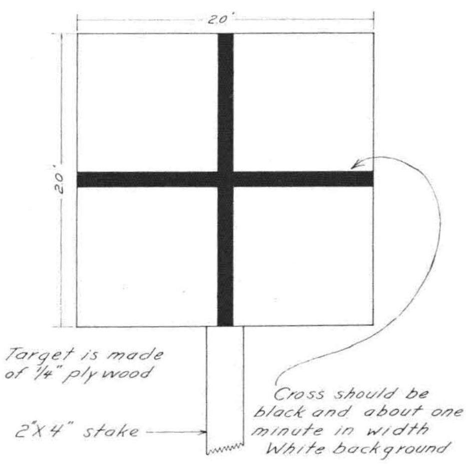



FIG. 7. A typical target.

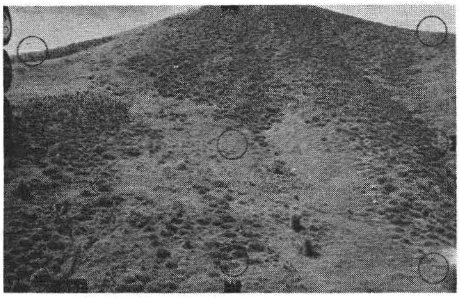


FIG. 8. A highly satisfactory calibration range.

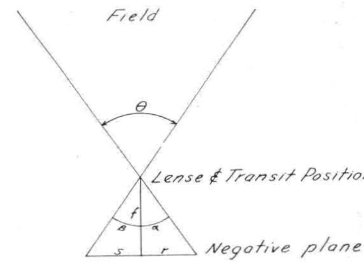
The same adjustments are used with modifications required by the short viewing distance. In addition, the use of the photogoniometer requires a careful recovery of the interior orientation of the plate. All elements of the adjustments should be made with the idea of achieving 10 to 12-second accuracy.

After the photogoniometer has been calibrated, the glass positives are placed in position, and vertical angles to all identified points are measured. Care must be used in setting the plate and in measuring the angles, as the precision of the entire operation depends upon the accuracy with which the angles are measured.

## Comparator Method of Measuring Angles

The comparator method of measuring angles on a terrestrial photograph gives angles of equal accuracy to those measured by the photogoniometer. The approach is different in that linear distances are measured rather than angles. These distances are converted to angular measurement. A comparator suitable for this use is shown in Figure 11. It is mounted on a light table and, with plate illuminated, measurements are easily made. The comparator shown measures distances in $X$- and $Y$-directions. The scales are graduated in millimeters and have verniers reading to the nearest 0.1 mm. The scale magnification is such that distances can be interpolated to the nearest 0.02 mm.

Mathematics involved in converting linear distance measurements on a terrestrial photo to angular measurements are shown in Figure 12. As there are several steps involved in obtaining an angle from linear distances, keeping accurate records is important. Forms can be set up to handle the computations, and so arranged




From trigonometry $\tan\theta = \frac{\tan\alpha + \tan\beta}{1 - \tan\alpha\tan\beta}$

from the sketch $\tan\alpha = \frac{r}{f}$ and $\tan\beta = \frac{s}{f}$

substituting

$$\tan\theta = \frac{\frac{r}{f} + \frac{s}{f}}{1 - \frac{r}{f}\cdot\frac{s}{f}} = \frac{\frac{r+s}{f}}{1 - \frac{rs}{f^2}} = \frac{\frac{r+s}{f}}{\frac{f^2 - rs}{f^2}} = \frac{(r+s)f^2}{(f^2 - rs)f} = \frac{(r+s)f}{f^2 - rs}$$

therefore $\tan\theta(f^2 - rs) = (r+s)f$

expanding $f^2\tan\theta - rs\tan\theta = (r+s)f$

or $f^2\tan\theta - (r+s)f - rs\tan\theta = 0$

dividing thru by $\tan\theta$

$$f^2 - \frac{(r+s)f}{\tan\theta} - rs = 0$$

Q.E.D.

FIG. 9. Establishment of principal distance.

that the final entries are the corrected vertical and horizontal angle to each picture point. When the distance to the picture point is obtained, the differences in elevation can be computed.

## Accuracy of the Method

The accuracy of angles measured on photographs is largely dependent upon the care with which the work is done. The table in Figure 13 shows the accuracy of the angles measured on the Lenore Project in Wyoming. The arithmetical mean of all the angles is 0.39 minutes and 98 per cent of the angles measured were within one minute. A minute in a mile equals 1.5 feet. On 40-foot maps, the supplemental control tolerance is one-tenth of the contour interval or 4 feet. If only one observation were made, the distance would be limited to less than 3 miles. If it is planned to use a more distant point, it is necessary that the point be seen from several terrestrial photographs, and angles be measured on each one. When the final elevation is adjusted by weighting, according to the distance involved, it is felt that an acceptable elevation can be established.

Given an area of rugged topography, it is felt that a standard-accuracy map, with a 40-foot contour interval, can be compiled with no more field work than a triangulation net, including vertical angles, plus stereoscopic terrestrial photography taken

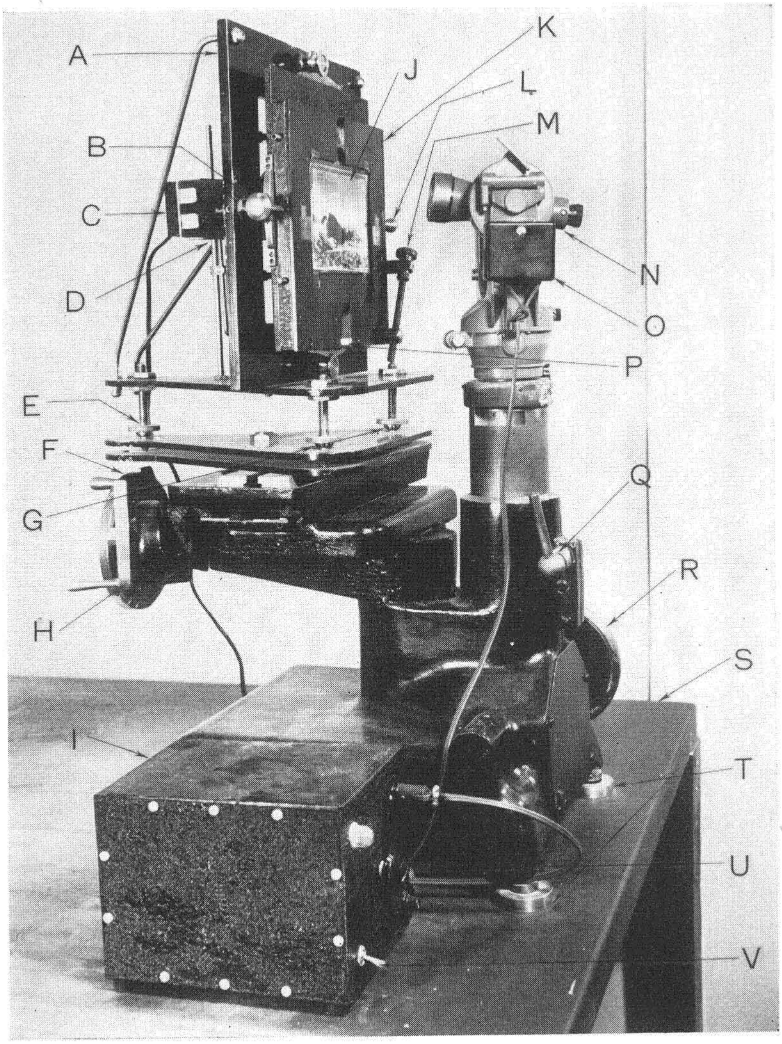



FIG. 10. Instrument designed and developed by Rocky Mountain Region for measuring angles on a terrestrial photograph.

A Plate holder frame
B Pressure knob "X" motion (interior orientation)
C Light, small fluorescent tubes
D Photographic plate locks (invisible)
E Rotation of plate holder frame about "x" axis
F Z motion
G Rotation of plate holder frame about "Z" axis
H "X" motion
I Transformer box
J Photographic glass plate
K Plate holder
L "X" motion for plate (interior orientation)
M Swing (plate holder)
N Wild T 1
O Light source for T 1
P "Y" motion for plate (interior orientation)
Q Lock "y" motion theodolite
R "Y" motion theodolite
S Slate table
T Leveling screws
U Rheostat
V Switch

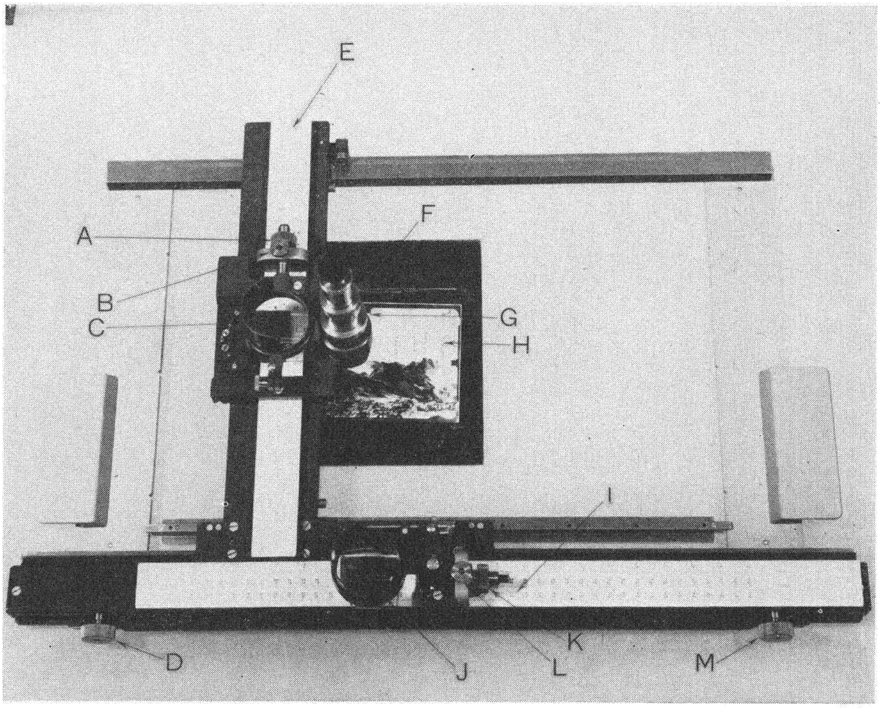



FIG. 11. Comparator suitable for converting distances to angular measurement.

A "Y" motion, slow
B "Y" motion, lock
C Reading glass
D Left rotation knob
E "Y" scale
F Reading microscope
G Microscope lock (invisible)
H Picture point identification
I "X" scale
J Reading glass
K "X" motion, slow
L "X" motion, lock
M Right rotation knob

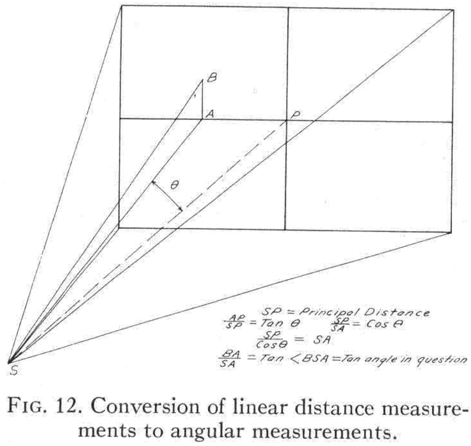



FIG. 12. Conversion of linear distance measurements to angular measurements.

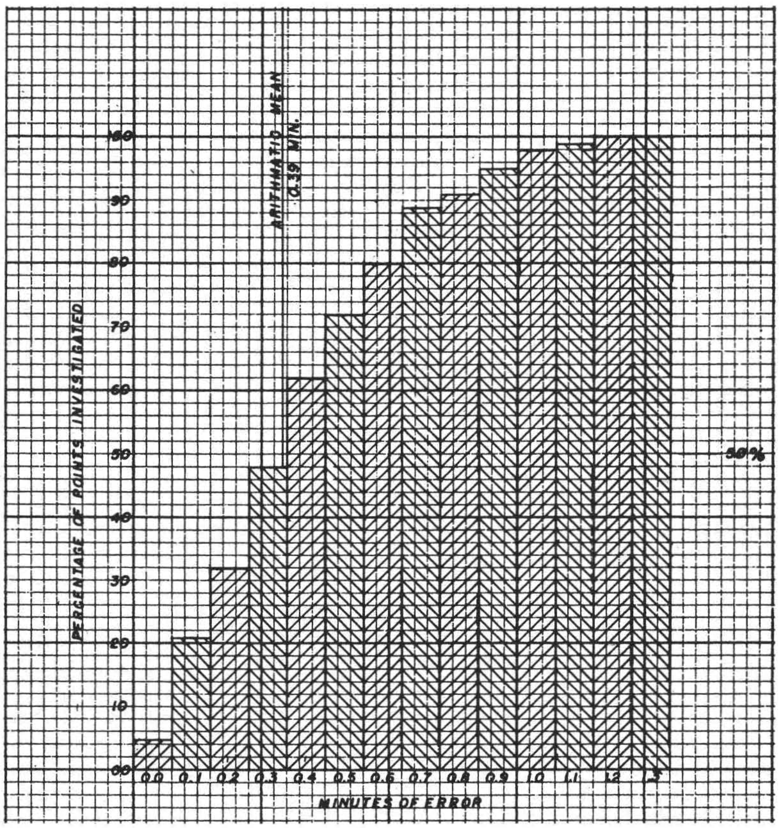



FIG. 13. Comparison between field and office angles on Wild phototheodolyte camera plates.

from each triangulation station. As stated earlier, it may be necessary to occupy an occasional supplemental station in order to see into the entire area.

It has been shown that a tremendous amount of difficult field work can be eliminated by using the phototheodolite to obtain supplemental control. As the men become more familiar with the method, it is hoped that the costs can be reduced further and the instrument more widely used.