Contributions to General Geology, 1958

GEOLOGICAL SURVEY BULLETIN 1081

This bulletin was printed as separate chapters A–G

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1960

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

CONTENTS

[The letters in parentheses preceeding the titles designate separately published chapters]

Graphic-Locator Method in Geologic Mapping

By DAVID J. VARNES, TOMMY L. FINNELL, *and* EDWIN V. POST

CONTRIBUTIONS TO GENERAL GEOLOGY

GEOLOGICAL SURVEY BULLETIN 1081-A

A description of a device for locating points on a contour map and how it has been used in geologic mapping

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1959

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C. - Price 15 cents (paper cover)

CONTENTS

ILLUSTRATIONS

GRAPHIC-LOCATOR METHOD IN GEOLOGIC MAPPING

By DAVID J. VARNES, TOMMY L. FINNELL, and EDWIN V. POST

ABSTRACT

The graphic locator is a simple device that is used with a topographic map and telescopic alidade or other sighting instrument to determine the point at which a line of sight intersects the ground surface. It may be used to plot features of geologic interest which are identifiable from an observation point of known location and elevation. The locations are generally sufficiently accurate if the line of sight intersects the ground surface at a moderate to high angle. Field tests have shown that use of the locator can greatly speed routine geologic mapping in areas of moderate relief and furnish reliable location for points in cliffs that cannot be examined on foot.

PRINCIPLES OF THE METHOD

By DAVID J. VARNES

The use of the graphic-locator method in geologic mapping was described briefly in an earlier paper by the writer.[1] That paper has been out of print from time to time and perhaps is not conveniently accessible to many geologists who may be interested in learning the method. The present summary places a description of the technique in more permanent record, amplifies and amends the earlier description where necessary, and presents evaluations of the method by other geologists.

The purpose of the graphic locator is to determine, by a simple graphical and instrumental procedure, the point at which a line of sight intersects the surface of the ground. The position of the line of sight in space, that is, its origin, azimuth, and inclination, are determined by other instruments; the surface of the ground is defined by a contour map. Given these data, one may use the locator to determine the point of intersection and to plot it on the topographic sheet.

[1] Varnes, D. J., 1946, Geologic mapping by means of graphic locator: U.S. Geol. Survey Circ. 12, 5 p., 2 figs.

The location of a point of interest on a topographic map is one of the principal operations of field geologic mapping and one of the most time consuming. The locator was designed to lessen the time and effort required to locate points in routine mapping and to obviate the occasional inconvenience and hazard of obtaining locations in rugged terrain. The graphic locator eliminates the need of a stadia rod in determining the position on a topographic map of any point within the range of visibility of the observer, subject only to the limitation that the line of sight must intersect the ground surface at an angle of more than about 15°. Geologic features thus located are automatically adjusted to local variations in the accuracy of the topographic map. This is generally an advantage. If, however, the absolute position of mineral veins or other special features is required, relative to a triangluation net and without regard to local topography, this location should be made by other means.

The principles of the method doubtless have been applied before. The writer was stimulated in developing the mechanical part of the operations by learning that W. S. Burbank, of the U.S. Geological Survey, used a "cut-and-try" method of determining the intersection of a line of sight with the surface of steep cliffs. A horizontal distance to the point of interest was guessed, the difference in elevation computed from the inclination of the sight, the altitude of the point on the ray was compared with the contour reading at the point, and the process was repeated until agreement was reached.

Arthur H. Frazier, also of the U.S. Geological Survey, was of great help in simplifying the writer's original design for a tool to eliminate the computation and speed the operation.

DESCRIPTION OF THE GRAPHIC LOCATOR

The graphic locator consists of a single rectangle of transparent plastic material, about 3 inches square and one-sixteenth inch thick.

Two scales, graduated in divisions corresponding to the contour interval of the topographic map with which it is to be used, are marked or engraved on the under side of the rectangle, one at the right and one at the left edge. The space between the divisions represents one contour interval or convenient multiple thereof. The distance between graduations is the linear distance that equals the contour interval at the scale of the map. Figure 1 illustrates the use of the graphic locator in mapping an area in the San Juan region, Colorado, on a topographic map having a contour interval of 25 feet

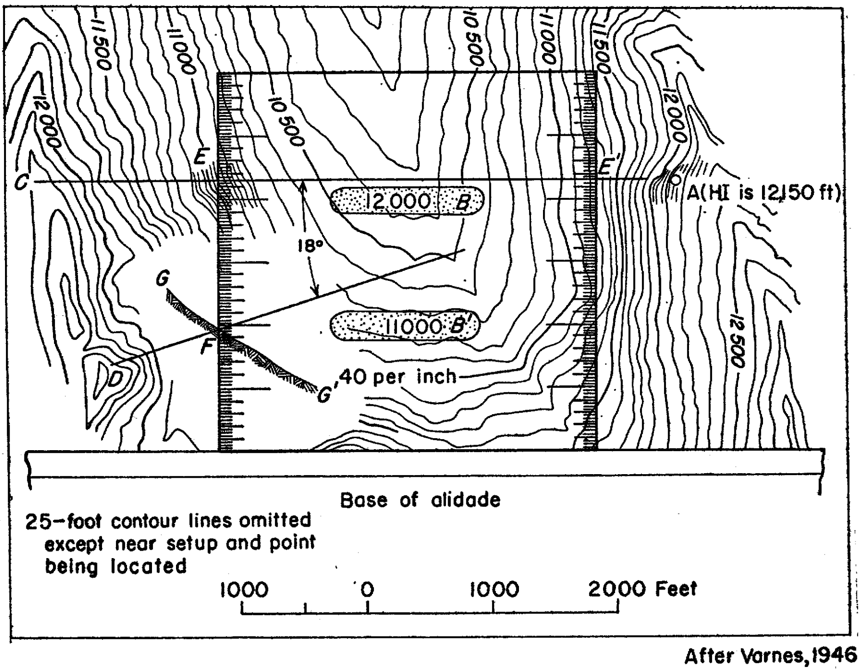


FIGURE 1.—Diagram showing technique in using graphic locator.

and a horizontal scale of 1 inch=1,000 feet. The scale divisions on the model, computed from the equation

$$25\times 12\times \frac{1}{1{,}000\times 12}=1/40 \text{ inch}$$

are one-fortieth inch apart.[2] The etched areas *B* and *B′*, in figure 1, between the major scale divisions, are used for recording with pencil the range of elevations for any particular setup.

Because of the simplicity of its construction, sets of these graphic locators can readily be made for use with maps having any specified contour interval or horizontal scale.

PROCEDURE FOR USING THE GRAPHIC LOCATOR

The procedure for using the graphic locator (see fig. 1, for example) is as follows:

1. Location of the planetable setup point *A* is plotted on the topographic map by resection or other suitable means.

2. Elevation of the alidade (or height of instrument, HI) is determined by vertical angle measurements or other means to be 12,150 feet.

[2] Varnes, D. J., op. cit., p. 2.

NOTE.—Fig. 1, above, is not at the original scale of 1 : 12,000.

3. Reference elevations are written in the opaque areas *B* and *B′* on the graphic locator, assuming that the range in elevations for the shot used in this example will be between 10,000 and 13,000 feet.

4. Telescopic alidade is sighted at point to be plotted; ray *A–C* is drawn on map and the vertical angle read. If an open-sight alidade is used, the line of sight is drawn and the angle is read with a Brunton compass.

5. From the ray *A–C* the vertical angle *CAD* is plotted with an 8-inch protractor and a segment of the line *A–D* drawn. In the example, the angle is minus 18°.

6. The graphic locator is placed over the ray *A–C* so that the scale readings at both edges (*E* and *E′*) correspond to the HI of the instrument (12,150 feet). While held firmly in this position, the straightedge of the alidade base is placed against either the top or bottom edge to serve as a guide for shifting the graphic locator laterally.

7. The locator is then shifted along the straightedge until the edge of the scale at *E* intersects line *A–C* at the estimated position on the map of the point being shot.

8. Next, it is noted whether the scale reading at *F* (the point where line *A–D* crosses the edge of the scale) is greater or less than the contour reading at *E*. If, for example, the contour elevations of the estimated position at *E* is 10,900 feet, the scale reading at *F* would be about 10,975 feet. This means that the line of sight has not yet intersected the ground surface at point *E*. A profile of the ground surface, *G–G′*, has been added to figure 1 to indicate the relation of the ground surface to the line of sight.

9. If the graphic locator is moved farther to the left so that the contour reading at *E* is 11,000 feet, then the scale reading at *F* will read about 10,930 feet, meaning that the line of sight has penetrated the surface and the point as located by this second estimate lies beneath the ground surface. The point sought must, therefore, lie between the 10,900- and 11,000-foot contour lines on *A–C*. The range between the trial points is then quickly reduced by moving the graphic locator back and forth between the 10,900- and 11,000-foot contour lines.

10. When the position of the graphic locator is such that the contour elevation at *E* is the same as the scale reading at *F* (10,950 feet in the example) the point of intersection at *E* is the point on the map that is sought.

The method of using the locator may be reversed. In this procedure, the geologist walking a contact on the side of a hill may take bearings and vertical angles with his Brunton compass to a point of known location and elevation shown on the topographic map. The known point is then used as a "setup" and the usual procedure is followed to determine the location of the observation. If bearings and vertical angles are taken to several known points from the geologist's position, the locator technique may be combined with, and checked by, the standard method of location by resection.

INHERENT ERRORS AND ADVANTAGES

The degree of accuracy with which points may be determined with the graphic locator depends upon the accuracy of the topographic map, upon the accuracy of manipulation of the instrument, and upon the relief of the terrain.

To evaluate the combined errors that may be inherent in the construction and manipulation of the graphic locator, a number of "shots" were taken between points on a topographic map whose position and elevation had previously been determined by topographers. The contour map was therefore very accurate in the immediate vicinity of these known points and any error in relocating these points by the process described above would be inherent either in the instrument, the procedure, or a combination of both. The test was carried out in the office on 32 known points. Angles were computed from the horizontal and vertical distances as scaled from the map and plotted with an 8-inch protractor. The operation was thereafter completed in exactly the same manner as would normally have been done in the field.

It was found that the major source of error between the measured distance and distance as determined by the graphic locator lies in the angle that the line of sight makes with the surface of the ground in the vicinity of the point that is being located. The distribution of points plotted on figure 2 shows that at low angles (grazing shots) large errors may occur because the point at which the line of sight intersects the ground surface is generally difficult to determine. Conversely, at higher angles location becomes increasingly more accurate. Figure 2 shows that for angles greater than 25° to 30° the error is consistently less than 1 percent and that for angles greater than 15° the mean error is less than 1 percent. Thus, the graphic locator cannot be used effectively if the line of sight makes an angle of less than 15° with the surface of the ground in the vicinity of the point being located.

Although the absolute error in feet may tend to increase with length of shots, owing to possible errors in plotting the vertical angle, the percentage error showed no definite relation to the length of shot. The 32 shots plotted on figure 2 range in horizontal distance from

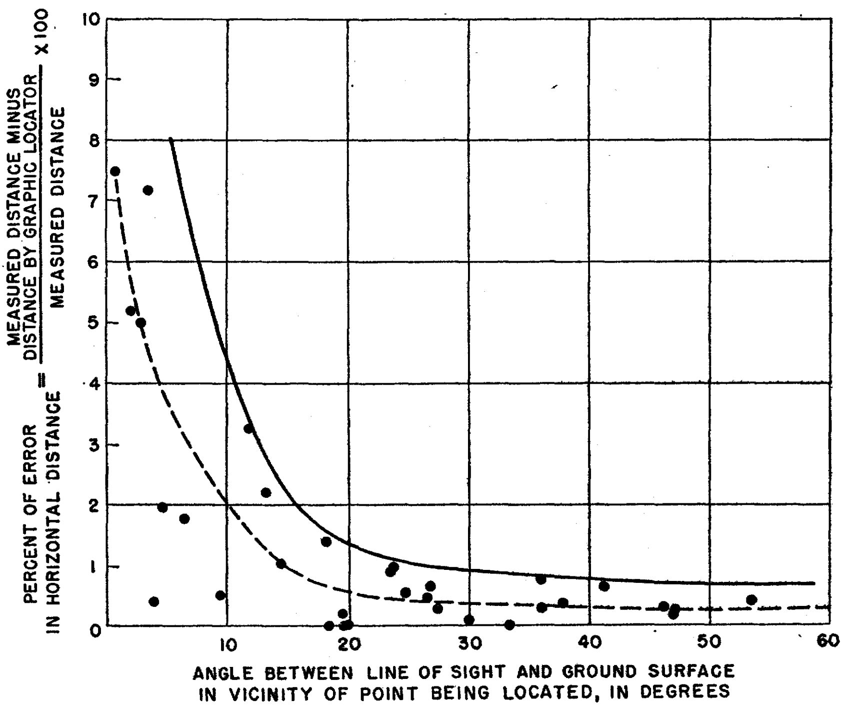


FIGURE 2.—Range of observed errors in horizontal distance as a function of angle between line of sight and ground surface. Solid line is approximate upper limit of error, and dashed line is approximate mean error.

1,220 to 5,900 feet; they average 3,100 feet, which is beyond the range at which a 13-foot stadia rod can be used accurately with ordinary procedure.

Field tests made by the writer indicate that the graphic locator has the following characteristics:

1. A location may be fixed within 3 minutes after the alidade is set up and the position and elevation of the setup are determined.

2. Results obtained with the graphic locator, as checked by actual rod determinations in the course of geologic mapping, are sufficiently accurate for most geologic use. Where the rod cannot be used, the graphic locator offers a reliable alternative, provided the line of sight intersects the ground surface at an angle of more than about 15°.

3. The graphic locator is especially suited for long shots, beyond the range of the rod.

4. The locator is valuable for checking the accuracy of questionable rod shots.

5. The instrument is useful for determining from a topographic map alone the area visible from any selected point.

6. Use of the graphic locator results in a great saving of time in mapping rough terrain because the number of rod shots required is reduced. The services of a rodman are not required for location of features that may be identified by the instrument man. If the outcrop requires examination, the geologist on the outcrop need not carry a rod but simply signal for a shot to be taken on himself.

EVALUATION OF THE GRAPHIC-LOCATOR METHOD

By Tommy L. Finnell and Edwin V. Post

DEER FLAT AREA, SAN JUAN COUNTY, UTAH

The graphic-locator method of locating geologic contacts on topographic maps was used to delineate a low-amplitude monoclinal fold near the Hideout No. 1 mine, Deer Flat area, White Canyon district, San Juan County, Utah.[3] In about 3 hours, the horizontal and vertical positions of the top of the Hoskinnini tongue of the Moenkopi formation and the top of the Moenkopi formation for 12,000 feet of the outcrop along the southeast side of Deer Flat were determined with a graphic locator, topographic base map, and telescopic alidade; about 12,000 feet of the northwest side of Deer Flat was similarly surveyed in about 2 hours. A single planetable station was used on each side of Deer Flat. The distances to the points sought ranged from 4,250 to 10,600 feet—well beyond the range at which accurate results can be expected with a 13-foot stadia rod. The angle between the line of sight and the surface of the ground in the vicinity of the points sought ranged from about 14° to 31°; only 2 of the angles were less than 15°.

The difference of elevation between the planetable and the points sought was determined trigonometrically, using the horizontal distance determined with the graphic locator and the vertical angle read from the vertical angle arc of the telescopic alidade. The writers believe that this procedure might lead to somewhat more accurate elevations than those obtained by interpolation between contours.

ACCURACY AND SPEED OF THE GRAPHIC-LOCATOR METHOD IN DEER FLAT MAPPING

Cross sections comparing the results of the graphic-locator survey at Deer Flat with the results of a transit survey (fig. 3) show that, on the southeast side of Deer Flat, the graphic-locator elevations ranged from 11 to 33 feet higher than the true elevations, and on the northwest side the graphic-locator elevations ranged from 16 feet

[3] Finnell, T. L., and Gazdik, W. B., 1958, Structural relations at the Hideout No. 1 mine, Deer Flat area, San Juan County, Utah: Econ. Geology, v. 53, no. 8, p. 949–957.

lower to 25 feet higher than the true elevations. The contour interval of the topographic map used is 40 feet, and the differences in elevations are within the limits of topographic map accuracy (not more than 10 percent of random points are shown at more than one-half contour interval from their true elevation). The configurations of the two contacts are very similar, and it is inferred from figure 3 that the graphic-locator method is sufficiently accurate to indicate the presence of low-amplitude flexures, though for special purposes more precise surveying methods may be required to determine the position and shape of the flexures to a greater degree of accuracy.

About 1¼ man-days were spent in mapping 2 geologic contacts with the graphic locator, and about 11½ man-days were spent in remapping one of the geologic contacts with transit and stadia.

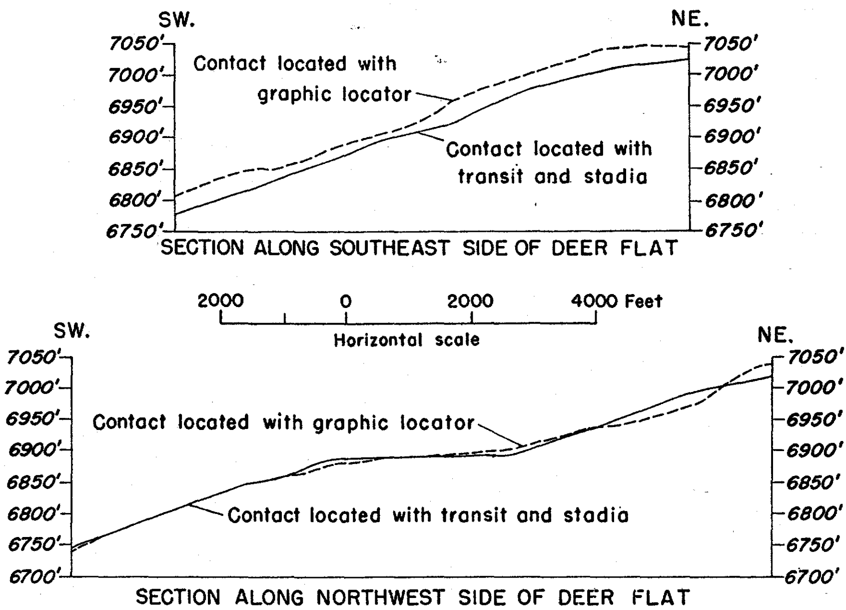
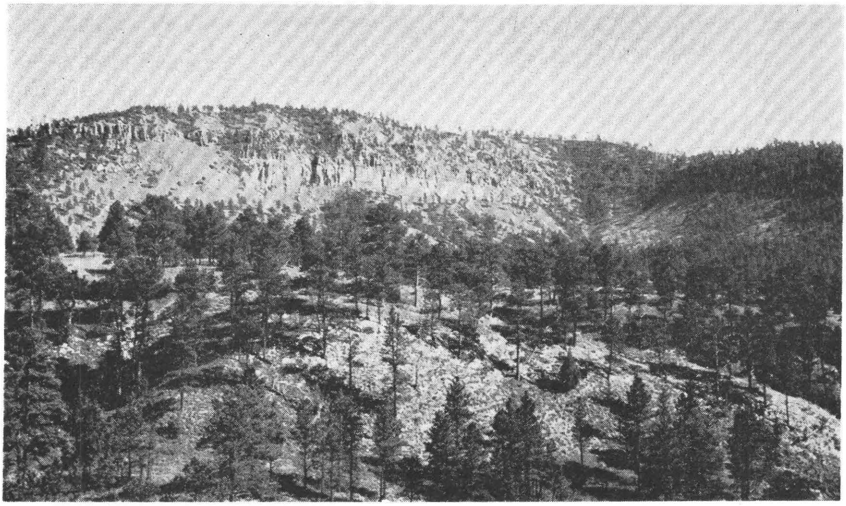


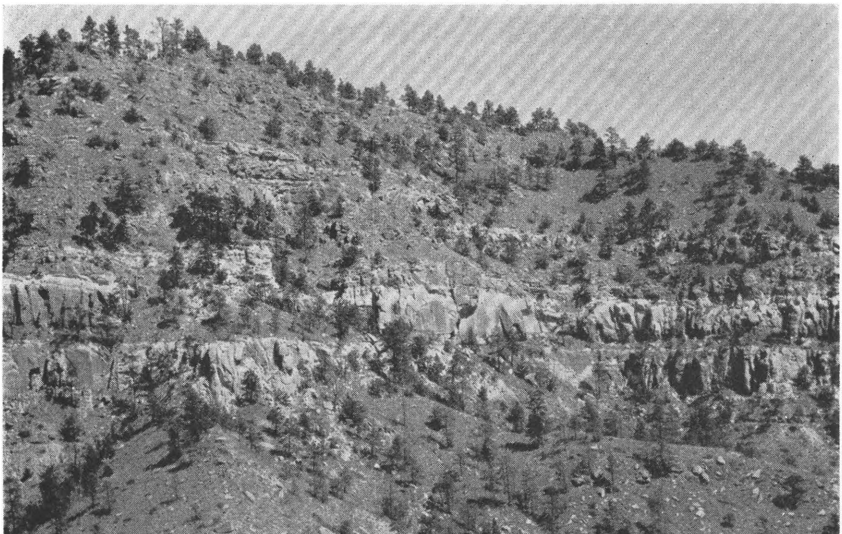
FIGURE 3.—Diagrammatic sections along the sides of Deer Flat, San Juan County, Utah, showing relative elevations of contact as determined by graphic locator (dashed line) and as determined by transit and stadia rod (full line). Vertical scale exaggerated × 10.

CASCADE SPRINGS QUADRANGLE, FALL RIVER COUNTY, S. DAK.

The graphic locator was used during the summer of 1956 as a supplementary geologic mapping technique in the Cascade Springs quadrangle in the southern Black Hills, Fall River County, S. Dak. Most of the quadrangle had already been mapped on a 1:7,200 topographic base with a 10-foot contour interval, using a surveying



A. Cliff is in east-central part of quadrangle. Lower white part of cliff is Unkpapa sandstone; upper darker part is Lakota sandstone. Photograph was taken from the setup at which the cliff, about 1 mile away, was mapped.



B. Detail of area in southeastern part of quadrangle. Contacts between light-colored Unkpapa sandstone and the darker Lakota and between units within the Lakota were mapped from a distance of 3,450 to 4,000 feet.

TYPE OF TERRAIN MAPPED BY GRAPHIC LOCATOR IN CASCADE SPRINGS QUADRANGLE, FALL RIVER COUNTY, S. DAK.

altimeter reading to 10 feet to establish the vertical location of geologic boundaries.

The Cascade Springs quadrangle includes an area of youthful topography developed under semiarid conditions on a terrain of relatively flat-lying sandstones and interbedded mudstones. Because of the large scale and extreme detail of the mapping, each lithologic unit in the sandstone-mudstone sequence was mapped, and considerable walking along canyon walls was required to trace out the various rock units.

Several cliffs in the quadrangle (pl. 1) posed problems as to how they could be mapped safely with the same degree of accuracy as the more accessible and, consequently, less dangerous parts of the quadrangle. The graphic-locator technique proved to be an excellent solution to this problem.

MAPPING WITH THE GRAPHIC LOCATOR

About 4½ miles of steep canyon wall was mapped with the graphic locator in considerably less than half the time it would have taken to map it using conventional methods. In addition, some work previously mapped with an altimeter was checked by graphic locator after the latter technique was found to be satisfactory for our purpose. Many of the shots were made at distances approximating 1 mile (pl. 1*A*). They compared very closely with points determined by altimetry and appeared to be better adjusted to the existing topography than the few rod shots that were attempted. It was found that, if a long rod shot in rugged terrain were plotted by distance, the calculated elevation of the rod shot would not match the elevation of the contour line on the base map at the point plotted.

Figure 4 is a cross section of one area in which the graphic locator was used in the southeastern part of the Cascade Springs quadrangle, illustrated by plate 1*B*. The length of shots ranged from 3,450 to 4,000 feet; the slope of the hillside was about 30°, and the angle between the line of sight and the ground surface ranged from 22° to 26°. The maximum error in horizontal distance for these conditions is less than 1½ percent. (See fig. 2.)

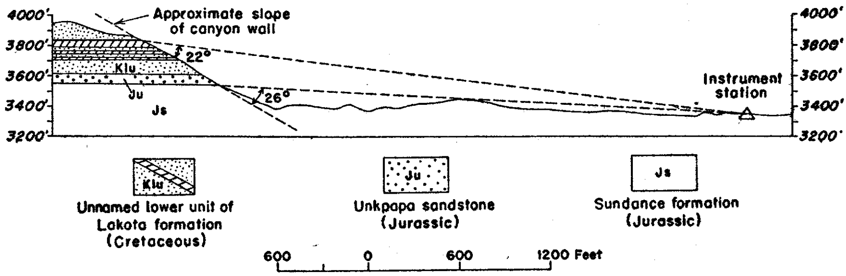


FIGURE 4.—Cross section showing maximum and minimum angles between line of sight and valley wall in mapping slopes in the southeastern part of Cascade Springs quadrangle, Fall River County, S. Dak.

CONCLUSIONS

Geologic mapping in the Deer Flat area showed that the graphic locator provided a rapid, practical method of mapping on topographic maps in regions of rugged to moderate relief. Low-amplitude flexures can be detected with this method in about one-twentieth of the time required for a transit and stadia traverse of the same outcrop, and the structures can then be delineated by more precise methods, as special purposes may require.

The graphic locator proved extremely useful in mapping steep inaccessible canyon walls in the Cascade Springs quadrangle, it gave results as accurate as those of surveying altimeters, and it provided an advantage over walking the contacts because the geologist found himself better able to trace beds through areas of intermittent outcrop when he could view a large area and map it from a distant vantage point.

○