DEPARTMENT OF COMMERCE

U. S. COAST AND GEODETIC SURVEY

O. H. TITTMANN

SUPERINTENDENT

SURVEYING

A PLANE TABLE MANUAL

BY

D. B. WAINWRIGHT

Assistant

APPENDIX No. 7—REPORT FOR 1905

(Reprint with corrections, January, 1915)

WASHINGTON

GOVERNMENT PRINTING OFFICE

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A PLANE TABLE MANUAL.

By D. B. Wainwright, *Assistant.*

Preliminary Statement.*

A topographic map is the delineation upon a plane surface, by means of conventional signs, of the natural and artificial features of a locality.

Every point of the drawing corresponds to some geographic position, according to some method adopted for representing the surface of the spheroid on a plane, which is called the *projection.*

Since it is a representation in miniature, the distance between any two points on the map is a certain definite fraction of the distance between the same points in nature. This ratio is called the *scale.*

Each point, besides being projected on a horizontal plane, has its elevation relative to a level surface, in some way indicated. The level surface adopted for the map is called the *datum plane*, and the representation of the variations in the vertical element, the modeling of the country, is called the *relief.*

CONTROL.

All topographic surveys of importance are based upon a system of triangulation.

A sufficient number of points, whose geographical positions have been determined by triangulation, properly distributed over the area to be surveyed, forms the framework for controlling the accurate location of the various details.

* Advantage has been taken of the opportunity afforded by the preparation of a new edition of the Plane Table Manual to make a new arrangement of the "Three-point problem," with the intention of simplifying the description of the conditions found in practice and the several steps required for the graphic solution of the problem with the plane table according to Lehman's method. This method is the most rapid one, in the hands of an experienced topographer, but for those who may have only occasional use for a graphic solution Bessels's method or the tracing paper protractor method is recommended.

Instruments and Adjustments.

THE PLANE TABLE.

The principal instrument in use by the Coast and Geodetic Survey for mapping details is the plane table. For this purpose it is a universal instrument. All the necessary operations for producing a map are executed with it in the field directly from the country as a model.

Other instruments are employed as auxiliaries to it under certain conditions, as will be seen later on under the head of "Field practice," but in general it fulfills all requirements alone.

Description (Illustration 1).—The plane table is composed of a well-seasoned drawing board* about 30 inches in length, 24 inches in width, and three-quarters of an inch thick, with beveled or rounded edges. It is commonly made of several pieces of white pine, tongued and grooved together, with the grain running in different directions to prevent warping. It is supported upon three strong brass arms, to which it is attached by screws passing through them and entering the underside of the board, the three holes for the reception of the screws being guarded by brass bushings and situated equidistant from each other and from the center of the table. By means of these screws the board can be removed at will.

The movements (Illustrations 1 and 2) of the tables in use by the Coast and Geodetic Survey are made from several different models, but as the principal features are the same in all designs the description of one type will suffice for all.

The arms to which the board is fastened rest upon the sloping upper face of a rather flat hollow cone of brass, to which they are permanently fixed. Upon its lower edge or periphery this cone is fashioned into a horizontally projecting rim, the inferior face of which is as nearly as possible a perfect plane, and this in its turn rests upon a corresponding rim of somewhat greater diameter projecting slightly beyond it. This second rim forms the upper and outer flange of a circular metal disk in the form of a very shallow cylinder. The inferior face or plane of the upper flange or rim has, at its contact with the superior face of the lower, a horizontal rotary movement about a common center which is also the center of the instrument, and the two are held together by means of a solid conical axis of brass extending upward from the center of the inner face of the lower disk. A socket of similar shape fits exactly over this axis, projecting downward from the inner side of the apex of the conical or upper disk. The two plates are held together by means of a screw with a milled head, capping the cone from the outside, and which can be loosened or removed at pleasure.

A tangent screw and clamp fastened to the edge of the upper rim permit, when loose, the revolution of the table about its center, and, when clamped to the lower limb, hold the table firm while the tangent screw gives a more delicate movement.

Three equidistant vertical projections of brass, grooved on the underside, and cast in one piece with the under face of the lower disk, extending from the periphery toward the center, rest upon the points of three large screws which come through a heavy wooden block below. This block, which is the top of the stand and is approximate in form to an equilateral triangle, is 2¼ inches thick when made of wood.

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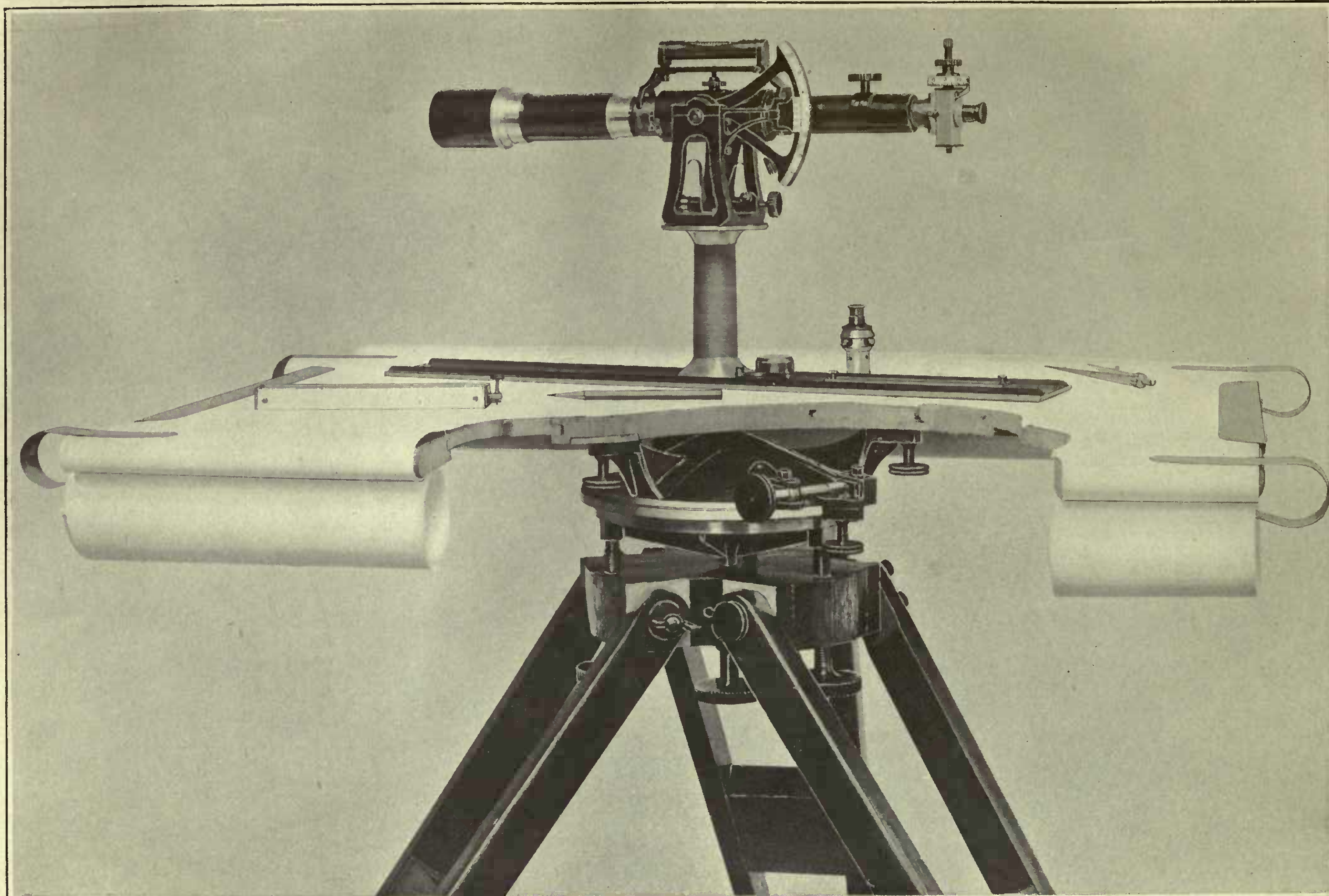
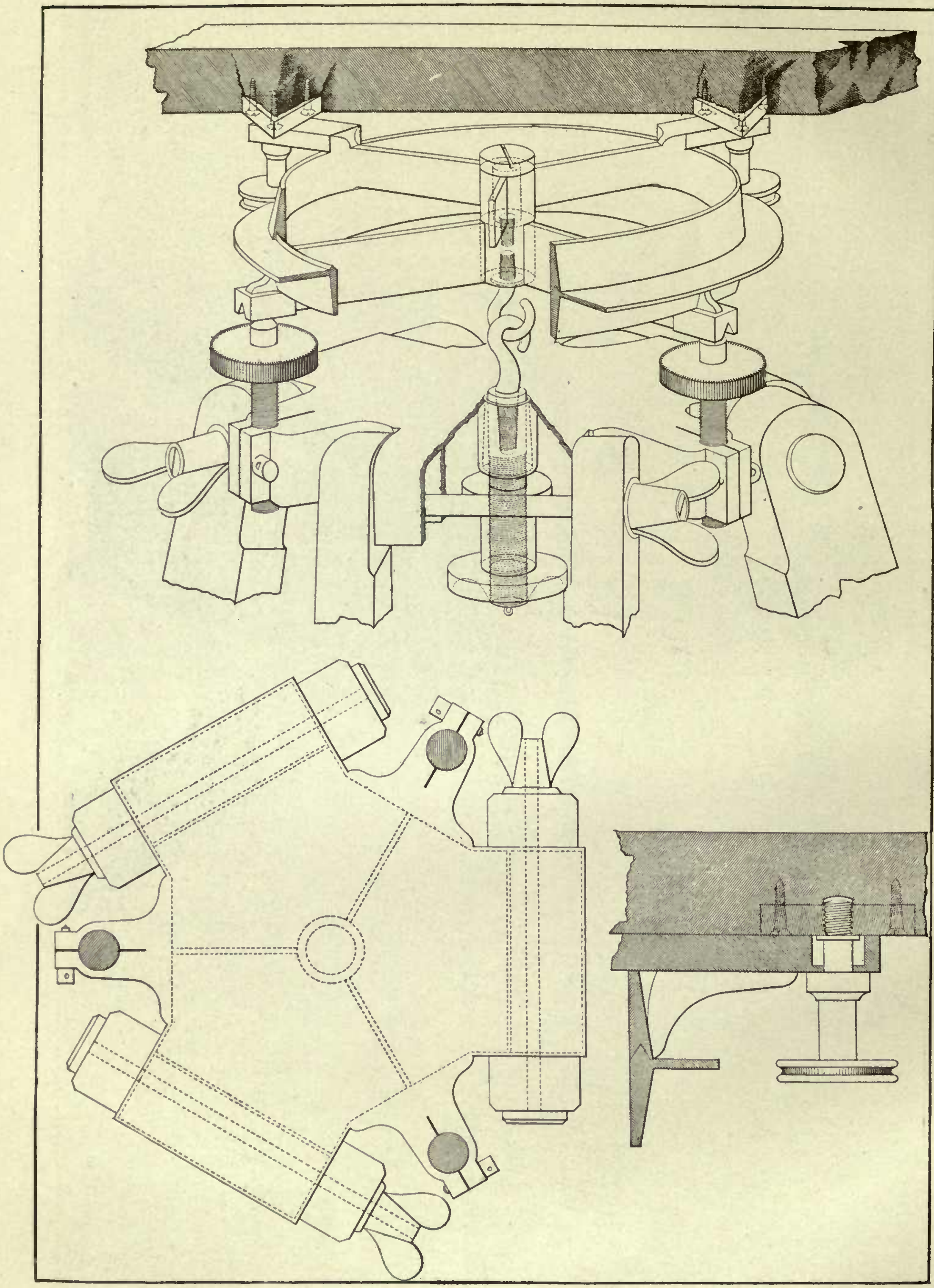
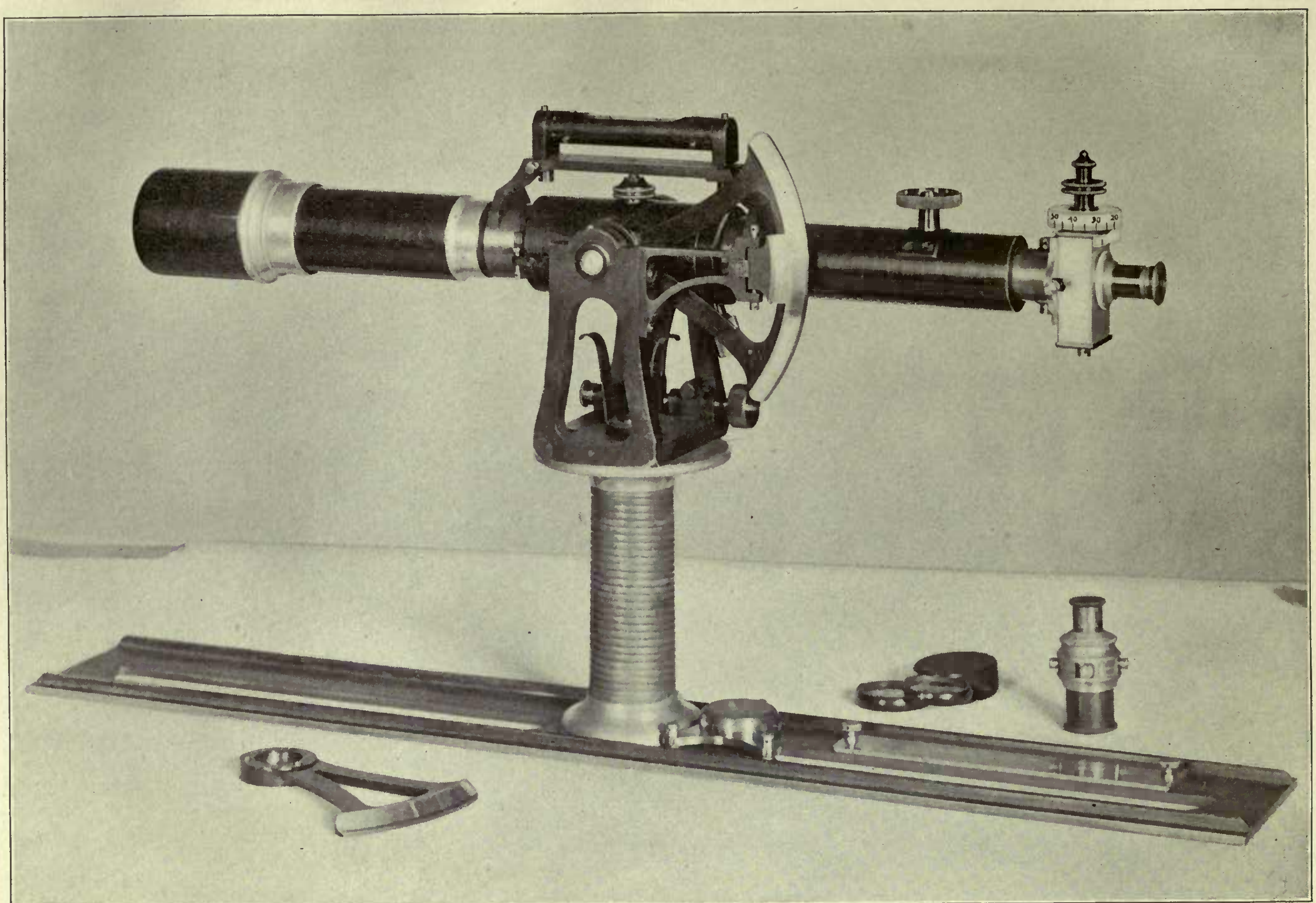
* It is contemplated having the board made of a special aluminum alloy.



PLANE TABLE AND ALIDADE.



PLANE TABLE MOVEMENT.



ALIDADE.

The three screws last mentioned have large milled heads, are quite stout, and play through the block below by means of brass female screws let into it. They are the leveling screws of the instrument and are equidistant from its center.

Upon the underside and center of the metal lower disk is a socket containing a ball with a brass arm, which projects through the center of the block from beneath. The lower end of the arm is threaded, and upon it plays a female screw with a large milled head, which can be relaxed or tightened at pleasure. The screw clamps the whole upper part of the instrument to the stand; it is loosened only before leveling and kept securely clamped at all other times.

The block, made either of wood or brass,* is supported upon three legs, and with them forms the tripod or stand of the instrument, the legs being of such a length as to bring the table to a convenient height for working, and so arranged as to be taken off at will, or closed so that their brass-shod and pointed ends can be brought together or moved outward, as may be required. They are made on the open or skeleton pattern, and each is securely attached to a segment of the tripod head by a long brass bolt.

MOUNTAIN PLANE TABLE.

A small plane table, with a board measuring only 14 by 17 inches, is employed in reconnaissance, mountain work, or as an auxiliary to one of the standard size. All the various parts are reduced in size to correspond with the board, and the construction of the movement simplified.

THE ALIDADE.

The type of alidade in general use (Illustration 3) consists of a skeleton rule (12 inches long by 2½ inches wide) nickel-plated underneath, from and perpendicular to which rises a metal column (3 inches high), surmounted by Y's, receiving the transverse axis of the telescope, to one end of which axis is firmly attached a graduated arc of 30°, each side of a central 0°, an accompanying vernier being attached to the Y support. The arc moves with the telescope as it is raised or depressed, and it is used in the measurement of vertical angles to determine heights. A clamp and a tangent screw placed on the other side of the telescope, opposite the arc, controls its vertical movement.

The telescope is fitted accurately near its center of gravity within a closely fitting cylinder, to which is solidly attached the transverse axis. The telescope revolves within the cylinder 180°, stops being fitted for that range. This affords an easy mode of adjusting the cross lines to the axis of revolution, and for correcting with a striding level the errors of level and collimation and revolution of the telescope.

Upon the tube of the telescope are turned two shoulders, on which rest a striding spirit level, which can be readily reversed or removed at pleasure. The eyepiece carries the usual reticule with screws for the collimation adjustment, and to this is attached a glass diaphragm, having one vertical and three horizontal lines engraved upon it. One of the horizontal lines crosses the middle of the diaphragm, the other two are placed equidistant from it, one above and one below. The interval between them remains a constant chord for the measurement of distance upon a graduated staff or rod.

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* Now made of a special aluminum alloy.

In some cases short auxiliary lines have been added dividing the interval into still smaller chords.

Several of the alidades are furnished with a micrometer eyepiece so attached that the thread is horizontal, and has a vertical movement for measuring the angular distance of a fixed length on a rod which remains a constant chord.

To the rule of the alidade are attached two spirit levels, one in the longitudinal direction of the rule and the other at right angles to it.

A declinatoire (shown in Illustration 1) accompanies the alidade and is carried in the same packing box. It consists of a rectangular brass box 7 inches long by 2 wide, with an arc at each end graduated to 15° on each side of the 0°. It contains a needle long enough to extend from arc to arc, and resting on a pivot midway the box. The sides running lengthwise the box are parallel to a line connecting the zero marks of the two arcs.

The metal clamps, for holding the projection on the board, are of two kinds: U-shaped for the ends, and the side clamps, the latter being made of thin metal strips about 12 inches in length, with two or more springs attached to grip the underside of the board.

Adjustments.—From the nature of the service in some sections of the country the plane table is often necessarily subjected to rough usage, and there is a constant liability to a disturbance of the adjustments; still, in careful hands, a well-made instrument may be used under very unfavorable conditions for a long time without being perceptibly affected. One should not fail, however, to make occasional examinations, and while at work, if any difficulty be encountered which can not otherwise be accounted for, it should lead directly to an examination of the adjustments.

1. *The fiducial edge of the rule.*—This should be a true straight edge. Place the rule upon a smooth surface and draw a line along the edge, marking also the lines at the ends of the rule. Reverse the rule and place the opposite ends upon the marked points and again draw the line. If the two lines coincide no adjustment is necessary; if not, the edge must be made true.

There is one deviation from a straight line, which, by a very rare possibility, the edge of the ruler might assume, and yet not be shown by the above test; it is when a part is convex and a part similarly situated at the other end concave, in exactly the same degree and proportion. In this case, on reversal, a line drawn along the edge of the rule would be coincident with the other, though not a true right line; this can be tested by a true straight edge.

2. *The levels attached to the rule.*—Place the instrument in the middle of the table and bring the bubble of either level to the center by means of the leveling screws of the table; draw lines along the edge and ends of the rule upon the board to show its exact position, then reverse 180°. If the bubble remains central it is in adjustment; if not, correct it one-half by means of the leveling screws of the table, and the other half by the adjusting screws attached to the level. This should be repeated until the bubble keeps its central position whichever way the rule may be placed upon the table. This presupposes the plane of the board to be true. The other level should now be examined and adjusted in a like manner.

Great care should be exercised in manipulation lest the table be disturbed.

3. *Parallax.*—Move the eyeglass until the cross hairs are perfectly distinct, and then direct the telescope to some distant well-defined object. If the contact remains perfect when the position of the eye is changed in any way, there is no parallax; but if it does not, then the focus of the object glass must be changed until there is no displacement of the contact. When this is the case the cross hairs are in the common focus of the object and eyeglasses. It may occur that the true focus of the cross hairs is not obtained at first, in which case a readjustment is necessary, in order to see both them and the object with equal distinctness and without parallax.

4. *Axis of revolution.*—Since the bearings of the pivots are fixed, the axis of revolution is assumed to remain parallel to the plane of the rule.

5. *Vertical line of diaphragm.*—Point the intersection of the vertical and the middle horizontal lines of the diaphragm on some well-defined distant object; revolve the telescope in its collar 180° and again observe the object. If the intersection covers it, the adjustment is perfect; if not, one-half the error must be corrected by moving the diaphragm, by means of the adjusting screws, and the other half with the tangent screw of the table. This operation should be repeated until the adjustment is perfect.

6. *Middle horizontal line of diaphragm.*—(1) Adjust the striding level by reversing it end for end and correcting its error—half the difference by its own adjustment, half by the tangent screw of the telescope.

(2) Point the telescope to a target, and note the reading, or make a mark where the wire points, when the bubble is in the middle.

(3) Revolve the telescope in its collar 180°, and note the reading or mark the place where the wire points, when the bubble is in the middle.

(4) The mean of the two pointings is the true level line, upon which the wire is to be adjusted, which may be done in this way: Keep the bubble in the middle and by means of the adjusting screws bring the middle wire to bisect a point half way between the two readings or marks. The adjustment may be verified by revolving the telescope as in (2) and if the middle wire again bisects the point the adjustment is perfect.

(5) If it is now desired to make the vernier read *zero* on the vertical arc, the table must be carefully leveled; and in order to do this more perfectly than can be done with the levels on the ruler, it may be done by observing the striding level; the telescope remaining clamped, the striding level should read the same in every position of the alidate when the table is perfectly level. (In general, this will be found too delicate a test, as the table is not sufficiently *even* for so sensitive a level to be employed.) The table being leveled, move the telescope with the tangent screw until the bubble is in the middle, and then set the vernier to read zero; the screw holes in it are oblong, so that it admits of being pushed either way.

(6) It is easy to have the adjustments near enough to serve for running curves of equal elevation, but in determining the heights of stations it is best to make the observations complete, with reversals, both of level and of telescope, taking the mean of the observations, by which the errors of adjustment are eliminated. This, in fact, is always done with the theodolite, and should be done with the alidade when precision is required.

The following may serve as an example:

TELESCOPE DIRECT.

Reading of vernier, level direct with bubble in center	+ 0° 1′	
Reading of vernier, level reversed with bubble in center	0′	
Mean	+ 0° 0′.5	
Station, reading	+ 2° 17′	
Angle of elevation (difference)		2° 16′.5

TELESCOPE INVERTED.

Reading of vernier, level direct with bubble in center	— 0° 2′	
Reading of vernier, level reversed with bubble in center	— 1′	
Mean	— 0° 1′.5	
Station	+ 2° 12′	
Angle of elevation (difference)		2° 13′.5
Mean		2° 15′

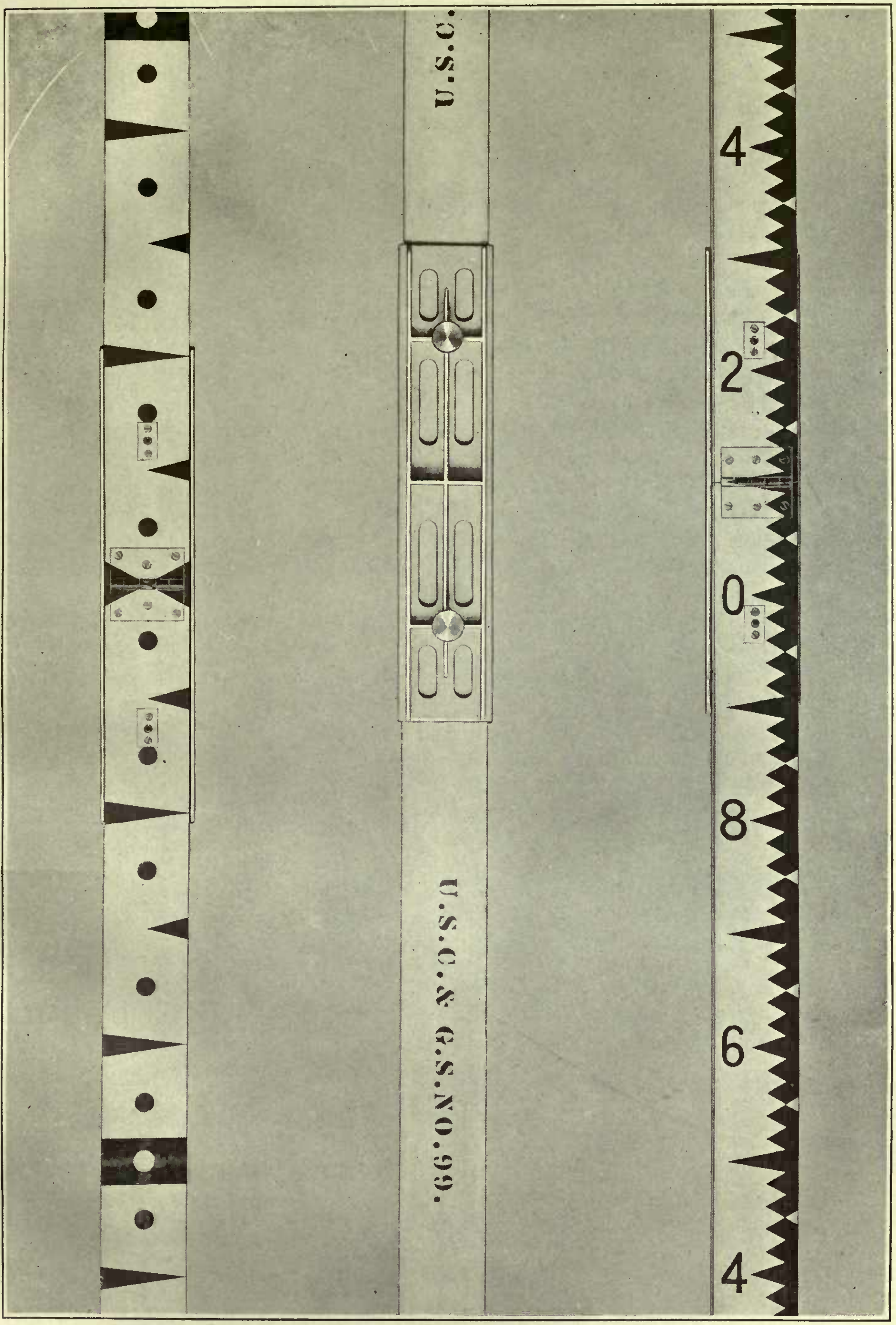
It will be seen, from analyzing these observations, that the level was one-half minute out of adjustment, the horizontal wire one and one-half minutes, and that revolving the telescope in its collar 180° changed its relation to the index on the vernier by 1′. The mean is free from all errors of adjustment.

*The stadia rod** (Illustration 3), used in the Coast and Geodetic Survey, is simply a scale of equal parts painted upon a wooden rod about 10 feet long, 4 inches wide, and 1¼ inches thick, so graduated that the number of divisions upon it, as seen between the upper and lower horizontal wires of the telescope when the rod is held at right angles to the line of sight, is equal to the number of units in the distance between the instrument and the rod.

Graduation.—In all cases the rod should be graduated for the particular instrument, and, if the best results are to be obtained, to suit the convenience of the observer.

In practice the alidade is mounted on a stand, and its center is plumbed over one end of a hundred-meter base, measured on level ground. A line, representing the zero of the graduation, having been drawn about 5 inches from one end of the rod, the latter is held vertical at the other end of the base, zero mark upward. The observer at the alidade then makes the upper horizontal line of the diaphragm coincide with the zero and directs the rodsman by signals where to draw a line which coincides with the lower horizontal line. This intercepted space on the rod is subdivided to read meters and the graduation continued to within a short distance of the bottom.

*For further details of the theory of stadia measurements see: Elemente der Vermessungs-Kunde, Bauernfeind, 1873, p. 322; Handbuch der Vermessungs-Kunde, Jordan, 1888, p. 554; Theory and Practice of Surveying, Johnson, 1898, p. 238; Gillespie's Higher Surveying, Staley, 1897, p. 311; Experimental Study of Field Methods, Smith, Bulletin of University of Wisconsin, Engineering series, Vol. I, No. 5.



STADIA RODS.

This graduation is represented by the equation

$$d=\frac{f}{i}s+(f+c),$$

where d=the distance from the center of instrument to rod (in this case 100 meters);

f=the focal length of the telescope (which is 35^{cm} for the average alidade);

i=the distance between the upper and lower wires of the diaphragm (4^{mm});

s=the length of the intercepted portion of the rod ($1^{m}.185$);

c=the distance from object glass to center of instrument $\left(=\frac{f}{2}\right)$

As indicated in the preceding equation, the readings of a rod graduated in this manner are not quite true for distances above or below 100 meters, since the vertices of the constant and similar angles (one subtending the chord represented by the intercepted space on the rod and the other by the space between the upper and lower wires) do not lie at the center of the instrument, but at a distance beyond the object glass equal to the focal length of the telescope, and therefore the intercept on the rod will not be proportional for all distances from the center of the instrument. To have it so, the instrument should be mounted at a distance back from the end of the base equal to one and a half times the focal length of the telescope ($f+c$). To all readings of a rod graduated according to this last method the constant quantity $f+c$ must be added.

The correction for the first method is small and can be ignored for mapping on a scale of 1–10000 or smaller.

The formula for the correction is:

$$K=(C+F)\left(1-\frac{B}{B'}\right)$$

Where K=correction in meters,

B=distance read on rod in meters,

B'=length of base, in meters, for which the rod was graduated.

The corrections for 50, 200, 300, and 400 meters are +0.262, —0.525, —1.050, —1.575 meters, respectively.

Inclined sights.—When the rod is held at a point above or below the instrument, the line of sight is inclined at an angle with the horizon, and a correction has to be applied to the reading to obtain the horizontal distance. If the rod is held perpendicular to the line of sight the reduced distance is simply the product of the cosine of the angle of inclination into the rod reading. If the rod is held vertical, which is the usual and also the safest method, there is an additional correction on account of the oblique view of the rod. These corrections can be ignored in the ordinary work of the Survey; that is, on a scale of 1–10000 or smaller, since for short distances they are too small to plot, and when the distances are long enough for them to become appreciable they are still small as compared to the uncertainty of the rod reading.

For the convenience of the topographer engaged on large scale work, tables for reducing readings of inclined sights can be found at the end of the Manual.

Micrometer eyepiece.—When a micrometer eyepiece is used in place of the stadia lines, a rod about 3.7 meters in length is employed, attached to which are two targets. A base is measured on level ground and the instrument either plumbed over one end or back of it a distance equal to $f+c$, depending upon the manner the rod is to be held for an inclined sight. The rod is then taken to one of the subdivisions of the base, consisting of an even multiple of the unit adopted; say 100, 200, or 300 meters, and the upper target being fixed, the lower target is set and fixed so that the angular measure of the interval by the micrometer will consist of an even multiple of turns of the micrometer screw. The rod is now held at the other subdivisions of the base, and the readings tabulated. A distance table is then prepared, by interpolation, for the intermediate distances.

Plane-table sheet.—From the standpoint of efficiency the plane-table sheet is the least satisfactory portion of the plane-table equipment. Owing to its hygrometric nature it is very susceptible to atmospheric changes: expanding and contracting unceasingly. This would be but an insignificant source of error or annoyance if it were equal in all directions. The map or plan would then simply change its scale, for which an allowance could readily be made. But the objectionable feature arises from the unequal expansion and contraction which changes the relative distance and directions of the points. It has been determined by experiment that strips cut longitudinally from drawing paper varied from 10 to 25 per cent more than strips cut transversely from the same paper.

Various substitutes* have been tried, but none have proved entirely satisfactory. The United States Geological Survey, to eliminate this distortion, employs two sheets of paragon paper, the size of the plane-table board, mounted with the grain at right angles, and with cloth between them.

This method is applicable to small scale surveys where a sheet the size of the table board covers a large area of country, or, on the other hand, to large scale cadastral surveys where the great amount of detail makes the rate of progress slow. But for intermediate scales and an area containing a moderate amount of detail, a longer sheet is much more economical, because a smaller number of points are needed to keep the work within the control of the triangulation than would be required if it was limited to the size of the table. A certain amount of overlapping work, of which there is more or less at the junction of the two sheets, would also be avoided.

The plane-table sheet of the Coast and Geodetic Survey consists of a sheet of Whatman's cold-pressed, hand-made antiquarian paper, 52 by 30 inches. It is backed with muslin, which extends about 1 inch beyond the edge of the paper to protect it from fraying.

To reduce the distortion to a minimum a sheet should be thoroughly seasoned before it is taken to the field or a projection laid down on it. This is effected by exposing it alternately to a very damp and a very dry atmosphere. On testing a sheet after a week of such exposure it will be found to have much less tendency to expand or contract unequally.

Paper stored away, piled up in stacks, does not properly season.

Scale.—The selection of the scale to be employed depends so much on the character of the country to be surveyed, the amount of detail to be included, and the uses to which the completed map will be put, that no general rule can be given for guidance. It must be remembered, however, that nothing is gained, either in economy or rapidity, by the use of small scales when the details are shown to be plentiful. The minute drawing involved proves a tax on the topographer and is a great time consumer.

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*Celluloid sheets are frequently used in Alaska. The pencil lines are neither washed out nor blurred by water accumulating on the sheet.

The scale adopted by the Coast and Geodetic Survey for the coast line from Maine to Delaware Bay is 1–10000; from Delaware Bay southward, 1–20000. Special surveys have been made on a scale as large as 1–1200.

PROJECTIONS FOR FIELD SHEETS.

It is presumed that determination has been made, by triangulation, of points most suitable for the use of the topographer who follows with the plane-table work, and that a sketch of the same is at hand, giving an approximate skeleton map of the area to be surveyed. The location or orientation (as it is frequently called) of the sheet is then based upon several important considerations.

It may be taken as a rule that the intervisibility of the points extends across valleys, from summit to summit, or across rivers, bays, and other bodies of water. So that generally the line of greatest depression of the valley (thalweg) should follow as nearly as practicable the middle of the sheet, regard being had for any abrupt change of direction or importance of lateral features; or, in other words, the areas to be surveyed should be divided as far as possible into water basins, extending from divide to divide, and not center upon a ridge forming portions of two basins. The reason for this being that from either slope of the basin points are visible on the opposite summits which will be common to the sheets which include the adjoining valleys, while from the middle of the valley points will be visible on both summits.

From the written descriptions of the points determined, discrimination should be made in regard to their temporary or permanent character. A flag in a tree is likely to have disappeared soon after its determination, and the usual cut of a triangle in its bark may have disappeared before the lumberman's ax, while a church spire, a light-house, a house chimney, a copper bolt in a rock, or a bottle buried beneath the surface of the ground is more likely to be recovered and to be of service to the topographer.

Two intervisible points, one of which may be occupied, or three inaccessible points, are all that are absolutely necessary upon a sheet for the commencement of work, for from, or upon these, all other points required may be determined, and it is oftener more important, from considerations of economy of time and facility for work, to have more regard for embracing the topographical subject in its entirety, where points may be determined at convenience, than to furnish a large number of determined points at the expense of the best orientation of the sheets in regard to topographical details.

In flat sections where the vertical question is scarcely a factor, the main question is generally a plan that will cover the area with the fewest sheets compatible with a sufficient overlap of common points; and where the object is a survey of one side of a river or other body of water, points on the opposite shore should be included when possible.

When it is possible, the sheet should be located by one familiar with the peculiar topography of the region to be surveyed, and with some knowledge from observation of the relative value of the points between which there may be any necessity for discrimination.

Where the surface is broken without any marked basins of large area, and when the sheet, on the scale determined upon, will cover several successive basins and dividing ridges, the consideration of reach from higher to higher summits should control as in the reach over one valley; thereby affording the best means for determining position and any desirable auxiliary points in the lower intermediate summits and in the valleys.

Points at the junction of confluent streams have usually large arcs of visibility, and are consequently of great value for purposes of orientation. If, therefore, such a point should be near but off the edge of a sheet of regular dimensions, and from the necessities at the opposite edge can not be included by it, it is often well to extend the length of the sheet so as to include the point, even though there may be no intention to complete topographic details upon the additional piece.

Light-houses are often of this character, the reasons governing the selection of their positions for light purposes having equal weight in the selection of such positions for survey signals.

The draftsman will be materially assisted in laying out the limits of the projection by drawing on a piece of tracing vellum a plan of the sheet, corresponding in size to the scale of the triangulation sketch. Take, for example, a sheet 52 inches in length by 30 in width, on which a projection on a scale of 1–10000 is to be drawn, the triangulation sketch being on a scale of 1–100000. The dimensions of the plan will then be one-tenth those of the sheet, viz, 5.2 by 3.0 inches. Placing the pattern over the sketch and shifting its position about over the locality to be surveyed, the limits which include the most favorable conditions for the projection will soon become apparent.

The Polyconic projection * has been adopted by the Coast and Geodetic Survey for mapping its work. The method of constructing one is as follows:

The limits of the sheet having been determined, the middle meridian A (see illustration 5) is located and drawn; then its intersection with the most central parallel is found, and the perpendicular B erected there.

Next turn to the page of the "Tables for a polyconic projection of maps" † in which is given the degree of latitude which includes the limits of the sheet. In this instance the latitude is 40°, to be found on page 223 of the tables. The number of minutes of latitude on the central meridian, above and below the central parallel, being known, take the corresponding distance from the column headed "Sums of minutes for middle latitude" and lay it off (C) above and below the central parallel, and with the same distance as radius, strike arcs D D D D above and below, from near the extremities of the perpendicular B. With a well-tested straightedge draw lines E E through the north and south minutes on the central meridian, and tangent to the two arcs D D to the right and left. This gives three parallel lines perpendicular to the central meridian. On the opposite page 222, from under the head of "Arcs of the parallel in meters," take out the value corresponding to the number of minutes of longitude east and west of the central meridian and lay off the whole distance F F′ F″ on each perpendicular, taking each distance from its appropriate latitude. Subdivide these into minutes G G′ G″.

For the areas usually covered by plane-table sheets the corrections X, for determining the abscissas from the arcs of parallels (Table VI, head "Coordinates of curv-

* See a Treatise on Projections, Craig, United States Coast and Geodetic Survey 1882. Chart and Chart Making, Pillsbury, No. 29, Proceedings United States Naval Institute.

† United States Coast and Geodetic Survey Special Publication No. 5, 1900.

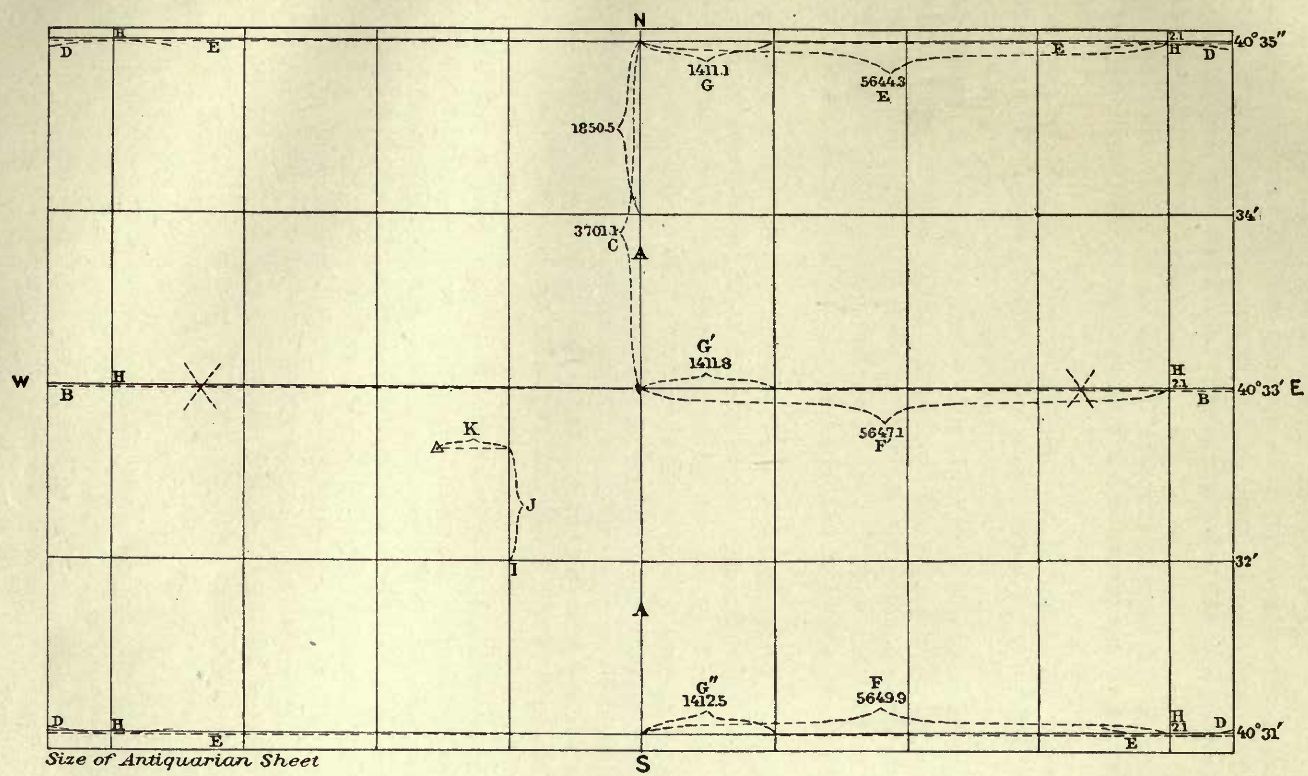


Diagram illustrating the mode of constructing the Polyconic Projection for Plane Table Work, Scale $\frac{1}{10000}$

Scale of Diagram, $\frac{1}{80000}$

ature"), are inappreciable and may be disregarded, the ordinates Y only being used. These give the distances to be set off from the lines B and E, perpendicularly toward the pole, for each minute of longitude counting from the central meridian. For ordinary field projections of scale 1–10000 the ordinate of the extreme minute only need be used, and the parallel drawn a right line from the point so found to the central meridian. This ordinate H being set off on each of the parallels, the meridians are all drawn in with a fine ruling pen, then subdivided into minutes, and the parallels carefully ruled in through the points of subdivision.

The projection is verified by applying the measure of a number of minutes of latitude and longitude, and by a comparison of diagonal measurements on different parts of the sheet.

All measurements should be carefully taken from the scale with a keenly pointed beam-compass, and the marks pricked in the paper should be as light as possible to be seen, so as to insure the greatest possible accuracy.

The draftsman is supplied with a list of triangulation points, which gives their relative distances, their latitudes and longitudes, and also the equivalents in meters of the *seconds* of latitude and longitude, according to which the points are now plotted on the sheet by measuring from the corresponding minutes. Thus in the diagram the distance J represents the seconds of latitude; K, the seconds of longitude of the trigonometric point.

The accuracy of the plotting is tested by a measurement of the respective distances between the points with a beam-compass, these distances being also given. The latitude and longitude are then plainly marked, usually on the north and east sides of the sheet, at one extremity of each parallel and meridian, and the pencil marks erased.

It sometimes becomes necessary to base topographic work upon a detached scheme of triangulation, before the usual astronomic observations have been made. In this case the only elements given are the distances from the points to two projected arcs of rectangular coordinates (which are assumed) and the distances between the points. The projection for plotting these consists simply of axes of ordinates and abscissas so laid on the sheet that it will embrace all the points required by the surveyor, and in the manner most convenient for his work; and the points are plotted from these by the intersection of two arcs with the distances of the points from the axes as radii, either north or south, east or west of the axes, as the plus or minus sign given may indicate. The only test is by the distances between the points, and there should be at least two from each. If the work be correctly done, a regular projection can be constructed on the sheet after it is finished and the required astronomic work is completed.

In case it so happens that for some special purpose it becomes urgent to undertake a piece of topography, when neither the data for projections nor coordinates are at hand, plotting by distances is the only resource left, and, of course, great care is necessary.

When a sheet has no projection—that is, no meridians and parallels, it is advisable to draw squares of 1 000 or any specified number of meters on it, by means of which the projection can ultimately be laid down correctly.

Accessories.—The usual accessories for plane-table work are: Large umbrella for shading table, binocular, pocket compass, 10 or 20 meter steel tape, Locke's level, clinometer, metal scale, dividers, pencils, rubber, block of emory or sand paper, table of heights, note, and sketch book.*

A metal chart case should always accompany the table to secure the sheet from sudden rain and other injury liable to occur in transportation of the sheet to and from the field and for its safe-keeping when not in use. Its diameter should not be less than 3 inches, for no sheet can be rolled to a less diameter without serious rupture of the fiber of the paper. It is also advisable to have a rubber cloth for covering the table when it is carried from station to station.

Approximate weights.—Plane-table movement, 18½ pounds, boxed, 34½ pounds; plane-table board, 8¼ pounds, boxed, 26½ pounds; plane-table alidade, 7 pounds, boxed, 21¼ pounds; plane-table tripod legs, 11 pounds; 2 stadia rods, 16½ pounds. Mountain plane table, set up complete with alidade, 19¾ pounds, boxed, 36 pounds; 2 stadia rods, 12¾ pounds.

FIELD WORK.

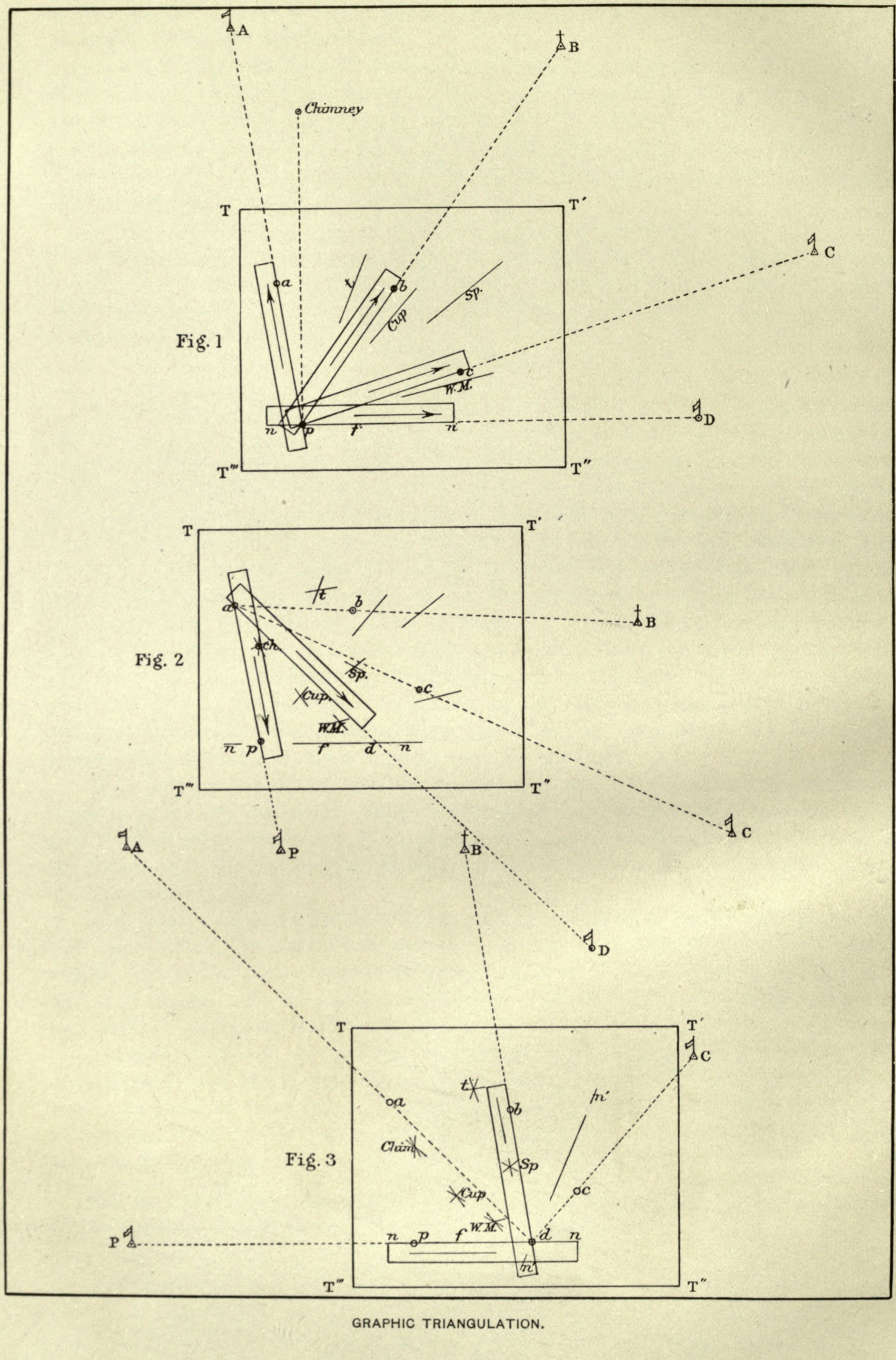
Organization of party.—In organizing a party for field work it is necessary to have one man to carry the table. His duty is to remain constantly with the instrument, never to leave it unguarded; and while the topographer is at work he holds the umbrella to shade the table from the sun and thus protect the observer's eyes from the glaring reflections from the paper and instruments. The table bearer should be taught at the beginning of the work the mode of setting the table over a point and taking it up from the same. In the first instance to grasp firmly two legs of the tripod and with the knee to extend the third one until it reaches the ground at the proper distance from the point, and then place the other two in position. The distances from the point will vary, as the ground may be level or sloping, in order to keep the tripod head vertically over the point and approximately horizontal, securing the latter condition by sighting over the head to the horizon. In taking up the table two legs should be grasped firmly and the table raised, resting upon the other leg, upon which the first two are closed, when the table is raised in place upon the shoulder.

Two rodsmen are needed, and the rapidity with which the work is executed largely depends upon their efficiency. When well trained they should be able to recognize the salient points of the features to be mapped, so that the topographer can draw in correctly the details from the least number of readings, in the absence of an aid to make a sketch of the intricate portions.

The amount of assistance an aid can give to his chief is limited only by his skill and experience. The logical inference being that he is in training to become a topographer himself, he takes charge of an increasing share of the work as he becomes more and more familiar with the methods employed. This enables his chief to turn his attention in other directions, which will expedite the survey and increase the output.

An outline, merely, of his duties can be suggested: Building signals, drawing plans of intricate details, sketching contours, selecting stations in advance, running traverse lines with auxiliary instruments, and finally in taking charge of the plane table in the absence of his chief, who is thus afforded the opportunity of inspecting some difficult area and formulating some plan to meet the conditions found there.

*For the Locke's level, clinometer, and pocket compass a Casella pocket alt-azimuth instrument may be substituted, as it combines all three in a very convenient form.



GRAPHIC TRIANGULATION.

The additional number of men required to complete the party will depend mainly on the means of transportation—wagon, horseback, or boat.

Preliminary reconnaissance.—Before commencing the instrumental work, a reconnaissance of the country should be made for the purpose of recovering triangulation stations and to locate signals at suitable points for subsequent determination and use. In the location of signals, either as permanent points or simply for temporary forward lines, a great deal depends upon the good judgment of the person placing them. Two purposes are to be subserved: First, the seeing of sufficient known points to give a good determination; and, second, to command a view of as great an area of country, and as many natural and artificial features for filling in the topography, as possible. It should be remarked, also, that in the course of prosecution of the regular work no favorable opportunity must be allowed to pass for locating a signal or determining a point which may at some future time be of service. Advantage should be taken of open places in the woods commanding roads or ravines. Piers or draws of bridges, or piles, giving lines up and down streams, which have precipitous and wooded banks; trees of unusual appearance in prominent positions, or bearing flags placed upon them for the purpose; points of rock, offshore or otherwise; lightning rods, cupolas, weathercocks, chimneys of factories, and other peculiar and marked objects come within this category. In fact, it may be set down as a rule that well-determined signals located at convenient distances over the sheet are more likely to be too few than too many.

Signal poles should be straight and perpendicular, and the flags upon them adapted in color to the background against which they will be seen when observed upon.

Graphic triangulation (Illustration 6).—Signals having been erected at each triangulation station, and also on all prominent hills within the area of the sheet, where they will be useful in providing additional control, the next proceeding will be to occupy one of the former points.

Care should be exercised in choosing a day for this portion of the work, as it is essential to have favorable weather for a satisfactory test of the plotted points in the field and for the determination of new ones.

On arrival at the station the table is set up approximately over the center mark, and the sheet secured to the table, so that it will be held firmly and evenly and not be disturbed in its position by the friction of the alidade, nor by ordinary winds. As the longest side of the board is usually made equal to the width of the sheet, and the sheet is usually longer than this width, the excess of length is rolled up inward, turned underneath the sides of the table and fastened with a metal spring clamp, biting from the top of the sheet on the table to the inside of the roll beneath. One clamp at each end of the roll serves to hold the roll ends securely. The sides of the sheet are sometimes held to the table by similar but shorter clamps, but it is preferable for the free movement of the alidade, and more secure against strong winds, that a metal strip, the length of the side between the end clamps, with spring clamps fastened to the outer edge, and biting the underside of the table, be used for holding down the edges of the paper.

The chief and controlling condition in work with the plane table, and without which no accurate work can be done, is that the table shall be oriented—that is, that all lines joining points on the sheet shall be parallel to the corresponding lines of nature.

Let T, T′, T″, T‴ (Fig. 1) represent the board of the plane table, upon which is spread the sheet; the plotted triangulation point *a* upon the sheet representing the signal A upon the ground; *b*, the spire B; *c*, the signal C; and *p*, the station P; the small letters on the sheet representing the centers of the signals on the ground, which are referred to by corresponding capital letters.

The table is placed approximately level over the station occupied, P, and oriented, also approximately, by the eye, so that the plotted points on the sheet are in approximate range with the station P and the signals or objects they represent in the field. Then plumb the point *p* over the station P, fixing the legs of the table firmly in the ground.

In maps of large scale it is important to plumb the plotted point exactly over the station, but on the usual field scales of the Coast and Geodetic Survey (1–10000 and 1–20000) an approximation with the eye is all that is requisite. To effect it more closely a small stone is held underneath the point and then dropped to test the position, or a plumb bob fastened to the table below the point serves the same purpose. Plumbing arms or forks are made and supplied by the instrument dealers.

The plotted point having been plumbed over the station as accurately as the scale of the work demands, place the alidade on the table so that the rule shall extend across and parallel with the line joining two of the leveling screws; loosen the large clamp screw under the tripod head, and with the leveling screws bring the bubbles of the two levels on the rule to the center; clamp the screw under the tripod head, and the table is level. Now, unclamp the revolving plate, place the edge of the rule upon the plotted points *p* and *b*, the telescope being directed toward the spire B, as shown by the arrow-head of the figure, and revolve the table until B is seen in the field of the telescope; clamp the revolving plate, and with the tangent screw of the movements bisect the top or center of the spire B with the vertical wire of the telescope. The table is now oriented, if the points have been correctly plotted and the proper objects sighted. To verify this, place the rule upon the point *p* again, and upon the points *a* and *c*, consecutively, and if the two signals A and C are bisected by the vertical wire of the telescope, the position is assured, and the lines connecting points of the sheet are parallel with the corresponding lines on the ground.

The failure to bisect A and C would indicate an error of plotting or an unequal change of the dimensions of the paper (distortion), which must be examined, and in case of the former, corrected, and in case of the latter, allowance made for, as indicated later on. (See distortion errors, page 316.)

The next proceeding is to draw the line to the next point which it is desirable to occupy or determine, either some natural object which can be occupied, or a temporary signal placed for that purpose, as the signal D.

The edge of the rule is placed upon the point *p*, and moved about that point as a center until the signal D is bisected by the vertical wire, and then a line, *f*, is drawn along the edge of the rule from *p* far enough to reach the estimated position on the sheet of the point *d*, and at each end of the rule the short check lines *n n* are drawn. These check lines can be used in reversing the alidade with the accuracy that is obtained by the greatest length of a range line. They may be indicated on the sheet, with names of objects, as in fig. 2—*ch.*, chimney; *t.*, tree; *cup.*, cupola; *sp.*, spire; *w. m.*, windmill; or numbered, and a record kept of the objects sighted, where details are complex.

In the same manner lines should be drawn to such objects as it is desired to determine. This determines only the one element of direction; it will be necessary to determine the distance from the point occupied either by measurement or by intersection from some other fixed point, at an angle not less than 30° nor more than 150°; all acute intersections should be verified by a direction from a third point.

The table is moved to the station A (Fig. 2) and placed over the point, oriented approximately, leveled, and the axis of revolution clamped as at station P. The rule is then set upon the line *a p*, the telescope directed toward the signal P, and the table put in position in the manner described. Then, keeping the edge of the rule upon *a*, direct the telescope to the signal D and draw the line *a d*, intersecting *f*, and determining the position of the point *d* upon the sheet, corresponding to D, and bearing the same relation in directions and distances from the points *p*, *a*, *b*, and *c* as the signal D does from P, A, B, and C. All lines to other objects which were drawn from *p*, and which objects can be seen from A, are intersected and determined in the same manner.

When a direction has been drawn from a station to any undetermined point that may be occupied, the position of the point may be determined by occupying it with the table, and orienting the table by the line drawn to it, and *resecting* upon a signal whose corresponding point is plotted upon the sheet.

The table is placed over the point D (Fig. 3), oriented approximately, leveled, etc., as at the previous stations. The edge of the rule is then placed upon the line *d p*, passing through the point *p*, so that the checks *n n* are just visible along the edge, and the telescope directed toward the signal P, and the table oriented. The rule is then placed with its edge bisecting one of the plotted points, such as *b*, which will give a good intersection (the nearer 90° the better) with the line *f*, and is moved about that point as a center until the spire B is bisected by the vertical web. A line is now drawn accurately along the edge of the rule through *b*, crossing the line *f*. If this line intersects the line *f* at the point *d*, the position of the latter is assured, and a delicate hole with the dividers should be pricked at the point, surrounded by a small circle in pencil.

Resection upon any other determined point will verify its position.

From this point, *d*, directions are observed and drawn to verify the previous intersections upon *chimney*, *tree*, *cupola*, *windmill*, etc.

There are occasions when occupying some station that several objects are seen whose position it is desirable to determine by prosection, but there is doubt of their being recognized from other stations. A new station is then occupied close by the first one and new lines drawn to the objects. The intersection thus obtained will necessarily be acute, but will materially assist in their identification from other localities.

All lines should be drawn lightly and carefully, close to the edge of the rule, with a hard, finely-sharpened pencil. If the table and alidade be in proper condition, the contact of the edge of the rule with the paper will be perfect throughout its length, and in drawing a line along the edge care must be taken to preserve the same inclination of the pencil and to keep it sharp. If the rule should be raised from the paper at any part, great care is to be observed that the pencil does not run under the edge and thus deviate from a straight line.

Amount of control.—There is no fixed ratio between the number of determined points and the number of square miles of the region to be surveyed or square inches of plane-table sheet.

The greater the number of points well distributed over the latter the less likelihood of error due to distortion of the paper.

A large number also makes it easy for the topographer to determine by resection subordinate stations for mapping the details, and in consequence fewer traverse lines need be run.

More than sufficient for these purposes are not necessary, and it is important when carrying on a graphic triangulation not to waste valuable time and favorable weather, but to advance this part of the work as rapidly as possible before the sheet becomes affected by exposure.

The three-point problem (Illustration 7).—A subordinate station is located at any desired place where a good view of the surrounding features can be obtained. If the position of this point has not been previously determined it is now effected by means of the resection of lines from three fixed points.

The special advantages of the plane table as a mapping instrument are due to the rapidity with which it obtains results by the method of graphic triangulation and to the facility it affords the topographer in determining his position at an unknown point by the graphic solution of the three-point problem.

When the latter method is applicable—that is, when the country is open and signals can be easily seen—its superiority over a system of traverse lines is manifest. The topographer is then at liberty to choose his ground without reference to his last station or to one succeeding. He is not tied down to a backsight nor restricted by the conditions imposed by a foresight. He need not set up his instrument on an area barren of detail nor cut his way through obstacles (bushes, hedges, trees) to establish a station at a commanding point of view.

The number and situation of the stations are governed solely by the amount and location of the information to be mapped. On the other hand, traverse stations are chosen on account of their visibility, and many of them are of no service whatever beyond carrying the line forward.

When the table is imperfectly oriented, the lines drawn from the three projected points, when sighting on the corresponding actual points, will not intersect at one point unless all four are on the circumference of a circle. (See Fig. 3, Indeterminate position.) Except in this case, two of the lines will be parallel, intersected by a third (see Fig. 4, Station on range line between two fixed points, and Fig. 2, Station on prolongation of range line), or they will form a small triangle called the *triangle of error.* (Figs. 1, 3, 5, and 6.) The solution of the three-point problem determines the location of the station occupied and orients the table simultaneously.

The relative positions of the three fixed points with reference to the new station have an important bearing on the strength of its determination.

In the following statement in regard to the different groupings of points met in practice, for the sake of brevity, the term "fixed points" will be understood to mean points already determined and plotted on the sheet; the "great triangle" referred to is one formed by the three fixed points, and the "great circle" is the circle passing through them.

When the new station is outside the great circle, the strength for determination of a position will be weak when the middle point as seen from the new station is the farthest of the three and the angles are small. (See Illustration 7, Fig. 3.) If the new station is located outside the circle, and some distance below it, the angles are small and the determination correspondingly weak.

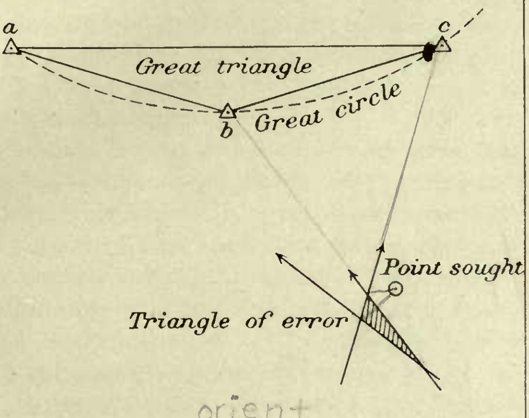


Fig. 1

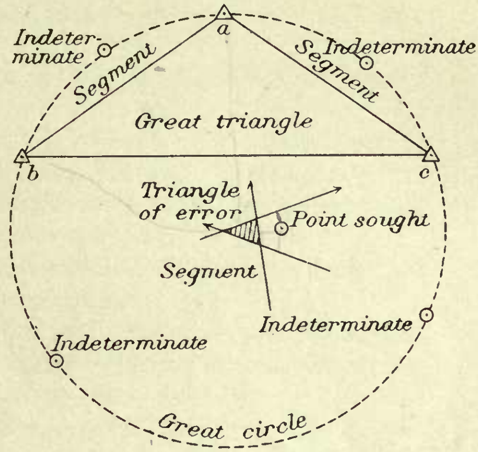


Fig. 3

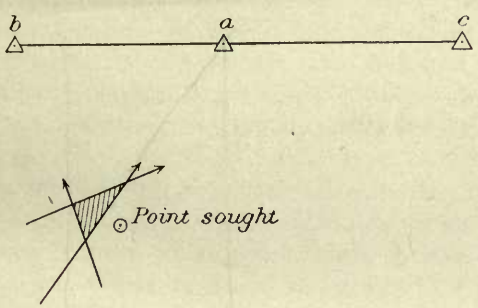


Fig. 6

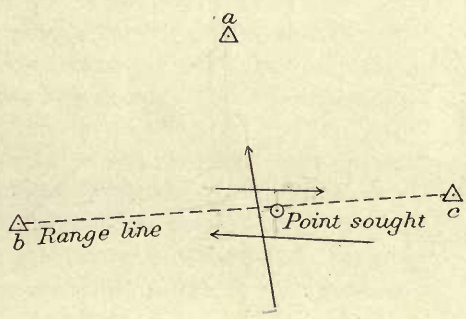


Fig. 4

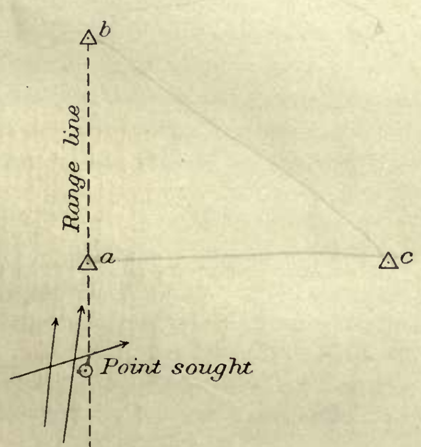


Fig. 2

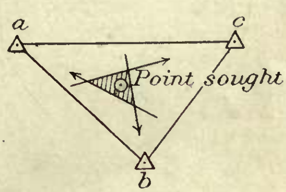


Fig. 5

THE THREE-POINT PROBLEM.

The determination increases in strength for given angles as the middle point approaches the new station. (Fig. 1.)

When one angle is small or 0° (points in range), the determination will be strong, provided the two points making the small angle or range are not too near each other when compared to the distances to the new station and to the third point; provided also the angle to the third point is not too small. (Fig. 2.)

When the new station lies on or near the great circle, its position is indeterminate. (See Illustration 7, Fig. 3.)

When the new station is within the great circle, the strength of its determination increases as it approaches the center of gravity of the great triangle. (Figs. 3, 4, 5.)

There are a number of graphic solutions, but all save three are better suited to the drafting room with its appliances than to the conditions which exist in the field.

Lehmann's method of solution is the simplest and most direct, and applies under all circumstances. The directions are stated in the form of rules.

The term "*point sought*" will be understood to mean the true position on the sheet of the projected point of the station occupied. The surveyor is assumed to be facing the signals, and the directions right and left are given accordingly.

Rule 1.—The point sought is always distant from each of the three lines drawn from the three fixed points in proportion to the distances of the corresponding actual points from the station occupied,* and it will always be found on the corresponding side of each of the lines drawn from the fixed points.†

The simplest case for the application of this rule occurs when the station to be determined is within the triangle formed by the three fixed points; the point sought must then be within the triangle of error to satisfy the conditions. (See Illustration 7, Fig. 5.)

Although Rule 1 is sufficient in itself for the solution of the problem, there are two subordinate rules which materially assist the topographer in reaching a decision as to the proper location of the point sought with reference to the lines from the fixed points.

Rule 2.—When the point sought is without the great circle it is always on the same side of the line from the most distant point as the intersection of the other two lines. (See Illustration 7, Fig. 1.)

Rule 3.—When the point sought falls within either of the three segments of the great circle formed by the sides of the great triangle the line drawn from the middle point lies between the point sought and the intersection of the other two lines. (See Illustration 7, Figs. 3, 4, 6.)

Application of rules.—In practice the topographer first decides the relation of the new station with reference to the fixed points, whether it is within the great triangle or in one of the segments or outside the great circle. He then determines the position of the

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* *Demonstration.*—A, B, C (Illustration 8, Fig. 1) are projections of the three signals from which it is desired to determine by resection the position of a fourth point, D. The table being out of position to the right, the triangle of error formed by the three lines from A, B, and C is ab, ac, bc. The true point occupied lies at D, being at the intersection of the circles AB ab, AC ac, BC bc. Now, if perpendiculars be drawn from D to the lines drawn from A, B, and C, we shall have

Da : Db :: DA : DB or Db : Dc :: DB : DC.

† That is, if it is on the right side of one line, it is on the right side of each one of the other two, and if on the left side of one, it is on the left side of each one of the other two.

point sought with reference to one line (if within one of the segments or without the great circle by Rule 2 or 3); it then follows from Rule 1 that it must be on the corresponding side of the other two lines. Finally, he estimates the relative distances of the three actual points from him and marks the position of the point sought a proportionate distance from the three lines.

EXAMPLES.

Illustration 7, Fig. 1: When the point sought is without the great circle, the intersection of the lines from B and C fall to the right of the line from A, the most distant point; therefore (Rule 2) the point sought must be on its right, and also (Rule 1) on the right of the line from B and C. Its exact position is then estimated according to Rule 1.

Illustration 7, Fig. 2: When the point sought is on or near the prolongation of a range line, it must be outside the parallel lines on the side of the line to the nearest fixed point of the range. In the figure it will be seen that the point sought must be outside the lines from A and B, and to their right to satisfy Rule 1, and also to the right of the line from C.

Illustration 7, Fig. 3: When the point sought is on the circle passing through the three fixed points, the position is indeterminate, as the three lines will intersect at one point, although the table is imperfectly oriented. Another selection of points must be made.

Illustration 7, Fig. 3: When the point sought falls within one of the segments of the great circle, the line drawn from A, the middle point is to the right of the intersection of the lines from B and C; therefore (Rule 3) the point sought must be on its right side, and also (Rule 1) to the right of the line from B and from C. Locate it exactly according to Rule 1.

Illustration 7, Fig. 4: When the point sought is on or near the range line between the fixed points, the point sought must be between the parallel lines to satisfy the conditions of Rule 1. Its position with reference to the intersecting line follows from the same rule. In the figure the point sought being between the lines from B and C, is to the right of each, therefore it is to the right of the line from A.

Illustration 7, Fig. 5: When the point sought falls within the great triangle, it must fall within the triangle of error. No other position would satisfy the conditions of Rule 1.

Illustration 7, Fig. 6: When the three fixed points are in a straight line. In this case the points are considered as being in the circumference of a circle of infinite diameter and the point sought always lying in one of the segments of the great circle. The treatment of this case is then identical with that of Illustration 7, Fig. 3.

The preceding cases are all examples of the conditions which may occur when the table is deflected to the right. By turning the printed side of the illustration to the light and looking at the figures through the paper, they will appear reversed, and they will then be examples of conditions which may occur when the table is deflected to the left.

Repetition.—When the true point has been estimated and marked on the sheet in accordance with the foregoing rules, a new orientation is made. If the lines from the three stations now intersect at that point, it proves the estimate to have been correct

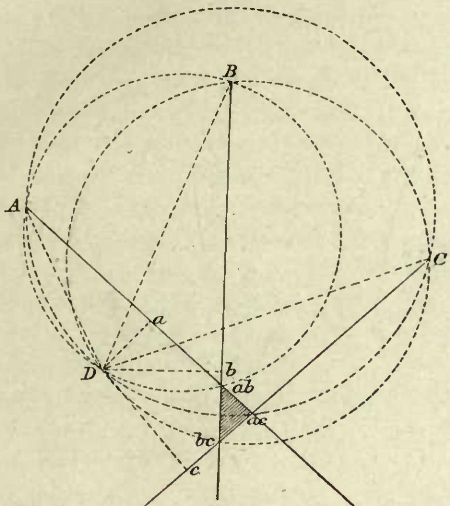


Fig. 1

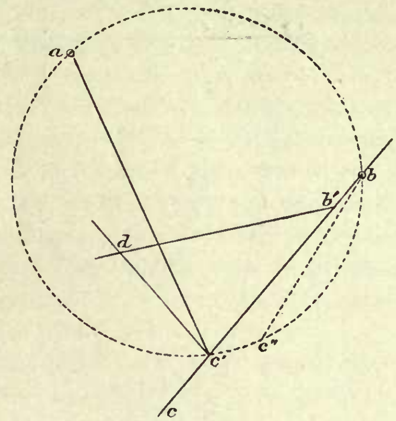


Fig. 6

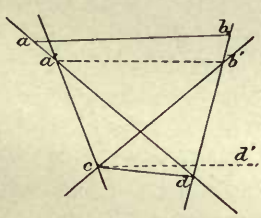


Fig. 2

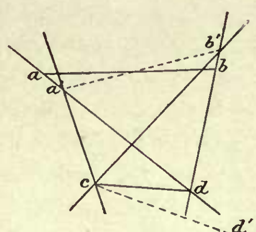


Fig. 3

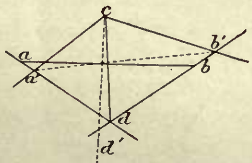


Fig. 4

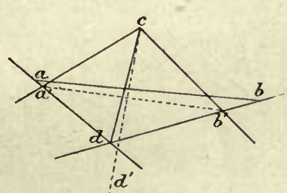


Fig. 5

THREE-POINT AND TWO-POINT PROBLEMS.

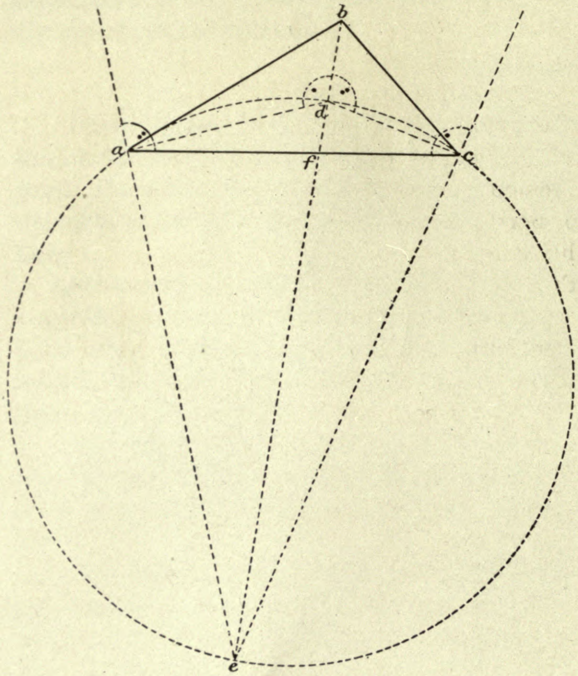


Fig. 1

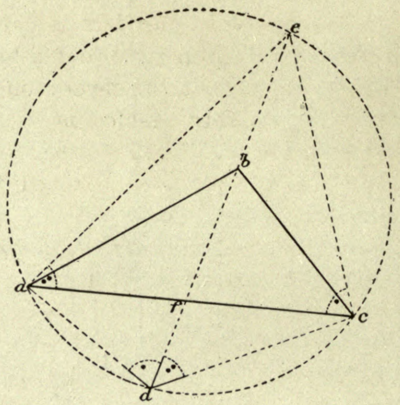


Fig. 2

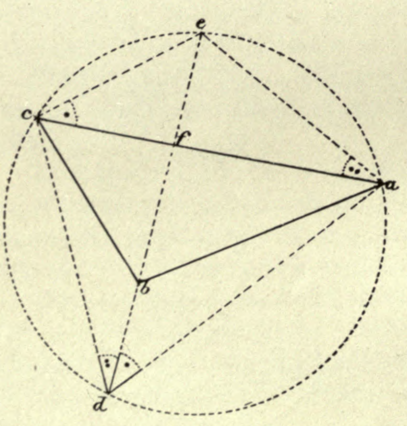


Fig. 3

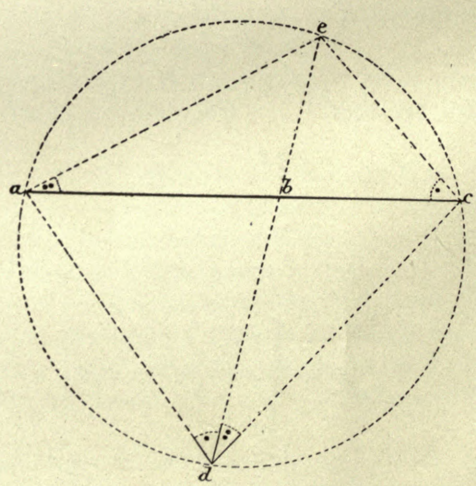


Fig. 4

BESSEL'S SOLUTION OF THREE-POINT PROBLEM.

and the position is determined. If a new triangle of error is formed, it indicates an erroneous estimate, and the operation must be repeated.

Orienting by estimation.—A small triangle of error is the result of a close orientation, which the topographer endeavors to accomplish at the first trial by taking advantage of any range that may exist either of signals or other details already plotted on the sheet. It will serve the same purpose if they are near enough in line to estimate a direction on the sheet to the farthest object, and then to orient by it.

The declinatoire may be used, but it is a slow and inaccurate method of orientation.

It is employed for this purpose by placing the straight edge of the box containing the needle upon a magnetic meridian, previously traced upon the map, and revolving the table until the needle points to 0°, or north, on the graduated arc at the end of the box. The magnetic meridian is roughly determined at any well-determined station, when the table is properly oriented by the use of the declinatoire itself, the meridian line being drawn upon the sheet along the straight edge of the box when the needle points to 0°. Or the table may be oriented by making the straight edge of the box coincide with one of the meridians of the projection and then turning the board until the needle points to the right or left of the zero, according to the amount and direction of the magnetic deviation.

Bessel's method by inscribed quadrilateral is the simplest method by construction. The objection to it arises from the fact that in practice the intersection of the construction lines often falls beyond the limit of the board.

By this method a quadrilateral is constructed with all the angles in the circumference of a circle, one diagonal of which passes through the middle one of the three fixed points and the point sought. On this line the alidade is set, the telescope directed to the middle point, and the table is *in position.* Resection upon the extreme points intersects in this line and determines the position of the point sought.

Illustration 9, Figs. 1, 2, 3, and 4. Let *a b c* be the points on the sheet representing the signals A B C on the ground. The table is set up at the point to be determined (*d*), and leveled. The alidade is set upon the line *ca*, and *a* directed, by revolving the table to its corresponding signal A, and the table clamped; then, with the alidade centering on *c*, the middle signal B is sighted with the telescope and the line *ce* drawn along the edge of the rule. The alidade is then set upon the line *ac* and the telescope directed to the signal C, by revolving the table, and the table clamped. Then, with the alidade centering on *a*, the telescope is directed to the middle signal, B, and the line *ae* is drawn along the edge of the rule. The point *e* (the intersection of these two lines) will be in the line passing through the middle point and the point sought. Set the alidade upon the line *be*, direct *b* to the signal B by revolving the table, and the table will be *in position.* Clamp the table, center the alidade upon *a*, direct the telescope to the signal A, and draw along the rule the line *ad.* This will intersect the line *be* at the point sought. Resection upon C, centering the alidade on *c* in the same manner as upon A, will verify its position.

The opposite angles of the quadrilateral *adce* being supplementary,

$\angle ace$ and $\angle ade$ are subtended by the same chord *ae*, and $\angle cae$ and $\angle cde$ are subtended by the same chord *ce;* consequently, the intersection of *ae* and *ce* at *e* must fall on the line *db;* or, the segments of two intersecting chords in a circle being reciprocally proportional, the triangles *adf* and *cef* are similar, and the triangles *cdf* and *aef* are similar, and *d*, *f*, and *e* must be in a right line passing through *b*.

In using this method the triangle formed by the three fixed points can be contracted or extended, as may be desirable, by drawing a line parallel to the one joining the two extreme points, and terminated by those joining the extremes with the middle point. The graphic solution can then proceed in the same manner as that described for an original triangle.

Tracing-cloth protractor.—The third method consists in laying off the angles between the three known points on tracing cloth or paper, and using this as a protractor, determine the position of the unknown point.

Fasten a sheet of tracing cloth or paper to the board, marking upon it a point to represent the unknown point. Draw through it lines toward the three known points. Then shift the tracing cloth over the sheet until each of the three lines passes through the plotted point corresponding to the point toward which it is drawn. The position of the unknown point will be at the intersection of these lines.

This method is less exact and not so convenient as the other two previously described, and is impracticable when the wind blows.

TWO-POINT PROBLEM.

The occasion may arise where it is desirable to place the table in position at a given point, from which only two determined points are visible. This may be done by the following methods:

One method possesses the virtue of requiring no linear measurements, and demonstrates in a very satisfactory manner the effectiveness of the table in determining position by resection.

(Illustration 8, Figs. 2, 3, 4 and 5.): Two points, A and B, not conveniently accessible, being given, by their projections *a* and *b*, to put the plane table in position at a third point, C. (The capital letters refer to points on the ground, and the small ones to their corresponding projections.)

Select a fourth point, D, so that the intersections from C and D upon A and B make sufficiently large angles for good determinations. Put the table approximately in position at D, by estimation or by compass, and draw the lines A*a* and B*b*, intersecting at *d*; through *d* draw a line directed to C. Then set up at C, and assuming the point *c* on the line *d*C, at an estimated distance from *d*, and putting the table in a position parallel to that which is occupied at D, by means of the line *cd*, draw the lines from *c* to A and from *c* to B. These will intersect the lines *d*A and *d*B at points *a'* and *b'*, which form with *c* and *d* a quadrilateral *similar* to the true one, but erroneous in size and position.

The angles which the lines *ab* and *a'b'* make with each other is the error in position. By drawing through *c* a line *cd'* making the same angle with *cd* as that which *ab* makes with *a'b'*, and directing this line *cd'* to D, the table will be brought into position, and the true point *c* can be found by the intersections of *a*A and *b*B.

Instead of transferring the angle of error by construction, we may conveniently proceed as follows, observing that the angle which the line *a'b'* makes with *ab* is the error in the position of the table. As the table now stands, *a'b'* is parallel with AB, but we want to turn it so that *ab* shall be parallel to the same line. Place the alidade on *a'b'* and set up a mark in that direction, then place the alidade on *ab* and turn the table until it again points to the mark, then *ab* will be parallel to AB, and the table is in position.

Another method is as follows (Illustration 8, Fig. 6):

Two points, A and B, not conveniently accessible, being given by their projections *a* and *b*, to put the plane-table in position at a third (undetermined) point, C.

Set up the table at the point sought as closely oriented as can be done by estimation, and resect upon A and B, intersecting the line *bc* at *c'*. The angle *ac'b* is the true angle at the point occupied, subtended by AB, being the angle of nature actually drawn; therefore, the true point must be on the circumference of the circle passing through *abc'*. Construct this circle. Measure off a base, CD, at least half the length of CB, at right angles, or nearly so, to *bc*, in either direction most convenient. Set up a signal at D, and with the alidade draw the line *c'd*. Remove the table to D, and, by means of a signal at C (the point sought), and the line *dc'*, bring the table into a position parallel to that which it occupied at C. With the alidade centering on *d*, observe the signal B, and draw the line *db'* intersecting *cb* at *b'*. *c'b'* is the distance of the point C from B, and this distance laid off on the circle *ac'b* as a chord from *b* will give *c''*, the true position of the point C. A fourth point may then be occupied, and by resection upon A, B, and C the accuracy of the determination of C verified.

Where it is possible to get the two signals A and B in range, it is easy to determine the position of a third point by a method long practiced by topographers.

Set up the table anywhere on the range line, and orient by the latter. Resect on the unknown point, drawing the line anywhere on the sheet most convenient. Leave a signal at the occupied point on the range line and set up the instrument at the unknown point. Orient by the line drawn when at the station on the range line, sighting on the latter station. The table will now be in a parallel position to that when on the range line, which is the true position, and the unknown point may be determined by resection upon the two fixed points and their projections.

Deflection of long lines.—In adjusting lines of intersection upon a point or object from a series of stations, when these lines do not coincide in one point, as they are usually derived from signals at unequal distances, the error should not be divided equally among them, but in proportion to their lengths if the discrepancies are not eliminated by the rules for distortion errors given later.

It should be borne in mind that very short lines from a determined point—as, for instance, to the corners of a fenced road, where the table occupies the center of the intersection of two roads—may be taken with no apparent error when the table is deflected to some extent from its true azimuth, but that in this case a prolonged line will be considerably out at its further extremity.

A long line should never be obtained by the prolongation of a short one from a back station where there is no small check line, or some other point in that prolongation already fixed.

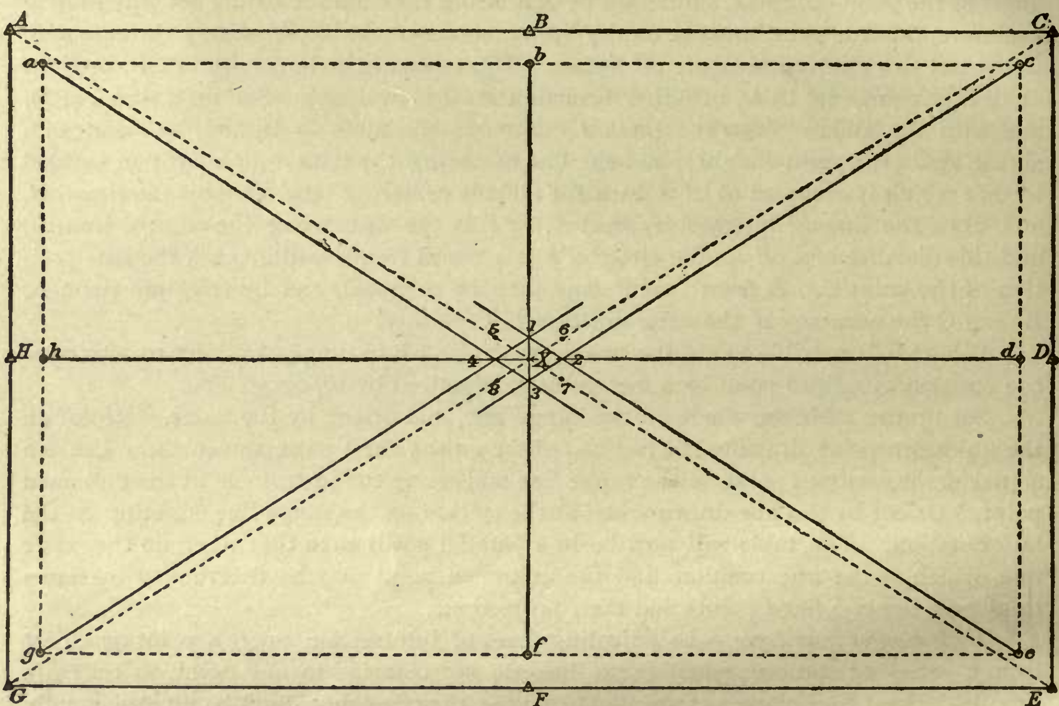
It will be apparent that the more nearly at right angles intersecting lines cross each other the more clearly the point will be defined; acute intersections, as far as possible, should be avoided, and, even when they are crossed by a third line at a satisfactory angle, a fourth line, or an accurate rod reading from a well-determined point, is advisable if within reach.

Sometimes a position is established by measuring along the estimated direction from a near-by fixed point and then orienting by this assumed position and a distant point. This method should be used with caution, but is generally reliable for rodding the detail in the vicinity.

*Distortion errors.**—The distortion of a plane-table sheet destroys the perfect proportions which exist between the fixed points and their plotted representatives on the sheet.

The diagram illustrates the effect distortion would have in the determination of a point.

NO. 10.



A, *B*, *C*, etc., are plotted in their true relations. After the sheet has contracted, *a*, *b*, *c*, etc., represent the relations those points have assumed. The paper contracts at a uniform but different rate in each direction.

The plane-table is supposed to be at *X*, the exact center of the figure, and it is required to determine the position by the distorted points *a*, *b*, *c*, etc. By reversing the telescope, we immediately ascertain that we are directly on the line *HD*. Reversal will also show that we are on the lines *AE*, *CG*, and *BF*. But the distortion is not apparent until the telescope is pointed at the signals, and the lines are drawn on the sheet. Then if we orient by the line *HD*, we shall produce the figure of the diagram, giving five determinations, 1, 2, 3, 4, and *X*, each made with four well-conditioned points. Any one of these conditions would be considered satisfactory if we had not the other points to show that something was wrong. To orient by the line *BF* will produce the same result. But if we take the diagonal *AE*, we shall have two positions at 5 and 7, formed by the intersection of the diagonal points, with the lines from the other points

* See Distortion of Plane Table Sheets, Ogden, Science, Vol. XI, No. 270.

running wild. Using the diagonal *CG* would give two points at 6 and 8, with the lines from the other points running wild as before.

Position by compromise.—There is no question that out of the nine positions developed by these settings, that at *X* is the only true compromise. When the sheet is distorted, all positions are compromises; and *X* is the true compromise in this case, for it is on the lines *CG*, *AE*, etc.: *a* below and *e* above, the line connecting *A* and *E*, by equal quantities. A line drawn through the distorted points *a* and *e* must pass through the middle point *X*. The positions 5, 6, 7, and 8 can not be true, because lines forming them will not pass through the opposite points when extended, which we know to be the condition that must be filled.

Rules:

(1) A station made with three points that are on the lines of contraction, the resecting lines forming nearly right angles at their intersection, will give the true position in relation to all points in the sheet (as *h*, *b*, *d*).

(2) A similar condition of right-angular intersection at the station, but the lines forming diagonals to the lines of contraction, will give the worst possible position for the station (as *a*, *c*, and *e*).

(3) A station made with three points on one of the lines of contraction will give the correct orientation of the table (*a*, *h*, and *c*) but not the correct position.

(4) In estimating errors of the point due to distortion, those situated on the lines of contraction require no allowance, however distant.

Application.—If the change in the sheet due to contraction or expansion gives the same percentage of the units of length, both lengthwise and transverse of the sheet, the points are still in their true relative position, and the projection is practically as good as when laid on the paper, but is on a slightly altered scale. When the percentage of change in the units of length is greater in one direction than the other, the sheet and projection are distorted; and to make a station by the three-point problem, the change of scale in each direction must be allowed for. The difficulty in making such allowances is not great, if the principal effects of distortion in the sheet are borne in mind. It would not be permissible, even were it practicable, to make new points on the sheet, as this would destroy the geographic position. It is necessary, therefore, to assume the new points by estimation, applying the percentage of change to the distances measured between the points on the lines of change—that is, on lines parallel to the edges of the sheet. If the point occupied and the point sighted to are on a line parallel, or nearly so, to one edge of the sheet, its movement from the distortion can only be along that line. When the position of the point sighted to is found situated to one side of the line parallel to the edge of the sheet, the distortion will also affect it in the direction at right angles to that edge, and the effect of the distortion will be most apparent when the angle of deflection is 45° and the position at as great a distance from the point occupied as the paper will permit. As the angle of deflection increases above 45° the effect becomes less and disappears at 90°, when the position will fall again in a line parallel to an edge of the sheet.

Referring to the diagram, Illustration 10, to make a station with the three points *a*, *b*, *c:* If the sheet were not distorted, the station would be at *X; A*, *B*, and *C* being the true positions plotted when the projection was drawn. But the sheet having contracted, *a*, *b*, and *c* show the relative positions of these points; therefore we make such allowance for the contraction derived from measuring the unit of length that we can place or imagine *a* and *c* to be where they belong, at *A* and *C*. *b* requires no change, as it is on a line parallel to the edge of the sheet. To locate *A* we must know the distances (approximately) *h* to *a* and *h* to *X*, which, multiplied by the percentages of contraction (in this case), will give the distance of *A* above and to the left of *a*. The same process locates *C*.

If the station were to be made with the points *a*, *c*, and *e*, all three points would have to be imagined in a new position by the same process that *A* has been located.

Stations made in this way will be good for all local sketching within an area that the contraction of the sheet is inappreciable; but to take cuts on distant objects from such a station the orientation of the table must be changed. If an object is somewhere near the direction of *a* and the table at the compromise station *X*, the table must be oriented by *a* and *X*, the imaginary position *A* being discarded.

The same processes apply to all positions on the sheet for the station occupied.

Height of instrument.—Having obtained the horizontal position on the sheet of the occupied point, the next proceeding in the logical sequence is the determination of the height of the instrument above some datum plane, in order to locate and draw the contours of the area surrounding the station. The angle read and the distance between the occupied point and the observed point measured from the map, the height is computed by means of the tables to be found at the end of the Manual, or the result can be obtained mechanically by using the hypsograph.

This instrument was designed by Assistant Fremont Morse for use in the Coast and Geodetic Survey and differs from the ordinary form of topographic slide-rule used by engineers in three particulars: First, it is circular instead of rectilinear; second, it does not give elevations in the same unit as the distances, but gives heights in feet when the distances are measured in meters; and third, the arguments used for determining the heights are the horizontal distance and angle of elevation instead of inclined distance and angle of elevation.

The instrument will indicate the difference of height (uncorrected for curvature and refraction) for any distances and angles encountered in ordinary topographic work, with an error much smaller than the probable error of observation of the plane-table alidade.

For complete description and directions for use, see Appendix 4, Report for 1902.

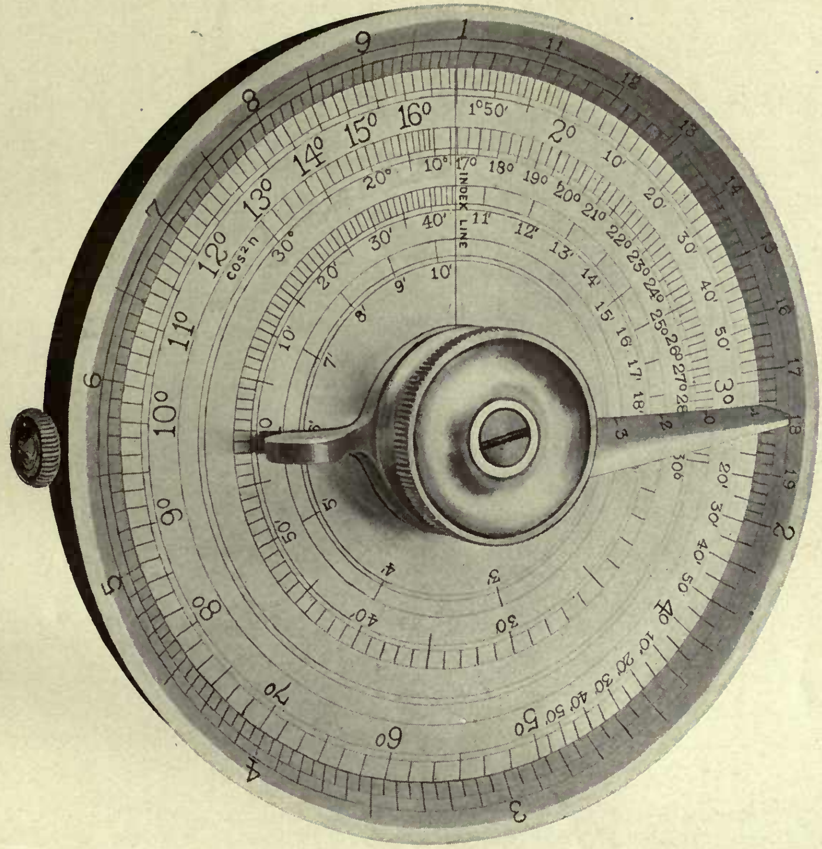
Relief.—There are two methods of representing it—by hill shading and by contours.

Hill shading is generally effected by a system of lines, called hachures, drawn in the direction of the slope. When it is steep, the hachures are thick and closely spaced. On the other hand, a gentle incline will be indicated by fine lines widely separated.

*Contours** or horizontal curves are the outlines of horizonal sections of ground at different elevations with designated equal intervals between their planes, delineated in their true positions relatively to each other and to the rest of the map, and conforming to the scale of the map itself; or, briefly, a contour is a curve produced by the intersection of the horizontal plane with the surface of the ground. They may also be described

*For interesting articles on the diagrammatic properties of the contour line see: On Contour and Slope Lines, Cayley, London & Ed. Mag., 1859, pp. 264-268; On Hills and Dales, Clerk Maxwell, ibid, 1870, pp. 421-426; Properties of Matter, Tait, 1890, pp. 70-81.

NO. 11.



HYPSOGRAPH.

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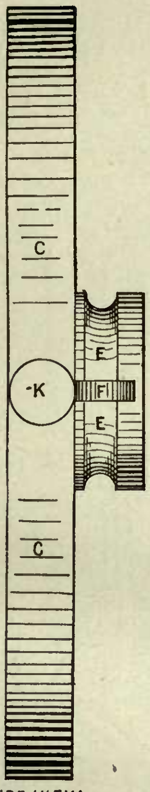
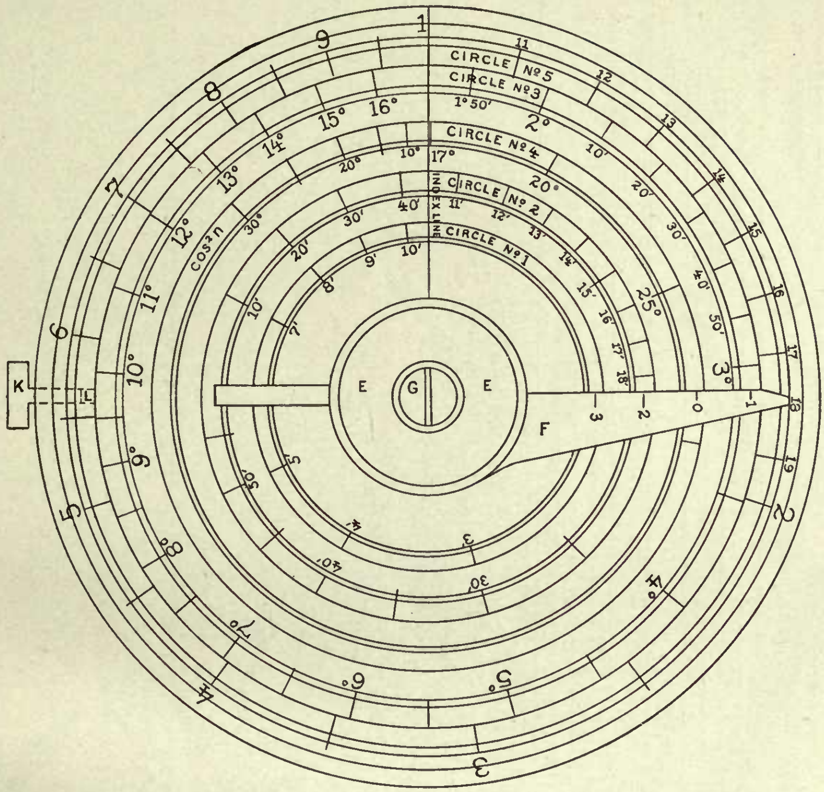
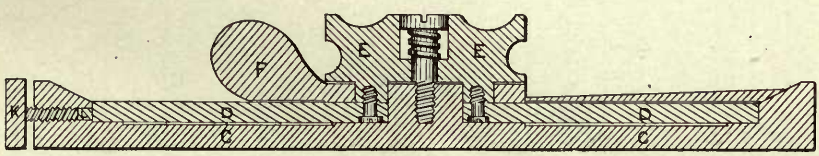


SIDE VIEW



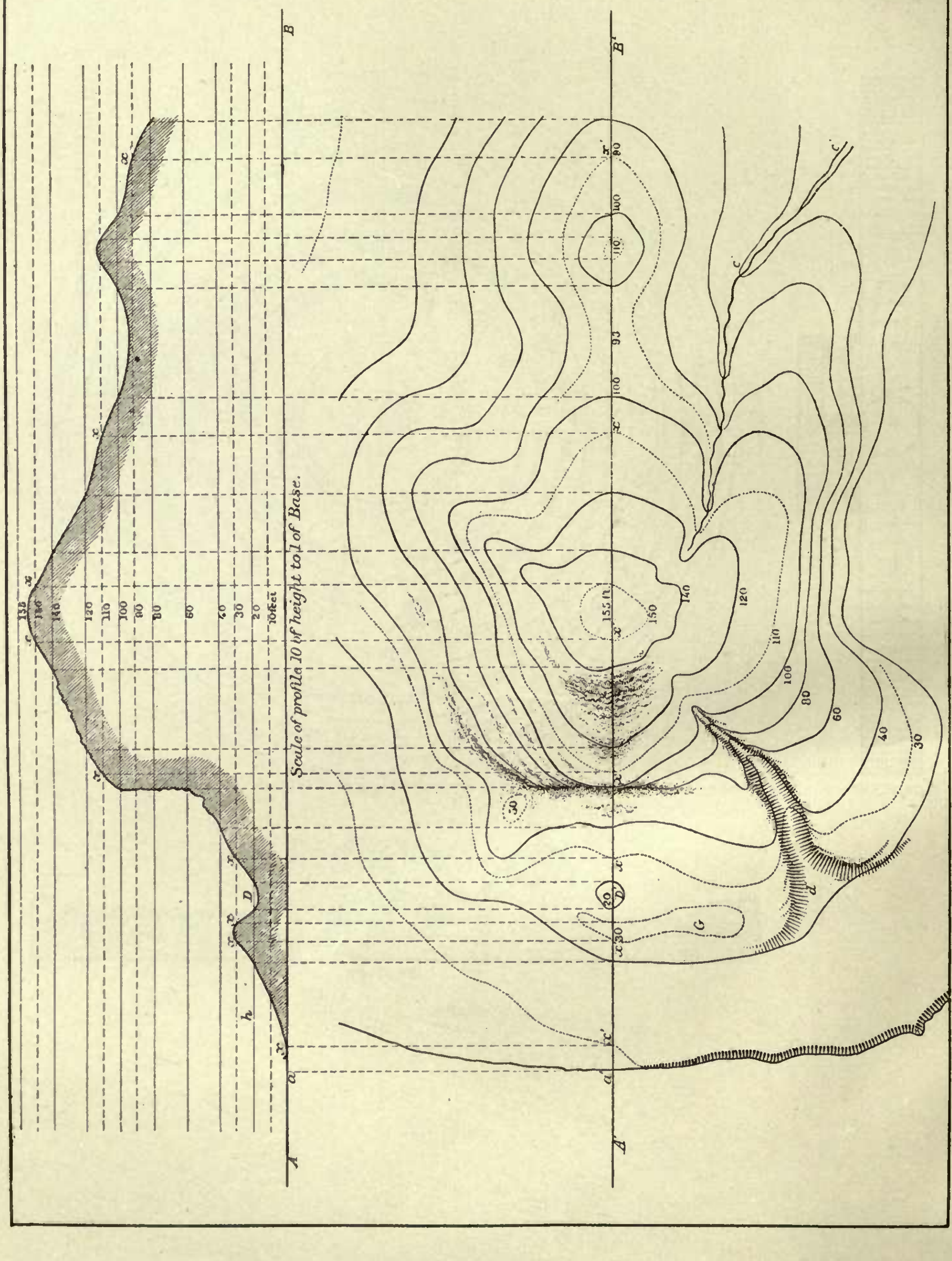
TOP VIEW



SECTION

HYSOGRAPH.

Diagram illustrating the mode of constructing Profile from Plan



Crest, Face, and Talus of a Granite Cliff (*Eagle Cliff, Mt. Desert Id.*)

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No. 15

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Eagle Cliff, Mt. Desert Id. (Looking West.)

as imaginary shore lines formed at stated or regular elevations, by water which is supposed to rise successively to these elevations over the face of the country.

Profile.—As each curve has equal vertical ordinates at all points, the elevation or profile of a hill, as well as a model in relief, can be constructed from the map, when it is accurately executed on a large scale, without further field measurements.

A profile of a hill is the outline or trace formed with its surface by a vertical plane cutting the hill in any direction.

Illustration No. 13 shows the profile through the line *A′ B′* of the hill *h*, as represented on a topographic map. The full parallel lines upon the profile represent the successive heights or sections of the hill of 20 feet, and the broken or intermediate lines *x x x* those of 10 feet. A reference to the letters of the diagram is all that is necessary to a full understanding of the subject: *a* is the shore line or high-water line upon the map, *x x x* are the auxiliary 10-foot curves; *f′* the coincidence of curves upon the chart at the perpendicular face of the hill *f*, upon the section. This is the only case where contours of different heights run into each other upon a topographic plan. *D′* is a depression in the face of the hill, represented on the profile by *D*. *d′* is a barranca or dry broken gully, and *c′ c′* a water course.

It will be plain that if we were to suppose the water to rise to a height of 20 feet above the high-water line, to *h* on the profile, the 20-foot curve upon the map would become the shore line and the depression *D′* would fill up and become a pond of water; and if the water were to rise to a height of 30 feet, the dotted broken line would form a shore line, and the knoll *G* would become an island.

Advantages and disadvantages of hill shading and contours.—In a mountainous country the method of hill shading presents a picture which expresses more forcibly to the eye the configuration of the country than a system of contours. But the objection to its sole use arises from the fact that, although one ridge is perceived to be higher than another, there is no guide for stating in terms of some linear unit this difference in elevation. It also obscures the symbols representing other details on the surface.

A system of contours furnishes a convenient means for obtaining the heights on any part of a map, but does not adapt itself to the representation of the small but important accidents of the ground, such as gullies, ledges, rocks, etc.; nor does it satisfactorily delineate such features as cliffs, bluffs, quarries, railroad cuts, and embankments.

For these reasons the Coast and Geodetic Survey has adopted both methods, employing hachures for the smaller features and where the steepness of the slope would make the contour lines approach together so closely that individual lines would become indistinguishable, and relying on the contours to delineate less precipitous ground.

The two systems can be seen combined when it is necessary to indicate a rocky and broken mountain face. (Illustrations 14 and 15.)

The contour interval customarily used on the Coast and Geodetic Survey field sheets is 20 feet. When, however, the contour runs very near to some remarkable accident of ground, as a prominent spur or indentation, a slight deviation above or below its true plane is admissible to include this feature, although it is preferable to avoid doing so, if possible, by the introduction of an auxiliary curve.

In abruptly mountainous and comparatively inaccessible regions, where sketching must be relied upon, 100-foot curves may suffice to develop all necessary features.

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Datum plane.—Probably the best plane of reference for heights of points on the earth's surface is the mean level of the sea, since the mean of the rise and fall of the tides is approximately this level. In practice, however, mean high water is usually taken, as it includes all land not covered by the tide range, and is the line dividing land and water.

Reference signal.—It is advisable in commencing the survey of a region bordering on tide water to locate one or more signals at the assumed high-water line, carefully noting the height of the top of the flag above the same, to be used in measuring angles of depression for heights from points occupied during the progress of the graphic triangulation. As the heights of other points are determined in the course of the survey and verified from observations from two or three other points, these in turn may be used for the same purpose.

The following are the methods of surveying curves of equal elevation:

First. The determination of the position and heights of a number of characteristic points of the terrene, and with these as guides tracing the contour lines.

This is the method generally used in surveys embracing such areas as the sheets of the Coast and Geodetic Survey on scales of 1-10000 and 1-20000.

It has the merit that the development of the terrene proceeds with the survey of the skeleton, and does not necessitate a return to a station when once occupied. In connection with the determination of position by resection it works harmoniously and economically, since points that would be selected for position as having the best outlook are likely to be the characteristic ones of the terrene.

Second. Surveying and leveling the skeleton and its traverses.

Third. Surveying and leveling the profile lines.

The profile is a traverse line on which are determined the heights of the points at which the surface changes slope. The points where this line is intersected by the successive contour interval are easily determinable with the level and rod.

Fourth. Surveying and leveling the base of each level section.

To determine the base of each level section the table is set up in position where this level intersects the profile, and using the alidade as a leveling instrument, with a target fixed on the rod at the height of the optical axis of the telescope, the line is traced by locating the rod in successive positions at characteristic points of the terrene, when the target comes in the horizontal plane of the optical axis, direction and distance of the rod being determined and drawn in each case. A line drawn through these points, recognizing features between the stations, locates the curve. In this operation allowance should be made for curvature and refraction, when the distance becomes sufficiently great to make it a factor.

Fifth. Surveying and leveling the parts of several level sections from one station.

When parts of several level sections are run from one station, set up the table at a point on a contour, and observe on a staff the height of the optical axis of the alidade. Set a target on the staff above this height as many contour intervals as its length will include. The aid carries the staff below the instrument and is signaled to stop when the target comes in the horizontal plane of the optical axis, and at successive steps traverses the lower curve. The target is then lowered on the staff one contour interval and the next curve above is traced in the same manner, continuing the proceeding until the level of the instrument is reached, when the table is moved to an upper station

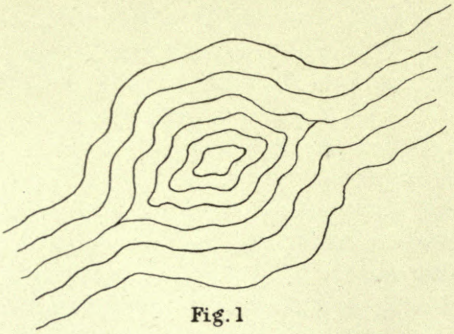

Fig. 1

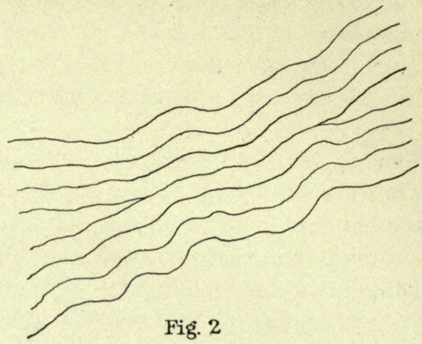

Fig. 2

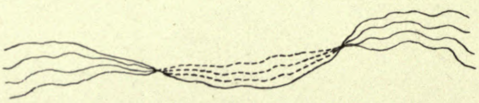

Fig. 3

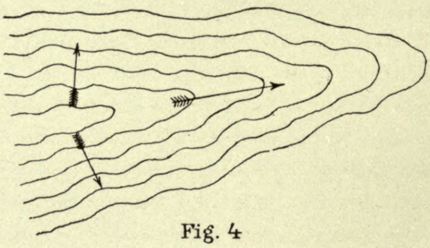

Fig. 4

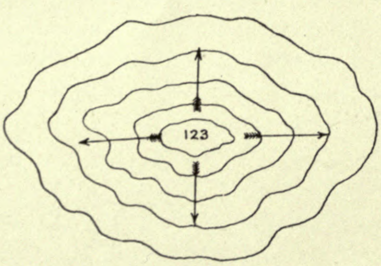

Fig. 5

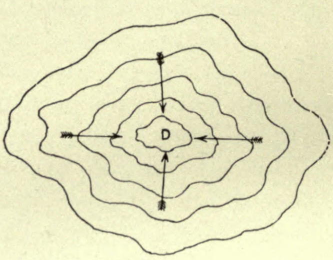

Fig. 6

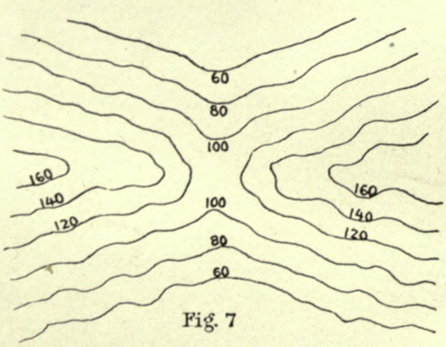

Fig. 7

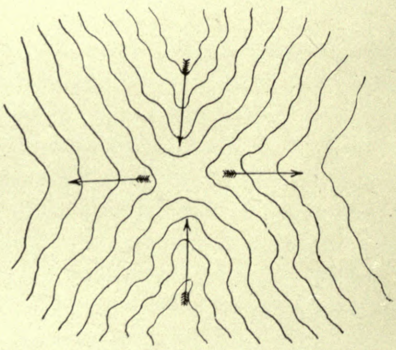

Fig. 8

TYPICAL CONTOUR GROUPS.

and the proceeding continued until the summit is reached. (Applies only to very small contour intervals.)

Sixth. The division of the terrene into squares, triangles, or parallelograms.

By the mode of regular division of the surface into squares, triangles, or parallelograms, pegs are driven at regular intervals, and their heights determined by level in the way that may be most convenient, a spirit-leveling instrument being the most accurate.

Station routine.—The topographer having determined his position on the sheet, and also the height of the instrument, proceeds to map the natural and artificial details of the area surrounding the station. For this purpose the direction of each detail is obtained by pointing the telescope upon it, the edge of the rule cutting the station point; its distance is determined by reading the stadia rod held there for the purpose. This distance is then taken off the metal scale with a pair of dividers and plotted along the edge of the rule.

While this is in progress the alidade is used both as a level for the observation of objects of the same height as the instrument and for measuring angles of elevation and depression to such of the plotted details whose position at critical points of the contours would materially assist the topographer in tracing them.

Number of elevations to be determined.—No rule can be laid down as to the number of elevations that should be determined from each plane-table station or for a given area. It will depend on the skill of the topographer and the modeling of the ground. The number will be adequate when he is confident of tracing, by their aid, the contours with an accuracy sufficient for the scale and the purpose of the survey.

It would indicate careless and slovenly work if the contours were found on examination to deviate frequently from their true position on the sheet by more than half an interval for a slope of less than 5° in an open country. When the slope is steeper, or in wooded regions, a greater latitude is permissible, but even here, in representing the crests of ridges, prominent hill tops, and valley floors, this limit of half an interval should not be departed from for good work.*

Contour sketching.—The topographer will be assisted in sketching contours, where the modeling is intricate, by lightly drawing a skeleton composed of the ridge lines and thalweg lines (lowest lines of valleys) in their proper positions around the station. On the ridge lines will be found the extreme outward or convex bends of the contours, and on the thalweg lines the extreme inward or concave bends.

It can be readily imagined that if each spur and each small depression was represented by its appropriate line, and on each of them were located, either by observation or estimation, points having elevations equal to some multiple of the contour interval, it would be only necessary to connect those points having the same elevation with a smooth curve to have a correct plan of the contours.

It will simplify the sketching at a station to draw the highest, lowest, and middle contours first, as they will then serve as guides for estimating the position of the others.

Typical contour groups (Illustration 16).—It should be remembered that a contour never splits, as shown in Fig. 1; nor do two contours run into one, as shown in

* For some pertinent remarks on this subject see Bulletin of the University of Wisconsin, Eng. Series, Vol. 1, No. 10, Topographical Surveys; their methods and values. J. F. Van Ornum, pp. 360–361.

Fig. 2; nor cross each other, except in the rare instance of an overhanging cliff, as shown in Fig 3.

When an auxiliary contour is introduced, no more of it is drawn than is sufficient to delineate the special feature which makes it necessary. A principal contour, on the other hand, can not have an end within the map; if it commences at one edge it must terminate at another.

A closed contour encircled by one or more closed contours is either a hill, as shown in Fig. 5, or a depression, as shown in Fig. 6; the arrows showing the direction in which water would run. The summits of all the hills of importance should have their elevations determined and marked on the map. All depressions without an outlet and which do not contain a pond or lake should be marked with a D at their lowest point.

A series of contours, as shown in Fig 4, is either a croupe (the end of a ridge or promontory) or a valley. If a croupe, the contours will have their concave sides toward the higher ground; if a valley, the contours will have their concave sides toward the lower ground.

A combination of four sets, like Fig. 7, with convex sides turned toward each other, represents a dip in a ridge, or the junction of two ridges, and is called a saddle.

A pass in a mountain range generally takes the form shown in Fig. 8.

Order of development of contours.—As the progress of topographic work is usually from the shore line inward, this affords the most favorable direction for drawing the curves of equal elevation, and as it is desirable that all work at a station shall be completed when it is first occupied to avoid the necessity of returning to it, the curves should be drawn by estimation from the shore line to the points sighted and determined for position and height, to be checked by drawing from those points when in turn occupied. The heights of a sufficient number of points must be determined to guard against any wide range of estimate of height by the eye.

In abrupt slopes of considerable extent the use of a pocket clinometer is valuable in determining the degree of slope, and in order to draw the curves by the widths of their zones (the cosines of angles of slope) from a paper scale prepared for the purpose. (See Illustration 32.)

Filling in.—Having completed the work at a given station, the topographer proceeds with his party and instruments to an adjoining locality, where he selects a new station from which he can gather the details of an area bordering upon the one last surveyed. In this manner the skeleton map is filled in by successively occupying stations over the whole expanse of the sheet.

Traverse lines.—In a wooded country, where it is impossible to find open space with range sufficient to see enough points for determination of position by resection, it is necessary to run traverses along the roads, with offsets to such lateral features as it may be practicable to reach without the expenditure of excessive labor and time in opening lines of sight. The levels, when necessary, are carried along with the line by observing vertical angles with the alidade upon some mark on the rod, taking back and fore sights at alternate stations.

Main traverse.—The standard table is used on main roads and whenever the details are important and numerous.

The traverse line is started by occupying some point previously determined and sending the telemeter rod ahead to a place selected for its advantageous position, in reference either to the surrounding features or facility in obtaining a new section of the traverse.

Having sighted to this point, read and plotted the distance, short guide lines should be drawn along the edge of the ruler at both ends and numbered or lettered, so they may be identified from others of like character. The table is then moved to the forward station, approximately oriented by estimation, and the plotted point carefully plumbed over the one on the ground.

The alidade is now placed on the table, and the table oriented by bringing the edge of the ruler close up to the guide lines; then revolving the table until the vertical wire bisects the rod or signal left for that purpose at the last station.

The same processes which were employed at the initial station are now repeated; the detail is mapped and the new station in advance occupied in turn, the line progressing in this manner by successive steps.

In running traverses, great care should be taken to sight as low as possible upon the fore and back signals, so as to avoid any error of deflection which might arise from the inclination of the signal poles.

Subordinate traverse.—When the line is unimportant and few features present themselves to be noted, an auxiliary plane table oriented by a declinatoire or a transit, fitted with stadia wires, may be employed.

When this method is pursued with a second table the forward rod station is not occupied, but another is chosen in advance of it, from which it can be seen where the instrument is set up and oriented with the declinatoire. Sighting the alidade to what is now the back station, the distance is read and plotted along the edge of the ruler, and the point so determined represents the one occupied by the table.

The pivot on which the declinatoire needle rests should be examined frequently as the least roughness will cause the needle to drag and introduces serious deflections in azimuth.

All traverse lines should start and end at well-determined points. This will serve to check the accuracy of the work. If the closing error is not too large, the line should be adjusted by distributing it throughout its length. The line is run on a spare sheet when an auxiliary table is used; then traced, "swung in," and adjusted between the two fixed points.

Determinations for hydrography.—Where the topography surveyed includes the shore line of a body of water, the hydrographic survey of which is intended to follow the topographic work, as in the Coast and Geodetic Survey, it is the duty of the topographer to locate and determine the shore signals, and it is only necessary to state that they should be so placed as to furnish the hydrographic party with as many points as is desirable for the determination of positions on the water.

Natural or artificial objects along the shore, or in plain sight from the water, such as fence ends, rocks, prominent houses, etc., should be determined and marked upon the sheet.

Lines to buoys and other permanent floating objects at anchor should be, as far as practicable, taken at the same stage of the tide, or direction of current.

The mean low-water mark should be delineated, and when it is beyond the reach of the plane-table and presents no marked points for determination, or is of a character that will not permit the use of the instrument—as along the swampy shores in the

South, where the muddy shoals extend far seaward, and among the shifting quicksands of our great estuaries and bays—it may be left to be traced by the work of the hydrographic parties. The channels through mud flats of this character should be indicated, however, if only approximately, by cuts and tangents, or the determination of stakes at the turning points. Where the fall of the tide exposes rocks and ledges, shingle beaches, etc., their character and extent should be delineated and distinguished from the sandy beaches, as these features are most difficult and laborious for the hydrographic survey to represent.

High-water and storm-water line.—In tracing the shore line on an exposed sandy coast care should be taken to discriminate between the average high-water line and the storm-water line.

Determination of inaccessible points.—On a precipitous coast, where the shore line is inaccessible and can not be determined by ordinary methods, the salient features are located, when occupying commanding stations, by observing the vertical angles upon them, and drawing direction lines to them. Then using the elevation of each station as a base the distance to each feature is computed and platted.

The same method applies to outlying rocks, and is often employed where there is any doubt of their being identified from different places.

Large-scale surveys.—As has been previously stated, 1–10000 and 1–20000 are the scales customarily used in the execution of the topographic work of the Coast and Geodetic Survey, as they are the ones best suited for the charting of the coast line and harbors of the United States.

Other surveys for special purposes have been made from time to time on scales both larger and smaller, and the field practice has been modified according to the requirements of the scale used.

A topographic survey of the District of Columbia outside the thickly populated limits of the city of Washington was made between the years of 1880 and 1891 on a scale of 1–4800.

The methods pursued are here described, as they are typical of other surveys on a large scale.

Based on a sufficiently minute triangulation, the plane-table and stadia, wye level, and rod were used for all determinations of details. The relief was elaborately indicated by contour intervals of 5 feet. The datum plane is the same as used by the engineer department of the District, on which is based all the levels used for grades of streets and sewers in the city of Washington, the survey being made for the purpose of extending streets and avenues beyond the city limits.

From this datum, along all roads, avenues, and railroads, and where roads were infrequent, across country, lines of level were run, and after careful checking in the usual manner bench marks were placed in position convenient to all parts of the region.

The plane-table stations were established so as to easily overlook every part of the field and so close together that each was surrounded by the others within the range of a single reading of the stadia rod.

The mode of procedure was as follows:

The plane-table was placed in position by a graphic solution of three-point problem. At the same time the height of the level was determined above some near bench mark and the target of the level rod fixed, so that when it was in the line of sight of the level the bottom of the rod would rest on the ground where the elevation corresponded to that of some contour. The level rodsman then began his journey along this imaginary horizontal line, holding the rod for the observation of the levelman at each noticeable change in the configuration of the ground. The levelman directed the rodsman by signals at each point until the rod was in position on the contour line, when the stadia rod was substituted and its distance read and plotted on the plane-table sheet. The rodmen followed the contour line in both directions from the table as far as the stadia rod could be conveniently read. Generally two and sometimes three contours were run from one level station, and on their completion a turning point was fixed and the level shifted to higher or lower ground, as the circumstances required.

A survey of Craney Island, Virginia, was made in the same manner on a scale of 1–1200.

RAPID SURVEYS.

Military reconnaissance.—In almost every field of operations, from the commencement of the civil war to its close, the plane-table was used.

Until this time very little was known, save in theory, of the value of the plane-table as a reconnoitering instrument, and all the officers engaged in the work testify that, for rapidity and accuracy in the execution of military reconnaissance, it is more effective than any other instrument.

The system usually adopted, in default of triangulation, was to measure a base with an ordinary chain and to do triangulation with the plane-table.

In detailed surveys for the Army, where a topographer averages from 1 to 3 square miles a day, on large scales a chained base of from one-half to three-quarters of a mile for the survey of an area of 25 square miles is found sufficient.

At Chattanooga, from two different bases of about half a mile each, plotted on separate sheets, and carefully measured once with a common 20-meter chain, the same chain being used to measure both bases, after considerable intermediate plane-table triangulation carried on by two officers, two objects were determined 2½ miles apart, common to both sheets, which were on a scale of 1–10000, and the discrepancy was but about 15 meters. Many other points of junction indicated this to be the maximum error. In this case the leaves were mostly off the trees and the hills afforded good points. The sheets covered about 20 square miles each. At Nashville there was a discrepancy of about 10 meters in 2 miles.

At other times, when the character of the country or the pressure of time did not admit of the measurement of a preliminary base and plane-table triangulation, the work was commenced by starting from a single point and extended by linear measurement with the chain or stadia, intersections from the ends of the chained lines being taken to determine objects, which, as the work progressed, could also be used as checks upon the chaining. Where circumstances permitted, an occasional return with the chain to a back point, either to close a series of lines upon it or to start afresh, was resorted to. This work was generally carried on over roads and the interior filled in by sketching and intersections as far as practicable. Some of the tests of this latter work, where the operations of two officers joined, were remarkably close.

A very efficient topographic officer estimates that with the usual number of hands and a good sketcher to aid, in a country of average variety of detail, in which all the houses, prominent barns and outbuildings, streams, roads, general outline of woods, and approximate curves are to be shown, on a scale of 1–10000, an area of between 2 and 3 square miles can be filled in daily, with sufficient accuracy for military purposes.

This rapidity of work, however, could not be expected in or near towns or populous districts. It is doubtful if, under average conditions, the work would be more than one-half this amount.

In some thickly wooded sections and where time is limited, it has been found advisable to run the main roads with the plane table and fill in with the compass, which is more rapid but less accurate than where the entire work is done with the plane table alone. The usual method employed where these methods were combined, was as follows: Where the army was stationary, or moving leisurely, one main road was run with the plane table, the operator being accompanied by assistants well practiced in the use of the compass. Upon arriving at any important road or water course an assistant was sent to the right and left, starting from a plane-table point, determined by the chaining, and running as far as was requisite and then returning to the main road again to repeat the operation, the compass notes, of course, being kept in a book prepared for the purpose. Prominent points determined by the plane table were used as checks in the compass work. The intervening topography, where no compass or plane-table work had been done, was sketched in by the chief of the party, in which accurate pacing became of great value.

With compass and notebook.—Plane-table methods can be utilized to advantage when compass, pencil, notebook, and ruler are the substitutes for an instrumental outfit. The book serves as the sheet and board combined, and the ruler, as it was in the early days of the art, becomes the alidade.*

Photogrammetry.†—In the topographic reconnaissance made for the Alaska Boundary Survey by the Coast and Geodetic Survey, the camera with constant focal length has been used as an adjunct to the small mountain plane table. The latter was used to plot the shore line and adjacent topography, also to determine as many peaks of the interior country as possible by the intersection of lines of direction. All camera stations were determined geographically and hypsometrically, and plotted upon the plane-table sheet. The topographic details beyond the reach of the plane-table were added to the map in the Office by the photogrammetric methods.

The rugged mountains of southeast Alaska appear particularly well adapted for this mode of procedure, as identical points can be readily picked out from different panorama views, owing to the characteristic shapes of the mountain peaks, snow fields, glaciers, etc.

Periods of fair weather are also very short and of rare occurrence in that locality, and a great deal of topographic material can be gathered photographically in a short time, which when plotted will cover a large territory if a sufficient number of reference points on the views have been located instrumentally.

The plotting proper can be carried out to any degree of minuteness and detail; the only requirement is that a sufficient number of camera stations shall have been occupied

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*See "Sketching without instruments," in Topography, Drawing, and Sketching, by Lieut. Henry A. Reed, U. S. Army, 1886.

†See United States Coast and Geodetic Survey Report, 1893, Appendix 3, and Report for 1897, Appendix 10.

to fully cover the territory in question, so that every topographic feature of prominence has been seen or photographed from at least two stations.

By this application of photogrammetry the plane-table methods of determining topographic details are extended to the Office, inasmuch as the same features are selected from the panorama views and plotted geographically which would have been located by the plane-table. But the actual time spent in the field is reduced at the expense of the time needed for office work.

Survey in advance of triangulation.—Where it is necessary to make a topographic survey in advance of the determination of points by triangulation, a reconnaissance is first made for the location of a base line and selection of points to be determined with the plane table.

The base is measured with sufficient accuracy and conveniently, with a steel tape which has been compared with a standard at a fixed tension, and to one end of which is attached a spring balance to secure the same tension during measurement. The successive lengths are marked by lines cut on copper tacks driven in wooden stubs firmly set in the ground. The temperature is noted at frequent intervals as the work progresses, and the corrections are applied to the length of the base when completed.

The base is then properly located on the sheet in reference to the area to be embraced and its length carefully set off. It is well at the same time to mark in three or four different parts of the sheet lengths of 1 000 meters for the purpose of determining at any time the true scale of the sheet, variable by the different hygrometric conditions of the atmosphere.

Signals having been erected at the selected points, the extremes of the base are occupied with the table and the points, as far as may be reached with good intersections, determined from them and lines of direction drawn to all the points visible, to serve as checks upon their determination from other points furnishing directions for good intersections. The survey then proceeds as usual.

It is well at the beginning of work to draw (using the declinatoire) the magnetic meridian, at some determined point near the middle of the sheet for the purpose of putting the table in approximate position at any station with the declinatoire. The manner of doing this is described elsewhere.

Before finishing the field work it is important, when the sheet has no projection, to provide data for drawing a true north and south line. This is done by drawing from a point upon the sheet, when the table is in position, a line in the vertical plane through Polaris and the point occupied and recording the time of observation. The azimuth of the star at that time being known, a true north and south line can accordingly be set off.

If a small transit instrument is at hand and carefully adjusted for movement in vertical plane, an assistant with a lantern can be located where the vertical plane through Polaris and the point occupied intersects the ground, at as great a distance from the point as the ground will admit within the limit of communication by light signals. When such a position is marked the direction from the point occupied may be determined by daylight.

If, in the absence of a transit, the alidade has not vertical range sufficient to observe Polaris, an illuminated plumb line may be used for the alignment.

OFFICE WORK.

All the topographic features of a survey should be drawn in pencil upon the sheet in the field, while they can be seen. Sketching and plotting in the office from notes, unless the country be near at hand for ready reference in case of doubt or defective data, is objectionable. When this is unavoidable, the sketches should be transferred to the sheet as soon as possible after being made, while fresh in the mind of the person by whom they were made, and by whom they should be plotted. Days which, from inclemency of the weather, are unfavorable for out-of-door work should be allotted to this purpose, and advantage should be taken of them, also, for retouching any details of the sheet which may have become indistinct, as it is very important that they should not be left indefinite or become obliterated; for when the inking is done, as it generally is, at a distance from the field of operations, the necessity for this care is obvious. Nos. 4 and 5 pencils are good for this purpose, for which very hard or very soft and black pencils are equally unsuited.

In the inking of a topographic sheet three requisites to its proper appearance when finished should be borne in mind—clearness, neatness, and uniformity.

The lines and objects should be clear and sharply defined, nothing being left obscure or doubtful; the paper should be kept unsoiled, and erasures avoided as far as possible, and the style and strength of the drawing should be the same throughout. It is an important matter that an easy and natural appearance should be given to the sheet, for, as before remarked, a mere rigid adherence to conventional signs is not all that is necessary; while there should be no deviation in this respect, at the same time the draftsman should strive to *represent the country.* There is a great difference with regard to this among topographers. Two correct sheets of the same section of ground, executed by different persons, may be inked, and while one will have a stiff and ungraceful look, the other will appear artistic and natural, giving at once the impression of a true representation of the country surveyed.

Office work should not be commenced until the topography is entirely completed, as no inked or partially inked sheet should ever be used in the field. Sometimes, for the special examination of old work, or for the insertion of some recent artificial or natural changes, this becomes necessary, but there is always a risk of injuring an inked sheet by exposure to the weather or by using it upon a plane table.

The inking should begin with the high and low water lines. The high-water line or shore line proper should, in all cases, be full and black, the heaviest line on the sheet, and in this, as in all the rest of the ink work, the lines of the surveyor should be strictly adhered to.

The topography as drawn in the field is supposed to be correet when the sheet is finished, and no office amendments or changes are admissible. The low-water line is drawn, not so full as the former, but clear, black, and uniform, consisting of a dotted line for sand and mud and the conventional sign where it is formed by shells, rocks, or coral reefs.

Neither the inner border of a marsh nor a shoal covered at high tide has a distinct continuous line to mark its limits, each being represented in its proper form and within its area by its conventional sign only, but the shape should be well and correctly defined. All objects between high and low water, covered at full tide, should be represented less boldly than the other features on the sheet, but not faintly or indefinitely.

The roads should be inked plainly and evenly, with their sides parallel, except where the survey shows a deviation from the general width. Main thoroughfares when fenced are drawn with a full line, subordinate roads where fenced should be shown by the usual sign, and where there is ro inclosure a line of dashes should indicate the roadside, and then should follow the fences and houses. In drawing the latter, care must be taken that the corners and angles exhibit a sharp, clear outline, which adds much to the appearance of the sheet.

The general skeleton of the survey being now completed, the contours are drawn with a bold, uniform, plain red line, without break, over all the other work, following accurately the full range of level of each of the contours on the sheet.

After this comes the general filling in, by conventional signs, of sand, marsh, grass, cultivation, orchards, rocks, hachures, etc. Some practice is needed to execute the sand work regularly and neatly. It should never be done hurriedly, though of course rapidity in this respect follows practice. The lines representing marsh, and the delineation of grass on the fast ground, should always run in the same direction over the whole sheet and be parallel to the top of the sheet and the title. The appended drawings (Illustratious 17, 18, 19, 20, and 21) give the conventional signs as adopted by and now used by the Coast and Geodetic Survey.

The most difficult part of the inking for a beginner is the lettering, which now follows, and for which samples are given (Illustration 22). It is expected that every topographer shall have learned to draw sufficiently well to ink his sheet in a clear and distinct manner and letter it with some regard to neatness and graphic effect, as the appearance of an otherwise well-inked sheet is marred by careless or indifferent lettering.

The location of the names upon the sheet should be such as not to cover or obliterate any detail or feature of the survey, and the letters should be put on neatly and gracefully, and in point of size and form according to the specimens furnished. The title should follow, with such notes as may be necessary to explain any peculiarity of the sheet or survey.* This title and lettering should, as far as practicable, be so placed that when the sheet is held with the top (the north end of the map) from you it can be easily read; in other words, as nearly parallel to the top or upper end of the sheet as the nature of the work will admit. All names well established and recognized in a neighborhood, both general and local, should be collected during the survey, and their correct orthography ascertained, and in case of any doubtful or disputed orthography a report should be made giving any traditions or authorities which bear upon the subject. No illuminated or German text, old English, or what is known as "fancy printing," should be indulged in, a strict adherence to simplicity being required.

The minutes of the parallels of latitude and meridians of longitude should be marked in figures at the upper and right-hand ends, respectively, the degrees on the center parallel and center meridian only.

When buoys are determined by the topographer, and their names, colors, numbers, or kind are known, they should be placed on the sheet and so marked.

* The topographers in the Coast and Geodetic Survey are required to write the title and notes on a separate sheet of paper and attach it to the plane table sheet. This portion of the lettering is done at the Office.

The triangulation points should be surrounded by a small red triangle. Barns, houses, prominent trees, and other objects determined by the plane table that may be used as points of reference in making additions to the sheet subsequent to the survey should be indicated by a small blue circle.

TABLES AND FORMULÆ.

Table for reducing readings of inclined sights on a rod held perpendicular to the line of sight.

Angle	Hypothenuse				
	100 meters	200 meters	300 meters	400 meters	500 meters
5°	99.62	199.24	298.86	398.48	498.10
10°	98.48	196.96	295.44	393.92	492.40
15°	96.59	193.19	289.78	386.37	482.96
20°	93.97	187.94	281.91	375.88	469.85
25°	90.63	181.26	271.89	362.52	453.15
30°	86.60	173.21	259.81	346.41	433.01
35°	81.92	163.83	245.75	327.66	409.58
40°	76.60	153.21	229.81	306.42	383.02
45°	70.71	141.42	212.13	282.84	353.55

When it is desired to use the preceding table, a sight must be attached to the rod or the proper position of the rod left to the judgment of the rodsman. The usual and safer way is to have the rod held vertical for all readings. There are then two corrections to be applied, one to reduce the inclined distance to a horizontal one and one for the oblique view of the rod.

The equation for reducing the readings is:

$$\text{Horizontal distance} = r \cos^2 v + (c+f) \cos v$$

Where r = reading of vertical rod;

v = angle of elevation or depression;

c = distance of object glass to center of instrument;

f = focal length of telescope.

The following table gives the coefficient of reduction by which the rod reading is to be multiplied. It is based on the assumption that $c+f$ is to be added to the result to obtain the distance to the center of the instrument.

Example: Given an angle of elevation or depression 8° 10′ and the reading of the inclined sight on vertical rod = 173.1 meters.

From the table:

Factor for 1 meter for 8° 10′ multiplied by 100	=	97.98	meters.
" " 7 " " " " " " 10	=	68.59	"
" " 3 " " " "	=	2.94	"
" " 0.1 " " " "	=	.09	"
Horizontal distance		169.60	"

To which $c+f$ is to be added.

*Table of coefficients for reducing readings of inclined sights on a vertical rod to horizontal distance.**

Angle of inclination	Horizontal projection of								
	1 m.	2 m.	3 m.	4 m.	5 m.	6 m.	7 m.	8 m.	9 m.
0° 10′	.99999	1.99998	2.99997	3.99997	4.99996	5.99994	6.99994	7.99993	8.99993
20′	.99997	1.99993	2.99990	3.99986	4.99983	5.99980	6.99977	7.99973	8.99970
30′	.99992	1.99984	2.99977	3.99969	4.99962	5.99954	6.99946	7.99939	8.99932
40′	.99986	1.99973	2.99959	3.99946	4.99932	5.99919	6.99905	7.99892	8.99878
50′	.99979	1.99957	2.99936	3.99915	4.99894	5.99873	6.99852	7.99831	8.99810
1° 00′	.99970	1.99939	2.99909	3.99878	4.99848	5.99817	6.99787	7.99757	8.99726
10′	.99959	1.99917	2.99875	3.99834	4.99793	5.99752	6.99711	7.99669	8.99628
20′	.99946	1.99891	2.99838	3.99783	4.99729	5.99676	6.99622	7.99568	8.99514
30′	.99932	1.99863	2.99794	3.99725	4.99657	5.99589	6.99520	7.99452	8.99384
40′	.99915	1.99831	2.99746	3.99659	4.99572	5.99489	6.99406	7.99323	8.99239
50′	.99908	1.99801	2.99693	3.99590	4.99488	5.99386	6.99284	7.99182	8.99080
2° 00′	.99878	1.99756	2.99635	3.99513	4.99391	5.99269	6.99147	7.99025	8.98904
10′	.99857	1.99714	2.99571	3.99428	4.99285	5.99142	6.99000	7.98857	8.98714
20′	.99834	1.99669	2.99503	3.99337	4.99171	5.99006	6.98840	7.98675	8.98509
30′	.99810	1.99620	2.99429	3.99239	4.99049	5.98859	6.98669	7.98479	8.98289
40′	.99784	1.99568	2.99351	3.99135	4.98918	5.98702	6.98485	7.98268	8.98053
50′	.99756	1.99511	2.99267	3.99023	4.98778	5.98534	6.98290	7.98046	8.97802
3° 00′	.99726	1.99452	2.99178	3.98904	4.98630	5.98357	6.98083	7.97809	8.97635
10′	.99695	1.99390	2.99085	3.98780	4.98474	5.98169	6.97865	7.97560	8.97255
20′	.99662	1.99324	2.98986	3.98648	4.98309	5.97972	6.97634	7.97296	8.96958
30′	.99627	1.99255	2.98882	3.98509	4.98136	5.97764	6.97391	7.97019	8.96646
40′	.99591	1.99182	2.98773	3.98364	4.97955	5.97546	6.97137	7.96728	8.96319
50′	.99553	1.99106	2.98659	3.98212	4.97765	5.97318	6.96871	7.96424	8.95978
4° 00′	.99513	1.99027	2.98540	3.98054	4.97567	5.97081	6.96595	7.96108	8.95621
10′	.99472	1.98944	2.98416	3.97888	4.97360	5.96832	6.96304	7.95776	8.95249
20′	.99429	1.98858	2.98287	3.97716	4.97145	5.96574	6.96003	7.95432	8.94862
30′	.99384	1.98769	2.98153	3.97537	4.96922	5.96306	6.95691	7.95075	8.94460
40′	.99338	1.98676	2.98014	3.97352	4.96690	5.96028	6.95366	7.94704	8.94043
50′	.99290	1.98580	2.97870	3.97160	4.96450	5.95740	6.95030	7.94320	8.93611
5° 00′	.99240	1.98481	2.97721	3.96961	4.96202	5.95443	6.94683	7.93923	8.93164
10′	.99189	1.98378	2.97567	3.96756	4.95945	5.95134	6.94323	7.93512	8.92702
20′	.99136	1.98272	2.97408	3.96544	4.95680	5.94816	6.93952	7.93088	8.92224
30′	.99081	1.98163	2.97244	3.96326	4.95407	5.94489	6.93570	7.92652	8.91733
40′	.99025	1.98050	2.97075	3.96100	4.95125	5.94150	6.93175	7.92200	8.91225
50′	.98967	1.97934	2.96901	3.95868	4.94835	5.93802	6.92769	7.91736	8.90703
6° 00′	.98907	1.97814	2.96722	3.95630	4.94537	5.93445	6.92358	7.91260	8.90167
10′	.98846	1.97692	2.96538	3.95384	4.94230	5.93077	6.91923	7.90769	8.89615
20′	.98783	1.97566	2.96349	3.95132	4.93915	5.92698	6.91481	7.90264	8.89048
30′	.98718	1.97436	2.96155	3.94873	4.93591	5.92310	6.91029	7.89748	8.88467
40′	.98652	1.97304	2.95956	3.94609	4.93261	5.91913	6.90566	7.89218	8.87870
50′	.98584	1.97169	2.95753	3.94337	4.92921	5.91506	6.90090	7.88674	8.87259
7° 00′	.98515	1.97030	2.95544	3.94059	4.92574	5.91089	6.89604	7.88119	8.86634

*Computed by J. A. Flemer, Assistant, Coast and Geodetic Survey.

Table of coefficients for reducing readings of inclined sights on a vertical rod to horizontal distance—Continued.

Angle of inclination	Horizontal projection of								
	1 m.	2 m.	3 m.	4 m.	5 m.	6 m.	7 m.	8 m.	9 m.
10′	.98444	1.96888	2.95331	3.93775	4.92218	5.90662	6.89105	7.87549	8.85993
20′	.98371	1.96742	2.95112	3.93483	4.91854	5.90225	6.88596	7.86967	8.85337
30′	.98296	1.96592	2.94889	3.93185	4.91481	5.89777	6.88073	7.86370	8.84667
40′	.98220	1.96441	2.94661	3.92881	4.91101	5.89322	6.87542	7.85762	8.83982
50′	.98142	1.96285	2.94427	3.92570	4.90712	5.88855	6.86997	7.85140	8.83282
8° 00′	.98063	1.96126	2.94189	3.92252	4.90315	5.88378	6.86441	7.84504	8.82568
10′	.97982	1.95964	2.93946	3.91928	4.89910	5.87892	6.85874	7.83856	8.81839
20′	.97899	1.95798	2.93698	3.91598	4.89497	5.87396	6.85296	7.83196	8.81096
30′	.97815	1.95630	2.93446	3.91261	4.89076	5.86891	6.84707	7.82522	8.80337
40′	.97729	1.95459	2.93188	3.90918	4.88647	5.86377	6.84106	7.81836	8.79565
50′	.97642	1.95284	2.92926	3.90568	4.88209	5.85851	6.83493	7.81134	8.78777
9° 00′	.97553	1.95106	2.92658	3.90211	4.87764	5.85317	6.82870	7.80423	8.77975
10′	.97462	1.94924	2.92386	3.89848	4.87310	5.84772	6.82234	7.79696	8.77159
20′	.97370	1.94740	2.92110	3.89480	4.86849	5.84219	6.81589	7.78959	8.76328
30′	.97276	1.94552	2.91828	3.89104	4.86379	5.83655	6.80931	7.78207	8.75483
40′	.97180	1.94361	2.91542	3.88722	4.85902	5.83083	6.80263	7.77444	8.74624
50′	.97083	1.94166	2.91250	3.88333	4.85416	5.82499	6.79583	7.76667	8.73750
10° 00′	.96985	1.93970	2.90954	3.87938	4.84923	5.81907	6.78892	7.75876	8.72861
10′	.96884	1.93769	2.90653	3.87537	4.84421	5.81306	6.78190	7.75074	8.71959
20′	.96782	1.93565	2.90347	3.87129	4.83912	5.80695	6.77477	7.74259	8.71042
30′	.96679	1.93358	2.90037	3.86716	4.83395	5.80074	6.76753	7.73432	8.70111
40′	.96574	1.93148	2.89721	3.86295	4.82869	5.79443	6.76017	7.72591	8.69165
50′	.96467	1.92934	2.89402	3.85869	4.82336	5.78803	6.75271	7.71738	8.68206
11° 00′	.96359	1.92718	2.89077	3.85436	4.81795	5.78154	6.74513	7.70872	8.67232
10′	.96249	1.92498	2.88748	3.84997	4.81247	5.77496	6.73746	7.69995	8.66245
20′	.96138	1.92276	2.88414	3.84552	4.80690	5.76828	6.72966	7.69104	8.65242
30′	.96025	1.92051	2.88076	3.84101	4.80126	5.76152	6.72177	7.68202	8.64227
40′	.95911	1.91822	2.87732	3.83643	4.79553	5.75464	6.71375	7.67286	8.63196
50′	.95795	1.91590	2.87385	3.83180	4.78974	5.74769	6.70564	7.66358	8.62153
12° 00′	.95677	1.91355	2.87032	3.82709	4.78386	5.74063	6.69741	7.65418	8.61095
10′	.95558	1.91116	2.86674	3.82232	4.77790	5.73348	6.68906	7.64464	8.60023
20′	.95438	1.90876	2.86313	3.81750	4.77187	5.72625	6.68062	7.63500	8.58938
30′	.95315	1.90631	2.85946	3.81261	4.76576	5.71892	6.67207	7.62522	8.57838
40′	.95192	1.90384	2.85575	3.80766	4.75958	5.71150	6.66341	7.61533	8.56724
50′	.95066	1.90132	2.85199	3.80265	4.75332	5.70399	6.65465	7.60532	8.55598
13° 00′	.94940	1.89880	2.84820	3.79759	4.74698	5.69638	6.64577	7.59516	8.54456
10′	.94811	1.89623	2.84434	3.79245	4.74056	5.68868	6.63679	7.58491	8.53302
20′	.94682	1.89364	2.84045	3.78726	4.73407	5.68088	6.62770	7.57452	8.52133
30′	.94550	1.89101	2.83651	3.78201	4.72751	5.67301	6.61852	7.56402	8.50952
40′	.94417	1.88835	2.83252	3.77669	4.72087	5.66505	6.60922	7.55339	8.49757
50′	.94283	1.88566	2.82849	3.77132	4.71415	5.65698	6.59981	7.54264	8.48548
14° 00′	.94147	1.88295	2.82442	3.76589	4.70736	5.64884	6.59031	7.53179	8.47326

Table of coefficients for reducing readings of inclined sights on a vertical rod to horizontal distance—Concluded.

Angle of inclination	Horizontal projection of								
	1 m.	2 m.	3 m.	4 m.	5 m.	6 m.	7 m.	8 m.	9 m.
10′	.94010	1.88020	2.82030	3.76040	4.70050	5.64060	6.58070	7.52080	8.46090
20′	.93871	1.87742	2.81613	3.75484	4.69355	5.63226	6.67097	7.50968	8.44840
30′	.93731	1.87462	2.81192	3.74923	4.68654	5.62385	6.56115	7.49846	8.43578
40′	.93589	1.87178	2.80767	3.74356	4.67945	5.61534	6.55123	7.48712	8.42302
50′	.93446	1.86892	2.80338	3.73784	4.67229	5.60675	6.54121	7.47567	8.41013
15° 00′	.93301	1.86602	2.79903	3.73204	4.66505	5.59806	6.53107	7.46408	8.39710
16° 00′	.92402	1.84805	2.77208	3.69610	4.62011	5.54414	6.46816	7.39218	8.31620
17° 00′	.91452	1.82904	2.74355	3.65806	4.57258	5.48710	6.40161	7.31613	8.23065
18° 00′	.90451	1.80902	2.71352	3.61803	4.52253	5.42704	6.33154	7.23605	8.14056
19° 00′	.89400	1.78800	2.68201	3.57600	4.47001	5.36402	6.25802	7.15203	8.04603
20° 00′	.88302	1.76604	2.64906	3.53208	4.41510	5.29812	6.18114	7.06416	7.94718

TABLE I.—*Table showing the height in feet corresponding to a given angle of elevation and a given distance in meters.**

Meters	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
Angle	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
1′	0.3	0.4	0.6	0.6	0.8	0.9	1.0	1.2	1.3	1.5	1.7	1.8	2.0	2.2	2.3	2.5	2.7	2.8
2	0.6	0.8	1.0	1.2	1.5	1.7	1.9	2.1	2.4	2.6	2.9	3.1	3.4	3.7	3.9	4.2	4.5	4.7
3	0.9	1.2	1.5	1.8	2.2	2.5	2.8	3.1	3.4	3.8	4.2	4.4	4.8	5.3	5.6	5.9	6.3	6.6
4	1.2	1.5	2.0	2.4	2.8	3.2	3.6	4.1	4.5	4.9	5.4	5.8	6.3	6.8	7.2	7.6	8.1	8.6
5	1.5	1.9	2.4	2.9	3.5	4.0	4.5	5.0	5.5	6.1	6.6	7.1	7.7	8.3	8.8	9.4	9.9	10.5
6	1.8	2.3	2.9	3.5	4.2	4.8	5.3	5.9	6.6	7.2	7.9	8.5	9.1	9.8	10.4	11.1	11.7	12.4
7	2.1	2.7	3.4	4.1	4.8	5.5	6.2	6.9	7.6	8.4	9.1	9.8	10.6	11.4	12.1	12.8	13.5	14.3
8	2.4	3.1	3.9	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.4	11.1	12.0	12.9	13.7	14.5	15.3	16.2
9	2.7	3.5	4.4	5.2	6.2	7.0	7.9	8.8	9.7	10.7	11.6	12.5	13.4	14.4	15.3	16.2	17.2	18.1
10	2.9	3.8	4.9	5.8	6.8	7.8	8.8	9.8	10.8	11.8	12.8	13.8	14.9	15.9	16.9	17.9	19.0	20.0
11	3.2	4.2	5.3	6.4	7.5	8.6	9.6	10.7	11.8	13.0	14.1	15.1	16.3	17.5	18.6	19.7	20.8	21.9
12	3.5	4.6	5.8	6.9	8.2	9.3	10.5	11.7	12.9	14.1	15.3	16.5	17.7	19.0	20.2	21.4	22.6	23.8
13	3.8	5.0	6.3	7.5	8.8	10.1	11.4	12.6	13.9	15.2	16.6	17.8	19.2	20.5	21.8	23.1	24.4	25.7
14	4.1	5.4	6.8	8.1	9.5	10.9	12.2	13.6	15.0	16.4	17.8	19.1	20.6	22.0	23.4	24.8	26.2	27.6
15	4.4	5.7	7.2	8.6	10.2	11.6	13.1	14.5	16.0	17.5	19.0	20.5	22.0	23.6	25.0	26.5	28.0	29.5
16	4.7	6.1	7.7	9.2	10.8	12.4	13.9	15.5	17.1	18.7	20.3	21.8	23.5	25.1	26.7	28.2	29.9	31.4
17	4.9	6.5	8.2	9.8	11.5	13.1	14.8	16.5	18.1	19.8	21.5	23.1	24.9	26.6	28.3	30.0	31.7	33.4
18	5.2	6.9	8.7	10.4	12.2	13.9	15.7	17.4	19.2	21.0	22.8	24.5	26.3	28.2	29.9	31.7	33.5	35.3
19	5.5	7.3	9.1	10.9	12.8	14.7	16.5	18.4	20.2	22.1	24.0	25.8	27.7	29.7	31.5	33.4	35.3	37.2
20	5.8	7.7	9.6	11.5	13.5	15.4	17.4	19.3	21.3	23.3	25.2	27.2	29.2	31.2	33.2	35.1	37.1	39.1
21	6.1	8.0	10.1	12.1	14.2	16.2	18.2	20.3	22.3	24.4	26.5	28.5	30.6	32.7	34.8	36.8	38.9	41.0
22	6.4	8.4	10.6	12.6	14.9	17.0	19.1	21.2	23.4	25.5	27.7	29.8	32.0	34.3	36.4	38.5	40.7	42.9
23	6.7	8.8	11.1	13.2	15.5	17.7	20.0	22.2	24.4	26.7	29.0	31.2	33.5	35.8	38.0	40.3	42.5	44.8
24	6.9	9.2	11.5	13.8	16.2	18.5	20.8	23.1	25.5	27.8	30.2	32.5	34.9	37.3	39.6	42.0	44.3	46.7
25	7.2	9.6	12.0	14.4	16.9	19.3	21.7	24.1	26.5	29.0	31.4	33.8	36.3	38.8	41.3	43.7	46.2	48.6
26	7.5	9.9	12.5	14.9	17.5	20.0	22.5	25.0	27.6	30.1	32.7	35.2	37.8	40.4	42.9	45.4	48.0	50.5
27	7.8	10.3	13.0	15.5	18.2	20.8	23.4	26.0	28.6	31.3	33.9	36.5	39.2	41.9	44.5	47.1	49.8	52.4
28	8.1	10.7	13.4	16.1	18.9	21.5	24.2	26.9	29.7	32.4	35.2	37.8	40.6	43.4	46.1	48.8	51.6	54.3
29	8.4	11.1	13.9	16.7	19.5	22.3	25.1	27.9	30.7	33.6	36.4	39.2	42.1	45.0	47.8	50.6	53.4	56.2
30	8.7	11.5	14.4	17.2	20.2	23.1	26.0	28.9	31.8	34.7	37.6	40.5	43.5	46.5	49.4	52.3	55.2	58.2
40	11.5	15.3	19.2	22.9	26.9	30.7	34.6	38.4	42.3	46.1	50.0	53.9	57.8	61.7	65.6	69.4	73.3	77.3
50	14.4	19.1	23.9	28.7	33.5	38.3	43.2	47.9	52.7	57.6	62.4	67.2	72.1	77.0	81.8	86.6	91.5	96.3
1° 00	17.2	22.9	28.7	34.4	40.2	46.0	51.7	57.5	63.3	69.0	74.8	80.6	86.4	92.3	98.0	104	110	115
1 10	20.1	26.7	33.5	40.1	46.9	53.6	60.3	67.0	73.8	80.5	87.2	93.9	100.7	107.5	114.3	121	128	134
1 20	23.0	30.5	38.3	45.8	53.6	61.2	69.0	76.6	84.2	91.9	99.6	107.3	115.1	123	131	138	146	154
1 30	25.8	34.4	43.0	51.6	60.3	69.0	77.7	86.1	94.7	103.4	112.0	120.7	130	138	147	155	164	173
1 40	28.7	38.2	47.8	57.3	66.9	76.6	86.3	95.6	105.2	115	124	134	144	153	163	173	182	192
1 50	31.6	42.0	52.6	63.0	73.6	84.2	94.9	105.2	115.7	126	137	147	158	169	179	190	200	211
2 00	34.4	45.8	57.4	68.9	80	92	103	115	126	138	149	161	172	184	195	207	218	230
2 30	43.0	57.3	71.7	86.0	100	115	129	144	158	172	186	201	215	230	244	259	273	287
3 00	51.6	68.8	86.2	103.2	120	138	155	172	190	207	224	241	259	276	293	310	328	345
3 30	60.2	80.4	100.5	120.5	141	161	181	201	221	241	261	281	302	322	342	362	382	402
4 00	68.9	91.8	114.8	137.7	161	184	207	230	253	276	299	322	345	368	391	414	437	460

***Curvature and refraction taken into account for angles of elevation. This table should not be used for angles of depression.**

Example of use of table of heights.

[Angle of elevation from point A to point B, distant from each other 1756 meters=1° 56′.]

	Meters.	Feet.
1° 50′......	1700	179.00
1° 50′......	50	5.26
1° 50′......	6	.63
0° 06′......	1700	10.40
0° 06′......	50	.29
0° 06′......	6	.04
		195.62

Point B is 195.62 feet above point A.

Formula for determining heights by a vertical angle and distance.—The difference of level consists of two parts—that which arises from the angle of elevation above the horizontal plane of the station and that which is due to the curvature of the earth. The former depends upon the angle and distance, the latter upon the distance and the earth's radius. If a' be the angle of elevation in minutes of arc, d the distance, h the height, then, as the tangent of 1′ is $\frac{1}{3437}$, we have for the first part $h=\frac{1}{3437}a'd$, if h and d are both expressed in the same units of length, but if d is expressed in meters and h in feet, one meter being 3.28 feet, we get $h=\frac{1}{1048}a'd$. For the fraction $\frac{1}{1048}$ we may conveniently and with sufficient accuracy put $\frac{1}{1000}$ less $\frac{1}{20}$ of $\frac{1}{1000}$, and thus find the rule: *Multiply the distance in meters by the number of minutes of arc, point off the thousandth part, and subtract the twentieth part of the number thus obtained.* This will give the first portion of difference of height, whether elevation or depression.

The second term, depending on the curvature, varies as the square of the distance, and amounts to 0.22 foot in 1000 meters, including the effect of ordinary refraction. As with the instruments under consideration extreme accuracy is not attainable, it is plain that for distances under 1000 meters this term may be neglected. When the distance is greater, we have the following rule: *Take the thousandth part of the distance in meters, square the same, having regard to the first decimal figure, and multiply by* 0.22. This term is always positive. If the first term be an elevation, it is increased; if a depression, it it diminished by the second term.

Example.—Distance=5500 meters; angle of elevation, 36′.

$\frac{1}{1000}d \times a'$	=198.000	$\frac{1}{1000}d$	= 5.5
subtract $\frac{1}{20}$	9.9	square	=30.2
		multiply by	0.22
first term	188.1		
second term	6.6	second term	6.64
sum	194.7=difference of elevation in feet.		

TABLE II.—*Table showing the height, in meters, corre-*

(Curvature and refraction

	100	200	300	400	500	600	700	800	900	1000	1100	1200
0° 1′	0.03	0.06	0.09	0.13	0.16	0.20	0.24	0.28	0.32	0.36	0.40	0.45
2	0.06	0.12	0.18	0.24	0.31	0.37	0.44	0.51	0.58	0.65	0.72	0.79
3	0.09	0.18	0.27	0.36	0.45	0.55	0.64	0.74	0.84	0.94	1.04	1.14
4	0.12	0.24	0.36	0.48	0.60	0.72	0.85	0.97	1.10	1.23	1.36	1.39
5	0.15	0.29	0.44	0.59	0.74	0.90	1.05	1.21	1.36	1.52	1.68	1.84
0° 6′	0.18	0.35	0.53	0.70	0.89	1.07	1.26	1.44	1.62	1.81	2.00	2.19
7	0.20	0.41	0.62	0.82	1.04	1.24	1.46	1.67	1.89	2.10	2.32	2.44
8	0.23	0.47	0.70	0.94	1.18	1.42	1.66	1.90	2.16	2.39	2.64	2.89
9	0.26	0.53	0.79	1.06	1.33	1.59	1.87	2.14	2.41	2.68	2.96	3.24
10	0.29	0.58	0.88	1.18	1.47	1.77	2.07	2.37	2.68	2.98	3.28	3.59
0° 11′	0.32	0.64	0.97	1.29	1.62	1.94	2.27	2.60	2.93	3.27	3.60	3.74
12	0.35	0.70	1.05	1.41	1.76	2.12	2.48	2.84	3.20	3.56	3.92	4.29
13	0.38	0.76	1.14	1.52	1.91	2.29	2.68	3.07	3.46	3.85	4.24	4.63
14	0.41	0.82	1.23	1.64	2.05	2.47	2.88	3.30	3.72	4.14	4.56	4.98
15	0.44	0.88	1.32	1.76	2.20	2.64	3.08	3.53	3.98	4.43	4.88	5.33
0° 16′	0.47	0.93	1.40	1.87	2.34	2.82	3.29	3.77	4.24	4.72	5.20	5.68
17	0.50	0.99	1.49	1.99	2.49	2.99	3.49	3.90	4.50	5.01	5.52	6.03
18	0.52	1.05	1.58	2.10	2.64	3.17	3.70	4.23	4.77	5.30	5.84	6.38
19	0.55	1.11	1.66	2.22	2.78	3.34	3.90	4.46	5.03	5.59	6.16	6.63
20	0.58	1.17	1.75	2.34	2.93	3.51	4.11	4.70	5.29	5.88	6.48	7.08
0° 21′	0.61	1.23	1.84	2.45	3.07	3.69	4.31	4.93	5.55	6.17	6.80	7.43
22	0.64	1.28	1.93	2.57	3.22	3.86	4.51	5.16	5.81	6.47	7.12	7.78
23	0.67	1.34	2.01	2.69	3.36	4.04	4.72	5.40	6.08	6.76	7.44	8.12
24	0.70	1.40	2.10	2.80	3.50	4.21	4.92	5.63	6.34	7.05	7.76	8.47
25	0.73	1.46	2.19	2.92	3.65	4.39	5.12	5.88	6.60	7.34	8.08	8.82
0° 26′	0.76	1.52	2.28	3.04	3.80	4.56	5.33	6.09	6.86	7.63	8.40	9.17
27	0.79	1.57	2.36	3.15	3.95	4.74	5.53	6.33	7.12	7.92	8.72	9.52
28	0.82	1.63	2.45	3.27	4.09	4.91	5.74	6.56	7.38	8.21	9.04	9.87
29	0.84	1.69	2.54	3.38	4.24	5.08	5.94	6.79	7.65	8.50	9.36	10.22
30	0.87	1.75	2.62	3.50	4.38	5.26	6.14	7.02	7.91	8.79	9.68	10.57
0° 40′	1.16	2.33	3.50	4.66	5.84	7.00	8.18	9.35	10.53	11.70	12.88	14.06
50	1.45	2.91	4.37	5.83	7.29	8.75	10.22	11.68	13.14	14.62	16.08	17.55
1 00	1.75	3.49	5.24	6.99	8.74	10.50	12.25	14.01	15.76	17.52	19.28	21.04
1 10	2.04	4.08	6.12	8.16	10.20	12.24	14.29	16.33	18.38	20.43	22.48	24.53
1 20	2.33	4.66	6.99	9.32	11.66	13.99	16.33	18.66	21.00	23.34	25.68	28.03
1° 30′	2.62	5.24	7.86	10.48	13.11	15.73	18.36	20.99	23.62	26.25	28.88	31.52
1 40	2.91	5.82	8.74	11.65	14.56	17.48	20.40	23.32	26.24	29.16	32.09	35.01
1 50	3.20	6.40	9.61	12.82	16.02	19.23	22.44	25.65	28.86	32.08	35.29	38.51
2 00	3.49	6.99	10.48	13.98	17.49	20.98	24.48	27.98	31.48	34.99	38.49	42.00
2° 30′	4.37	8.74	13.11	17.28	21.85	26.22	30.60	34.97	39.35	43.73	48.11	52.49
3 00	5.24	10.48	15.73	20.97	26.22	31.47	36.72	41.97	47.22	52.47	57.73	62.99
3 30	6.12	12.24	18.36	24.48	30.60	36.72	42.85	44.97	55.10	61.23	67.36	73.49
4 00	6.99	13.99	20.98	27.98	34.98	41.98	48.98	55.98	62.99	69.99	77.00	84.01
	100	200	300	400	500	600	700	800	900	1000	1100	1200

* Curvature and refraction taken into account for angles of

*sponding to given angles of elevation and distances in meters.**

taken into account.)

1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	
0.49	0.54	0.59	0.64	0.69	0.74	0.80	0.85	0.90	0.96	1.02	1.08	1.14	0° 1′
0.87	0.95	1.02	1.10	1.18	1.26	1.35	1.43	1.52	1.60	1.69	1.78	1.87	2
1.25	1.35	1.46	1.57	1.68	1.79	1.90	2.01	2.13	2.24	2.36	2.48	2.60	3
1.63	1.76	1.90	2.03	2.17	2.31	2.45	2.59	2.74	2.88	3.03	3.18	3.33	4
2.00	2.17	2.33	2.50	2.67	2.83	3.00	3.18	3.35	3.52	3.70	3.88	4.05	5
2.38	2.57	2.77	2.96	3.16	3.35	3.56	3.76	3.96	4.16	4.37	4.57	4.78	0° 6′
2.76	2.98	3.20	3.43	3.66	3.88	4.11	4.34	4.57	4.80	5.04	5.27	5.51	7
3.14	3.39	3.64	3.89	4.15	4.50	4.66	4.92	5.18	5.44	5.70	5.97	6.24	8
3.52	3.80	4.08	4.36	4.64	4.93	5.22	5.50	5.79	6.08	6.37	6.67	6.96	9
3.90	4.20	4.51	4.82	5.14	5.45	5.77	6.08	6.40	6.72	7.04	7.36	7.69	10
4.27	4.61	4.95	5.29	5.63	5.98	6.32	6.67	7.01	7.36	7.71	8.06	8.42	0° 11′
4.65	5.02	5.39	5.76	6.13	6.50	6.87	7.25	7.62	8.00	8.38	8.76	9.14	12
5.03	5.42	5.82	6.22	6.62	7.02	7.43	7.83	8.24	8.64	9.05	9.46	9.87	13
5.41	5.83	6.26	6.69	7.12	7.55	7.98	8.41	8.85	9.28	9.72	10.16	10.60	14
5.78	6.24	6.70	7.15	7.62	8.07	8.53	8.99	9.46	9.92	10.39	10.86	11.32	15
6.16	6.65	7.13	7.62	8.11	8.59	9.08	9.58	10.07	10.56	11.06	11.55	12.05	0° 16′
6.54	7.05	7.56	8.08	8.60	9.12	9.64	10.16	10.68	11.20	11.73	12.25	12.78	17
6.92	7.46	8.00	8.55	9.09	9.64	10.19	10.74	11.29	11.84	12.40	12.95	13.51	18
7.30	7.87	8.44	9.01	9.59	10.16	10.74	11.32	11.90	12.48	13.06	13.65	14.23	19
7.68	8.28	8.88	9.48	10.08	10.69	11.30	11.90	12.51	13.12	13.73	14.35	14.96	20
8.05	8.68	9.31	9.94	10.58	11.21	11.85	12.48	13.12	13.76	14.40	15.04	15.69	0° 21′
8.43	9.09	9.75	10.41	11.07	11.74	12.40	13.07	13.73	14.40	15.07	15.74	16.42	22
8.81	9.50	10.19	10.88	11.57	12.26	12.95	13.65	14.34	15.04	15.74	16.44	17.14	23
9.19	9.90	10.62	11.34	12.06	12.78	13.51	14.23	14.96	15.68	16.41	17.14	17.87	24
9.57	10.31	11.06	11.81	12.56	13.31	14.06	14.81	15.57	16.32	17.08	17.84	18.60	25
9.94	10.72	11.50	12.27	13.05	13.83	14.61	15.39	16.18	16.96	17.75	18.54	19.32	0° 26′
10.32	11.13	11.93	12.74	13.55	14.35	15.16	15.98	16.79	17.60	18.42	19.23	20.05	27
10.70	11.53	12.37	13.20	14.04	14.88	15.72	16.56	17.40	18.24	19.09	19.93	20.78	28
11.08	11.94	12.80	13.67	14.53	15.40	16.27	17.14	18.01	18.88	19.76	20.63	21.51	29
11.46	12.35	13.24	14.13	15.03	15.92	16.82	17.72	18.62	19.52	20.42	21.33	22.23	30
15.24	16.42	17.60	18.79	19.97	21.16	22.35	23.54	24.73	25.82	27.12	28.31	29.50	0° 40′
19.02	20.49	21.97	23.44	24.92	26.40	27.88	29.36	30.84	32.32	33.81	35.29	36.78	50
22.81	24.57	26.33	28.10	29.87	31.64	33.41	35.18	36.95	38.72	40.50	42.28	44.06	1 00
26.59	28.64	30.70	32.75	34.81	36.87	38.94	41.00	43.06	45.13	47.19	49.26	51.33	1 10
30.37	32.72	35.06	37.41	39.76	42.10	44.46	46.82	49.17	51.53	53.89	56.25	58.61	1 20
34.16	36.79	39.43	42.07	44.71	47.35	49.99	52.64	55.28	57.93	60.58	63.23	65.88	1° 30′
37.94	40.87	43.80	46.73	49.66	52.59	55.52	58.46	61.40	64.34	67.28	70.22	73.16	1 40
41.72	44.94	48.16	51.38	54.61	57.83	61.06	64.28	67.51	70.74	73.97	77.21	80.44	1 50
45.50	49.02	52.53	56.04	59.56	63.07	66.59	70.10	73.63	77.15	80.67	84.20	87.72	2 00
56.87	61.26	65.64	70.03	74.42	78.81	83.20	87.59	91.98	96.38	100.78	105.17	109.57	2° 30′
68.24	73.51	78.76	84.02	89.29	94.55	99.82	105.10	110.35	115.62	120.89	126.16	131.44	3 00
79.63	85.76	91.89	98.03	104.18	110.31	116.45	122.59	128.74	134.88	141.03	147.18	153.33	3 30
91.02	98.03	105.04	112.06	117.07	126.09	133.10	140.12	147.14	154.18	161.19	168.21	175.24	4 00
1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	

elevation. This table should not be used for angles of depression.

Illustration 34 is a diagram showing the method of constructing a scale for taking off the heights corresponding to a given angle and distance.

*Table of factors for computing differences in elevation.**

To obtain the difference in elevation in feet multiply the horizontal distance in meters by the factor in this table corresponding to the observed angle of elevation or depression. The factors are given for each ten minutes, but the value for the nearest minute may be interpolated, using the column of differences for one minute. The result is still to be corrected where necessary for the effect of curvature and refraction.

TABLE III.

Angle °	0′	10′	20′	30′	40′	50′	60′	Difference for 1 minute (fourth decimal place)
0	0.0000	0.0095	0.0191	0.0286	0.0382	0.0477	0.0573	9.5
1	0.0573	0.0668	0.0764	0.0859	0.0955	0.1050	0.1146	9.6
2	0.1146	0.1241	0.1337	0.1432	0.1528	0.1624	0.1719	9.6
3	0.1719	0.1815	0.1911	0.2007	0.2102	0.2198	0.2294	9.6
4	0.2294	0.2390	0.2486	0.2582	0.2678	0.2774	0.2870	9.6
5	0.2870	0.2967	0.3063	0.3159	0.3255	0.3352	0.3448	9.6
6	0.3448	0.3545	0.3641	0.3738	0.3835	0.3932	0.4028	9.7
7	0.4028	0.4125	0.4222	0.4319	0.4416	0.4514	0.4611	9.7
8	0.4611	0.4708	0.4806	0.4903	0.5001	0.5098	0.5196	9.8
9	0.5196	0.5294	0.5392	0.5490	0.5588	0.5687	0.5785	9.8
10	0.5785	0.5884	0.5982	0.6081	0.6179	0.6278	0.6377	9.9
11	0.6377	0.6476	0.6576	0.6675	0.6774	0.6874	0.6974	9.9
12	0.6974	0.7073	0.7173	0.7273	0.7374	0.7474	0.7574	10.0
13	0.7574	0.7675	0.7776	0.7877	0.7978	0.8079	0.8180	10.1
14	0.8180	0.8282	0.8383	0.8485	0.8587	0.8689	0.8791	10.2
15	0.8791	0.8893	0.8996	0.9099	0.9201	0.9304	0.9408	10.3
16	0.9408	0.9511	0.9615	0.9718	0.9822	0.9926	1.0031	10.4
17	1.0031	1.0135	1.0240	1.0344	1.0449	1.0555	1.0660	10.5
18	1.0660	1.0766	1.0872	1.0978	1.1084	1.1190	1.1297	10.6
19	1.1297	1.1404	1.1511	1.1618	1.1726	1.1833	1.1941	10.7
20	1.1941	1.2050	1.2158	1.2266	1.2375	1.2485	1.2594	10.9
21	1.2594	1.2704	1.2813	1.2924	1.3034	1.3144	1.3255	11.0
22	1.3255	1.3367	1.3478	1.3590	1.3702	1.3814	1.3926	11.2
23	1.3926	1.4039	1.4152	1.4266	1.4379	1.4493	1.4607	11.4
24	1.4607	1.4722	1.4836	1.4952	1.5067	1.5183	1.5299	11.5
25	1.5299	1.5415	1.5532	1.5649	1.5766	1.5884	1.6002	11.7
26	1.6002	1.6120	1.6239	1.6358	1.6477	1.6597	1.6717	11.9
27	1.6717	1.6837	1.6958	1.7079	1.7200	1.7322	1.7444	12.1
28	1.7444	1.7567	1.7690	1.7814	1.7937	1.8061	1.8186	12.4
29	1.8186	1.8311	1.8436	1.8562	1.8688	1.8815	1.8942	12.6
30	1.8942	1.9069	1.9197	1.9326	1.9454	1.9584	1.9713	12.9
31	1.9713	1.9843	1.9974	2.0105	2.0236	2.0368	2.0501	13.1
32	2.0501	2.0634	2.0767	2.0901	2.1036	2.1171	2.1306	13.4
33	2.1306	2.1442	2.1578	2.1715	2.1853	2.1991	2.2130	13.7
34	2.2130	2.2269	2.2408	2.2548	2.2689	2.2831	2.2973	14.0
35	2.2973	2.3115	2.3258	2.3402	2.3546	2.3691	2.3837	14.4
36	2.3837	2.3983	2.4130	2.4277	2.4425	2.4574	2.4723	14.8
37	2.4723	2.4873	2.5023	2.5175	2.5327	2.5479	2.5633	15.2
38	2.5633	2.5787	2.5942	2.6097	2.6253	2.6410	2.6568	15.6
39	2.6568	2.6726	2.6885	2.7045	2.7206	2.7367	2.7530	16.0
40	2.7530	2.7692	2.7856	2.8021	2.8186	2.8353	2.8520	16.5
41	2.8520	2.8688	2.8857	2.9026	2.9197	2.9368	2.9541	17.0
42	2.9541	2.9714	2.9888	3.0063	3.0239	3.0416	3.0594	17.6
43	3.0594	3.0773	3.0953	3.1134	3.1316	3.1499	3.1683	18.1
44	3.1683	3.1868	3.2054	3.2241	3.2429	3.2618	3.2808	18.8

* Computed by G. R. Putnam, Assistant, Coast and Geodetic Survey.

*Table of corrections for curvature and refraction.**

The correction in feet for the combined effect of curvature and refraction is given for each 100 meters' distance, the thousands of meters being given in the column to the left and the hundreds in the upper line. The correction is to be added to the *difference* of elevation for angles of *elevation* and *subtracted* for angles of *depression*, or it is always to be added to the uncorrected *elevation* of the point to be determined from point of observation.

Example: At a station whose elevation is 1000 feet (at telescope), angle to signal=3° elevation, horizontal distance=5000 meters. From Table III factor is 0.1719, which multiplied by 5000=859.5 feet. From Table IV correction is 5.5 feet. Corrected difference of elevation=859.5+5.5=865 feet, which added to 1000=1865 feet for elevation of signal. If the above angle to signal be 3° depression, then corrected difference of elevation=859.5—5.5=854 feet, which makes height of signal=1000—854=146 feet.

TABLE IV.

Distance in meters	0	100	200	300	400	500	600	700	800	900	1000
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2
1000	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.8	0.9
2000	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.9	2.0
3000	2.0	2.1	2.3	2.4	2.6	2.7	2.9	3.0	3.2	3.4	3.5
4000	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3	5.5
5000	5.5	5.8	6.0	6.2	6.5	6.7	7.0	7.2	7.4	7.7	8.0
6000	8.0	8.2	8.5	8.8	9.1	9.4	9.7	10.0	10.2	10.6	10.9
7000	10.9	11.2	11.5	11.8	12.1	12.5	12.8	13.1	13.5	13.8	14.2
8000	14.2	14.5	14.9	15.3	15.6	16.0	16.4	16.8	17.2	17.6	18.0
9000	18.0	18.4	18.8	19.2	19.6	20.0	20.4	20.8	21.3	21.7	22.2
10000	22.2	22.6	23.0	23.5	24.0	24.4	24.9	25.4	25.8	26.3	26.8
11000	26.8	27.3	27.8	28.3	28.8	29.3	29.8	30.3	30.8	31.4	31.9
12000	31.9	32.4	33.0	33.5	34.1	34.6	35.2	35.7	36.3	36.9	37.4
13000	37.4	38.0	38.6	39.2	39.8	40.4	41.0	41.6	42.2	42.8	43.4
14000	43.4	44.1	44.7	45.3	46.0	46.6	47.2	47.9	48.5	49.2	49.8
15000	49.8	50.5	51.2	51.9	52.5	53.2	53.9	54.6	55.3	56.0	56.7
16000	56.7	57.4	58.2	58.9	59.6	60.3	61.0	61.8	62.5	63.3	64.0
17000	64.0	64.8	65.6	66.3	67.1	67.9	68.6	69.4	70.2	71.0	71.8
18000	71.8	72.6	73.4	74.2	75.0	75.8	76.7	77.5	78.3	79.1	80.0
19000	80.0	80.8	81.7	82.5	83.4	84.2	85.1	86.0	86.9	87.7	88.6

* Computed by G. R. Putnam, Assistant, Coast and Geodetic Survey.

Table of factors for computing differences in elevation.

To obtain the difference in elevation in *meters*, multiply the horizontal distance in meters by the factor in this table corresponding to the observed angle of elevation or depression. The factors are given for each ten minutes, but the value of the nearest minute may be interpolated, using the column of differences for one minute. The result is still to be corrected where necessary for the effect of curvature and refraction.

TABLE V.

Angle	0′	10′	20′	30′	40′	50′	60′	Difference for 1 minute (4th dec. place)
°								
0	0.0000	0.0029	0.0058	0.0087	0.0116	0.0145	0.0175	2.9
1	.0175	.0204	.0233	.0262	.0291	.0320	.0349	2.9
2	.0349	.0378	.0407	.0437	.0466	.0495	.0524	2.9
3	.0524	.0553	.0582	.0612	.0641	.0670	.0699	2.9
4	.0699	.0729	.0758	.0787	.0816	.0846	.0875	2.9
5	.0875	.0904	.0934	.0963	.0992	.1022	.1051	2.9
6	.1051	.1080	.1110	.1139	.1169	.1198	.1228	2.9
7	.1228	.1257	.1287	.1317	.1346	.1376	.1405	2.9
8	.1405	.1435	.1465	.1495	.1524	.1554	.1584	3.0
9	.1584	.1614	.1644	.1673	.1703	.1733	.1763	3.0
10	.1763	.1793	.1823	.1853	.1883	.1914	.1944	3.0
11	.1944	.1974	.2004	.2035	.2065	.2095	.2126	3.0
12	.2126	.2156	.2186	.2217	.2247	.2278	.2309	3.0
13	.2309	.2339	.2370	.2401	.2432	.2462	.2493	3.1
14	.2493	.2524	.2555	.2586	.2617	.2648	.2679	3.1
15	.2679	.2711	.2742	.2773	.2805	.2836	.2867	3.1
16	.2867	.2899	.2931	.2962	.2994	.3026	.3057	3.2
17	.3057	.3089	.3121	.3153	.3185	.3217	.3249	3.2
18	.3249	.3281	.3314	.3346	.3378	.3411	.3443	3.2
19	.3443	.3476	.3508	.3541	.3574	.3607	.3640	3.3
20	.3640	.3673	.3706	.3739	.3772	.3805	.3839	3.3
21	.3839	.3872	.3906	.3939	.3973	.4006	.4040	3.3
22	.4040	.4074	.4108	.4142	.4176	.4210	.4245	3.4
23	.4245	.4279	.4314	.4348	.4383	.4417	.4452	3.4
24	.4452	.4487	.4522	.4557	.4592	.4628	.4663	3.5
25	.4663	.4699	.4734	.4770	.4806	.4841	.4877	3.5
26	.4877	.4913	.4950	.4986	.5022	.5059	.5095	3.6
27	.5095	.5132	.5169	.5206	.5243	.5280	.5317	3.7
28	.5317	.5354	.5392	.5430	.5467	.5505	.5543	3.8
29	.5543	.5581	.5619	.5658	.5696	.5735	.5774	3.8
30	.5774	.5812	.5851	.5890	.5930	.5969	.6009	3.9
31	.6009	.6048	.6088	.6128	.6168	.6208	.6249	4.0
32	.6249	.6289	.6330	.6371	.6412	.6453	.6494	4.1
33	.6494	.6536	.6577	.6619	.6661	.6703	.6745	4.2
34	.6745	.6787	.6830	.6873	.6916	.6959	.7002	4.3
35	.7002	.7046	.7089	.7133	.7177	.7221	.7265	4.4
36	.7265	.7310	.7355	.7400	.7445	.7490	.7536	4.5
37	.7536	.7581	.7627	.7673	.7720	.7766	.7813	4.6
38	.7813	.7860	.7907	.7954	.8002	.8050	.8098	4.7
39	.8098	.8146	.8195	.8243	.8292	.8342	.8391	4.9
40	.8391	.8441	.8491	.8541	.8591	.8642	.8693	5.0
41	.8693	.8744	.8796	.8847	.8899	.8952	.9004	5.2
42	.9004	.9057	.9110	.9163	.9217	.9271	.9325	5.4
43	.9325	.9380	.9435	.9490	.9545	.9601	.9657	5.6
44	.9657	.9713	.9770	.9827	.9884	.9942	1.0000	5.7

Table of corrections for curvature and refraction.

The correction in *meters* for the combined effect of curvature and refraction is given for each 100 meters distance, the thousands of meters being given in the column to the left and the hundreds in the upper line. The correction is to be added to the *difference* of elevation for angles of *elevation* and subtracted for angles of *depression*, or it is always to be added to the uncorrected *elevation* of the point to be determined from point of observation.

Example: At a station whose elevation is 304.80 meters (at telescope), angle to signal 3° elevation, horizontal distance 5000 meters. From Table V factor is 0.0524, which multiplied by 5 000= 262.00. From Table VI correction is 1.67 meters. Corrected difference of elevation=262.00+1.67=263.67 meters, which added to 304.80=568.47 meters for elevation of signal. If the above angle to signal be 3° depression, then corrected difference of elevation 262.00—1.67=260.33 meters, which makes height of signal=304.80—260.33=44.47 meters.

TABLE VI.

Distance in meters	0	100	200	300	400	500	600	700	800	900	1000
0	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.07
1000	0.07	0.08	0.10	0.11	0.13	0.15	0.17	0.19	0.22	0.24	0.27
2000	0.27	0.29	0.32	0.35	0.38	0.42	0.45	0.49	0.52	0.56	0.60
3000	0.60	0.64	0.68	0.73	0.77	0.82	0.86	0.91	0.96	1.01	1.07
4000	1.07	1.12	1.18	1.23	1.29	1.35	1.41	1.47	1.54	1.60	1.67
5000	1.67	1.74	1.80	1.87	1.94	2.02	2.09	2.17	2.24	2.32	2.40
6000	2.40	2.48	2.56	2.65	2.73	2.82	2.91	3.00	3.09	3.18	3.27
7000	3.27	3.36	3.46	3.55	3.65	3.75	3.85	3.96	4.06	4.16	4.27
8000	4.27	4.38	4.49	4.60	4.71	4.82	4.93	5.05	5.16	5.28	5.40
9000	5.40	5.52	5.65	5.77	5.89	6.02	6.15	6.28	6.41	6.54	6.67
10000	6.67	6.80	6.94	7.08	7.22	7.36	7.50	7.64	7.78	7.93	8.07
11000	8.07	8.22	8.37	8.52	8.67	8.82	8.98	9.13	9.29	9.45	9.61
12000	9.61	9.77	9.93	10.09	10.26	10.42	10.59	10.76	10.92	11.10	11.27
13000	11.27	11.45	11.62	11.80	11.98	12.16	12.34	12.52	12.71	12.89	13.08
14000	13.08	13.26	13.45	13.64	13.83	14.03	14.22	14.42	14.61	14.81	15.01
15000	15.01	15.21	15.41	15.62	15.82	16.03	16.24	16.44	16.65	16.87	17.08
16000	17.08	17.30	17.51	17.73	17.95	18.17	18.39	18.61	18.83	19.05	19.28
17000	19.28	19.51	19.73	19.96	20.19	20.43	20.66	20.89	21.13	21.37	21.61
18000	21.61	21.86	22.10	22.34	22.58	22.83	23.08	23.33	23.58	23.83	24.08
19000	24.08	24.34	24.60	24.85	25.11	25.37	25.63	25.89	26.15	26.42	26.68

Comparison of feet and meters.

[1 meter=3.280869 feet.]

Meters.	Feet.	Feet.	Meters.
1.............	3.2808	1.............	0.3048
2.............	6.5617	2.............	0.6096
3.............	9.8425	3.............	0.9144
4.............	13.1233	4.............	1.2192
5.............	16.4042	5.............	1.5240
6.............	19.6850	6.............	1.8288
7.............	22.9658	7.............	2.1336
8.............	26.2467	8.............	2.4384
9.............	29.5275	9.............	2.7432

NOTE.

The following illustrations, Nos. 17 to 28, show the conventional signs adopted by the United States Geographic Board.

WORKS AND STRUCTURES

Canal or Ditch

Aqueduct or Waterpipe

Aqueduct Tunnel

Canal Lock (*point up stream*)

Wagon Roads
- *Metaled*
- *Good*
- *Poor or Private*
- *On small-scale maps*

Trail or Path

Railroads
- *Railroad of any kind (or Single Track)*
- *Double Track*
- *Juxtaposition of*
- *Electric*
- *In Wagon Road or Street* — *Steam* — *Electric*

Tunnel

Railroad Station of any kind

Telegraph Line
- *Symbol (modified below)*
- *Along road*
- *Along road (small-scale maps)*
- *Along trail*

Electric Power Transmission Line

Fences
- *Fence of any kind (or board fence)*
- *Stone*
- *Worm*
- *Wire* — *Barbed* — *Smooth*
- *Hedge*

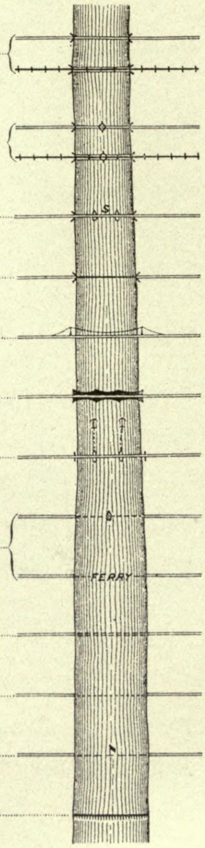
WORKS AND STRUCTURES
CONTINUED

Bridges
- General Symbol
- Drawbridges (on large-scale charts leave channel open)
- Truss (W, Wood; S, Steel)
- Foot
- Suspension
- Arch
- Pontoon

Ferries

Fords
- General Symbol (or Wagon and Artillery)
- Infantry and Cavalry
- Cavalry

Dam



Buildings in general

Ruins

Church .... or

Hospital .... HOS

Schoolhouse .... or SH

Post Office .... PO

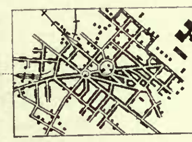
Telegraph Office .... or TO

Waterworks .... WW

Windmill .... or

NO. 19.

WORKS AND STRUCTURES
CONTINUED

City, Town, or Village 

City, Town, or Village (generalized) 

City, Town, or Village (*small-scale maps*)
- *Capital*
- *County Seat*
- *Other Towns*

Cemetery — CEM or †

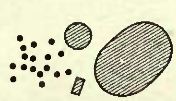
Mine or Quarry of any kind (*or open cut*)

Prospect

Shaft

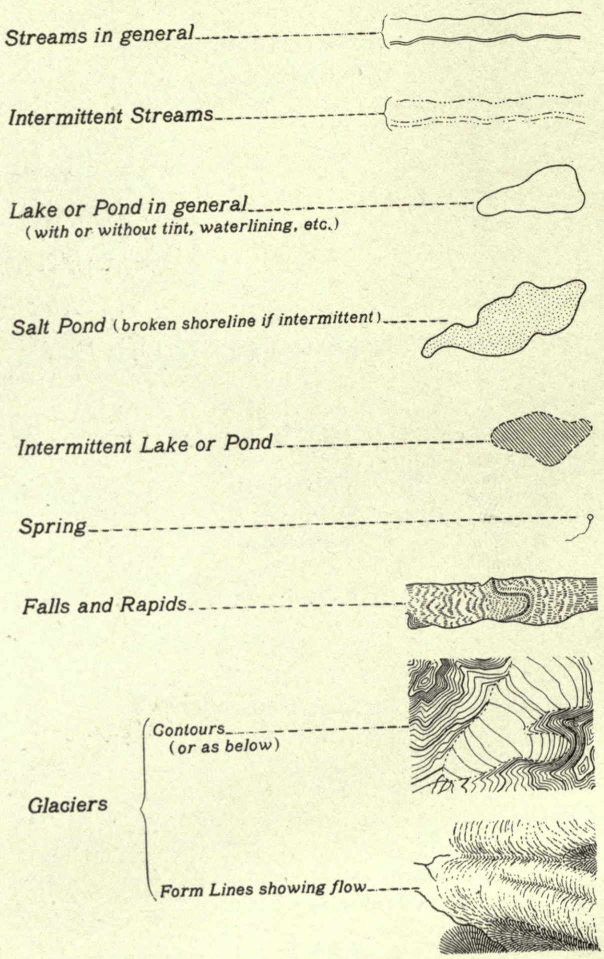
Mine Tunnel
- *Opening*
- *Showing direction*

Oil Wells

Oil Tanks (*abbreviation OT*) 

Coke Ovens

DRAINAGE



LETTERING

Names of natural land features, vertical lettering
Names of natural water features, slanting lettering

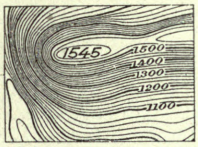
NO. 21.

RELIEF

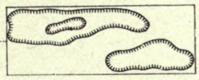
(Shown by contours, form lines, or shading as desired)

Hill Shapes — Form lines, hachures, stipple, or other shading

Contour System

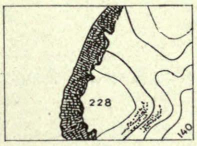


Depression Contours, if otherwise ambiguous, hachured thus

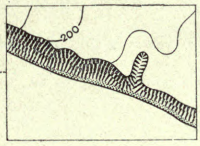


Bluffs

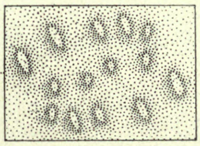
Rocky (or use contours)



Other than rocky (or use contours)



Sand Dunes

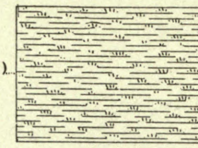


Levee

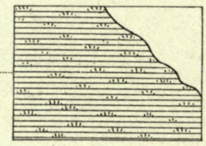
LAND CLASSIFICATION

Marsh

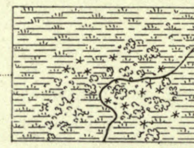
- *Marsh in general (or Fresh Marsh)*



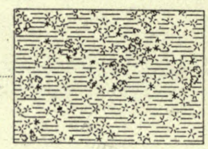
- *Salt*



- *Wooded*

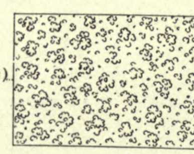


- *Cypress Swamp*

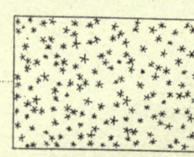


Woods of any kind (or as shown below) — *Flat green tint*

Woods of any kind (or Broad-Leaved Trees)



Pine (or Narrow-Leaved Trees)



Palm

Palmetto

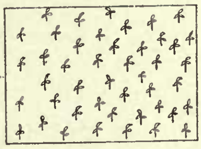
LAND CLASSIFICATION
CONTINUED

Mangrove

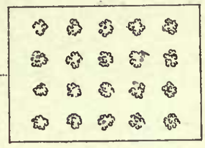
Bamboo

Cactus

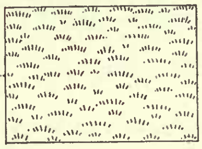
Banana



Orchard

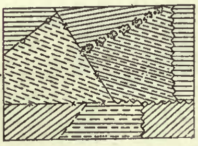


Grassland in general



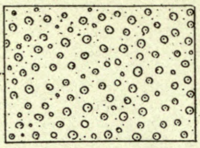
Tall Tropical Grass

Cultivated Fields in general



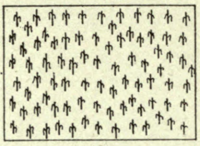
LAND CLASSIFICATION
CONTINUED

Cotton

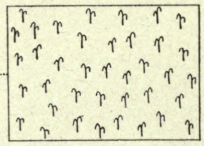


Rice

Sugar Cane



Corn



BOUNDARIES, MARKS, AND MONUMENTS

National, State, or Province Line

County Line

Civil Township, District, Precinct, or Barrio

Reservation Line

Land-Grant Line

City, Village, or Borough

Cemetery, Small Park, etc.

Township, Section, and Quarter Section Lines (*any one for township line alone, any two for township and section lines*)

Township and Section Corners Recovered

Boundary Monument

Triangulation Station

Bench mark BM × 1232

U. S. Mineral Monument ▲

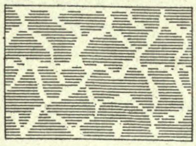
NO. 25.

HYDROGRAPHY, DANGERS, OBSTRUCTIONS

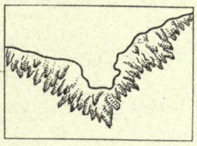
Shorelines { *Surveyed* .... / *Unsurveyed* ....

Shores and Low-Water Lines

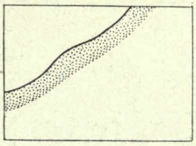
Tidal Flats of any kind (or as shown below)



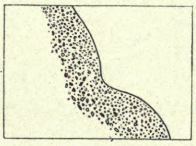
Rocky Ledges ....



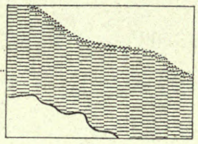
Sand ....



Gravel and Rocks ....

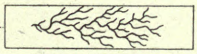


Mud ....

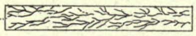


Coral Reefs ....

Kelp ....



Eel Grass ....



Rock under water .... +

Rock awash (*at any stage of the tide*) .... *

Rock whose position is doubtful .... PD

Rock whose existence is doubtful .... ED

HYDROGRAPHY, DANGERS, OBSTRUCTIONS
CONTINUED

Overfalls and Tide Rips

Limiting Danger Line

Whirlpools and Eddies

Wreck of any kind (*or Submerged Derelict*)

Wreck or Derelict not submerged

Cable (*with or without lettering*) — — — — — — — — — — — —

Current, not tidal, velocity 2 knots 2 kn →

Tidal Currents
- *Flood, 1½ knots* 1½ kn →
- *Ebb, 1 knot* 1 kn →
- *Flood, 2d hour* or
- *Ebb, 3d hour* or

No bottom at 50 Fathoms 50 50

Depth Curves

1 Fathom or 6 Foot Line

2 Fathom or 12 Foot Line

3 Fathom or 18 Foot Line

4 Fathom Line

4½ Fathom Line

5 Fathom Line

6 Fathom Line

10 Fathom Line

20 Fathom Line

30 Fathom Line

40 Fathom Line

50 Fathom Line

HYDROGRAPHY, DANGERS, OBSTRUCTIONS
CONTINUED

100 Fathom Line

200 Fathom Line

300 Fathom Line

500 Fathom Line

1000 Fathom Line

2000 Fathom Line

3000 Fathom Line

Abbreviations relating to Bottoms

M. mud, S. sand, G. gravel, Sh. shells, P. pebbles, Sp. specks, Cl. clay, St. stones, Co. coral, Oz. ooze, bk. black, wh. white, rd red, yl. yellow, gy. gray, bu. blue, dk. dark, lt. light, gn. green, br. brown, hrd. hard, sft. soft, fne. fine, crs. coarse, rky. rocky, stk. sticky, brk. broken, lrg. large, sml. small, stf. stiff, cal. calcareous, dec. decayed, rot. rotten, spk. speckled, fly. flinty, gty. gritty, grd. ground, str. streaky, vol. volcanic.

AIDS TO NAVIGATION, ETC.

Life-saving Station L.S.S. (T)
[(T) *indicates telegraphic connection*]

Light of any kind (*or Lighthouse*)

Lighthouse, on small scale chart

Light Vessel of any kind

Light Vessels showing number of masts

Light with Wireless

Light Vessel with Wireless

Light with Submarine Bell

Light Vessel with Submarine Bell

Light with Submarine Bell and Wireless

Light Vessel with Submarine Bell and Wireless

AIDS TO NAVIGATION, ETC.
CONTINUED

Beacons { *Lighted* ....
Not lighted .... Bn

Sectors, shown by dotted lines

Abbreviations relating to Lights

F. *fixed*, Flg. *flashing*, Fl. *flash*, Fls. *flashes*, Sec. *sector*, Rev. *revolving*, E. *electric*, W. *white*, R. *red*, V. *varied by*, Grp. *group*, Occ, *occulting*, Int. *intermittent*. Alt. *alternating*. m. *miles*, min. *minutes*, sec. *seconds*.

Buoys {
Buoy of any kind (*or Red Buoy*) ....
Black ....
Striped horizontally ....
Striped vertically ....
Checkered ....
Perch and Square ....
Perch and Ball ....
Whistling (*or use first four symbols with word " whistling "*) ....
Bell (*or use first four symbols with word " bell "*) ....
Lighted ....

Spindle or Stake (*add word " spindle " if space allows*) ....

Abbreviations relating to Buoys

C. can, N. nun, S. spar, H. S. horizontal stripes, B. black, R. red, W. white, V. S. vertical stripes, G. green, Y. yellow, Gh. checkered.

Anchorage { *Of any kind* (*or for large vessels*) ....
For small vessels ....

Mooring Buoy ....

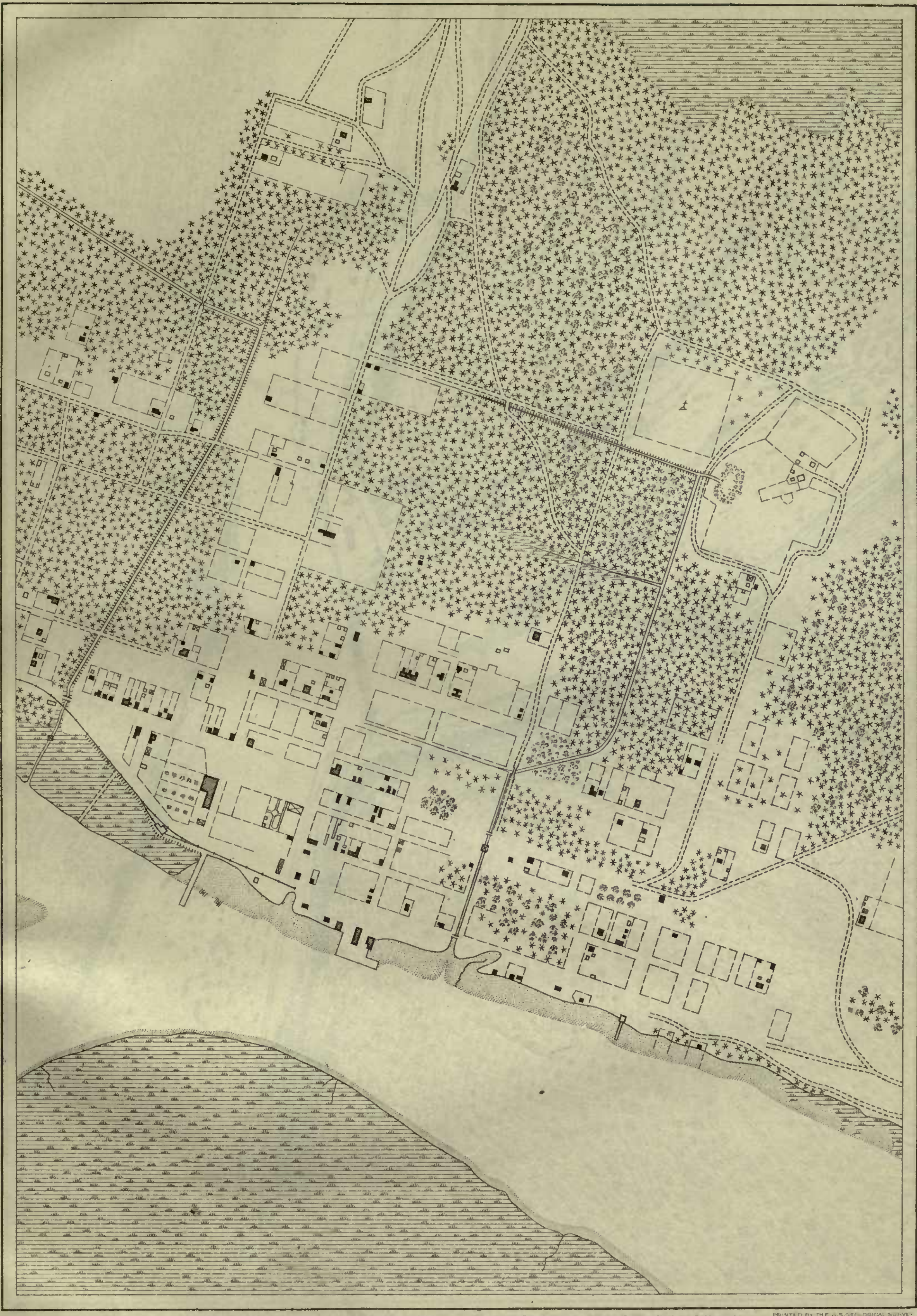
Range or Track Line .... - - - - - - - - - - - -

DECIMILLI-METRES						
60	ENGRAVING			*ENGRAVING*		
55	DIVISION			*DIVISION*		
50	CAPITOL			*CAPITOL*		
45	HARBOR			*HARBOR*		
40	ISLANDS			*ISLANDS*		
35	RIVERS			*RIVERS*		
30	SOUNDINGS			*SOUNDINGS*		
25	DIRECTIONS			*DIRECTIONS*		
20	POINTS	*POINTS*	Points	*Points*	POINTS	*POINTS*
15	CREEKS	*CREEKS*	Creeks	*Creeks*	CREEKS	*CREEKS*
12	CHANNELS	*CHANNELS*	Channels	*Channels*	CHANNELS	*CHANNELS*
10	SHOALS	*SHOALS*	Shoals	*Shoals*	SHOALS	*SHOALS*

ABCDEFGHIJKLMNOPQRSTUVWXYZ

ABCDEFGHIJKLMNOPQRSTUVWXYZ

Specimens of Lettering



Sparsely settled Town, Salt Marsh, Pine Woods, Ditches, Fences, and Undefined Roads

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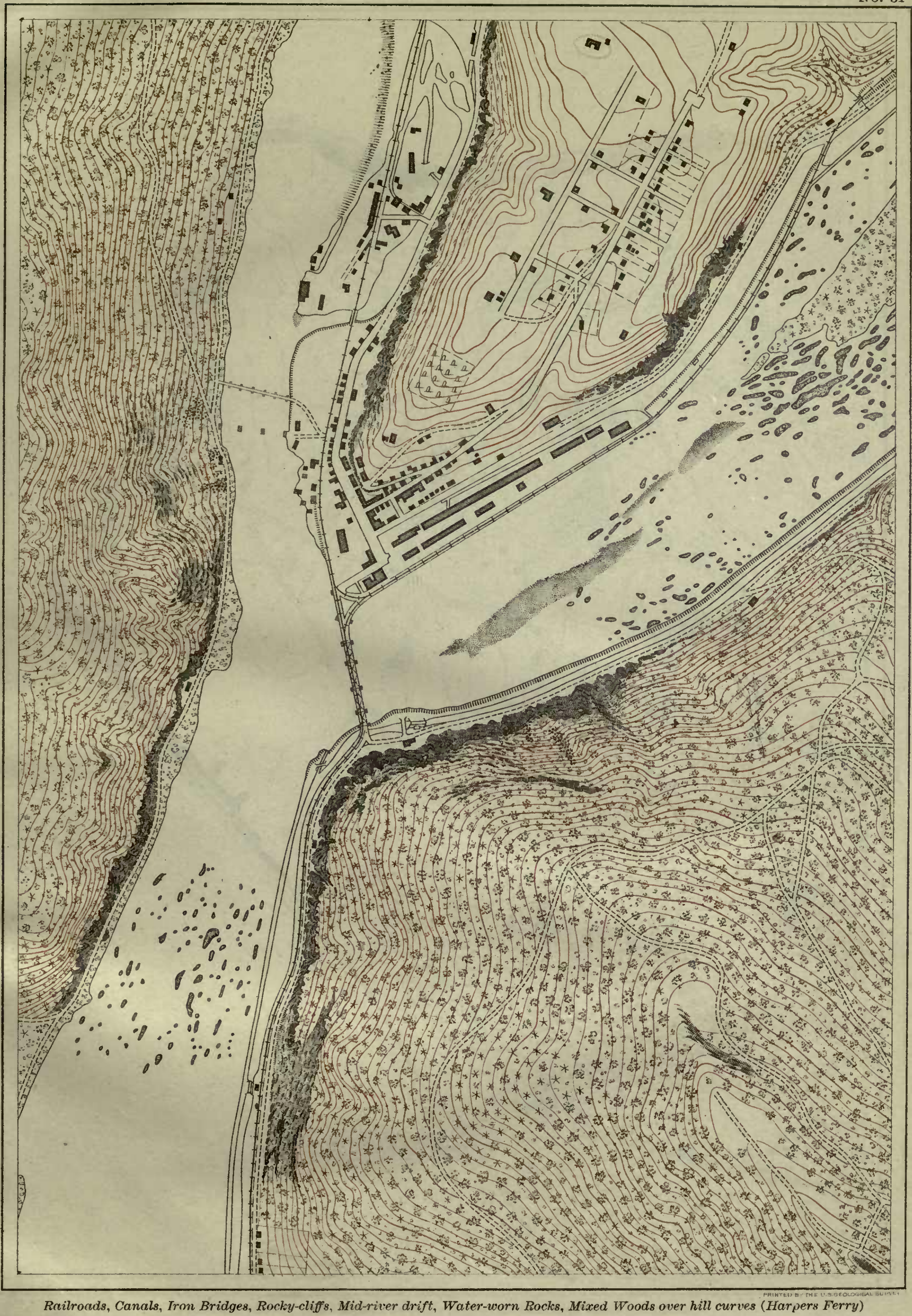

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Railroads, Canals, Iron Bridges, Rocky-cliffs, Mid-river drift, Water-worn Rocks, Mixed Woods over hill curves (Harpers Ferry)

Eroded drift banks, with boulders set free; and scrub deciduous woods (Gay Head)

Blocking of Cities, Large Buildings, Suburban Villas and Grounds, Fresh Marsh

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Erosion of Soft Stratified Rock and Gulch (Santa Cruz, California)

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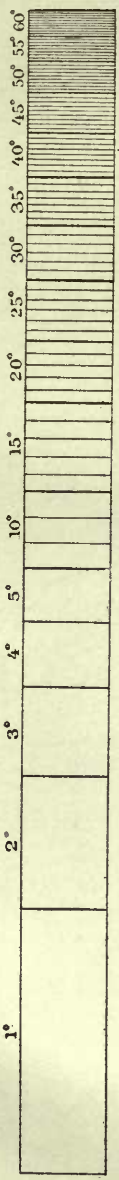
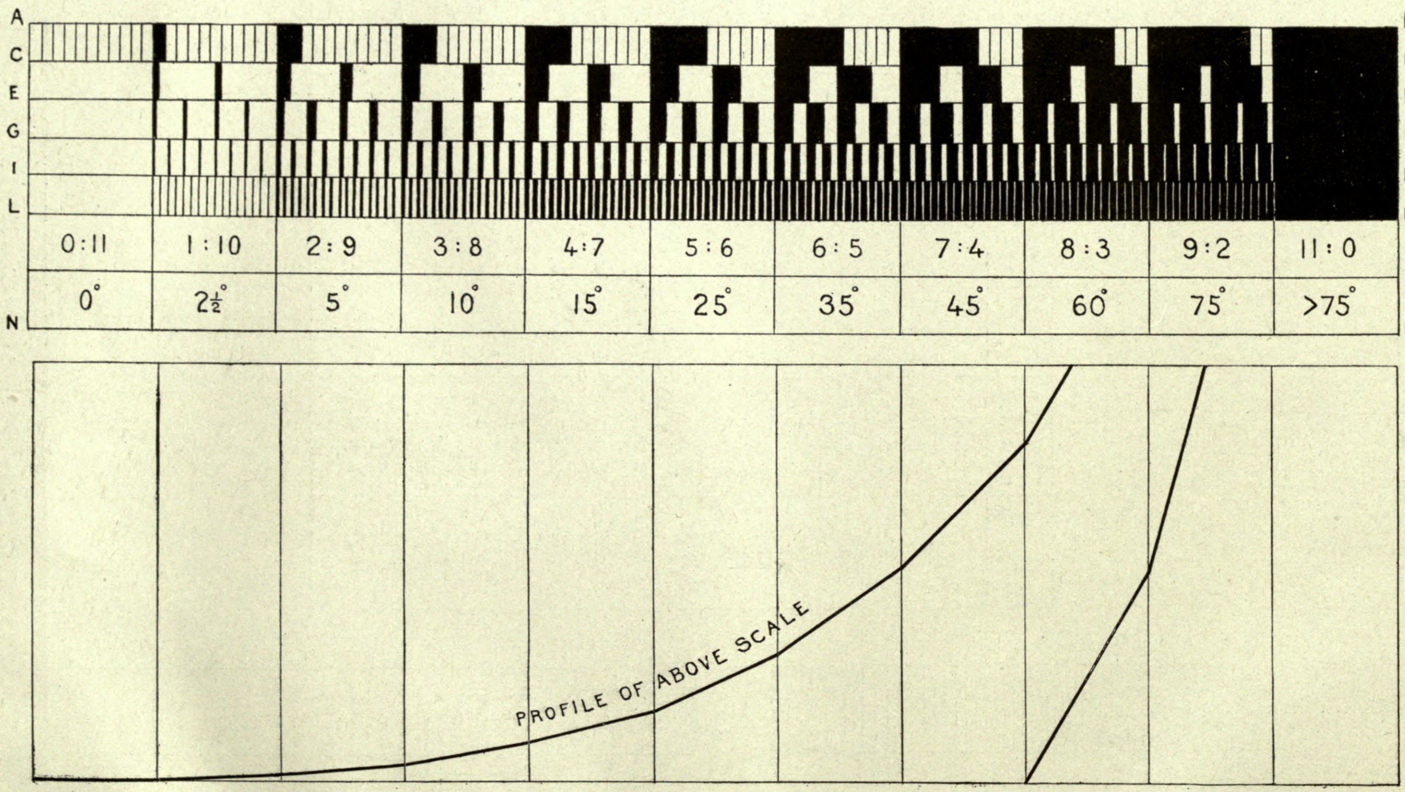
Hill Curves for every 20 feet difference of level. Scale $\frac{1}{10,000}$

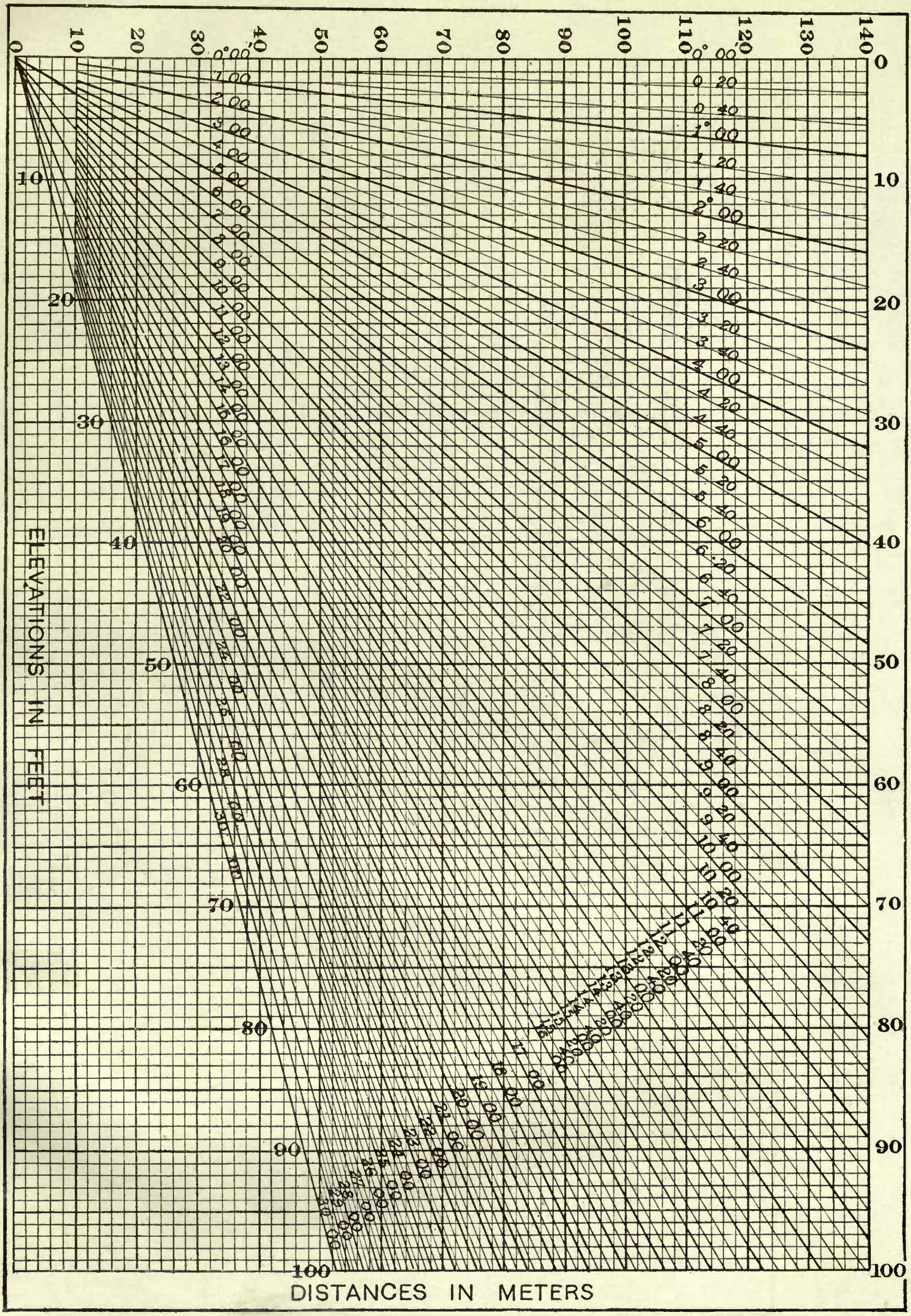


Slope.	Proportion of Height to Base.	Length of Base to 1 foot of Height (in feet.)	Length of Base to 20 feet of Height (in feet.)	Length of Base to 20 feet of Height (in meters.)
1°	1 to 57	57 . 29	1145 . 8	349 . 1
2°	1 to 29	28 . 64	572 . 8	174 . 5
3°	1 to 19	19 . 08	381 . 6	116 . 3
4°	1 to 14	14 . 30	286 . 0	87 . 1
5°	1 to 11	11 . 43	228 . 6	69 . 7
10°	1 to 6	5 . 67	113 . 4	34 . 6
15°	1 to 4	3 . 73	74 . 6	22 . 7
20°	1 to 3	2 . 75	55 . 0	16 . 7
25°	1 to 2	2 . 14	42 . 8	13 . 1
30°	1 to 1.7	1 . 73	34 . 6	10 . 5
35°	1 to 1.4	1 . 43	28 . 6	8 . 7
40°	1 to 1.2	1 . 19	23 . 8	7 . 2
45°	1 to 1	1 . 00	20 . 0	6 . 1
50°	1 to 0.8	0 . 84	16 . 8	5 . 1
55°	1 to 0.7	0 . 70	14 . 0	4 . 3
60°	1 to 0.6	0 . 58	11 . 6	3 . 6

U. S. C. AND G. SURVEY SCALE OF SHADE.



NO. 37.



0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
ELEVATIONS IN FEET
DISTANCES IN METERS