Military Topography and Photography

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and

Photography

BY

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PREFACE

In writing this book, it has been the aim of the author to present the different subjects and their expositions in a logical, clear, and precise way, and, at the same time, the whole subject completely and comprehensively.

Topography can not be learned from books alone. In fact, the function of the book is to present the principles in a logical and intelligent manner which are to govern topographical operations in the field. Facility and precision in applying those principles can be acquired only through practice and experience. The author believes that anybody who studies this book will know how to start, to execute, and to finish, any task in topography that may be assigned to him, whether it be a single or combined rapid sketch, or an extended topographical survey. Only by those to whom the latter task has been assigned can a clear knowledge of these requirements be fully appreciated.

Photo-Topography has been covered sufficiently to serve as a guide for those who are or may be provided with photo-topographic surveying instruments.

The author has not included in his chapter on "Special Problems," geodetic methods, adjustments, and computations of latitude, longitude, and spherical triangles, for the military topographer will not be confronted with those operations. These subjects, however, have been treated sufficiently in the text to enable him to take advantage of geodetic data of areas he may be required to sketch.

The subject of photography has been included on account of its close relation to topography and general military importance.

The author has assumed that all officers have had plane surveying, the same being a required subject of entrance examination, and has therefore left out many elementary things which would only make "padding." The padding of the book with numerous visibility problems, etc., which the instructor, or the student himself, can originate from maps at hand, has also been avoided. Topographical operations and problems, however, have been sufficiently covered in order that the book may serve as a complete field manual.

The author wishes to acknowledge his indebtedness and to express his appreciation and thanks to the Superintendent of the Coast and Geodetic Survey, to the Director of the U. S. Geological Survey, to the Superintendent of the U. S. Naval Observatory, to the Eastman Kodak Co., to W. & L. E. Gurley, to Carl Zeiss of Jena, and to Th. Scheimpflug of Wien, for their manuals, texts, reports, and other publications with which they have so considerately furnished him. Also, for the many electro plates and half tones, acknowledgments of which have also been made with the insertions of the same.

The author also wishes to express his indebtedness to Lieut. J. W. Heard, 14th Cavalry, who read the MSS, and to Lieut. Roderick Dew, 17th Infantry, who assisted him in the final proof reading, for the invaluable help they rendered to him.

Should the reader notice any error, or any explanation that seems obscure, the author would appreciate having his attention called to the same, in order that future editions may be corrected, made more clear and complete.

F. D. C.

Camp Eagle Pass, Texas,
December, 1915.

CHAPTER I

MILITARY MAP READING

Definition of Map. A map is a representation of the earth's surface, or a portion of it, showing the relative size and position of the parts represented according to some given scale or projection. The representation is usually on a plane surface.

Classes of Maps. All maps may be divided into two general classes—plane and topographical. Plane maps include cadastral and all other maps, showing the meets and bounds of private and public property, the boundaries of governments, location of roads, rivers, etc.: in brief, all maps in which the horizontal coördinates only of the parts represented are shown. Topographical maps include all those in which the conformation of the ground is represented. This conformation may be represented by relief, by hachures, or by contour lines.

Maps may also be divided into civil and military maps, according to the uses for which they are intended or put. All maps are of some military use, but military maps proper include only those which have been made for military operations and study. Such maps are much more complete than is required of other information and cadastral maps. In addition to a more accurate representation of the conformation of the ground, they show the extent and character of the vegetation, etc. Military maps of the United States Army are divided into three general classes: (1) Road Sketches, (2) Area Sketches, and (3) War Game and Fortress Maps.

Road Sketches. Road sketches are rapid topographical sketches of roads and trails and the adjacent terrain. They may be either (a) *Individual Road Sketches*, or (b) *Combined Road Sketches*. The former are of limited extent, generally of a single road, and executed by one person: the latter cover a network of roads and are executed by several persons sketching simultaneously.

AREA SKETCHES. Area sketches are rapid topographical surveys of sections of the terrain. Rapid military topographical surveying is called "military sketching" and should be distinguished from precise military topographical surveying, usually referred to as, "military topographical surveying," or simply "military surveying." Area sketches are divided into three general classes; (a) Position, (b) Outpost, and (c) Place Sketches.

POSITION SKETCHES. Position sketches are rapid military topographical surveys of sections to which the sketchers have access. They may be either (a) *Individual Position Sketches*, or (b) *Combined Position Sketches*, according as to whether they are made by single sketchers, or by several sketchers working simultaneously and in conjunction.

OUTPOST SKETCHES. Outpost sketches are rapid military surveys of sections along the outposts and as far towards the hostile position as can be sketched from the line of observation. Similar to position sketches, they may be divided into (a) *Individual*, and (b) *Combined Outpost Sketches.*

PLACE SKETCHES. Place sketches are rapid military topographical surveys of sections made from but one point of observation. They may be either (a) *Eye Sketches*, or (b) *Memory Sketches.* Eye sketches are those place sketches of areas in which the sketcher was able to complete his map while remaining at a single point of observation. Memory sketches are those in which the terrain is sketched from memory. Often the only maps of the terrain,—of its roads and trails, within hostile areas will be "Memory Sketches."

WAR GAME AND FORTRESS MAPS. These are precise military topographical surveys of limited areas, or of fortresses, and used principally for map maneuvers and study. They include field maneuver maps.

ELEMENTS OF TOPOGRAPHICAL MAPS

RELATIONS OF POINTS ON THE TERRAIN. For every two points on the terrain there are always three and only three relations between them: (1st) the relation of direction; (2nd) the relation of distance; and (3rd) the relation of elevation.

That is, one point with respect to another, lies in a certain direction from it, is a certain distance from it, and is of the same elevation or is so much higher or lower in elevation.

Direction

Method of Expression. In order to express the relation of direction between two points, it is necessary to assume one point as a base point and to designate the other point with respect to it. It matters not which point is selected as the base point. Thus, of two points, A and B, on the terrain, we may select point A as the base and say the direction of point B is north; or we may select point B as the base, and say that the direction of point A is south. Direction is usually designated by the points of the compass; as, north, west, northeast, south.

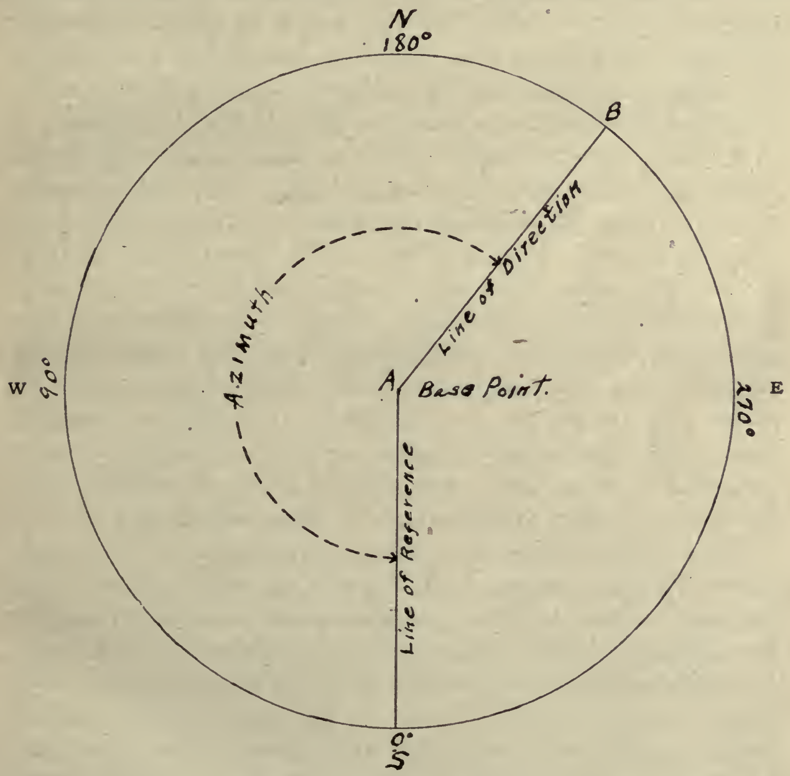


Fig. 1.

southeast, etc. In survey work a more precise method of direction designation is necessary and circular measure is used. In using circular measure for the designation of direction, it is necessary to have a point of reference for the zero of the circle or scale. This point may be the true north or south, or the magnetic north or south. The point on the terrain taken as the base point is considered as the center of an imaginary horizontal circle, the zero of which circle is considered the true north or south, or the magnetic north or south, and the imaginary line joining the base point and the zero of the imaginary circle, the line of reference; and the line joining the base point with the point whose direction is to be designated, the line of direction. The line of reference and the line of direction form an angle with each other at the base point whose magnitude can be accurately expressed in circular measure. The direction between two points is expressed in surveying as the angle, in circular measure, which the line of direction makes with the line of reference; also, as the azimuth or bearing.

Magnetic Declination. The magnetic needle points towards the north only in a few places on the surface of the earth, in most places it points more or less away from the true north, even as much as 20°. The angle which the magnetic needle makes with a true north and south line at any point of the earth's surface is called the magnetic declination for that point. This magnetic declination varies not only with the longitude, but also with the latitude. The variation, however, is not constant for the same longitude or latitude, so that the lines connecting points of equal magnetic declination are very irregular in curvature. Such lines are called *isogonic* lines. Lines of no magnetic declination are called *agonic* lines.

The magnetic declination at any point is not constant. There are cyclic variations throughout the day, the month, and the year. There is also a progressive variation, which appears to be periodic in its character, like the motion of a pendulum, but which takes several hundred years for its cycle. This secular variation at any point on the earth slowly increases from zero to a maximum in one direction; it then slowly decreases to zero and increases to a maximum in the other direction, and so on. In addition to the above variations, there are variable variations due to magnetic disturbances, to storms, and to magnetic attractions. Electric and steam railways, telephone and telegraph lines, pipe lines, etc., are sources of large variable variations, while any steel object near a compass will affect the magnetic needle to some extent. Iron ores which contain magnetite or pyrrhotite affect the magnetic needle also. Lunar and annual variations may be neglected, and also the diurnal variation for military work. The secular and irregular variations, however, must be allowed for. Charts showing isogonic lines for the year may be obtained from the Government Printing Office, Washington, D. C. Where the magnetic conditions are so uncertain as to make the direction determined by it unreliable, other methods must be used to determine directions.

Bearing. If the line of reference be extended beyond the base point, then the line of direction will form two angles with it, which are supplements to each other, and the smaller of the two angles is called the bearing of the direction point with respect to the base point. The bearing of a point or line is never over 90°, and it is always measured from the north or south towards the east or west. Whenever the line of reference is a true north and south line, the bearing of any point or line with respect to it, is called the true bearing; whenever the line of reference is the magnetic declination of the base point, the bearing of any point or line with respect to it, is called the magnetic bearing.

Azimuth. The azimuth of a line, or of a point with respect to another point, is the angle which it makes with the line of reference, measured clockwise from the true or magnetic south. Whenever the true south is used as the zero of the circle, the angle is called the true azimuth; whenever the magnetic south is used, the angle is called the magnetic azimuth. When the word azimuth is used, the true azimuth is usually intended, and when the word bearing, the magnetic bearing is usually intended.

The back-azimuth of a line (or of a point with respect to another) is the angle which the line makes with the true or north and south lines passing through the other extremity of the line. The difference between the true azimuth and the true back-azimuth of a line is never exactly 180°, except when the true azimuth is 0° or 180°; for all other azimuths the difference is 180° plus or minus a small increment or decrement. This is due to the convergence of the terrestrial meridians which are the only true north and south lines. For a line running directly east and west, this difference will amount to about one minute for every five miles.

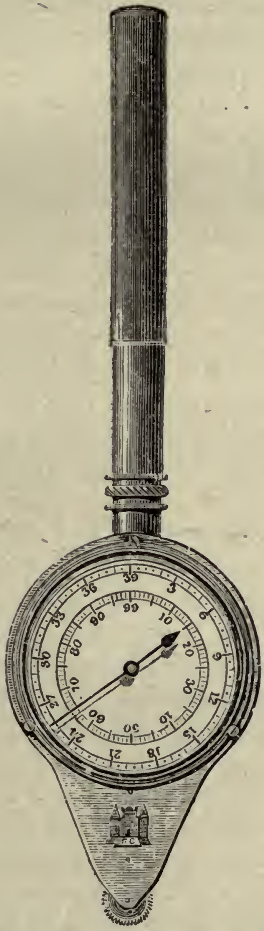
The magnetic needle points at the true north pole and at the north magnetic pole in only a few places on the earth. This is due to the fact that the magnetic north is not at the true north pole, and second, that the lines of magnetic forces which run from one magnetic pole to the other are not straight lines. Isogonic lines, although of irregular curvature, are not magnetic lines of force, but merely lines joining those points of the earth having the same magnetic declination and running in a general north and south direction. The reader must thoroughly clear this matter up in his own mind.

Methods of Measurement. In circular measure, angles are measured in degrees, minutes and seconds. The azimuth of a line is always measured from the south and in a clockwise direction. The azimuth of the west is therefore 90°, of the north 180°, of the east 270°, and of the south 0°, and so on. Bearings are measured from both the north and the south and in a clockwise or counter-clockwise direction according to the quadrant in which the bearing lies. The true north is usually designated as "due north"; south, "due south"; east, "due east"; west, "due west"; northeast, "north, 45° east," etc. It is thus seen that in azimuths, the circle or scale is divided into 360°; while in bearings, the circle is divided into four equal quadrants of 90° each, the north and south being designated as 0° respectively, and the east and west as 90° respectively.

In addition to circular measure, the direction of a point may be designated or measured by giving its horizontal coördinates. For example, we might say that point A is 10 miles north and five miles east of, point B. This method is very little used.

Distance

Method of Expression. Distance is the space or interval between two points, and it is expressed in terms of some unit



*Map Measure

of length, such as, feet, yards, leagues, meters, kilometers, etc. The distance between two plotted points on a map is called their map distance, and it is expressed in inches, centimeters,

*Courtesy of W. & L. E. Gurley.

etc., or in terms of their actual ground distance apart, such as, feet, yards, miles, etc.

A straight line is the shortest distance between two points, and in plane surveying is, therefore, the line of distance. In geodetic surveying, however, where the curvature of the earth must be taken into consideration, the distance between two points is the arc which they intercept on the great circle passing through them. The great circles of the earth, as it is well known, are not perfect circles; for the form of the earth is that of an ellipsoid of revolution. The magnitude in lineal measurements of the units of latitude and longitude are computed in the United States from the Clark's Ellipsoid of 1866. The curvature of the earth is 7.92 inches per mile and varies as the square of the distance. This curvature must be allowed for in taking level sights of any great distance.

Methods of Measurement. There are three general methods used to measure distance; (1st) by chaining, in which a surveyor's chain or steel tape is applied to the distance; (2nd), by telemeter, in which the distance is determined from the magnitude of the intercept of two stadia wires on a stadia rod, which intercept is directly proportional to the distance; and (3rd), by triangulation, in which the distance is computed from the triangle which that distance forms with two other lines, the length of one of the latter sides and the sizes of the angles of the triangle being known. This from the trigonometric fact that if one side and the angles of a triangle are known, the other two sides may be computed from them.

Difference in Elevation

Methods of Expression. The elevation of a point is its vertical distance above a datum plane, or when spoken of with respect to the earth in geographical and geodetic purposes, the distance above the terrestrial ellipsoid of revolution determined by sea level. Difference in elevation between two points is, therefore, the difference between their vertical distances above the same datum plane, and may be expressed either by the difference in feet or meters, or by the slope. In a general sense, the slope may be defined as the angle which the line joining the two points of different elevations, makes with a horizontal line in the same vertical plane. This word, however, is used both in a descriptive and quantitative sense. In the former, the slope of the ground between two points is described as uniform, convex, concave, etc.: in the latter, the degree of the slope is expressed either in percentage, in gradient, or in degrees.

The percentage of a slope is the ratio between the difference in elevation between the extremities of a slope and their horizontal distance; or decimally expressed, the per cent. The gradient is the ratio between the difference in elevation between the extremities of a slope and their horizontal distance, fractionally expressed. The degree of a slope is the angle between the slope of the ground and a horizontal line in the same vertical plane.

Methods of Measurement. The height of a column of mercury varies inversely with the elevation, so that a scale properly graduated to indicate the height of the column at different elevations, may be used to determine elevations. The mercury column is so non-portable, that it has no practical value as an instrument to determine elevations. The Aneroid Barometer which in size and shape resembles a watch, is very portable and is much used in determining elevations. In this barometer, the column of mercury is replaced by a thin metal diaphram which receives the atmospheric pressure on one side and indicates it on a scale. In view of the fact that temperature, humidity, etc., vary the pressure of the atmosphere, the barometer can be used only to determine the difference in elevation between two points occupied closely in succession, and not absolute elevations. This for field sketches may be taken from the following equation:

$$E = [e - e'] + [(t + t') - 100]$$

Where E equals the true difference in elevation; e and t, the barometric reading in feet and temperature (Fahr.) at higher station; and e′ and t′, the barometric reading in feet and temperature (Fahr.) at lower station—assuming the two stations to have been occupied in succession as rapidly as possible.

The spirit level is the most precise way in measuring elevations. A line of levels is run between the two points which should give the true difference in elevation between them.

If the distance between two points be determined by the stadia and the vertical angle be read at the same time, the difference in elevation can be computed from the trigonometric formula: that the difference in elevation is equal to the tangent of the slope angle times the horizontal distance.

By Contour Intervals: A contour is the line of intersection of a horizontal plane with the slope of the ground. More specifically, it is the line of intersection of concentric ellipsoids of revolution with the slope or surface of the earth. The ellipsoid of revolution determined by the surface of the sea is taken as the zero contour. In order to show the conformation of the ground contour lines are drawn for every five, ten, twenty, sixty, . . . feet of elevation, according to the scale of the map. Contour lines may be easily understood by imagining the sea to rise twenty feet, then the new shore line would represent the twenty foot contour; now if it were to rise twenty feet more, the new shore line would represent the forty foot contour, and so on.

Contour interval, abbreviated V. I., is the vertical distance between adjacent contours. The horizontal distance, abbreviated H. D., is the horizontal interval between adjacent contours. On a given map, the V. I. is constant, but the H. D. varies with the slope of the ground represented. Since the number of contours shows directly the number of contour intervals, the difference in elevation between two points may be determined or found by counting the number of contour intervals between them. Thus, if the V. I. of a given map were 20 feet and there were three contour intervals between two points, their difference in elevation would be 60 feet.

Contour intervals, in addition to giving the difference in elevation between two points, also give the character and the degree of the slope between those points. If as in Fig. 2, we show a cross section (vertical) of the ground, the V. I. and H. D. will represent the legs of a right triangle, while the slope of the ground will represent its hypotenuse, and the angle BAC will be the slope angle.

In this triangle, ABC, it will be noticed that the tangent of the slope angle is BC divided by AC, or tan BAC $= \frac{\text{V. I.}}{\text{H. D.}}$ Since the V. I. in this equation for any given map is constant the H. D. will vary inversely with the tangent of the slope angle.

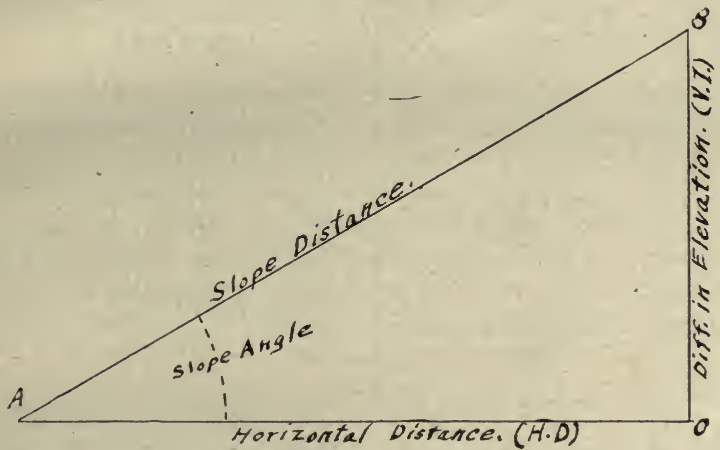
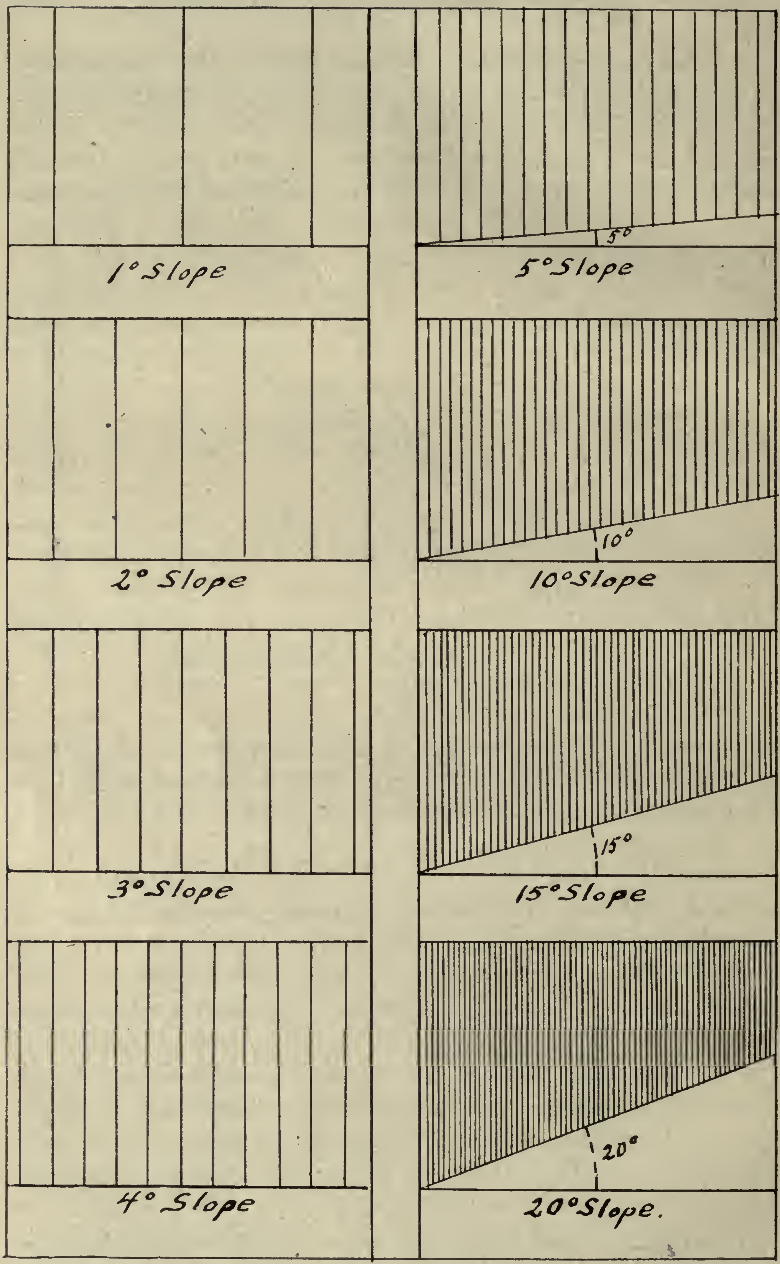


Fig 2.

The variation in the tangent of angles between 1° and 20° is so closely with the size of the angle, that we may disregard the tangent of the angle when less than 20°, and say that the H. D. varies inversely with the slope angle, or BAC $= \frac{\text{V. I.}}{\text{H. D.}}$. The following table of H. D.'s was computed from the tangent of the slope angle for a V. I. of 20 feet:

Slope Angle	*The H. D.*
1°	1146 Feet
2°	573 "
3°	382 "
4°	286 "
5°	229 "
10°	113 "
20°	55 "

If we assume that the H. D. varies inversely with the slope angle instead of with its tangent, the H. D. for 10° will be



1° Slope
2° Slope
3° Slope
4° Slope
5°
5° Slope
10°
10° Slope
15°
15° Slope
20°
20° Slope.

Fig 3.

114.6 feet, and for 20° it will be 57.3 feet. Comparing these figures with those in the above table it will be seen that the differences are so small that they may be ignored for angles less than 20°; contour lines for an angle twice as large will be, therefore, exactly twice as close together. Fig. 3 shows contours spaced for slopes of different degrees.

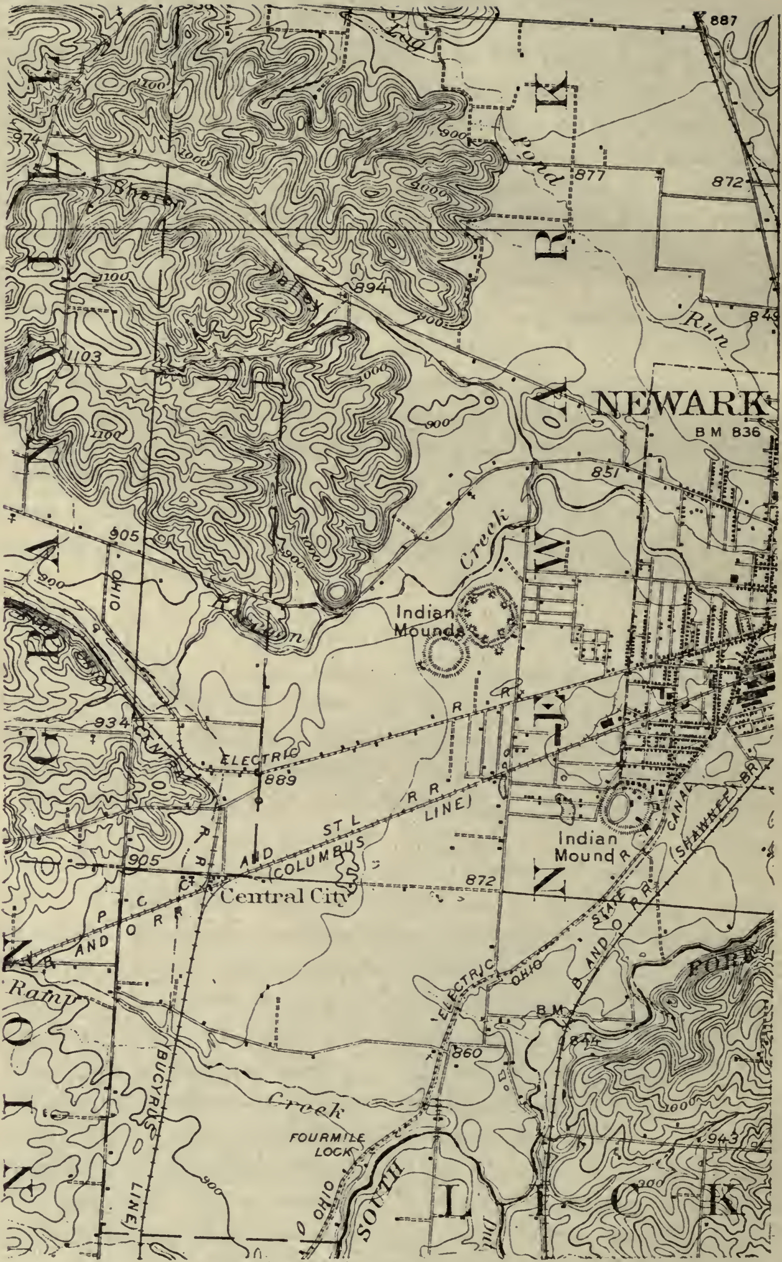
Character of the Terrain

By the character of the terrain we mean the conformation of the ground and the growth and objects on it. In some places the conformation of the ground is level or of uniform and easy slopes, in other places the ground is hilly or the planes cut with deep valleys, in other places the terrain is that of bold mountains with steep and rough slopes: by spacing the contour lines so as to correctly show the slope of the ground at each vertical plane of the earth, the conformation of the ground may be faithfully represented on a plane map.

Ground Conformation

The conformation of the ground may be shown by (1) *contours* (2) *hachures*, and (3) *relief*. The contour method is the most common as well as the most accurate: contour lines have already been explained. Hachures are short radiating lines pointing from higher elevations to lower: they are very difficult and tedious to make; they do not necessarily show absolute elevations and the elevations of points are usually shown in small figures on such maps. In relief maps the conformation of the ground is made to stand out by the effects of different degrees of shading of slopes; they are the best topographical maps where very small scales are used.

Planes. By a plane surface is meant a level section of the earth, which varies uniformly with the curvature of the earth. If the level were perfect there would be no contours at all, but even on our best representations of planes, such as the Great Planes, Mohave Desert, etc., there are small slopes, and there will always be the presence of contours on any topographical map. Planes include what are known as prairies or undulating planes; i. e., ground of small and easy slopes.



Contour Map—U. S. Geological Survey

Slopes. For uniform slopes, contours will be spaced equidistance apart; for convex slopes, the contours will be closer together at the bottom of the slope and farther apart at the top; for concave slopes the contours will be farther apart at

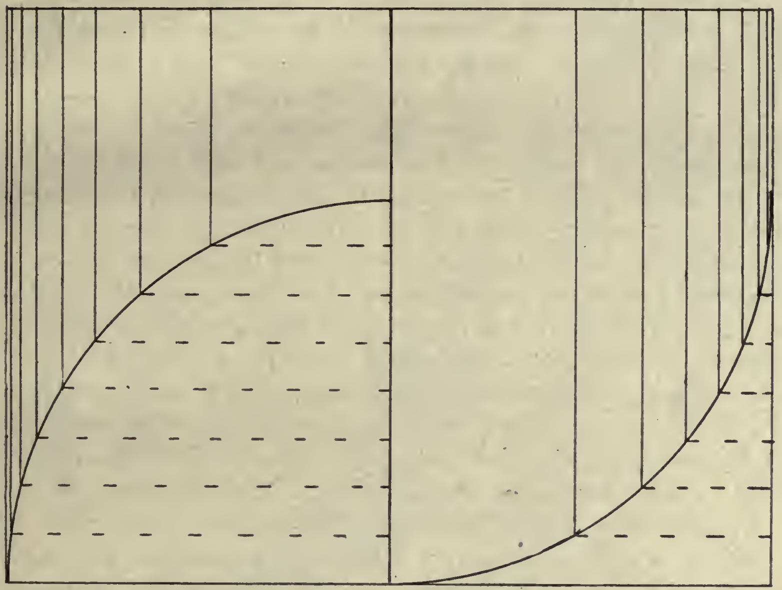


Fig. 4. Convex Slope Fig. 5 Concave Slope.

the bottom of the slope and closer together at the top. Slopes in old lands will generally be found convex at the top of hills and concave at the bottom.

Water Sheds. Water sheds are high ground, ridges, or spurs, that separate different drainage areas. Such ridges, spurs, or other high ground, always have contours of the same elevations on both sides; for a single ridge these contours close on themselves, while for spurs they will connect on the corresponding contours of the main ridge.

Water Courses. Water courses always define valleys. On either side of the water course, there will always be found some contours of the same elevations which always bend up stream before joining each other. This is true because all valleys become narrower at their head, and all streams have banks which are more or less high. These contours must follow the valley sides and stream banks until they intersect the usual surface of the stream where the corresponding contours of the opposite sides are connected with straight lines.

Cliffs. Cliffs are designated as steep cliffs, vertical cliffs, and overhanging cliffs, respectively, according as to whether the slope is over 45° but less than 90°, of 90° and of over 90°. When a slope is very steep the contours will be so close together on the map that the intermediate contours must be omitted throughout the length of such slopes, and only every fifth or tenth contour drawn according to the degree of the slope; when the ground forms a wall or vertical cliff, all the contours including the highest and the lowest ones for the cliff will run together and be represented by one line throughout the length of the vertical cliff; and for an overhanging cliff, contours of lower elevations will loop under those of higher elevations throughout the length of the overhanging cliff—an overhanging cliff is the only case in which one contour may cross another. A natural slope of 45° is very, very seldom seen, while a slope of even only 35° when viewed from the top or bottom by an untrained eye will seem to be from 70° to 75°.

Hills and Depressions. Hills and depressions are both represented by closed contours. Hills, however, generally have their exact elevation given in figures within the highest contour, while depressions usually have the inner edge of the lowest contour fringed with hachures.

Saddles of Cols. Whenever a ridge or hill has a dip in its top which forms two knolls, the dip between them is called a saddle or col. Such a conformation will cause two closed contours of the same elevation within the contour of the next lower elevation. Contours representing all conditions will be found in the chapter on conventional signs.

Graphic Representation

Streams, vegetation, and the constructions of man on the terrain are represented on maps by symbols which are usually suggestive of the things represented.

HACHURE MAP

From Lea's *The Valor of Ignorance*. Reproduced by permission of the publishers, Harper & Brothers.

Water. The boundaries of oceans and lakes, the courses of streams, rivers and canals, etc., are represented by blue lines accurately marking their map positions.

Artificial Construction. Steam and electric railroads, roads, buildings, cities, towns, etc., are represented by black lines which are suggestive of the things represented and mark their locations.

Vegetation. Trees, grass, orchards, forests, cultivated plants, etc., are represented by graphic symbols in green.

Scales of Maps

Since a map is a representation of the surface of the earth according to some given scale, each point or object on the earth must be shown in the same relation on the map as it occupies on the earth. Thus, if point A is five miles north of point B and ten miles east of point C, then the distance on the map between points A and B should be just one half as great as the distance between points A and C on the map, and points B and C should be shown in the same direction from point A on the map as they are on the ground. The scale of a map is therefore the ratio between the represented distances on the map and the corresponding actual distances on the ground. This scale may be expressed or represented in three ways. First, we may say that one inch on the map represents 10,000 inches on the ground; secondly, we may say that one inch on the map represents three miles on the ground; and thirdly, we may make a graphic scale for the maps whose units or divisions represent actual ground distances.

In order to simplify references to the map and to the ground the term, *Map Distance*, in this book will be understood to mean the actual length on the map between two plotted points, while the actual distance on the ground between two points will be understood to mean the *Ground Distance*. When points on the ground are directly referred to, they will be written in capitals: as, A, B, C, etc.; when plotted points on the map are referred to, they will be written in small letters; as, a, b, c, etc.

Representative Fraction. When a scale is expressed as the ratio between one unit on the map and the number of like units which it represents on the ground, it is written as a fraction and is called the Representative Fraction, or R. F. of a map. Thus:

$$\text{R. F.} = \frac{\text{M. D.}}{\text{G. D.}} = \frac{\text{1 unit on the map}}{\text{63360 units on the ground}}, \text{ or, } = \frac{1}{63360}$$

Words and Figures. The scale may be expressed in words and figures; as, 1 inch on map = 3 miles on ground, or that 1 inch on map = 100 miles on earth, etc.

Graphic Scales. We may draw a graphic scale on the margin of a map whose units represent actual ground distances. This is the best way of representing the scale of military maps, for by its use the mind is trained to think in ground units while looking at the map: in the other methods map distances have to be changed into ground distances.

Graphic scales are divided into three classes depending upon the purpose for which they are constructed or used: (1) *Reading Scales,* (2) *Working Scales,* and (3) *Slope Scales.* This classification is rather arbitrary, for a reading scale is often used as a working scale.

A reading scale is used in reading the map distance in terms of some well-known unit of lineal measure, as the inch, centimeter, etc., or to read map distances in terms of some well-known unit of land measure, such as the yard, mile, kilometer, etc. In the former case the reading scale is a scale of equal parts with the units marked in inches or centimeters; in the latter, the divisions or units on the scale are marked in ground distances, such as yards, miles, kilometers, etc.

A working scale is a scale of equal parts whose divisions represent some convenient number, as ten, twenty-five, or one hundred working units, such as paces, strides, distances passed over in a minute, etc.

A slope scale is a scale of equal parts whose divisions represent contour intervals for slopes of different degrees, and which is used to plot and to read slopes and to determine the difference in elevation between points.

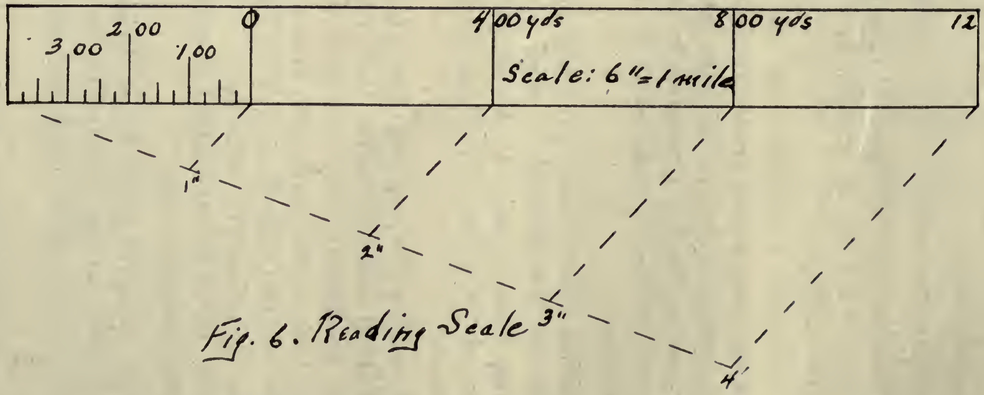


Fig. 6. Reading Scale

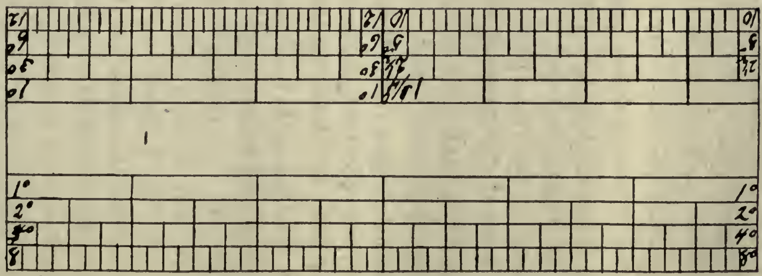


Fig. 7. Slope Scale.

Normal System of Scales, U. S. Army. Maps which are made to larger scales show less ground area for the same given map space, and the conformation of the ground on such maps can, therefore, be shown in greater detail by decreasing the contour interval and thereby increasing the number of contours.

If the ratio between the scale and the V. I. be kept constant, then no matter what the scale, the same degree of slope will always be shown by the same spaced contours. We have seen that the H. D. varies inversely with the degree of the slope up to 20°; it is also plain that the H. D. for the same V. I. and degree of slope will vary with the scale of the map: if therefore we vary the V. I. inversely with the scale of the map, we can keep the map distance of the H. D. for the same degree of slope, the same magnitude for maps of all scales.

Road sketches are made to a scale of 3 inches to 1 mile, with a V. I. of 20 feet; area sketches are made to a scale of 6 inches to 1 mile, with a V. I. of 10 feet; War Game and Fortress Maps are made to a scale of 12 inches to 1 mile, with a V. I. of 5 feet; Field Maneuver Maps are generally made to a scale of 3 inches to 1 mile, with a V. I. of 20 feet; there is also a Strategical Map which is made to a scale of 1 inch to 1 mile, with a V. I. of 60 feet.

From the following table it will be seen that in all army sketches and maps, the product of the M. D. in inches per mile and the V. I. in feet is always 60.

	M. D. (inches)		V. I. (feet)		Product
Road Sketches	3	×	20	=	60
Position Sketches	6	×	10	=	60
War Game, Fortress Maps	12	×	5	=	60
Strategical Maps	1	×	60	=	60
Maneuver Maps	3	×	20	=	60

If, therefore, it is desired to know the V. I. of a certain military map or sketch should be, it may be easily found by dividing 60 into the number of inches per mile on the map or sketch whose V. I. is desired.

To Construct a Reading Scale. In making any kind of a graphic scale for a map, the equal parts or divisions on it should represent a convenient number in hundreds of ground units, say feet or yards, so that these equal parts or divisions may be easily subdivided. For example, it is desired to construct a Reading Scale in yards for a map whose scale is, "6 inches to 1 mile"; the scale to be about six inches long.

1st, Find out how many yards on the ground is represented by six inches on the map; 2nd, Take the nearest convenient hundred of yards to the number thus found, and then find how many inches on the map represents the selected number of yards; 3rd, Divide the length in inches thus obtained into a convenient number of equal parts and subdivided the latter into convenient smaller units—similar to a measuring ruler.

Scale: "6 inches = 1 mile."

6 inches = 1,760 yards.

We shall select 1,600 yards as a convenient number of yards for our Reading Scale.

$$\begin{aligned} 1{,}760 \text{ yards} &= 6 \text{ inches}, \\ 1 \text{ yard} &= 6'' \div 1{,}760 = 6/1760 \text{ inches}. \\ 1{,}600 \text{ yards} &= 6/1760 \times 1{,}600 = 5.06 \text{ inches}. \end{aligned}$$

5.06 inches will therefore be the length of our scale. Measure off a distance of 5.06 inches and divide this distance into four equal parts as shown in the diagram in Fig. 6. Then each division is equal to 400 yards, and may be further subdivided into divisions of 100, 50, 25 yards, and so on.

To Construct a Slope Scale. In a previous paragraph, p. 11, it was seen that the H. D. between adjacent contours for a slope of 1° and a V. I. of 20 feet, is 1,146 feet, and that for all angles up to 20°, the H. D. can for all practical purposes be taken to vary inversely with the degree of the slope. For a map whose scale is 3 inches to 1 mile:

$$\begin{aligned} 3 \text{ inches} &= 5280 \text{ feet}, \\ 1 \text{ inch} &= 1760 \text{ feet}, \\ 1146 \text{ feet} &= \frac{1146}{1760} \text{ inches} = .65 + \text{inches}. \end{aligned}$$

It was also seen that the V. I. was made to vary inversely with the scale of the map. Thus the V. I. for a scale of 6 inches to 1 mile is 10 feet. Therefore the H. D. between adjacent contours for a slope of 1° and a V. I. of 10 feet is 573 feet. For a map whose scale is 6 inches to 1 mile, therefore:

$$6 \text{ inches} = 5280 \text{ feet,}$$
$$1 \text{ inch} = 880 \text{ feet,}$$
$$573 \text{ feet} = \frac{573}{880} \text{ inches} = .65 + \text{ inches.}$$

Therefore, for all maps made to the normal system of scales, U. S. A., slopes of the same degree will always be shown by contours spaced the same distance apart, no matter what the particular scale is, and the same slope scale can be used on any of these maps.

Now construct a scale as shown in Fig. 7. Instead of measuring .65 of an inch off directly for the H. D. of a 1° slope, it is more accurate to measure off (5 x .65 =) 3.25 inches and divide this length into five equal parts. This distance, .65 of an inch, divided into two gives the H. D. for a 2° slope; into four, a 4° slope; into eight, a 8° slope: similarly, into three, a 3° slope; into six, a 6° slope; into twelve, a 12° slope: and similarly, into one and one-fourth, a 1¼° slope; into two and one-half, a 2½° slope; into five, a 5° slope; into ten, a 10° slope, and so on.

The H. D. for a slope of 1¼° is (.65 ÷ 1¼ =) .52 of an inch. To get divisions of this magnitude measure off a line 2.6 inches long and divide it into five equal parts. The M. D. of the H. D. for any slope up to 20° can be found by dividing .65 inches by the degree of the slope.

Orientation of Maps. By the "Orientation of a Map" is meant turning the map in such a position in a horizontal plane so that the directions on the map coincide with those on the ground. The map may be placed in a horizontal plane by spreading it out on a table, or laying it flat on level ground, or holding it level in the hand. It might be well to mention a few facts of elementary geography, which, if kept in the mind, will prevent confusions of directions. If a man stands with his face towards the north, then his back will be towards the south, his right hand towards the east, and his left hand towards the west. In whatever way one faces, the top of the map is always north, the bottom south, the right-hand edge east, and the left-hand edge west. Since the top of a map is always north, it is therefore only necessary to know the north on the ground in order to bring the directions on the map into coincidence with the directions on the ground or to "orient the map," as it is commonly called. We may therefore orient a map with the aid of any method of determining directions on the ground.

(1) *Orientation by Compass:* When the compass is used to determine the approximately true north, the magnetic declination must be known and allowed for. Most maps have an arrow pointing towards the true north; this line is parallel with the border line on the side of map. In addition to the true north arrow, there is generally a secondary arrow making an angle with the true north arrow, which angle represents the magnetic declination for the locus of the map. If the secondary, or magnetic arrow on the map is made to point in the same direction as the needle of a compass, then the true north arrow will point towards the true north, and the map will be correctly oriented.

(2) *Orientation by the Sun:* In the northern hemisphere generally, and always north of the tropic of cancer, the sun at noon is directly south. If, therefore, the south of a map is directed towards the sun at noon it will be correctly oriented. It is not always possible, however, to know just when it is exactly noon, but by using the following method an approximate true north and south line may be determined. See Fig. 8. Take

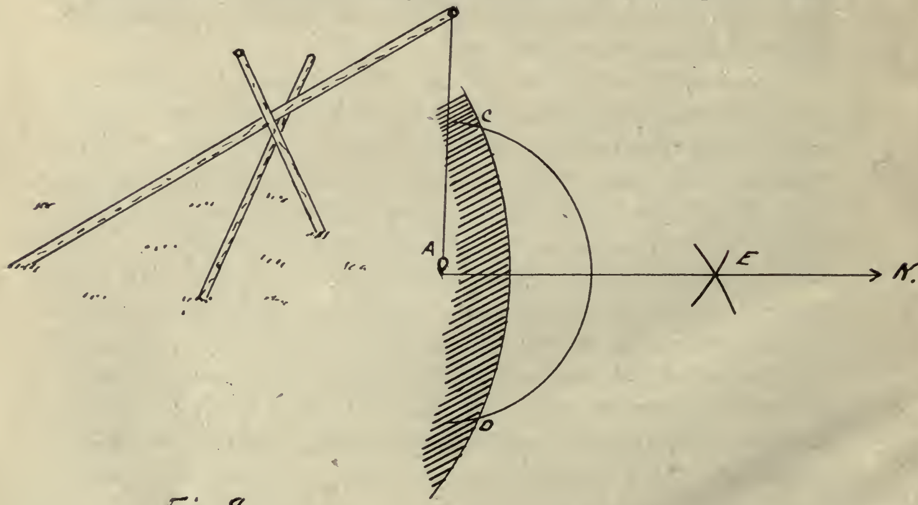


Fig. 8.

a straight stick three or four feet long and stick it into the ground so that it leans towards the north as nearly as it can be estimated. Support this stick by means of two crossed sticks which are securely stuck into the ground, and securely fasten the leaning stick to them by tying them together at their common junction with a small rope. Suspend from the free end of the leaning stick a plumb bob A by means of a cord of such length that the plumb bob is just free from the ground; observe at about thirty minutes before noon where the shadow from the free end of the leaning pole falls, and with the distance from this shadow to point A as a radius and point A as a center describe an arc of a circle on the ground, which ground should be level; observe and mark the point where the shadow from the free end of the leaning pole crosses the described arc after noon; bisect the arc connecting the two points C and D, where the shadow intercepts the described arc; join this point E with A and the line AE will be a true north and south line.

(3) *Orientation by North Star:* The North Star, or Polaris, with only a very small daily cyclic variation, is in the true north direction; therefore, by aligning two points on the earth with it (after night when it can be easily seen) an approximate true north and south line can be obtained. The method usually employed to do this is as follows: A plumb bob and line are suspended from an object, such as a tree limb, which is 8 or 10 feet from the ground, so that the plumb bob is just free from the ground—the plumb bob may be allowed to swing in a bucket full of water, especially if it is windy, in order to dampen its oscillations; by sighting on the plumb line and Polaris, one stake is driven about 10 feet directly south of the plumb line; and, by sighting on this stake and the plumb line another is driven the same distance directly to the north. These two stakes will then be in an approximately true north and south line. By the following modification of this method a much more accurate north and south line my be obtained.

Proceed as above, and after having established the two stakes, accurately determine on the top of the first stake by means of a small nail or movable peep sighting vane the exact point where the line of sight from Polaris to the plumb line strikes the stake;

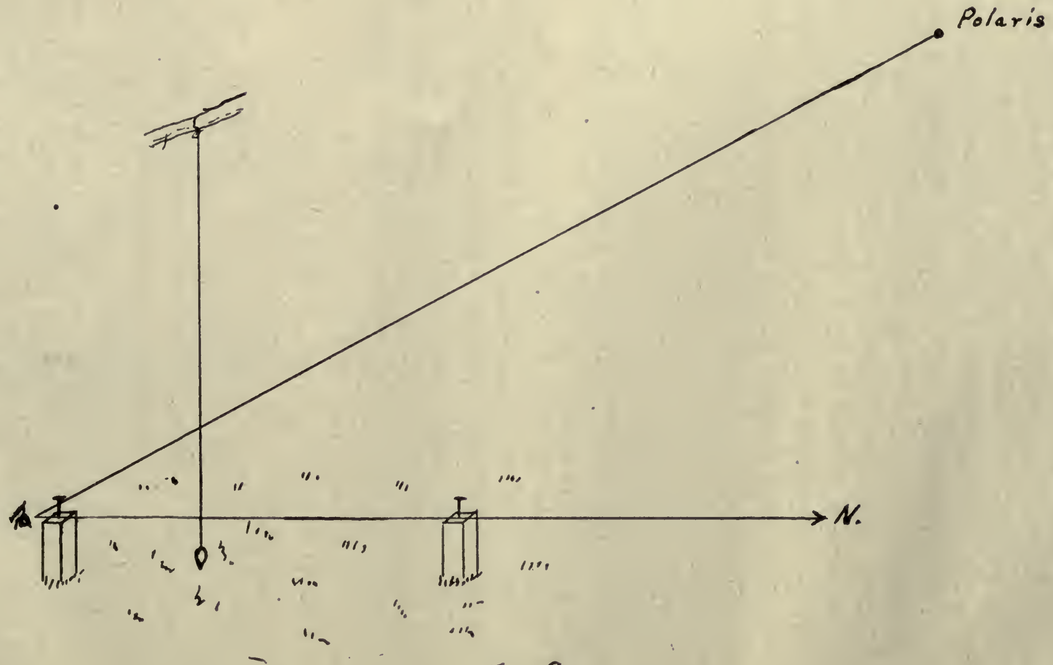


Fig 9.

then by means of a small nail mark the point on top of the second stake where the line of sight from the peep hole to the plumb line strikes the second stake; observe the clock reading of the "Great Dipper" (Ursae Major) or "Cassiopeia Chair," and from the table on page 247 find the azimuth of Polaris for that time. The line determined by the points on the two stakes, plus or minus the azimuth of Polaris for that time, is a true north and south line. The plumb line should be $\frac{1}{8}$ or $\frac{1}{10}$ of an inch in diameter and should be chalked white—both the plumb line and the small nail marker on the far stake should be illuminated by a lamp or lantern, which light should be shaded towards the first or observing stake.

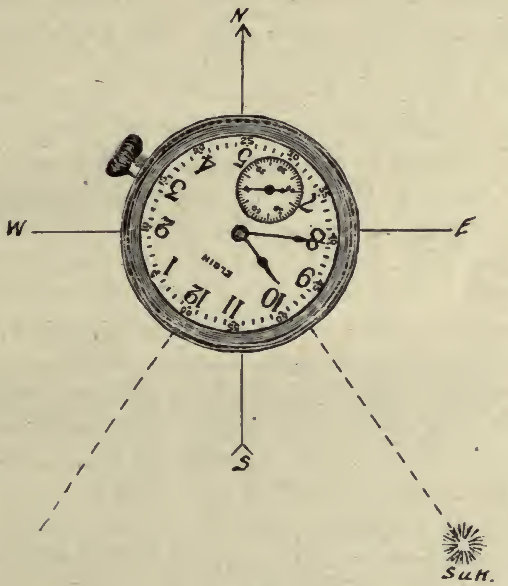


Fig. 10.

(4) *Orientation by Watch:* If the hour hand of a watch is pointed directly towards the sun, then the point on the dial half way between the hour hand and XII o'clock will point towards the true south.

(5) *Orientation by Comparisons:* Generally a ridge, road, railroad, fence, or other object on the map may be recognized

on the ground. In such cases it is only necessary to bring the line of direction of such ridge, road, railroad, or other object on the map into coincidence with its line of direction on the ground for the corresponding point and the map will be correctly oriented. This furnishes a rapid and fairly accurate method for orienting maps and is much used.

Location of Map Position. In order to read a map it is first necessary to orient the map, and then to locate one's ground position on the map. Often one is near a distinctive object on the terrain which is plainly plotted on the map by means of some appropriate conventional sign; one is then able to locate his map position at once. More often, however, one is not so fortunate; it is then necessary to resort to certain geometrical but simple aids in locating one's self. The geometrical aids are familiarly known as "Resection Problems."

(1) *By Two Plotted Points:* Two points, A and B, on the terrain are plotted on the map as, a and b (the points, A and B, may be conspicuous knolls, churches, or other easily recognized objects that are plotted on the map); the map is accurately oriented by means of one of the methods described above; a straight-edge ruler is then placed on the map so that it just touches point a, and with a as a center the ruler's edge is revolved about a to such a position that by sighting along its edge the point A on the terrain may be seen; a light pencil ray is then drawn along the edge of the ruler towards the observer. Similarly the ruler is aligned on b and B, and a ray from b is drawn towards the observer. The point where the two rays intersect will be the map position required. By looking at the diagram, Fig. 11 (a), no further explanation will be needed. The large square is supposed to be the actual ground while the smaller square is supposed to be the map.

(2) *By Three Plotted Points:* Often the magnetic declination of a place is not known, or the local magnetic attraction is so great as to make the compass unreliable, and it is not possible to orient the map by any of the other methods explained above; the map may then be both oriented and one's position determined by means of three plotted points. Three point resec-

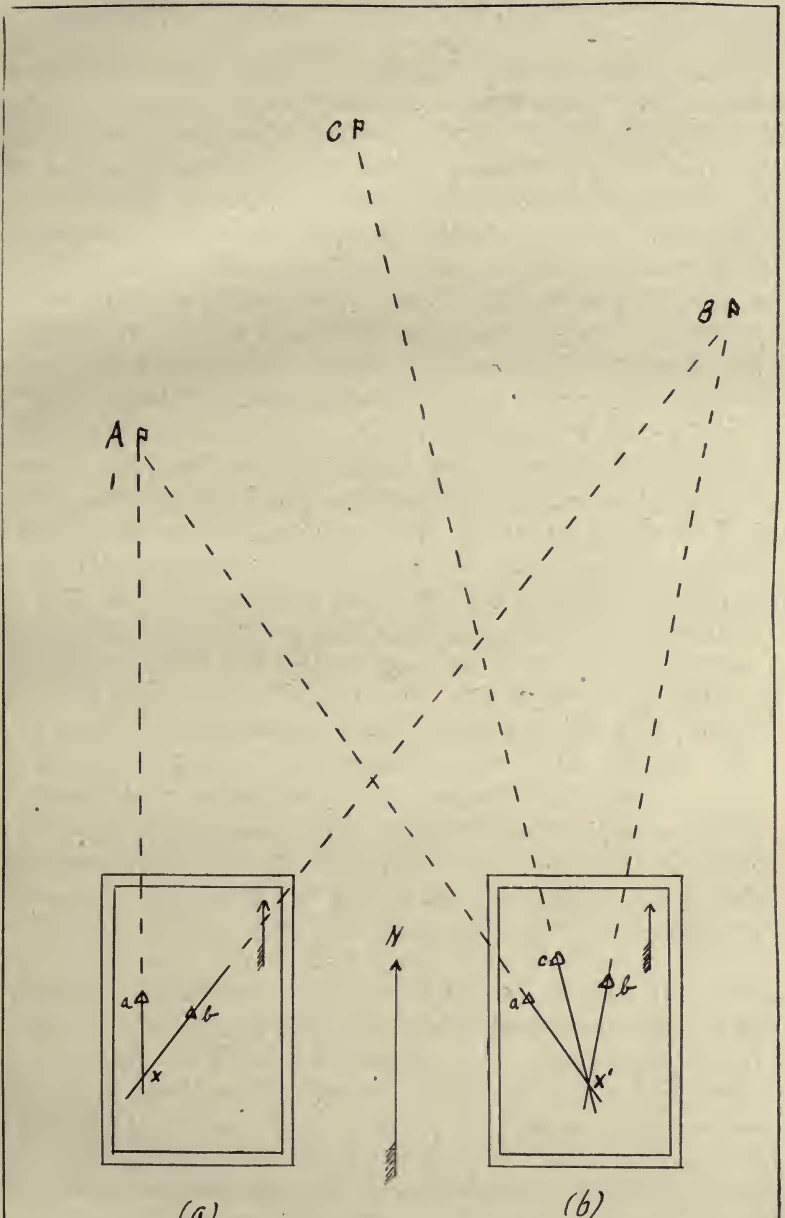


Fig. 11.

tion is usually applied either directly on the map by trials, or indirectly by means of tracing paper. Fig. 11 (b).

(a) *By Trials:* The map is first oriented as accurately as it can be by estimation; sight rays by means of a straight edge ruler are then taken on a and A, b and B, and c and C, respectively, and lines drawn towards the observer each time. If the three lines intersect in the same point, the map is correctly oriented; if not, the map is slightly revolved to the right or left according to the rules on pages 67-73, and rays are drawn until the three lines do intersect in a point. The "Three-Point Problem" may be included as a method of orienting maps.

(b) *By Tracing Paper:* A point o is conveniently plotted on a piece of tracing paper; with the tracing paper stationary, sight rays with a straight-edge ruler are taken from point o on objects A, B, and C, light pencil rays being drawn each time to represent them. The tracing paper is then applied to the map and so adjusted that the pencil rays exactly coincide with the respective plotted points a, b, and c at the same time; point o on the tracing paper is then exactly over the map position required.

(3) *By "Ranging In":* Often one is on some road, railroad, ridge, or other like object which he recognizes on the map, but he cannot tell just at what point along that road, railroad, or ridge he is, and he is able to see or recognize only one plotted point outside of that line. He may then locate his position by what is known as "ranging in." The map is first accurately oriented, a sight ray is then taken from a on A, the known plotted object, with a straight-edge ruler, and a light pencil ray drawn to represent it. Where this ray intersects the road, railroad, ridge, or other like object, is the map position required.

(4) *By "Lining In":* Sometimes one finds himself in a rather low piece of ground or a wooded place, where he can see only one plotted point, A, on the terrain, but he is able to see other ground which he is unable to recognize on the map. In such positions he can often locate his map position by what is commonly called "lining in." The map is accurately oriented and a sight ray from a on A is taken with a straight-edge ruler and a pencil ray is drawn on the map to represent it. He then

goes to the other ground he could not recognize, is able to locate a point on it by resection on other visible plotted points, and takes a ray on the initial point. Where this ray intersects the first ray drawn, is the map position required.

In locating one's self by resection, the angle formed by the intersecting lines should not be less than 30° nor more than 120°; in three-point problems the angle formed by the exterior intersecting lines is to be considered. In addition to the above general methods of resection, there are certain special applications or modifications which are taken up under "Plane Table Operations," page 61, which may also be used for map orientation and location.

Visibility

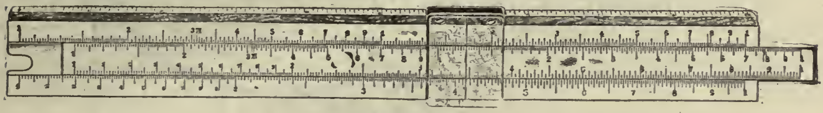
Of Points. Two points on the terrain are of course visible one from the other unless there is some object between them which obstructs the line of sight. Such obstructing objects may be hills, buildings, woods, or any other like feature of the terrain. We all know that points across a narrow valley are visible to points on the other side of that valley, while points on one side of a hill are invisible to points on the other side of that hill; but where the terrain between two points is of varied conformation, it is generally very difficult to tell whether the points are intervisible unless one of the points is actually occupied or the terrain is graphically represented. Since the actual conformation of the ground is represented on a topographical map by contours, the visibility of points to each other may be easily determined by observing the spacing and elevation of contours between them.

The conformation of the terrain between two points may be considered in two general classes—continuous and interrupted slopes. The slope between two points is said to be continuous when it is uniform, and interrupted when it is of several slopes of different degree. There are three kinds of continuous slopes, level, convex and concave. When the slope between two points is uniform and the ground open, those points are intervisible; when the slope is concave, they are also intervisible; but when the slope between two points is convex, they are invisible to each other. In general then for continuous slopes: *When the con-*

Relief Map

From Morton's *Elementary Geography*. By permission of American Book Company, Publishers.

tours near the higher of two points are farther apart than they are near the lower of those two points, the points are not intervisible, and vice versa.



*SLIDE RULE

When the ground between two points is composed of several slopes of different degree, it is much more difficult to tell from a map as to whether or not they are intervisible. It is only necessary, however, to determine whether there are any objects obstructing the line of sight. Such objects must of course be in the same horizontal line as the two points and above the line of sight between them, so it will only be necessary to tell whether any object in the same vertical plane as the two points is above the gradient of those two points. From Fig. 2, it may be seen that any two points of different elevations may define a vertical right triangle, in which the slope distance between the two points is the hypotenuse, and their vertical and horizontal distances the legs of that triangle. It will be remembered (p. 12) that the gradient of a slope is the ratio between its vertical projection to its horizontal projection, fractionally expressed. Thus, in Fig. 2, the gradient of slope AB is BC/AC, in which both BC and AC must be expressed in the same sized units.

From Fig. 12, it may be seen that if an object D′ of the terrain actually obstructs the line of sight between any two points, then a second right triangle ADE is formed by a vertical line dropped from the obstructing point, in which triangles the angle BAC is common, and angle ABC equals angle ADE. Therefore, since the homologous sides of similar triangles are proportional, $AC:AE :: BC:DE$, or $AC \times DE = AE \times BC$, but $AC \times D'E > AE \times BC$, from which we may formulate the rule that, *If the product of the horizontal distance between the two points times the difference in elevation between the lower point and the obstructing point is greater than the product of the horizontal distance between the lower point and obstructing point times the*

*Courtesy of W. & L. E. Gurley.

difference in elevation between the two points, then the two points are not intervisible; if less, they are intervisible. Point

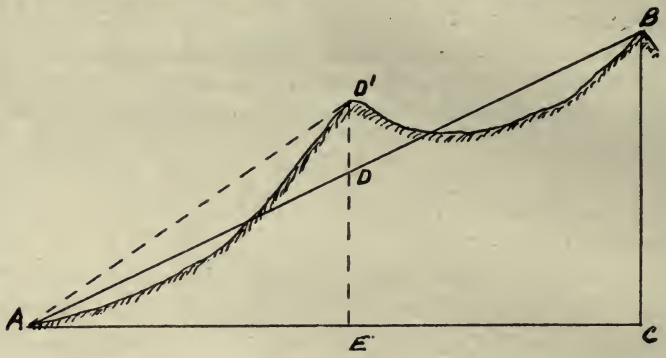


Fig. 12.

D′ is taken as the probable obstructing point. Similarly, from Fig. 12:

DE : BC :: AE : AC, and
BC/AC = DE/AE (Similar triangles), but
D′E/AE is greater than DE/AE.

Therefore, D′E/AE is greater than BC/AC (D′ is an obstructing point).

We may therefore formulate the following rule: *If the gradient of the two points whose intervisibility is sought be greater than the gradient of the lower of those two points and the probable obstructing point, they are intervisible; if less, they are not intervisible.*

It will be readily seen by inspecting a topographical map as to whether there is any object between two points which is likely to obstruct the line of sight between them: with sufficient practice one should also be able to tell by sight as to whether such object is an actual obstructing point within the limits of the probable accuracy of the map.

To determine visibility problems, therefore, it is only necessary to determine the horizontal and vertical projections of slopes and finding the product of or quotient between such projections. The horizontal projection of the slope between two points, i. e., their map distance apart, may be measured with a

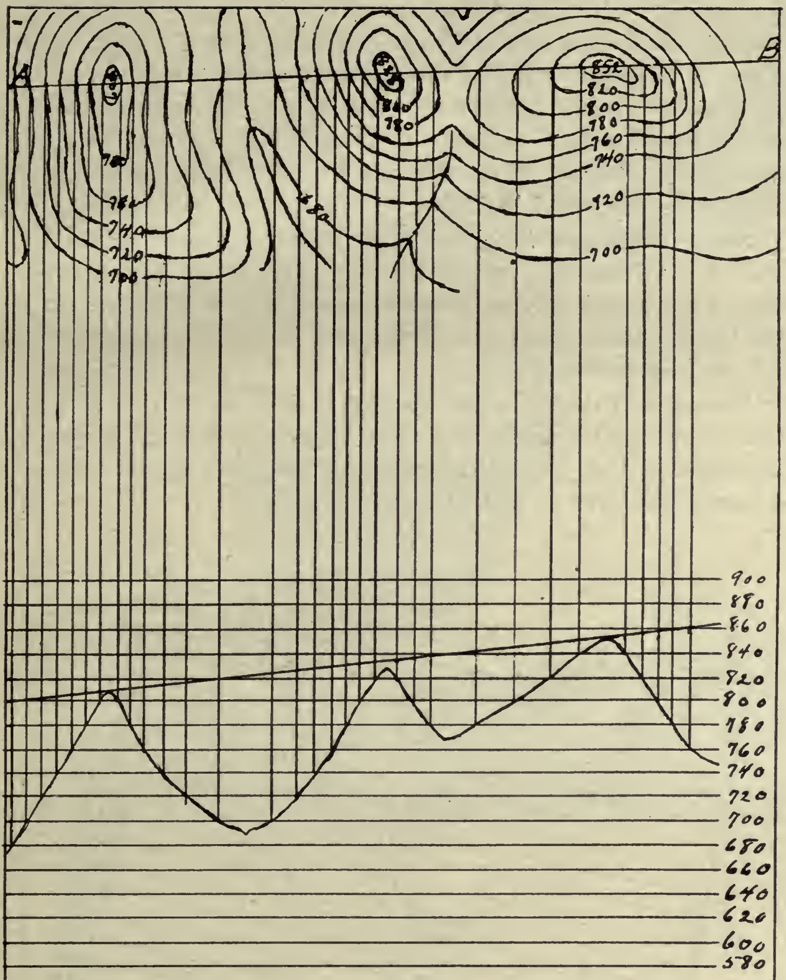


Fig. 13, Profile of Line AB.

Reading Scale in terms of ground units, or with a rule of equal parts in terms of inches or centimeters: since contours give the elevation of points directly the vertical projection of the slope between two points is equal to the difference in elevations between those points. It matters not whether the horizontal projection be expressed in inches or centimeters on the maps, or yards or meters on the ground; the vertical projection will always be expressed in feet or meters. The proportion between these projections may be solved on paper, with a slide rule, or in the head. Mere inspection of the map after sufficient practice will usually suffice.

Visibility of points in the same vertical plane may be graphically shown by using the lines of a common ruled sheet of paper as shown in Fig. 14, or by projecting the same in the form of a profile as shown in Fig 13.

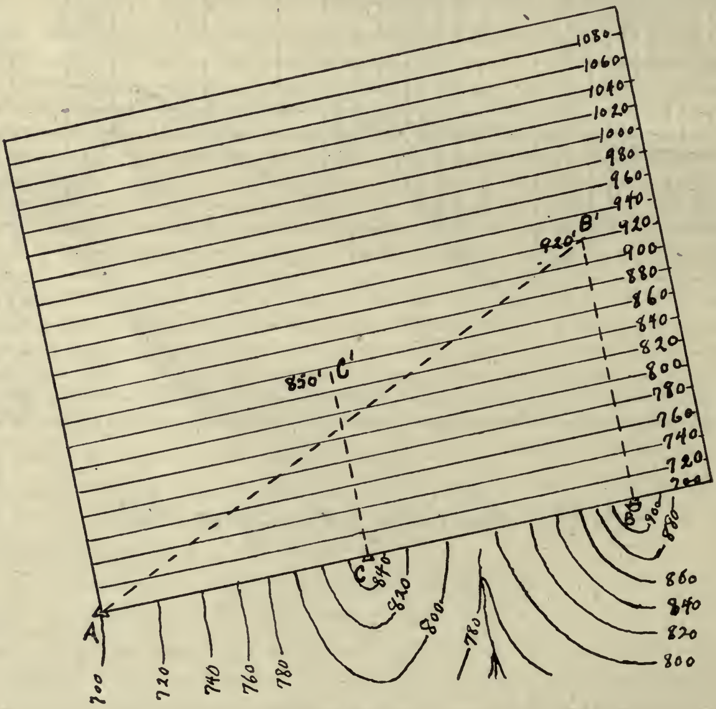


Fig. 14.

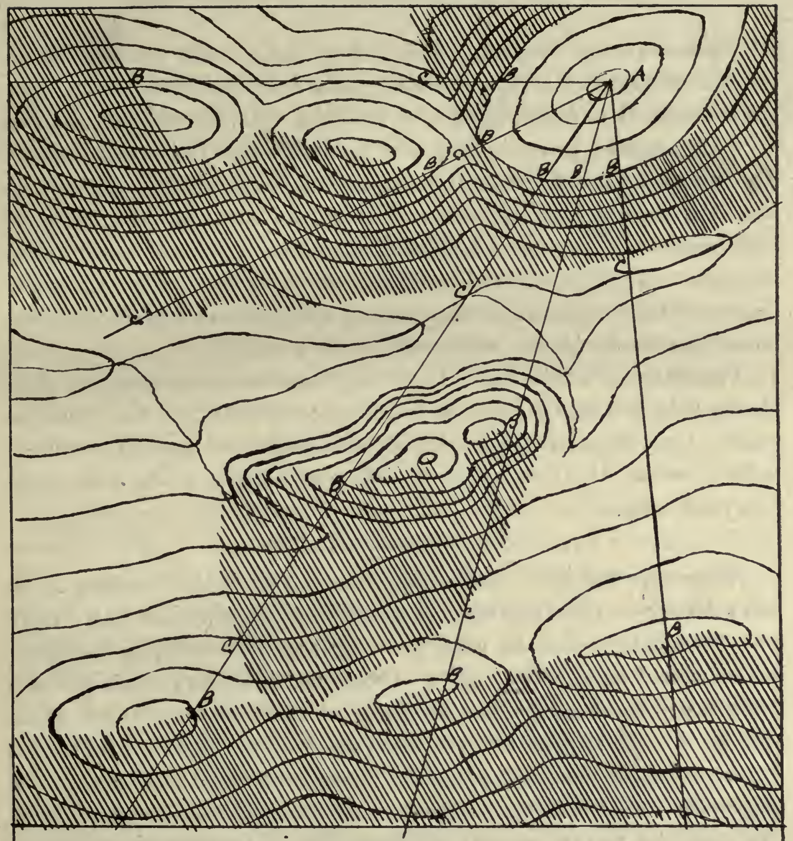


Fig. 15

Fig. 15.

Visibility of Areas. From Fig. 15 it will be seen that points B and C are the limiting points of visibility of the line or distance BC with respect to point A. If a sufficient number of such limiting points of visibility of different lines or distances be determined with respect to point A, such points will also be the limiting points of areas visible and invisible to point A. All points within such areas will of course be visible or invisible to point A. The shaded portions of the map in Fig. 15, show areas which are invisible to point A, while the unshaded portions show the visible areas with respect to point A.

Visibility Problems: In order to secure ease and rapidity in the solution of visibility problems, the student should practice much the determination of intervisibility of points between which points the terrain is of different slopes, using any good contour maps.

Map Interpretation

After one has first studied the subject of Map Reading, he is very likely to fall into the error of thinking that he can apply the foregoing rules of map reading mechanically, or perhaps what would be a more exact statement, his knowledge of map reading is confined to the mechanical rules he has learnt from the book. It should be remembered, however, that a map is a representation and not an exact reproduction of the terrain; to reproduce all the details of a terrain several miles square upon the sheet of paper several inches square is beyond the realm of practicability at least. A topographical map is much like a piece of literature in which no author can express complete thought by the use of words alone but by appealing to the imagination, to the intellect, by the use of subtle suggestions, by the choice use of adjectives and limiting and modifying phrases, the mind of the reader is led and directed through the same channels of thought and reasoning as the author's. Analogous to "literary interpretation," therefore, we have "map interpretation," and he who has no knowledge of the terrain and of the limits and possibilities of topographic sketching is like a person who knows how to pronounce words but has no conception of their meaning. No one can thoroughly interpret a topographic map who has not had experience as a sketcher. This does not mean that much benefit can not be gotten from a mere study of maps, but that all officers in the military profession should have had experience as topographic sketchers.

Of All Maps. In the interpretation of any map due allowance should first be made for the methods employed in its construction, the condition under which the sketcher worked, and the skill of the sketcher who made it. Topographic surveys using accurate control; such as, geodetic triangulation, control traverses, etc.; sketches made with a base line measured by pacing, or perhaps by estimation; the proximity of hostile forces; experienced or inexperienced sketchers—all these factors present considerations which the reader must know how to allow for.

Of Roads. Of all the features the roads will be the most accurate. This is due to their ease of access and of locating them. It is but human for the sketcher to do his best at those places which are likely to be visited most by those who are to use the map. Traverses will be run over roads or at least the more important ones as a framework of control for the adjacent sketching, or road crossings and changes in direction of roads will be determined by other accurate geometric methods; such as, resection, intersection, etc. For maps executed in the field, it may be safely assumed that horizontal points will be plotted within 1/50th of an inch of the determined map position; points determined by plane table methods for average sized maps will be plotted within 50 feet of their true map position as determined; while in sketches, points determined by estimation will vary according to the distance from the point or points from which they are estimated—distances estimated will vary from 0 to 10 per cent, or perhaps greater, of their true value, according to the skill of the sketcher.

Of Streams. The location of streams will be the next to roads (including railroads, etc.) in their accuracy. The courses of important streams will usually be determined by traverses, or important points on them determined by other accurate geometric methods.

Of the Conformation of the Ground. It is of course apparent that it is impracticable—too costly and too laborious, to determine a sufficient number of points on the terrain so as to make the horizontal location of contours so accurate that their error would always be within the limits of plotting—say 1/50th of an inch. The sketcher must therefore determine only a sufficient number of important or critical points to control his work, and then plot the contours by eye so as to represent the slopes and conformation of the ground as they appear to him. Even with the same control the most accurate sketchers will vary slightly in the spacing of contours by estimation, but all will faithfully represent the conformation of the ground. In the readings of the contours of a map, the conformation of the ground must be interpreted in the light of a knowledge of ground forms. Military problems depend greatly upon the tactical possibilities of the terrain, and when such problems are solved from maps, such knowledge is essential to proper solutions.

Of Forests. The presence of dense forests on the ground renders the details of its conformation of very little importance, but which in open ground would be of great military importance. The presence of forests renders the determination and plotting of details of the ground impossible; the sketcher does not enter forests in search of such details and he would not find them if he did. The contours running through woods should, therefore, be interpreted as representing only the broad conformation of the ground.

Of Conventional Signs. Conventional signs like print must be large enough to be seen and read. We cannot therefore draw them to scale, but must represent them by symbols of convenient size without regard to the scale of the map. Thus the size of a palm tree as shown in the official book of conventional signs, U. S. Army, when shown on a three-inch-to-one-mile map, is almost 300 feet high and 200 feet in diameter; an orchard-tree symbol is 125 feet in diameter; a single cannon is about 175 feet long, while a sentinel is 65 feet in diameter. As a rule only a few symbols are shown to represent a certain vegetation area; or the location of a single tree in an open area; or a sentry, picket, or support in an outpost position, and so on. The solid built sections in cities will be shown by solid blocks; dwelling houses in residential districts will be shown only conventionally by the proper symbols—not the exact number; all farm dwelling houses are shown but not the attached barns and other outhouses; detached barns and other buildings, however, will be shown.

On the Systematic Reading of Maps. To read a map it is first necessary to orient the map and then to locate one's position on it. A sufficient number of prominent points should next be located both on the ground and the map so as to keep one's idea of directions constantly true.

Military men have to read maps under two different conditions—1st, in conjunction with the terrain, and 2nd, from the map alone. In garrison school work, map problems will usually be given on maps whose terrain many of the officers have never seen; here the terrain must exist in the imagination of the student and a knowledge of ground forms is essential to a true picture. In maneuvers and campaigns, maps of the theater of operations will usually be furnished, so that such maps may be read in conjunction with the terrain.

A map cannot be read at a glance, but must be studied inch by inch. Preparatory to a detailed study of the map, however, the map should be looked at in a general way in order to get a general idea of the ground. The courses of streams should first be noted, this will at once give the sections of lowest and of highest elevations, the watersheds and valleys; it will show whether the streams beds are deeply cut or not and give a general idea as to the conformation of the ground.

If the map is then held straight out in front of the eye at a convenient distance, the hills, ridges and slopes should appear to stand out in relief, as if the map were a model of the ground itself. If an even hundred-foot contour which is common to the whole map be colored, say with red crayon, this effect will be even more vivid and its use is recommended. The streams of course should appear lower at their exits and higher at their sources.

After gaining a general idea of the terrain, the map should be studied in detail; the location and names of cities, towns, villages, farmhouses, churches, schoolhouses, etc., should be noted; the location, name and the directions and places to which they lead, should be noted of all roads, railroads, electric-roads, telegraph and telephone lines, etc.; the general visibility of areas to prominent points in the terrain should be determined; and the character and features of the terrain on the whole map should be systematically noted inch by inch.

With proper study and experience in map reading and sketching will come ease and thoroughness in their interpretation. A map should be so thoroughly studied during maneuvers and campaign that ground never seen before can be recognized by memory from the map, while points of reference which might be used in field orders should already be known by those who may have to carry into execution such orders.

ON CONTOURS IN GENERAL. The following rules in regard to contours should always be borne in mind:

a. All points on a contour line have the same elevation.

b. Where the contours are evenly spaced the slope is uniform.

c. If the contours are closer together at the bottom part of a slope, the slope is convex; if closer together at the top, the slope is concave.

d. All the contours of a vertical cliff form a single line.

e. Every contour either closes on itself or runs clear across the map.

f. On watersheds and spurs of hills, the lower contours bulge outwards from the higher contours; in water courses or ravines, the lower contours bend inwards towards the higher.

g. A series of concentric (closed) contours represents a hill. A closed contour containing within it no other contour generally represents a hill; a depression would be occupied by a pond or lake.

h. All contours adjacent to a stream whose elevations are lower than the source of a stream must cross that stream somewhere below its source.

i. A contour crossing a stream always turns upstream in crossing, forming an inverted V.

CHAPTER II

TOPOGRAPHICAL SURVEYING

General Remarks. Topographical surveying consists of two distinct operations carried on chiefly in conjunction, the control work and the sketching. The former is geometric and requires only a knowledge of and ability to use surveying instruments of precision, while the latter is artistic and requires much practice and a proper conception of ground forms and the ability to see them in their proper relation to one another in order to reach any degree of perfection. A topographical map is a representation to scale of the conformation of the ground; it is apparent that the actual conformation cannot be exactly reproduced on a map. A topographical map is therefore a generalization, more or less, of the terrain. The degree of generalization will depend: first, upon the scale of the map, the smaller the scale the greater the generalization; and secondly, upon the degree of accuracy required, the larger the number of locations geometrically determined the less the generalization and the more accurate the map. It would be possible to determine every critical point of the terrain, but a topographical survey so made would be so expensive that the mapping of any considerable area would be impracticable. Good sketching, therefore, requires correct generalization—the ability to take both a broad and a detailed view of the terrain in order to utilize the essential details in the interpretation of the important features of the terrain, and to bring them into proper correlation—to know in short what details may be omitted and what must be preserved in order to bring out the predominant features.

The military topographer must have a tactical knowledge of the military uses and requirements of a topographical map in order to make such a map. The visibility of points and areas, the character of slopes, the presence and condition of all roads, trails, passes, streams, vegetation, cultivation, artificial constructions, etc., are all essential to the military uses of maps.

Control Work

Geodetic Operations. The military topographer will seldom if ever, use geodetic methods; but the skeleton of control for accurate military surveys is usually the geodetic triangulation of the civil government, and since the use of this data requires a general knowledge of the subject matter, its operations will be presented in a general way first so that the military topographer can make use of the same.

Geodesy. In a general sense the first operation in any information survey is to locate the territory to be surveyed at its true location on the surface of the earth. The determination of the latitude and longitude of important locations and the areas of large territories are the functions of geodesy. Having determined the latitude and longitude of a base point, the geodetic locations of other important locations near it are computed from an elaborate system of triangulation. This consists in accurately measuring a base line of from four to ten miles long, one end of which is the base point whose coördinates of latitude and longitude have been determined by geodetic or astronomic methods, and upon this line constructing a system of triangles. Any side of any triangle so formed may be used as a base to form new triangles, and the system of triangles can be carried forward in any direction. This progression should not, however, be carried forward in any direction more than 250 miles from the original base line. At such a distance a new base line should be measured and the geodetic coördinates of one of its extremities determined by astronomic methods, in order to check the control work and to carry the triangulation further. In geodetic and geological surveys, single triangles are not allowed; each unknown point must be the vertex of at least three triangles with respect to a known line. This forms a check on the accuracy of the work and furnishes a means of properly distributing any errors. In each triangle one side and the three angles are known from which the two unknown sides can be computed. The diagram in Fig. 16 shows the simplest form of a geodetic or geological triangulation.

The Base Line. An open and level stretch of ground from four to ten miles long is selected. If this be not available then

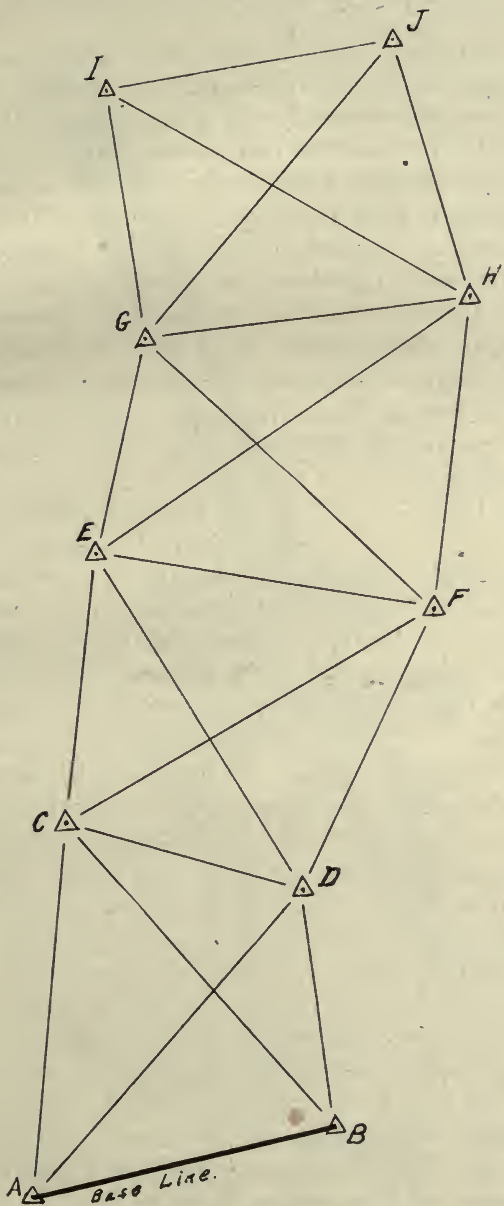
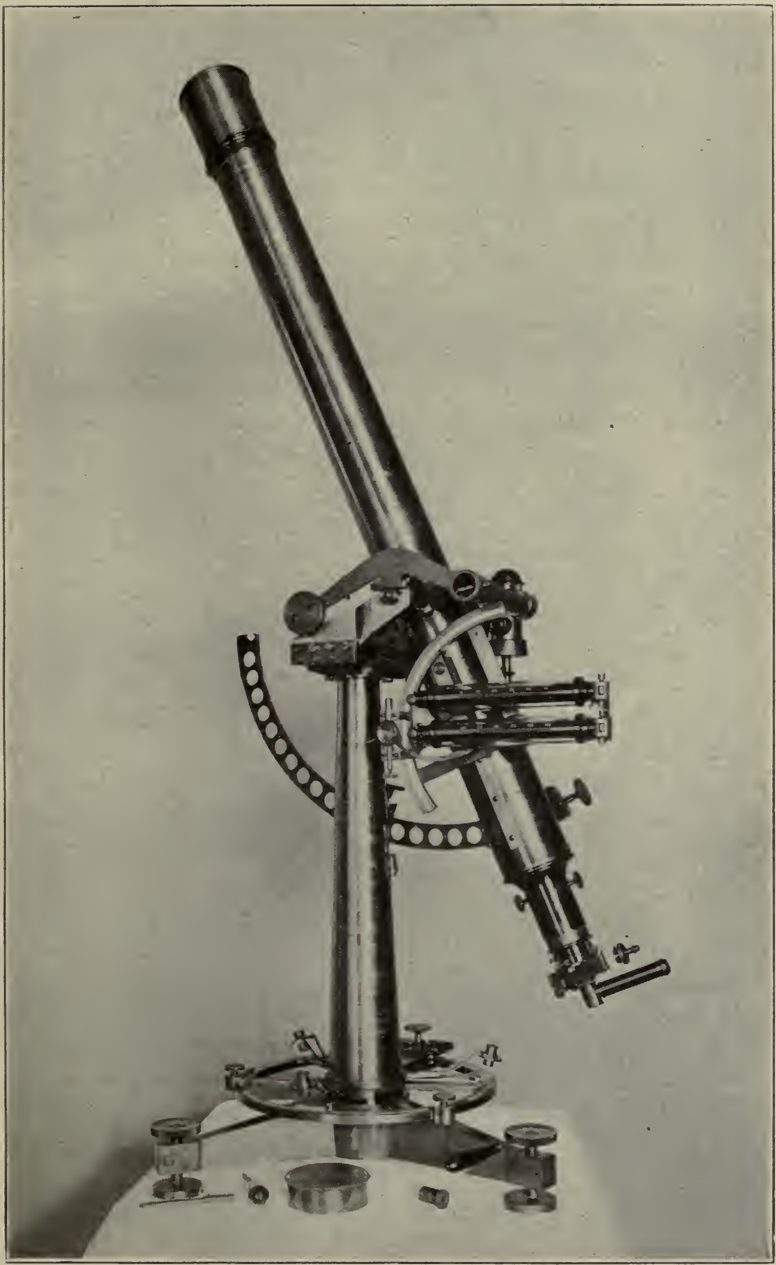


Fig. 16.

a stretch of uniform slope is selected, or, if necessary broken level stretches for the desired length are selected. Permanent stations or monuments are erected at both ends, and the latitude and longitude of one of the ends is determined by astronomic methods. The distance between the two ends or base stations is then measured with an invar or steel tape that has been calibrated with a standard for the occasion. Methods of precision are followed to get the measurement within the degree of accuracy required; corrections are made for tension, temperature, sag, slope and elevation. Base lines can be measured with a very high degree of accuracy, using either the invar or steel tape. The following shows the results obtained by the Coast & Geodetic Survey in 1907 on six base lines measured along the 98th Meridian:

Base Line	Probable Error	
	Invar Tape	Steel Tape
Point Isabel	1 in 2,310,000	1 in 1,300,000
Williamette	3,340,000	1,730,000
Tacoma	2,980,000	1,630,000
Stephen	2,940,000	1,120,000
Brown Valley	3,110,000	1,420,000
Royalton	2,460,000	2,260,000

Latitude Determination. Latitude may be determined in a number of ways, two are here given. One of the most precise methods used in geodetic work is to measure with a zenith telescope the zenith distances of two stars whose difference in zenith distances is very small. In practice a number of sets of such stars are observed and their mean taken for the latitude of the station. Formula: $z=\phi-s$, and $z'=s'-\phi$, from which $\phi=\frac{1}{2}(s+s')+\frac{1}{2}(z-z')$; in which ϕ=latitude of station, z and z'=zenith distances of the two stars, and s and s'=their altitudes. The simplest method is to measure the meridian zenith or altitude of a known star; then $\phi=s\pm z$. A sextant or transit may be used in this method; the known star may be the Sun, Polaris, or any other recognized star. The declination and right ascension of all important stars, the sun, and the moon, for the Greenwich Meridian are given in the Nautical Almanac.



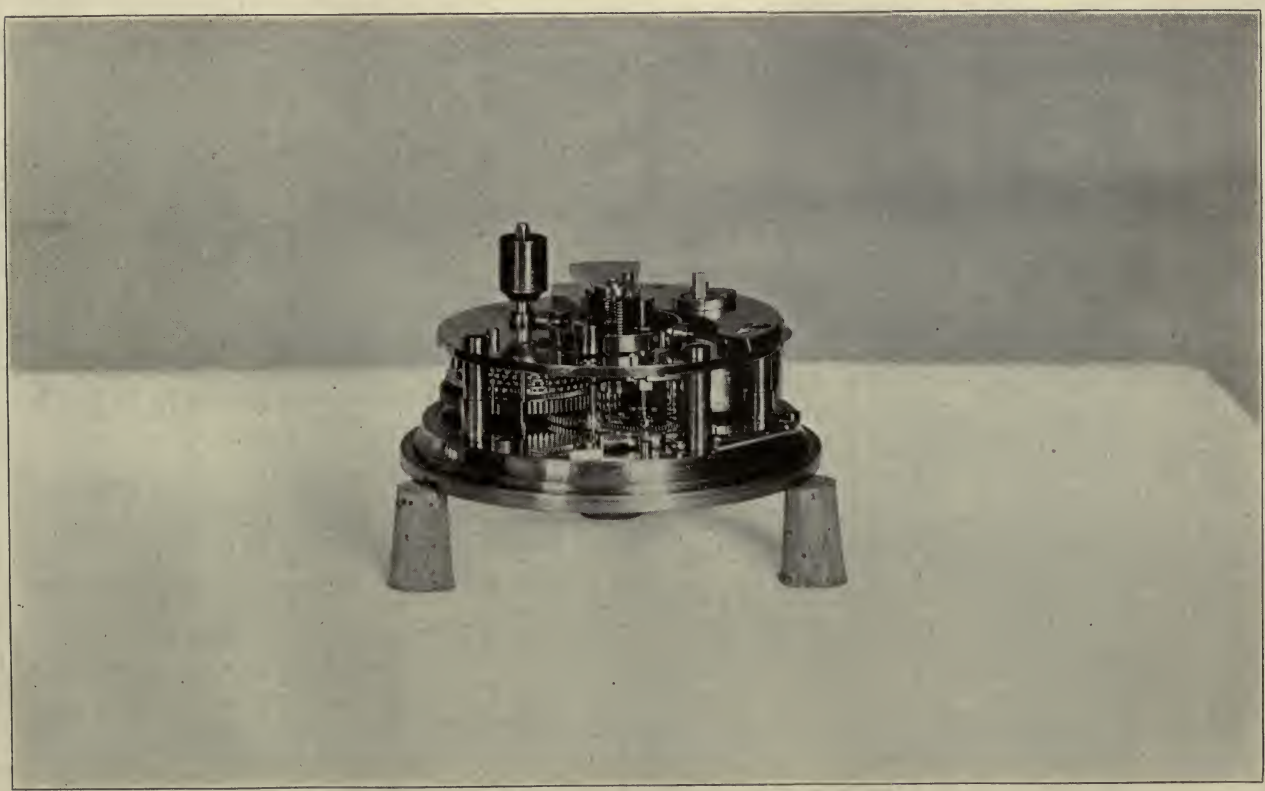
Zenith Telescope
Courtesy of the Coast & Geodetic Survey

The second method is often used in exploratory surveys and in reconnaissances, but it is not suitable for geodetic work.

Longitude Determination. The longitude of a point is found by accurately determining the difference in time between it and another point whose longitude is known. The other point is usually the Prime Meridian, which requires that accurate Greenwich time be had at the station whose longitude is to be found. Such time is kept on a chronometer or chronograph which has been taken to and set with one that has accurate Greenwich time. The time at which a known star transits the meridian of the station whose longitude is desired, is observed and recorded on the chronometer. The difference between this recorded time at which the known star transited the meridian of the station and the time at which it transited the Prime Meridian (given in the Nautical Almanac), is the true distance in time between them, from which their difference in longitude may be directly reduced (one second in time equals 15 seconds in longitude). In practice observations are taken from two stations some distance apart, one of which has had its geodetic coördinates already determined, and the time of each observation at each station is recorded simultaneously on the chronometer of each station by means of an electric circuit and key which gives a check on the chronometers and the time; several observations are taken on the star just before it crosses the meridian and several just after, rather than trying to observe the exact transit, which eliminates personal equations. The observations are taken on a number of known stars, their exact transits computed, and the mean taken for the true difference in time.

In exploratory surveys the transit of a known star may be determined with sufficient accuracy by a sextant. Observations both for latitude and longitude at sea are made with the sextant by measuring the altitude and azimuth of a known star. Washington or Greenwich time is kept with a chronometer on ship board.

Triangulation. After the base line has been measured and the coördinates of one of its stations (ends) determined, the

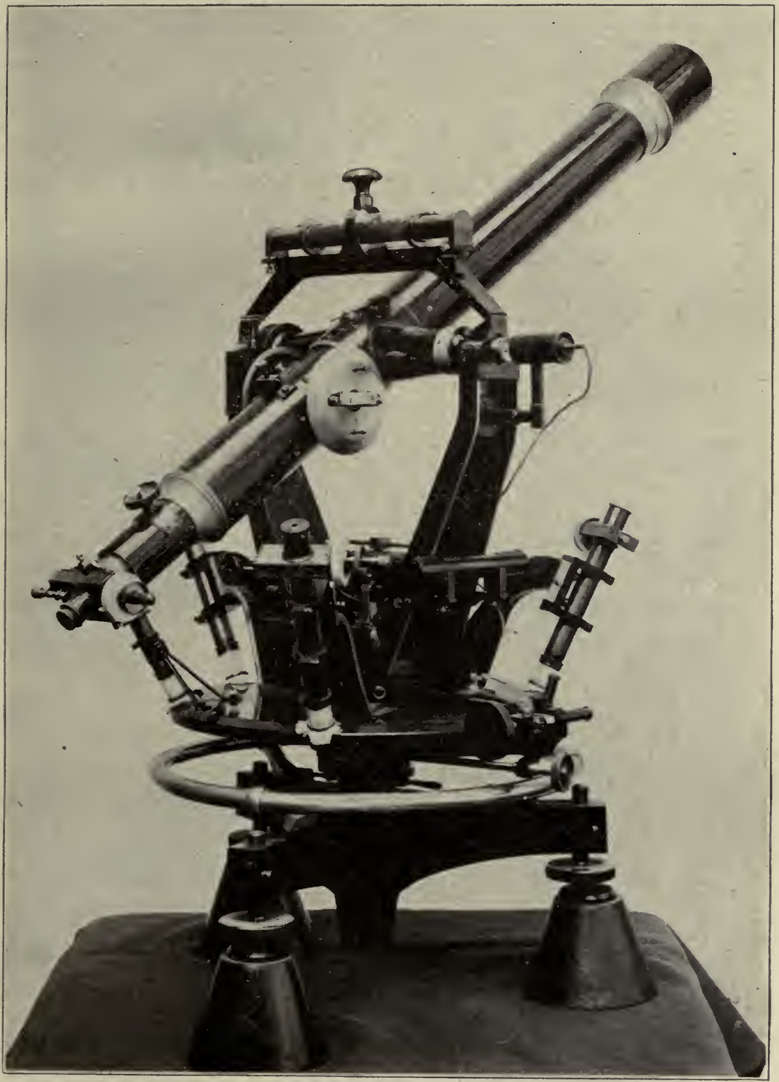


CHRONOMETER
Courtesy of the Coast & Geodetic Survey

azimuth of the Base Line is determined by sun observations. Triangulation stations are then selected to carry the triangulation forward. These stations are as a rule from eight to ten miles apart and the most prominent points of the terrain are selected for them (sometimes their distance apart is much greater). No point is selected as a station which would form with the base line from which its location is to be determined a triangle in which any angle is less than 30° nor more than 120°, the more equiangular the better. Each station is marked with a permanent monument which is usually a cement slab with a triangulation mark on the top of it. The monument is placed sufficiently deep to eliminate disturbances by frost and local causes. A tower or tripod marker is then erected over the monument, of such height or size that a theodolite may be set up either under it or on top of it; the marker for sighting on from adjacent triangulation stations consists generally of a prism frame covered with white cloth, although a mirror or heliograph marker is sometimes used; in very level countries towers of considerable height are necessary. Each triangulation station is then occupied with a theodolite, and the angles of each triangle are measured by the method of repetition or, in less accurate work, by direction. The sum of the angles of any triangles should not vary from 180° by more than 15″. The spherical excess is deducted and the angles adjusted by the method of least squares: for geodetic purposes triangles must be considered and adjusted as spherical triangles. From the known side and three known angles of each triangle, the other two sides are computed, and from this the geodetic coördinates of each triangulation station is determined.

The geodetic data of triangulation stations include:

(1) The Elevation above mean sea level of each station.
(2) The Latitude of each station.
(3) The Longitude of each station.
(4) The Azimuth of each two adjacent stations.
(5) The Back-Azimuth of each two adjacent stations.
(6) The Distance between each two adjacent stations.



THEODOLITE
Courtesy of the Coast & Geodetic Survey

Example:

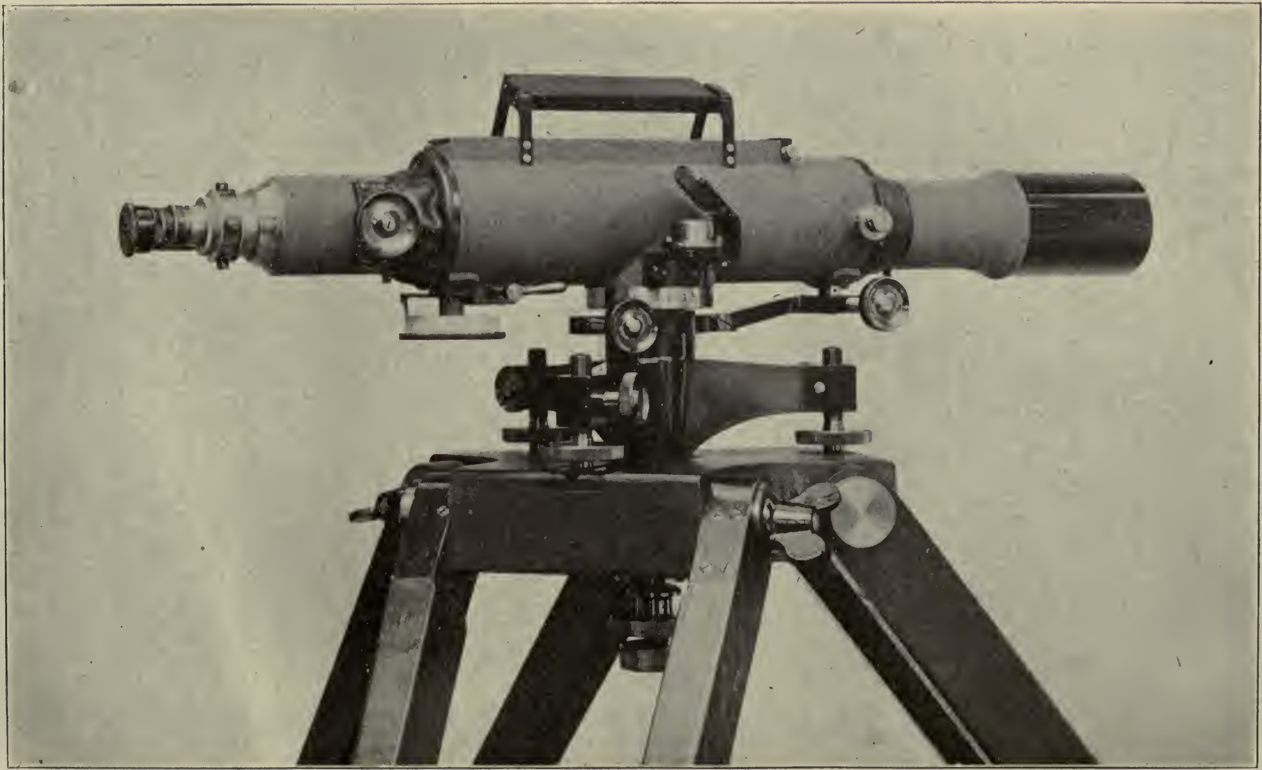
Station	Latitude Longitude	Secs. in Meters	Azimuth	Back-Azimuth	To Station	Distance
Two Tips	39°43′01″	37.8	19°03′20″	198°51′38″	Mt. Como	81,622 M
	119°09′31″	1330.0	198°13′31″	288°01′42″	Pah-Rah	27,774 M
			280°13′19″	100°48′57″	Carson Sk	81,253 M
Mucca	39°58′35″	1983.7	288°10′23″	109°08′18″	Carson Sk	136,436 M
	119°44′36″	854.9	331°55′11″	153°31′22″	Mt. Grant	176,388 M
			347°33′02″	167°43′20″	Mt. Como	108,514 M

Seconds of latitude and longitude are also given in their equivalent in feet or meters, and the magnitude of each second of latitude and longitude varies with the latitude of the station. For values see Table V.

Control Work of Military Surveys

A military survey may be made of a territory in which the the Coast and Geodetic survey or the Geological Survey have already established triangulation stations, or it may be in a territory that has never been visited by either of these surveys. In the former case, the military topographer will be relieved of much preliminary control work, by utilizing their data, which is always available to him. In foreign territories, such data of their government will perhaps not be available, but topographic work in such places will usually be confined to rapid military sketches aided by such maps as can be obtained.

Control Work With Geodetic Triangulation Stations. The geodetic stations are usually so far apart that they must be supplemented with other triangulation stations in order that sufficient stations will be visible to all probably plane table resection points. The number of the probable plane table resections points and their distribution will depend, first, upon the closeness of the terrain, and second, upon the degree of accuracy required. There should be at least three triangulation flags visible to each resection station. The visibility of triangulation stations will depend upon the closeness of the terrain and the distance at which they are used. Triangulation stations will usually be marked with flags and with the average conditions of day light the limit of visibility will be about four miles. When the terrain is close triangulation flags which are near a resection station are quite often invisible on account of an intervening hill or woods, but in such a case resection can



Geodetic Level
Courtesy of the Coast & Geodetic Survey

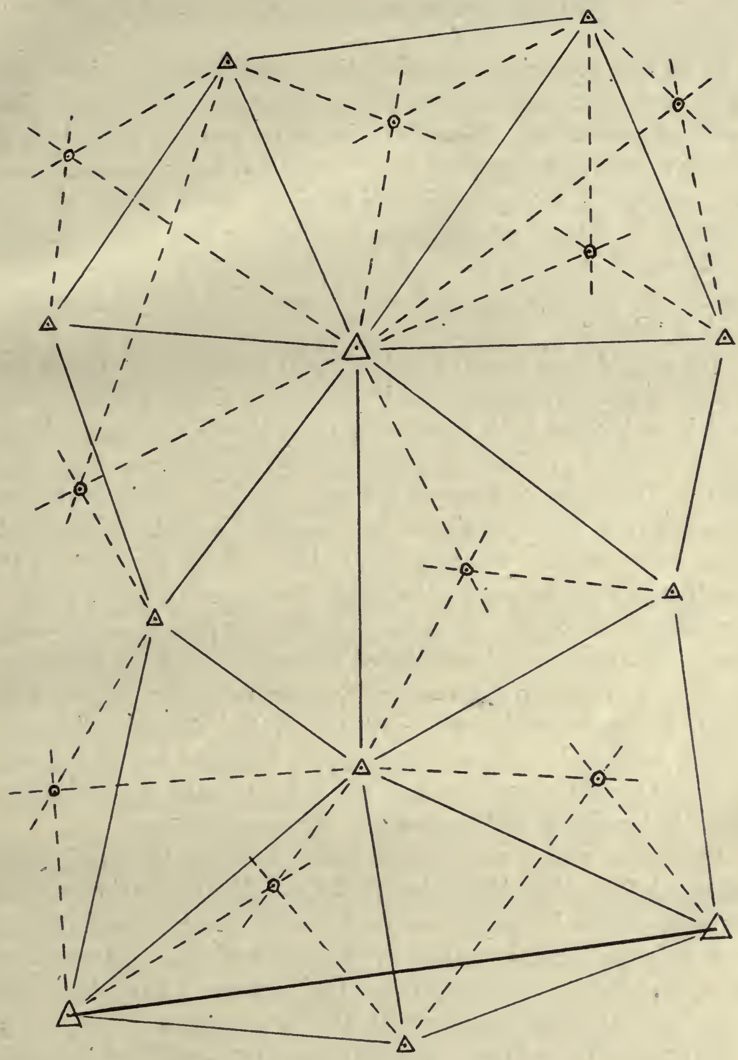
often be made on more distant triangulation flags. Triangulation flags established about every two miles will usually suffice for the average terrain. If entirely open, fewer flags will suffice; or if there are a few commanding hills; if the ground be level or covered with trees, it may be necessary to supplement the geodetic stations with control traverses for the requisite framework. No normal system of triangulation stations can be made, but the diagram in Fig. 17, will give the general idea of triangulation control.

Preliminary Reconnaissance. The topographer should first make a preliminary reconnaissance, mounted if possible, of his territory, from which to get a general idea of the conformation of the ground, and of the character of the vegetation in order to select the hills and ridges on which he should place his triangulation stations, and to intelligently plan his work.

Stations whose locations are determined by triangulation methods are classified into three divisions according to the degree of accuracy by which they are determined, (1) Primary Triangulation Stations, (2) Secondary Triangulation Stations, and (3) Tertiary Triangulation Stations. This classification must not be confused with the Primary, Secondary, and Tertiary Triangulation of the Coast and Geodetic Survey, which is entirely different.

Primary Stations consist of those triangulation stations which are determined with the greatest accuracy, and upon which the work is carried forward and from which other primary stations are determined. Secondary Stations are those triangulation stations which are not so accurately determined as primary stations—no corrections are made for adjustment, but from them tertiary stations are allowed to be determined by resection. Tertiary Stations are commonly called plane table stations and are determined by resection from primary and secondary stations. Their difference will be more easily seen after their methods of determination are explained; the determinations of tertiary stations are explained under "Plane Table Methods."

Primary Triangulation. In the preliminary reconnaissance the topographer from the geodetic data, should have been



△ Geodetic Stations.

△ Other Primary Stations.

⊙ Secondary Stations.

Fig. 17.

able to find or recover the geodetic triangulation stations within his territory, and he should then have each of these stations marked with a flag. This flag should be about a yard wide by about a yard and a quarter long—muslin is best; the flag should be principally white, but it will be more easily picked up at a distance if the last quarter of a yard of the flag is red; the flag staff should be a straight pole from 20 to 30 feet long—bamboo makes an excellent flag staff, and it should be braced at its base with a tripod.

He should then select a hill or knoll with respect to the two most suitable adjacent geodetic stations, which is visible to both and is so located with respect to them that an obtuse triangle will be formed in which no angle is less than 30° nor more than 120°. The distance between the two adjacent geodetic stations will always be the long side of this triangle, and the knoll should be so selected that the two other sides will be as short as the conditions with respect to the angles will permit. This will give two sides from five to six miles long each and upon which a system of triangles can be extended whose sides will be from four to six miles long, on the average. In most military survey work simple triangles will suffice, but the system should not be extended very far; such a system is not suitable for adjustment to other geodetic stations and the azimuth that is carried forward in longitude will constantly increase in error.

Prominent points should have been selected in the preliminary reconnaissance for the primary triangulation stations; these stations should be from four to five miles apart; the angles of each triangle are measured by the method of repetition and their sum should not vary from 180° by more than 15″; this error is distributed equally with the three angles.

Control Work Without Geodetic Data. When the topographer does not know and has no data of the geodetic coordinates of any point within his territory, there are a number of ways that he may proceed in his work. It should be remembered that in any survey, there must be a point of beginning; if there is none that has been established, the topographer should arbitrarily select a Base Point and do his survey work with respect to it; the survey work can be just as accurate and later it may be able to determine the geodetic coördinates of that point, and then the survey work can be transferred to a projection sheet.

Preliminary Reconnaissance. A preliminary reconnaissance should be made as in the preceding case—to become acquainted with the ground and to select triangulation stations.

Base Line. When there are no geodetic stations, it will be necessary to measure a Base Line upon which to form and extend the primary triangulation. This base line should be from two to five miles long, according to the extent and character of the survey. The accuracy generally required in the measurement of a Base Line in this work is 1:100,000; but if only a small area is to be surveyed and no other work is going to be based upon it, 1 :10,000 will suffice. The instructions given by the authority ordering the survey will cover this. For measurement of Base Line, see page 238.

One end of the base line should be the selected base point; and its elevation should be determined or assumed. If the territory be near the sea shore, or near a bench mark a series of levels (spirit) may be run from it. To determine the mean sea level, the level should be set up at a convenient point along the beach and the elevation of the surface of the sea with respect to the level should be determined every half hour throughout the day. The mean of the readings will give the height of the level above mean sea level.

The primary triangulation is now carried on as explained in the preceding case.

Secondary Triangulation. At the same time that the points are selected for the primary stations, other points are selected for the necessary secondary stations and the same marked with a flag unless a church-spire, house-chimney, or other distinctive object has been selected for a secondary station. Secondary stations are located by taking intersecting rays on them from three primary stations. These intersecting rays are true azimuth rays, the azimuth being obtained from the Geodetic data or determined by sun azimuth. The location of secondary stations can be determined by plotting those intersecting asimuth rays on the field sheet. The coördinates of primary stations are computed and the stations are located on the field sheet by plotting their coördinates. Secondary stations are not occupied with the transit.

Tertiary Triangulation. Tertiary Stations are those whose map positions are determined by resection. Their determination is fully treated under Plane Table Operations.

Control Traverses. In level sections, in wooded areas, and in deep, narrow valleys, triangulation flags cannot be seen, and in such places it is necessary to run control traverses for the framework of control; the area included within each traverse will vary; for secondary control within these areas, needle and back-sight traverses are run. Control traverses are often used in civil surveys for the location of roads and streams, but such use of them will be rather the exception in military surveys; for such work needle and back-sight traverses checked by triangulation will usually suffice.

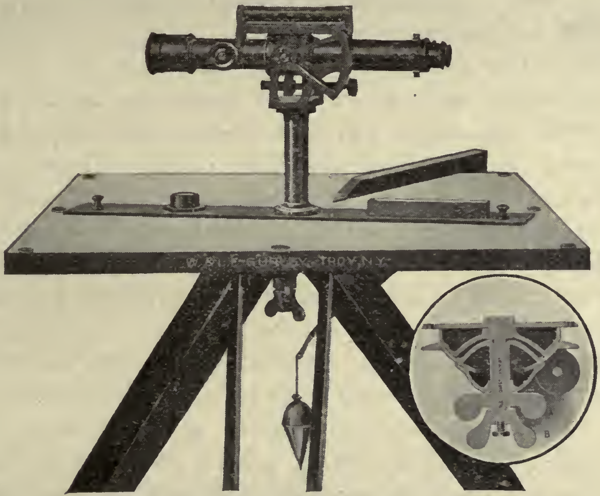
Control needle, and back-sight traverses, may replace all triangulation except the Geodetic, and even that in territories where it does not exist.

Triangulation Leveling. The difference in elevation between two points is equal to their horizontal distance apart times the tangent of their slope angle. In a triangulation system, the slope or vertical angles, from at least two known stations to each unknown station, are measured and the slope angle between every two stations is measured in both directions. This gives a very accurate check upon vertical or slope angles from which differences in elevations can be computed. Allowance should be made for the curvature of the earth ($7.92'' \times D^2$).

Plane Table Operations

The Plane Table consists of two general parts: (1) a plotting board, about $24'' \times 30''$, supported on a tripod, and (2) an alidade with telescope attached. The plotting board has attached to it on its under side supporting apparatus by means of which it may be leveled and revolved in a horizontal plane the same as a transit. There are either three or four leveling screws and a clamp screw which controls the vertical axis of the plane table; the clamp screw has a tangent screw attached to it for the more delicate orientation of the plane table. The telescope can be plunged in a vertical plane, and containing stadia wires, can be used in telemetric work. The edge of the alidade ruler and the line of collimation of the telescope are parallel. A magnetic box or trough compass and leveling tube are also attached to the plotting board.

The plane table is the ideal instrument for topographical plotting, but it is very clumsy and heavy to carry about in the field. All the operations that can be made with a transit can



*Plane Table and Alidade

be made with the plane table, but the observations are plotted directly instead of being first recorded. With the plane table, both the observations and plotting can be performed by one man. Military surveys, however, will usually be made with transit and sketching board, with one man acting as transit man and another as topographer.

Topographic Methods. There are a number of different methods by which topographic surveys may be made. These methods may all be divided into two general classes: (1) those in which the area is subdivided into squares by means of intersecting lines, the elevations of the intersections being deter-

*Courtesy of W. & L. E. Gurley.

mined, and (2) those in which the locations and elevations of certain critical or controlling points are determined geometrically. In the former method, called checkerboard system, the elevations of the intersections are written near the corresponding intersections on the plotting sheet, and contours are drawn between proper elevations. The contouring in this method is usually done in the office and the resulting topographic map represents the terrain only in a very general sense, unless the intersections are taken quite close together. Engineering surveys for cuts and fills are so made, but such surveys are too expensive for information surveys.

In the latter method the measurement may be made either (1) *with chain and level,* (2) *with transit and stadia,* (3) *with plane table and stadia,* (4) *with transit, sketching board and stadia,* and (5) *with photo-theodolite.* Unless otherwise specially stated all plane table operations will be explained for the plane table and stadia method in this book, these explanations with slight modification can be applied to the transit and sketching board method. Photo-topographic methods will be taken up separately.

Preparation of Field Sheets. The paper on which the field plotting is done should be so prepared as to reduce distortion from expansion and contraction. Ordinary paper expands and contracts along the grain greater than across the grain of the paper, which distorts the paper out of proportion and introduces errors that cannot be determined and allowed for. The U. S. Geological Survey uses two sheets of paragon paper mounted with the grain at right angles and with cloth between them. The Coast & Geodetic Survey uses Whatman's cold pressed hand made antiquarian paper backed with muslin. Tracing paper and linen may be used for less accurate work.

The Scale will be prescribed by the authority ordering the survey. Nothing is gained by making the scale too small even though the area to be surveyed is large. Military maps require many details not required in civil maps, and if the scale be too small, the minute plotting involved proves a tax on the topographer and is a great time consumer. It should be remembered that a map cannot be enlarged without multiplying and increasing the size of all errors, while in reducing a map the errors are reduced also. These considerations will require that the scale for field plotting should not be smaller than 1-25,000. Upon the other hand if the scale be too large then a sufficient number of triangulation stations cannot be plotted on the field sheet at the same time so as to do efficient field work. This will generally limit the scale to one not larger than 1-10,000. For general topographic work, a scale of 1-21,120, or three inches to one mile will be the best for field plotting.

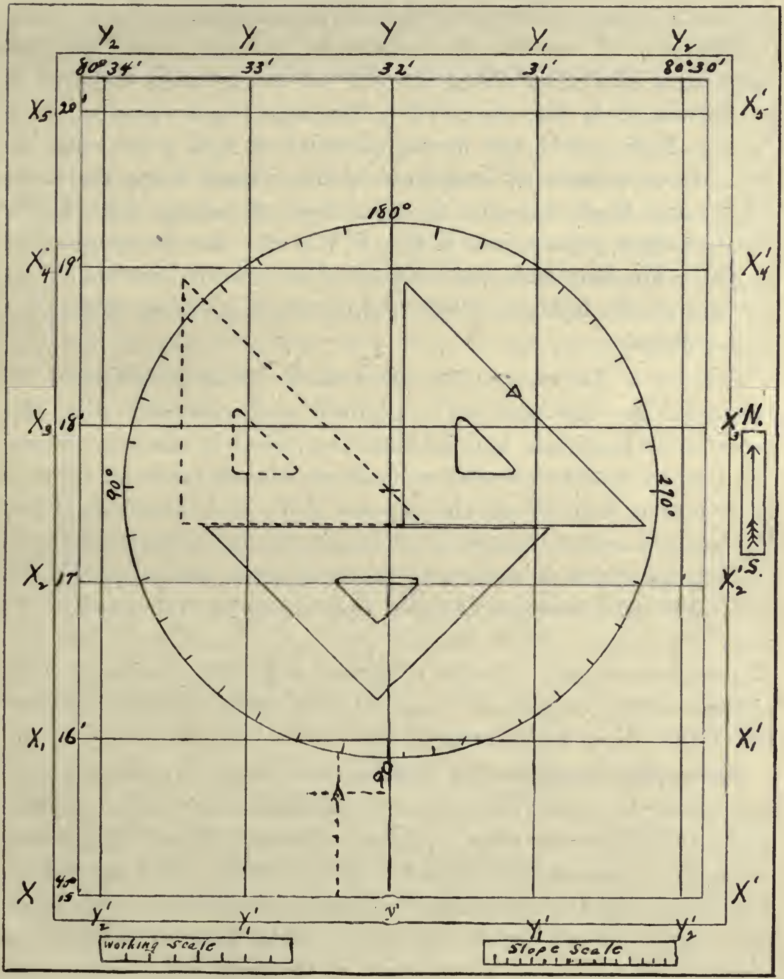


Fig. 18 Sketching Board.

Plotting the Coördinate Lines. Field sheets for large areas should be plotted on polyconic projections, but for field sheets which represent an area several miles square, the coordinates of longitude and latitude can both be plotted as parallel lines. If so plotted each minute of longitude and latitude are to be represented by meridian and parallel lines respectively, on the field sheet; a line YY' is drawn perpendicularly across the center of the field sheet; a line XX' is then drawn perpendicular to line YY' near the lower edge of the field sheet; from Table V the value of one minute in latitude is found, and that distance is measured off along line YY'; from as many times as it is contained in the line YY'; through these points, lines $X_1X'_1$, $X_2X'_2$, etc., are drawn parallel to XX'; the value in feet of one minute of longitude is then found from the same table, and that distance is measured off along line XX'; through these points lines $Y_1Y'_1$, $Y_2Y'_2$, etc., are drawn parallel to YY'. The longitude and latitude of coördinate lines should be marked on the field sheet to avoid errors in plotting triangulation stations.

Plotting Triangulation Stations. The coördinates of triangulation stations are computed and recorded with the seconds of longitude and latitude expressed in meters. From the nearest minute-parallel of latitude, the distance of seconds in meters is laid off on the proper Y_nY_n line; similarly from the nearest minute-meridian of longitude, the distance of seconds of longitude in meters is measured from the proper X_nX_n line. Through these points lines parallel to the Y_nY_n and X_nX_n lines are drawn. Their intersection is the location of the triangulation station. In the diagram, Fig. 18, a triangulation station whose coördinates are 40° 15′ 20M. North and 80° 32′ 7.9M. West has been plotted.

Secondary triangulation stations are plotted from intersecting azimuth rays from primary triangulation stations. The plane table is set up over a primary station, the plotting board correctly oriented, the alidade sighted on the secondary flags and pencil rays drawn along the edge of the alidade ruler after each sight. Such sights should be taken from at least three primary stations: the intersection of the three rays in the same point gives a check on the accuracy of the orientation of the plane table and the work.

Setting Up the Plane Table. In setting up a plane table there are three things to be accomplished: (1) to get the plane table level, (2) to get a certain point on the plotting board right over its corresponding position on the ground, and (3) to orient the board.

(1) Setting Up the Plane Table: The plane table should be placed so that the map station and its ground station are as nearly as practicable in the same vertical line. To do this clasp the two near legs of the tripod in the hands and with an outward sweep swing the loose leg to its proper place so that when the tripod legs form an angle of about 30° with each other, the map station is over the ground station; the plane table should be leveled as much as possible by moving the proper tripod leg in or out. If the topographer has misjudged the proper position for the tripod legs, the plane table must be moved bodily to its proper place. With practice the topographer will be able to judge very close to the proper position of rest for the loose leg of the tripod.

(2) Leveling the Plane Table: The plane table is leveled the same as a transit. The vertical plane of each pair of leveling screws must be marked on the board so that the same position may be brought over the same pair of leveling screws each time. The opposite screws of each pair must be turned simultaneously and either away from or towards each other, the left thumb moving in the direction in which it is desired the bubble to go.

(3) Orienting the Plane Table: Loosen the clamp screw and orient the plane table with the eye; then tighten the clamp screw and orient the table for fine adjustment by means of the tangent screw. If the table is oriented by means of the compass, the north and south line on the field sheet should be brought into coincidence with the true north and south line of the compass. For a more detailed description of the plane table, its adjustments, etc., see *Engineer Field Manual*, Part I. For orientation by resection, see pp. 67-73.

Instrument Stations. Any stations where the plane table is set up is an instrument station. If possible the instrument station should be in such a commanding place that the surrounding terrain within range of stadia readings, about one-half mile, may be seen. An instrument station should also be a critical point whenever possible. The location of plane table stations may be determined by (1) resection, or (2) meandation.

(1) *Location by Resection:* Resection is the locating of an unknown occupied point by means of intersecting lines of azimuths from known visible plotted points of the terrain. There are a number of methods that may be employed, and a graphic explanation of them will now be made.

The Two-Point Problem: Having given two visible plotted points, a and b, to determine the map position of an unknown occupied station X. (1) By compass orientation.

Set up, level, and orient the plane table at the unknown station X; pivot the alidade about the plotted point a, sighting its station A, and draw a light pencil ray along the edge of the alidade ruler; similarly pivot the alidade about the plotted point b, sighting its station B, and draw a light pencil ray. Where these two rays intersect is the map position x of the unknown station X. (Fig. 11a.)

The Two-Point Problem—Continued: (2) By graphic orientation. (Fig. 19.)

This method is used when only two plotted points can be seen and the "two-point method by compass orientation" is not sufficiently accurate. Set the plane table up at an auxiliary point Y, selected so that points A, B, X, and Y form a quadrilateral, and orient by compass or estimation; fasten a piece of blank tracing paper on the plane table and arbitrarily select on it a point y_1 to represent the map position of station Y; pivot the alidade ruler on point y_1, sight on points A, B, and X, and draw pencil rays y_1a_1, y_1b_1, and y_1x_1; now set up at station X, orient by placing alidade ruler along the ray y_1x_1, and sighting back on Y; select a point x_1 on ray y_1x_1 to represent the map position of the unknown station X; pivot the alidade ruler on point x_1, sight on points A, B, and Y, and draw pencil

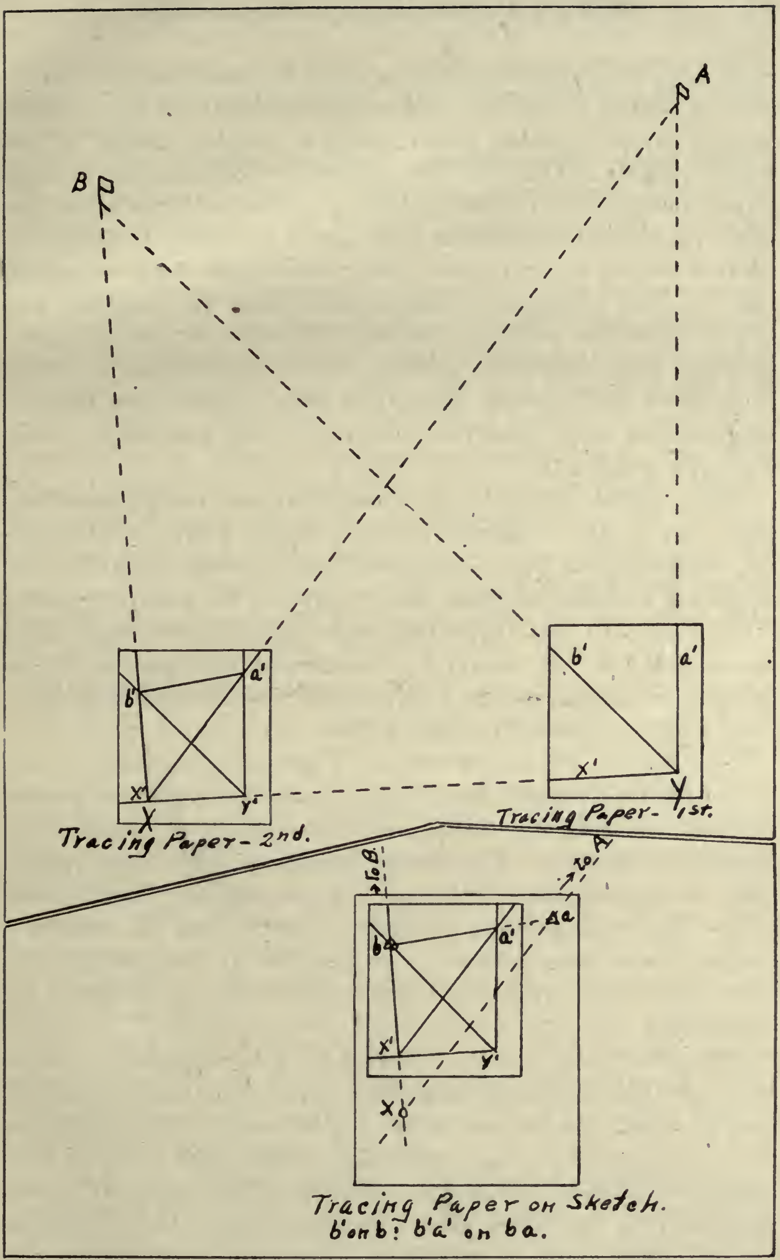

A
B
b'
a'
x'
y'
X
Y
Tracing Paper - 2nd.
Tracing Paper - 1st.
to B
to A
a
Tracing Paper on Sketch.
b' on b: b'a' on ba.

Fig. 19.

rays x_1y_1, x_1a_1, and x_1b_1; draw a line a_1b_1 connecting the intersecting points a_1 and b_1, and a quadrilateral $a_1b_1y_1x_1$ will be formed on the tracing paper which is exactly similar to the quadrilateral ABYX on the ground; unfasten the tracing paper and place it on the field sheet so that point b_1 coincides with the plotted point b, and the line a_1b_1 passes through the plotted points a and b; now place the alidade ruler along the line x_1b_1 and turn plane table so that point B is sighted and the board will be correctly oriented; remove the tracing paper, pivot on point a and by sighting A draw a pencil ray ax, similarly pivot on b and by sighting B draw a pencil ray bx; the intersection, x, of these two rays is the map position x of the unknown station X.

The quadrilateral $a_1b_1x_1y_1$ obtained by this method is not the same size as the quadrilateral abxy which would be obtained by connecting the actual map positions of points A, B, X, and Y; but it is similar in shape to it as well as the natural quadrilateral ABXY, and therefore, angle $a_1b_1x_1$ equals angle abx, and also ABX. It should be remembered that points on the ground are represented by capital letters, while their map positions are represented by small letters.

The Three Point Problem. Unless the plane table can be oriented accurately by compass, two known plotted points will not be sufficient except when the board is oriented by graphic orientation. This for the reason that any three points (the two known plotted stations and the unknown station) not in the same straight line determine a circle, and the unknown station whose map position is determined by interesting rays from the two known plotted points may have any location on that circle.

The plane table can be oriented by the compass to within about five minutes of the magnetic azimuth, and since this error may be either plus or minus, a maximum error of ten minutes is to be expected in the orientation of the plane table by the compass. For this reason, orientation by the compass is not permitted in the more accurate work; either the two-point problem by graphic orientation, or the three-point problem is then used. The latter is the better, for the intersection of three rays in the same point forms a check on the accuracy of the work. The Solar Attachment can also be used for plane table orientation.

The Three-Point Problem: Having given three visible plotted points, a, b, and c, to determine the map position of an unknown station X. (1) By Compass Orientation. (Fig. 11b.)

Set up, level, and orient the plane table (by compass or estimation) at the unknown station X; pivot the alidade ruler about the plotted points, a, b, and c, sighting their respective stations A, B, and C, and draw rays as explained in the two-point problem. If the three rays thus drawn intersect in the same point, the table is correctly oriented; if not, revolve the board slightly to the right or left by means of the tangent screw, draw new rays and repeat the operation until the three rays do intercept in the same point. The orientation of the board and the determination of the map position by this method can be greatly quickened by means of the Coast Survey Solutions.

Coast Survey Solutions of Three-Point Problems

In the Coast Survey solutions, the triangle formed by the three visible plotted points is known as the *Great Triangle;* the circle determined by these three points as the *Great Circle;* and the small triangle formed by the intersecting rays when they do not meet in the same point as the *Triangle of Error.* (Fig. 20.)

When the unknown station is on or near the Great Circle, its position is indeterminate.

Condition 1: When the unknown station X falls within the Great Triangle, the map point x is within the Triangle of Error. Solution: *If the ray from any of the visible plotted stations falls to the right of the intersection of the rays from the other two visible plotted stations, turn the plane table to the left, and vice versa.* Fig. 21.

When the unknown station X falls without the Great Triangle the map point x is without the Triangle of Error, and to the right or left of it, according as the plane table is out of position to the left or right. Solution: *If the ray from the*

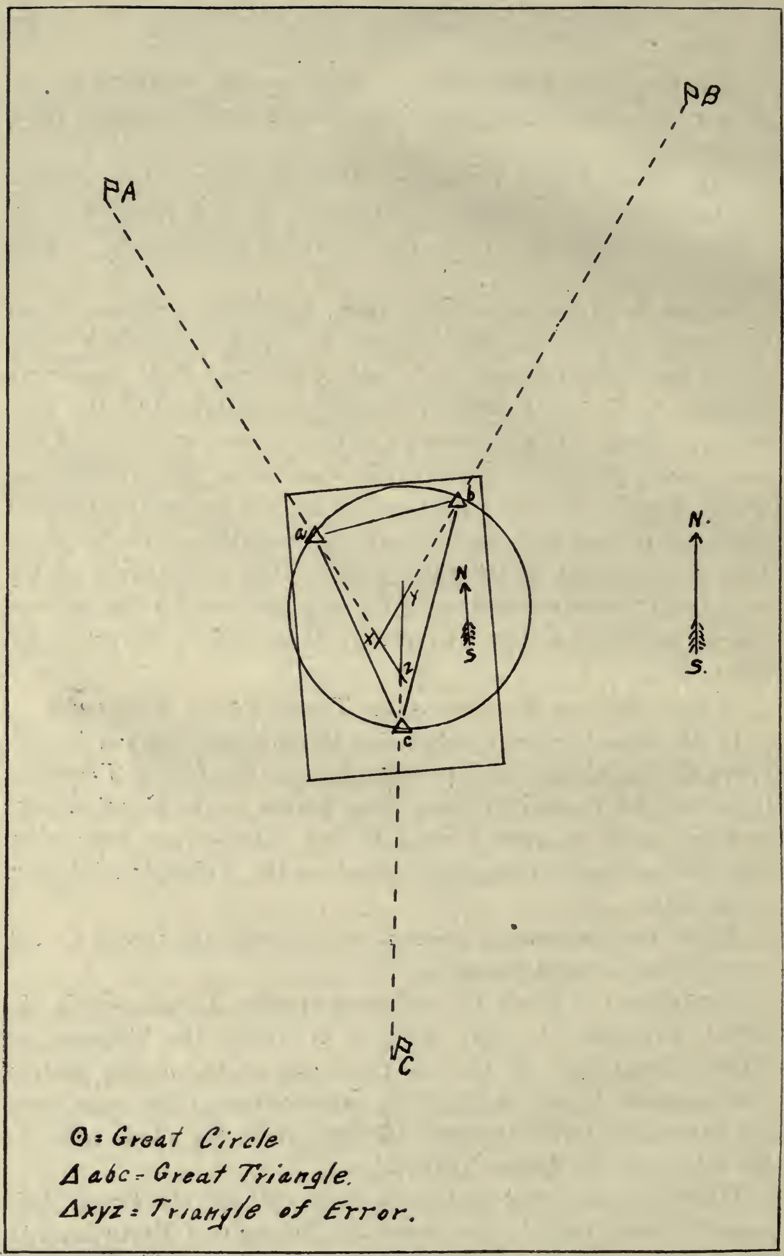
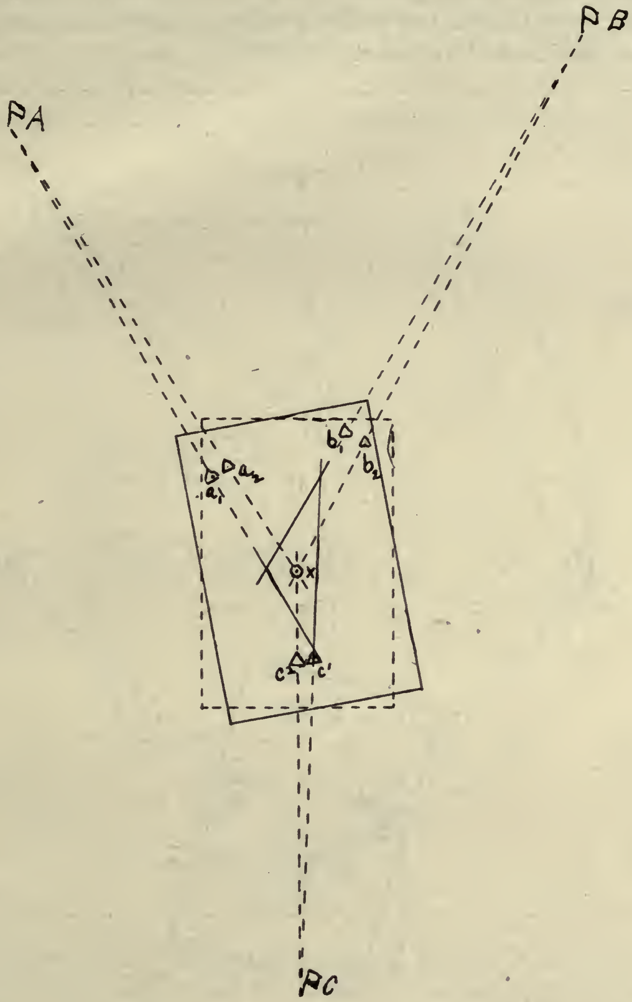

PA
PB
PC
a
b
c
x
y
z
N
S
N.
S.
⊙ = Great Circle
Δ abc = Great Triangle.
Δxyz = Triangle of Error.

Fig. 20.



Dotted Board Correctly Oriented.

Fig. 21.

middle visible station falls to the left of the intersection of the rays from the other two visible stations, revolve the plane table to the right, and vice versa. Fig. 22.

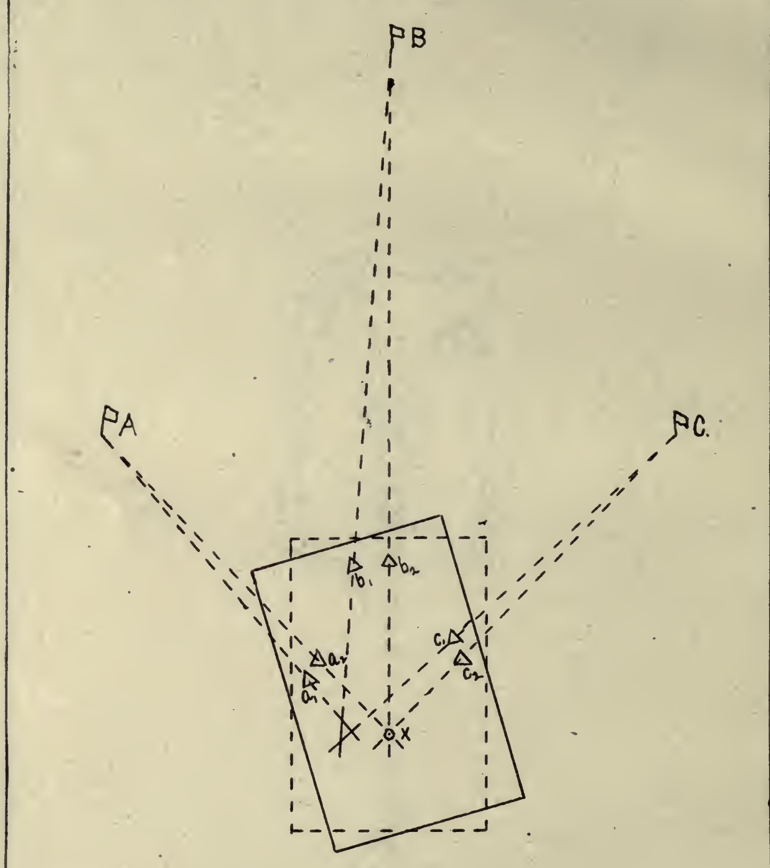


Fig. 22

Condition 2: When the unknown station X falls within any of the three segments between the Great Triangle and the Great Circle, the map point x is on the side of the ray from the middle station opposite to that of the intersection of the rays from the other two stations. Solution: *If the ray from the middle station is to the right of the intersection of the rays from the other two stations, turn the plane table to the right, and vice versa.* Fig. 23.

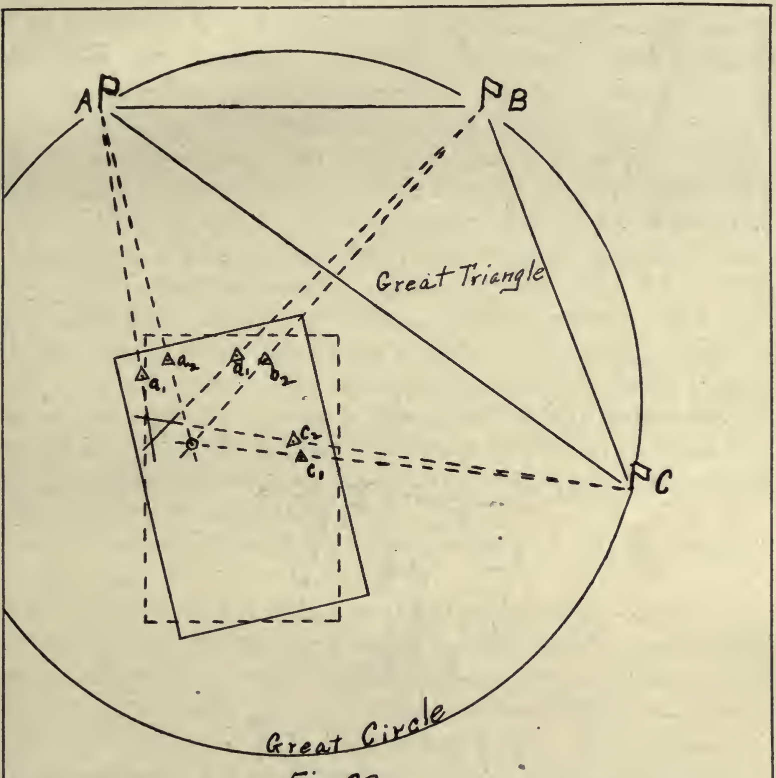


Fig. 23.

Condition 3: When the unknown station X is without the Great Circle and within the sector of an angle (produced) of the Great Triangle, the map position x is on the same side of the ray from the middle station as the intersection of the rays from the other two stations is. Solution: *If the ray from the middle station is to the right of the intersection of the rays from the other two stations, turn the plane to the left, and vice versa.* Fig. 22.

Condition 4: When the unknown point X is without the Great Circle and the middle point is on the near side of a line joining the other two stations, the map position x is without the

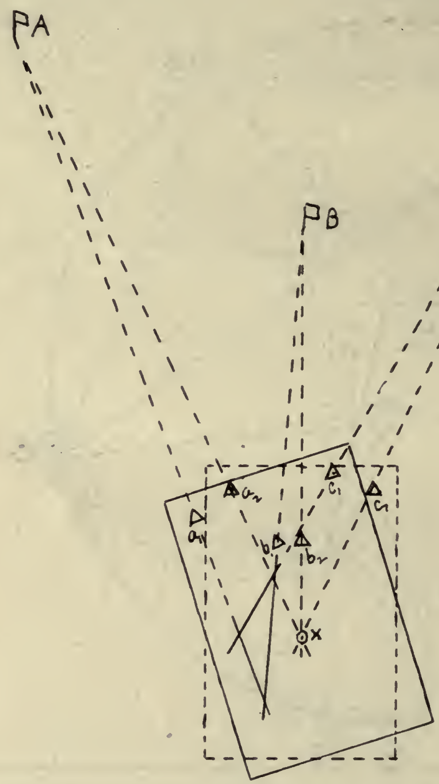


Fig. 24

Triangle of Error, and the ray from the middle station lies between it and the intersection of the rays from the other two stations. Solution: *When the ray from the right hand station is uppermost, turn the plane table to the right and vice versa.* Fig. 24.

For a more complete discussion of the above solutions see *A Plane Table Manual* by D. B. Wainwright, in Coast and Geodetic Survey report for 1905.

The Three-Point Problem, Continued: (2) By Graphic Orientation—Bessel's Method. Fig. 25.

(1) Set up, level and orient approximately by estimation or compass; (2) unclamp, and with the alidade ruler passing through c and a, turn the plane table to such a position that point A may be seen through the telescope; (3) clamp, and pivot the alidade about the point c, sighting point B and draw an indefinite ray; (4) unclamp, and with the edge of the alidade ruler passing through a and c, turn the plane table to such a position that point C is seen through the telescope; (5) clamp, and pivot the alidade about the point a, sighting point B, and draw a ray intersecting the ray drawn from c at some point x; (6) unclamp, and with the edge of the alidade ruler through points b and x, turn the plane table to such a position that point B may be seen through the telescope. The plane table is then correctly oriented. As a check azimuth rays may be drawn from the three visible points back through their plotted points: these rays should intersect in the same point.

The Three-Point Problem, Continued: (3) By Mechanical Orientation.

Set up, level, and attach a piece of tracing paper on the plane table. Assume an arbitrary point x on the tracing paper, and on this point pivot the alidade ruler; sight the three visible points, A, B, and C, in succession, drawing light pencil rays each time. These rays will all intersect at x. Now loosen the tracing paper ABD and so adjust it on the field sheet that the rays will exactly coincide with their plotted points a, b, and c: x on the tracing paper will then be over its true position on the field sheet. Mark x on the field sheet by pricking with a sharp pointed pencil. With the edge of the alidade ruler through points x and a, turn the plane table so that A can be seen through the telescope; clamp. The plane table is then correctly oriented.

In addition to the Two- and the Three-Point Problems, there are two modifications that are often useful, especially in "filling-in" work.

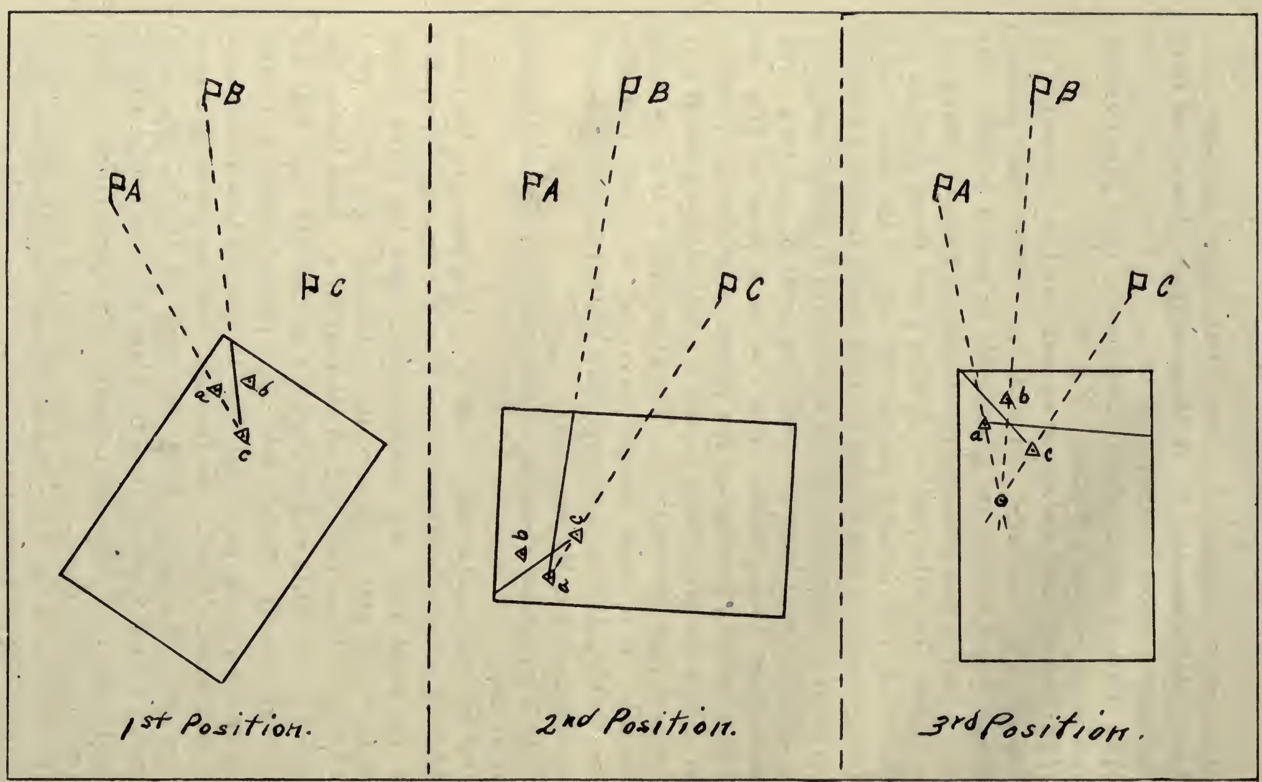


Fig. 25, Bessel's Method.

RANGING IN: Having given a direction line and one visible plotted point outside of that line, to determine the map position of an unknown point X on that line. Fig. 26.

The direction line may be a plotted road, railroad, stream, fence, ridge, or other like object. Set up on the unknown station X, level the plane table, and then orient by placing alidade along the plotted direction line and turning the plane table to such a position that the alidade telescope is sighted on the

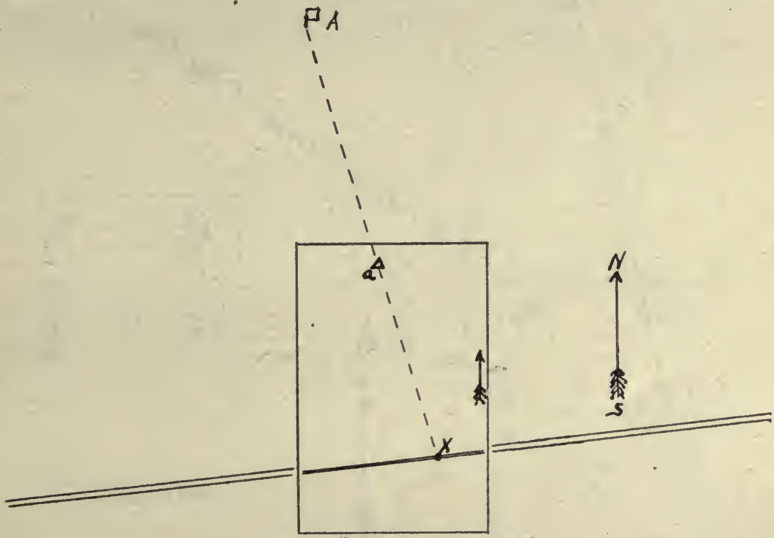


Fig. 26. "Ranging In"

actual direction line. Now pivot the alidade about the visible plotted point a until point A is sighted; draw a ray until it intersects the given plotted direction line. This intersection is the true map position of the unknown point A. Where a ridge or other broad line is used as the direction line, the result will of course not be so accurate.

LINING IN: Having given only one visible plotted point a, to determine the map position of an unknown point X by means of a subsequently determined instrument station. Fig. 27.

This method may be employed where only one visible plotted point is visible, the other visible terrain being unknown (unplotted). Set up at the unknown station X, level, and orient by the compass; pivot the alidade on the visible plotted point a and sight A; draw a ray indefinitely; mark the station on the ground with a stake. Now occupy another unknown point Y, visible to X and also to two or more visible plotted stations, and determine the map position y of Y by any of the methods explained above. Pivot the alidade ruler on y, and sighting X draw a

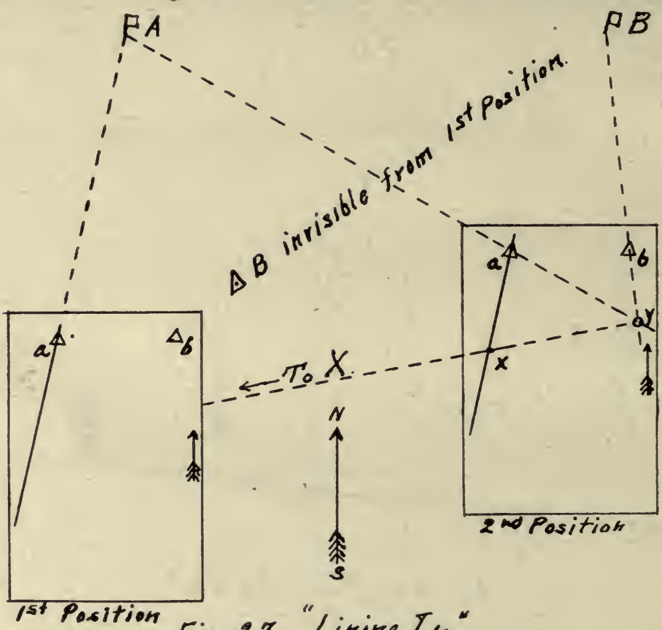


Fig. 27. "Lining In."

pencil ray to intersect the ray ax. This intersection is the map position of point X.

The following method may also be used, but if the angle formed at the known visible plotted point is less than 30°, the method should be used only in rapid exploratory surveys.

THE ONE-POINT PROBLEM: Having given a large area in which only one plotted point is visible, to determine the map position of an unknown point X within that area. Fig. 28.

Set up at the unknown point X, level, and orient by the compass; pivot the alidade ruler on the plotted point a, and sighting

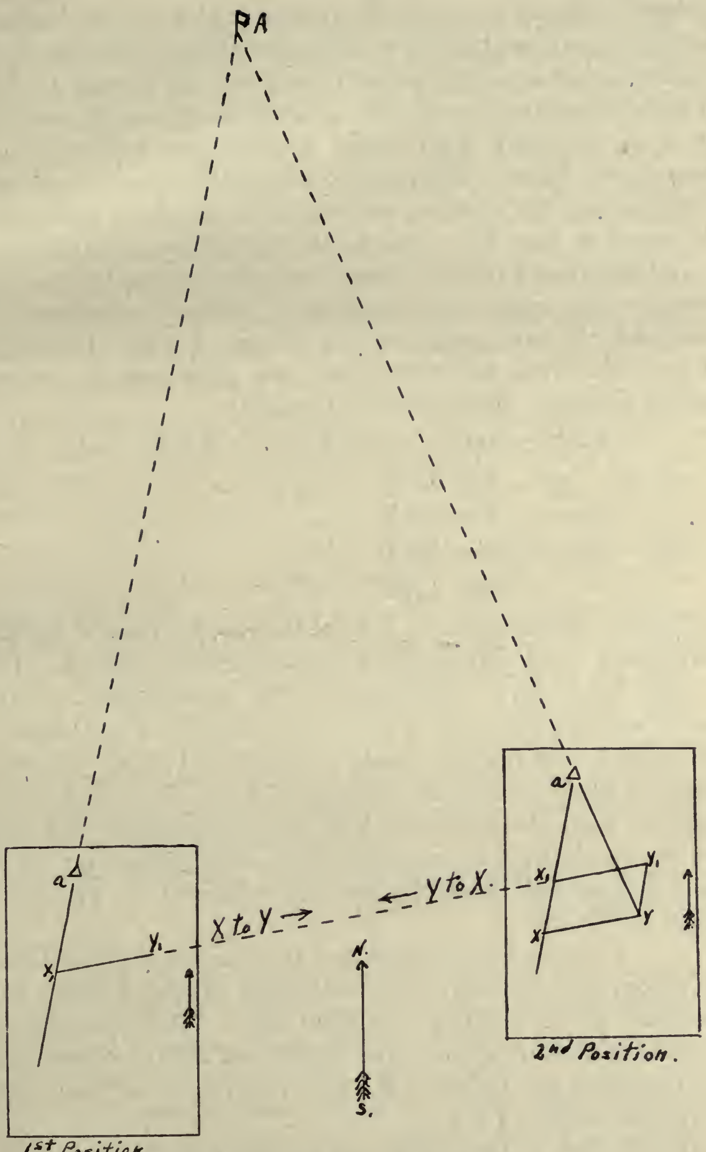


Fig. 28. One-Point Problem.

A draw a pencil ray; select an arbitrary point x_1 on the ray ax as the present location of x; pivot the alidade ruler on x_1, and sighting on an auxiliary point Y, at about right angle to A and at such a distance from X that an angle of at least 30° is formed at A in the angle XAY, draw a pencil ray calling it x_1y_1; measure the distance XY; set the plane table up at Y and orient it by placing the alidade ruler along the ray x_1y_1, and turning the board so that X is sighted; then pivot the alidade ruler on a, and sighting A, draw a pencil ray intersecting the ray x_1y_1; measure the angles ax_1y_1 and ay_1x_1 with a protractor. We now know the three angles of the triangle XAY and the length of one side, from which the other two sides may be computed by the following trigonometric formula:

$$\angle XAY = 180° - (\angle AXY + \angle AYX)$$

$$AX = \frac{\text{Sin } AYX}{\text{Sin } XAY} \times XY$$

$$AY = \frac{\text{Sin } AXY}{\text{Sin } XAY} \times XY$$

Measure off the distance AX on the ray ax_1 from a, the plotted point x is the map position of the unknown point X. Point y may be similarly determined. The measurement of these angles with a protractor is not very accurate: if the angles are measured with a transit directly, this method is fairly accurate when the angle at A is 30° or over. If x_1y_1 is plotted to scale from the measured distance, XY, the map position of x and y can be found by constructing the parallelogram x_1y_1yx, the point y being determined by the intersection of Aa with y_1y, as shown in Fig. 28.

(2) Location by Meandation: Whenever a traverse is made in topographic surveys, the sketching of the terrain along the route of the traverse is always done. This sketching will extend from about one-quarter to one-half mile to either side of the traverse: the traverse stations thus serve as topographic instrument stations too.

Meandation, or traversing, will be used when the ground is so level or so wooded as to render resection work impracticable. For primary control in meandation, control traverses are run;

for secondary control, needle and back-sight traverses—needle traverses when the magnetic needle can be depended upon, and back-sight traverses when it cannot. In the execution of control traverses, the character of the work required and the terrain will determine the areas of enclosure. Where long control traverses are run, the azimuth should be checked daily by sun azimuth and a difference over one minute for 15 set-ups should cause the rejection of the work completed since the preceding sun azimuth. The error of enclosure should not exceed one minute for fifteen set-ups, or stations, or about $.5' \times \sqrt{N}$, where N is the number of set-ups; and in lineal measurement the error should not exceed 1 in 500.

Critical Points. A critical point of the terrain is a location on it where there is an abrupt change in the slope or in direction. Such points are the top, the military crest, and the foot of hills; bends in streams and roads; road crossings; etc. There is an infinite number of critical points except on the most level of terrain, but for practical work it is only possible to determine geometrically the most important or control critical points. The intermediate points are determined by estimation, aiding and checking the estimates by comparison with the control critical points geometrically determined. Herein the skill and the judgment of the topographer are required—to know what points to measure, what points to estimate, and what points to ignore, in order to interpret them into a faithful and intelligent representation of the terrain.

In topographic surveys, critical points are determined geometrically in four ways—by radiation, intersection, resection and meandation.

(1) Location by Radiation: In this method the critical points within range of an instrument station are determined by plotting the direction, measuring the distance with tape or stadia, and determining the vertical angles of those points, all from that instrument station. With the plane table proceed as follows: (1) set up and level the plane table at the instrument station; (2) orient the plane table and locate the station by any method explained in the two preceding paragraphs, plotting the station as instrument station number one, abbrevi-

ated "I-1"; send a rodman to hold a stadia rod on the first critical point, a; pivot the alidade about the plotted point "I-1," sight the stadia rod, draw a pencil ray to represent its azimuth on the field sheet; read the stadia intercept on the stadia rod, and record the vertical angle; the stadia reading corrected for the horizontal (stadia reading $\times$ the cosine^2 of the vertical angle) gives the distance to measure off on the azimuth, I-1a, to determine on it the map position of the critical point a. Similarly, determine all the critical points around the instrument station and plot them on the field sheet. The determination of the elevation of critical points and the sketching of the terrain will be taken up later.

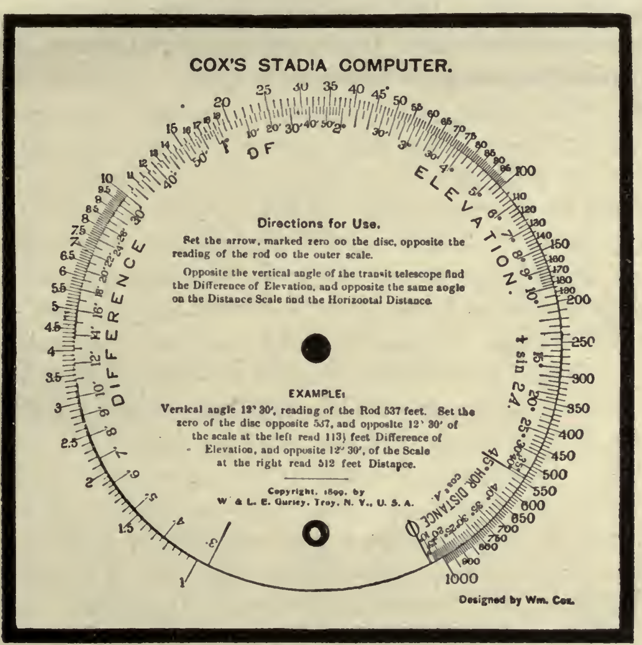
(2) Location by Intersection: Having given two instrument stations, I-1 and I-2, to determine the map position of a critical point X which is visible to both instrument stations.

Intersection as here applied is the determination of the location of a critical point by the intersection of azimuth rays to it from two or more instrument stations. Procedure: (1) Set up, level, orient, and locate the map position of the plane table at "I-1"; (2) pivot the alidade on "I-1," sight X and draw a pencil ray indefinitely (whenever a sight is taken on a critical point, its vertical angle is always read); (3) set up, level, orient, and locate the map position of the plane table at "I-2"; (4) now pivoting the alidade on the plotted point "I-2," sight X and draw a pencil ray indefinitely: the intersection of these two plotted rays is the map position of the critical point X.

Intersection dispenses with stadia men, but its use is more limited than that of radiation, for the points selected for intersection must be visible from two instrument stations and the angle of intersection should not be less than 30° nor more than 120°. A combination of both methods is of course the best. While locating the near accessible points by stadia readings, the more distant and inaccessible points can be determined by intersection. At each instrument station the topographer will take azimuth rays on all points that he wishes to determine by intersection; such points must be so named or described that they may be identified or recognized at some other instrument station. Objects appear different when viewed from different positions and it is also very difficult to identify stations when a large number remain unintersected at the same time.

(3) Resection and Meandation: Critical Points so determined are occupied the same as Instrument Stations.

Elevation of Instrument Stations and Critical Points. In topographic surveying the elevation of unknown points are determined from the difference in elevation between them and



*For Reducing Inclined Stadia Reading

known stations. The difference in elevation between two points is equal to either, (1) the slope distance between them times the sine of their vertical angle, or (2) the horizontal distance between them times the tangent of their vertical angle. If the vertical angle is less than 5°, the sine may be used when only the horizontal distance is known. To use Cox's Stadia Computer to solve elevation problems: (1) when the slope distance and vertical angle are known—set the "O" or index of the inner

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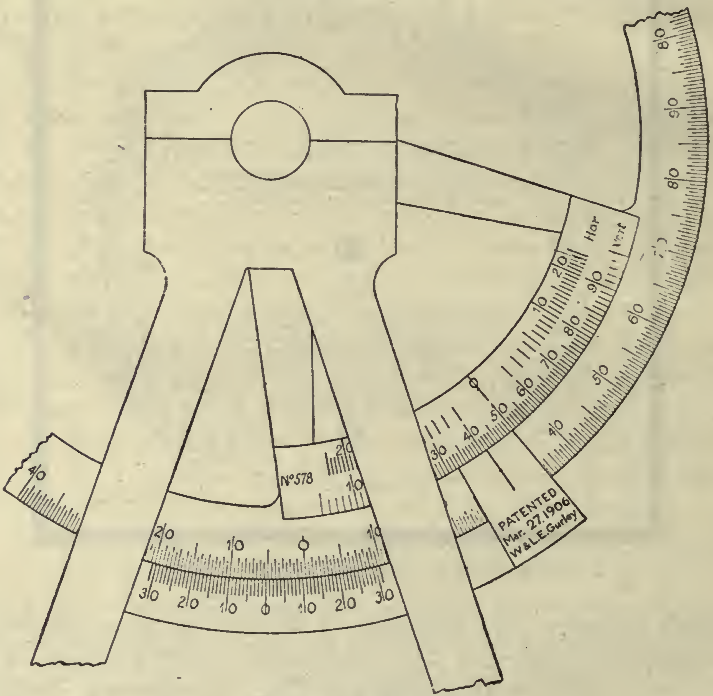
*Courtesy of W. & L. E. Gurley.

circle into coincidence with the number representing the slope distance on the outer circle; the difference in elevation will be that number on the outer circle which is in coincidence with the verticle angle as read on that portion of the inner circle labeled "Difference in Elevation"; (2) when the horizontal distance is known and the vertical angle is greater than 5°—set the number representing the vertical angle on that portion of the inner circle labeled "Hor. Distance" into coincidence with that number on the outer circle representing the horizontal distance, read for difference in elevation as in (1).



*Beaman Stadia Arc
For Mechanically Reducing Inclined Stadia Readings

(1) Elevation in Resection: Point I2 in Fig. 33 has been determined by resection on triangulation stations, A, B, and C; the vertical angle from I2 to ΔA is $+ 30'$; from I2 to ΔB,

*Courtesy of W. & L. E. Gurley.

$+54'$; and from I2 to ΔC, $+58'$. The elevation of ΔA is 1175 feet, of ΔB 1268 feet, and of ΔC 1226. To determine the elevation of I2, set the points of a pair of dividers to coincide with points ΔA and I2; then apply the points of the dividers to a reading scale and read the intercept in feet, which is the ground distance from I2 to ΔA: similarly measure the map distances of I2 to ΔB and of I2 to ΔC, respectively; with these distances as the horizontal distances and the vertical angles as read, solve the difference in elevation, using either the trigonometric formula, or Cox's Stadia Computer. These differences subtracted from the respective elevations of ΔA, ΔB, and ΔC, should all give the same value for the elevation of I2 (In long distances, correction should be made for the curvature of the earth). Where there is a slight variation take the mean as the most probable value. Usually the determination of elevation from the two outer triangulation stations is sufficient, but if the two values vary too much, the elevation from the third triangulation station should be taken as a check and to indicate the more probable correct elevation from the first two stations.

(2) Elevation in Meandation: The elevation of all instrument stations in traverses are determined and recorded. The distance between successive stations is measured by stadia or tape, the vertical angle is read from the transit or alidade telescope vernier. When distance is measured with the stadia the slope distance is obtained; when it is measured with a tape or chain, the horizontal distance is obtained. The difference in elevation between successive stations is added or subtracted according as to whether it is plus or minus, and the elevation is thus carried forward.

(3) Elevation in Radiation: One half the stadia reading from an instrument station to a critical point times the sine of twice the vertical angle gives the difference in elevation between them; this difference in elevation added to or subtracted from the elevation of the instrument station, according as to whether the vertical angle is plus or minus gives the elevation of the critical point.

(4) Elevation in Intersection: This method is just the same as in resection. Measure with the dividers the dis-

tance from the first instrument station to the intersection or critical point; similarly measure the distance from the second instrument station to the critical point; then solve for the differences in elevation, and add to or subtract from the respective elevations of the two instrument stations, according as to whether the vertical angle is plus or minus. The two results should be the same or nearly the same; take the mean as the more probable correct elevation of the critical point.

Sketching Operations

Plotting Direction. Direction as explained in a previous paragraph is the azimuth of a line. In sketching, the plotted azimuth or bearing of a line with respect to the field sheet must of course bear the same relation as the azimuth or bearing of a ground line with respect to the terrain. In topographic surveying the azimuth of a line is always determined, so in the description of sketching operations the azimuth will always be used in this book. If the bearing of a line is ever given, the topographer should change it to its azimuth. There are several methods by which the azimuth of a line can be plotted on the field sheet.

(1) With Alidade Ruler: This is the method used with the plane table. It should be remembered that the statement "the plane table is oriented" means that the field sheet on the plane table is oriented. *Having given the plane table set up, leveled and oriented at a station A, to plot the direction, or azimuth, to a visible point X.* Procedure: (1) Pivot the edge of the alidade ruler about the plotted point a, sticking a pin in point a so as to keep the alidade ruler in contact with a; (2) center the telescope on the visible point X; (3) draw a light pencil ray along the edge of the alidade ruler indefinitely from a towards the visible point X; this plotted pencil ray lies in the same direction on the field sheet as the direction of X from A on the ground.

(2) With T-Square and Protractor: This method is employed where the sketching board is used; the azimuth, or direction, on the ground being determined with a transit, prismatic compass, or other instrument. *Having given the direction, or*

azimuth, of a line AX determined with a transit or prismatic compass, to plot the same on a sketching board by means of a T-Square and Protractor. In this method the north and south line on the field sheet must be perpendicular to the left edge of the sketching board. We shall assume that the azimuth from A to X as determined to be 210°. Procedure: (1) Keeping the plumb edge of the T-square in contact with the left edge of the sketching board, bring the straight edge of the T-square in contact with the plotted point a; (2) with the straight edge of the protractor in contact with the straight edge of the T-square, bring the center point of the protractor over the plotted point a; (3) make a pencil mark at 210° (or 30°); (4) remove the protractor and T-square and through the plotted point a and the pencil mark draw a pencil ray indefinitely: the plotted line is the azimuth ray ax. It is assumed that either the rectangular or semi-protractor is used: the protractor should have two series of numbers on the scale, one from 0° to 180° and the other from 180° to 360°.

(3) With Paper Protractor and Triangles: This method is used where tracing paper or linen fastened over a paper protractor is employed for the field sheet: the sketching board is not oriented. *Having given the azimuth of a line AX determined with a transit or prismatic compass, to plot the same on the field sheet.* We shall assume the azimuth as determined to be 165°. Procedure: (1) Place one triangle so that its hypotenuse passes through the center point of the protractor and the division on the protractor scale representing 165°; (2) holding this triangle firmly in place, place a second triangle with its hypotenuse in contact with one leg of the first triangle; (3) now holding the second triangle firmly in place with one hand, slide the first triangle along the hypotenuse of the second triangle by means of the free hand until the hypotenuse of that (first) triangle comes in contact with the plotted point a; (4) then hold the first triangle in place and draw a pencil ray ax indefinitely from a along the hypotenuse of this triangle, in the same direction as the azimuth reading is from the center of the protractor: the plotted line is the azimuth ray ax.

Plotting Distance. Distance on a map is always plotted to some given scale. This scale, or ratio of map distance to ground distance has been discussed in a previous chapter. Distance can be plotted or measured off in several ways.

(1) With Reading Scale: Having given a plotted azimuth ax_1, the ground distance AX, to plot the map position x of the visible point X. Procedure: (1) place the edge of the reading scale along the plotted azimuth ax_1 with its zero division on the plotted point a; (2) at the division on the reading scale representing the ground distance AX make a pencil mark: this mark on ax_1 is the map position x of the visible point X.

(2) With Strip of Blank Paper: Having given a plotted azimuth ax_1, and the ground distance AX, to plot the map position x of the visible point X. This method is used where it is not possible to apply the reading scale directly. Procedure: (1) Place the edge of the strip of blank paper along the edge of a reading scale and mark on it a short line opposite the zero of the reading scale and another mark opposite the division on the scale which represents the ground distance AX: (2) place the strip of paper along the ray ax_1 with the first mark at the plotted point a and make a pencil mark on ax_1 opposite the second mark on the strip of paper: this pencil mark is the map position x of the visible point X.

(3) With Dividers: Having given a plotted azimuth ax_1, and the ground distance AX, to plot the map position x of the visible point X. This method is used where the reading scale is not available for using directly: this will usually be the condition in field work where the reading scale is fastened on, or drafted on the sketching board. Procedure: (1) Open the dividers so that when one point is on the zero of the reading scale, the other point is at that division of the scale which represents the ground distance AX; (2) now apply one point of the dividers to the plotted point a, and with the other point intercept the azimuth ax_1, making a small pin hole: this pin hole is the map position x of the visible point X.

In this section we have used the reading scale as a working scale, for our working units in topographic surveying are the foot, mile, etc. In rapid sketching we shall use the stride, pace,

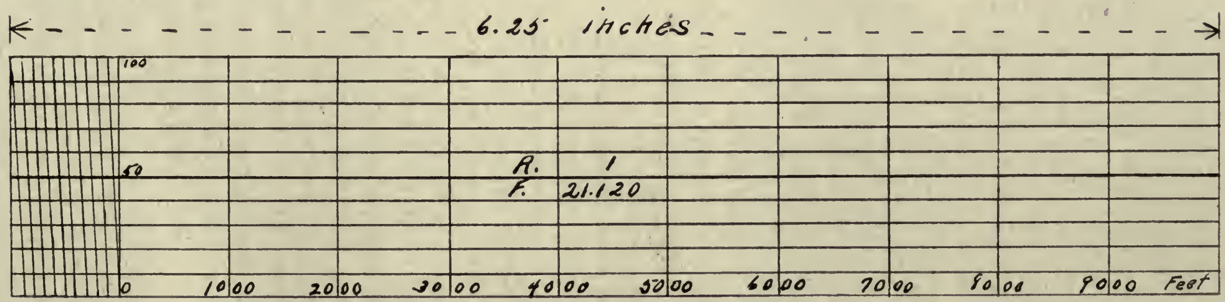


Fig. 29. Working Scale.

etc., as our working unit, and our scale will be a true working scale according to our definition. It is better to call a working scale in feet or meters a reading scale, even though at variance with our definition.

Plotting Slopes. All slopes may be divided into three general classes: (1) even, (2) convex, and (3) concave; the terrain is made up of a succession of these slopes and the dividing lines between these slopes are the controlling lines of the terrain. Since lines are determined by points, it is only necessary to determine the critical points of these controlling lines and we shall have a complete control over the whole area insofar as the conformation of the ground is concerned. The problem then reduces itself to plotting the simple slopes between these points, so spacing the contour lines as to produce an even, convex or concave slope of the degree desired. It is impracticable to run contour levels and traverses to locate each contour line; their spacing must be done by estimation, and with practice the topographer should soon be able to space and locate contour lines with a high degree of accuracy. It should be remembered that a faithful representation and not an exact reproduction of the terrain is desired; the essential details must be utilized so as to bring out the predominant features of the terrain. Often by slightly changing the horizontal position of a portion of a contour line, a more accurate representation of the character of the slope is secured. This may be shown in the diagram, Fig. 30b, in which AB is a profile of a slope in which x, a critical point has an elevation of 83 feet, while the 80 foot elevation is at y, a position considerably to the left. Now if the 80 foot contour were to be drawn along the 80 foot elevation line at this place a map as shown in Fig. 30a, would be produced and the inference in map reading would be that the slope between the 80 and 100 foot contours were an easy slope connecting regularly with the slopes between the 60 and 80 foot contours and the 100 and 120 foot contours; but if the 80 foot contour is made to pass through point x, the map as shown in Fig. 30c, is produced, and while the slope xz is shown a little longer than it really is, its degree or steepness is shown which is far more important than any harm from a slight

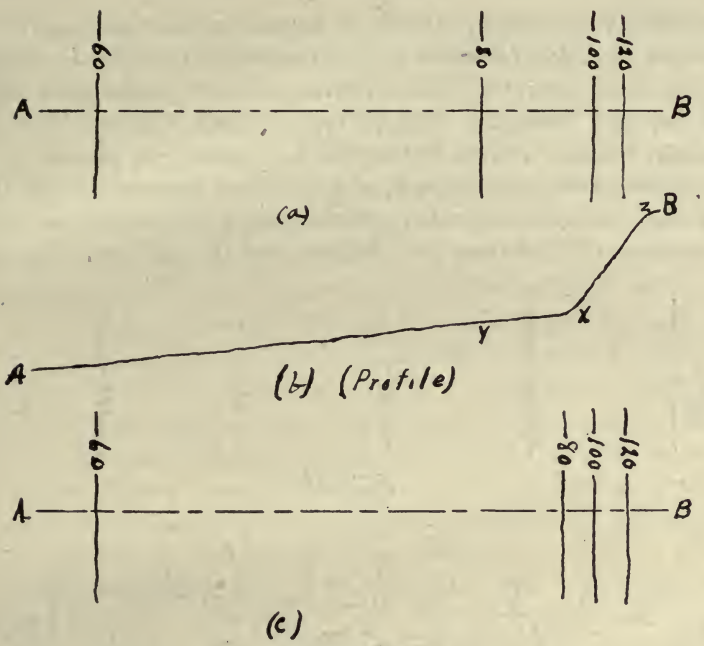


Fig. 30.

variation in the horizontal location of a portion of a contour line. To what extent the location of a contour may be changed in order to represent more accurately the character of the terrain can hardly be stated. The experienced topographer will know from the importance of that portion of the terrain which he wishes to represent. Often an intermediate dotted contour line can be very advantageously used.

(1) Even Slopes: In Fig. 3 are drawings showing the spacing of contours for even slopes of different degrees; with practice the topographer will be able to space contours by estimation, but beginners will have to use the slope scale. A concrete example of contour spacing will be given. *Having given two plotted critical points, a and b, elevation 75 and 170 feet respectively, with an even slope between, to plot the contours; V. I. 20 feet.* Procedure: Between points, a and b, the 80, 100, 120, 140, and 160 contours must be drawn; from a to the 80 foot contour is ¼ of a contour interval, from the 80th to

the 160th foot contours there are 4 contour intervals, and from the 160 foot contour to b is ½ of a contour interval—in all, 4¾ contour intervals. The distance ab must therefore be divided into 4¾ intervals. The 80 foot contour is placed ¼ of an interval from a towards b, the 160 foot contour is placed ½ of an interval from b towards a, and the space between the 80 and 160 foot contours is divided into four equal spaces for the three contours—the 100 foot, the 120 foot, and the 140 foot. Fig. 31.

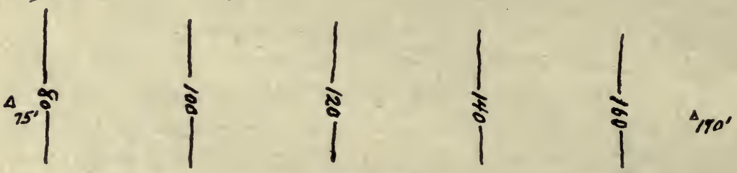


Fig. 31.

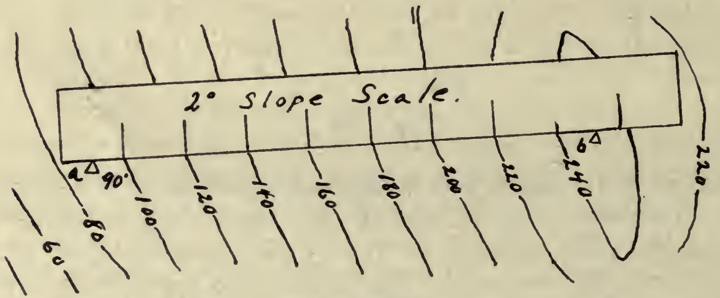


Fig. 32.

Having given two plotted critical points, a and b, the elevation of a 90 feet, and an even slope of 2° between them, to plot the contours. Procedure: (1) Place the edge of the 2° slope scale through the plotted points a and b so that point a is midway between two divisions; (2) make a pencil dot on the field sheet directly next to each division on the slope scale between points a and b: these pencil dots are the locations of all the contours between a and b. Fig. 32.

(2) Convex Slopes: For convex slopes the contours are nearer together at the bottom of the slope and farther apart at the top. The spacing must be such that the proper convexity is

shown; and the difference in elevation between the two critical points must be represented by the proper number of contour intervals.

(3) Concave Slopes: For concave slopes the contours are farther apart at the bottom of the slope and closer together at the top. As with convex slopes, the spacing of the contours must be such that the proper degree of concavity is shown, and the difference in elevation between the two critical points must be represented by the proper number of contour intervals.

(4) Changes between Slopes: Usually where the contours of two adjacent slopes have been plotted, no special notice need be taken of the point of juncture, or critical point, but where such critical point is an essential part of the terrain to be shown, the two including contours should be so plotted as to show the proper compound curvature, even though it is necessary to change slightly the horizontal position of a contour, as was shown in the beginning of this section.

Plotting Character of the Terrain. *(1) Natural Character of the Terrain.*

(a) Planes: The critical points of level ground and ground of even slopes are the limiting points of such areas. On large planes such points will usually have to be determined by traverses; these, with such other critical points that are determined to plot streams, roads, etc., will make the plotting of contours for planes an easy task.

(b) Hills and Valleys: There is always a valley or plane on each side of a hill, and a hill on each side of a valley. Their line of juncture in each case is, therefore, a control line whose critical points are common to each. These critical points with those which control the bottom of valleys and the top of hills, are the points essential to the plotting of hilly terrain. The hill between two valleys is called a "water shed," and this water shed may be a knoll, a well-defined ridge, or a broad table-land. In any vertical plane of a hill the critical points are the top, the military crest, and the foot of the same (its junction with the adjacent valleys); in any horizontal plane of a hill the critical points are the ends, the sides, changes in direction, and junction with other hills or ridges; in any vertical plane of a

valley the critical points are the bottom of the valley and its junctures with the adjacent hills; in any horizontal plane of a valley the critical points are the head, the mouth, the sides and the changes in direction of the valley. All important streams will be traversed which will give the control for the elevation and horizontal position for the bottom of their valleys.

(c) Mountains: The critical points of mountains are the same as those of hills, but are much more difficult to determine. The ascent and descent of mountains are very difficult to make so that the number of instrument stations are reduced to a minimum, while the location of critical points will usually be made by intersection. Many details on large mountains, which on level terrain would be essential can be ignored. Mountains over two thousand feet in height from their base can be more rapidly and easily surveyed and plotted by photo-topographic methods.

(d) Cliffs: In plotting steep cliffs intermediate contours are omitted. Thus with twenty foot contour intervals only the hundred foot contours are plotted through the length of the cliff. Through vertical cliffs all contours will unite in one line. In overhanging cliffs, the lower contours will cross the higher contours through the length of such cliffs, and such lower contours are dotted through the length which they cross higher contours.

(e) Streams: The critical points of a stream are its source, its mouth and its changes of direction. Where the stream is fairly straight only a sufficient number of points should be determined to insure the correct plotting of the stream. Usually traverses will be run to plot important streams—control traverses for the more important and needle—and back-sight traverses for the less important. Sometimes rivers may be more rapidly and easily surveyed and plotted by determining the important changes in direction throughout its course by resection. In such cases the critical points are occupied as resection instrument stations, or resection instrument stations are determined on the adjacent water sheds while the critical points on the stream are determined by stadia or intersection from these stations as shown in the diagram, Fig.

33. In many cases critical points along a stream cannot be seen or occupied, as where the stream flows through a swamp or thicket. In such cases it is usually possible to mark critical points along the stream by erecting at such points flag poles of such height with white streamers that they may be seen and intersected on from resection instrument stations on the adjacent highlands. With large scale maps the width of rivers must be determined and plotted.

(f) Lakes and Swamps: The shores of lakes and the edges of swamps are determined and plotted the same as the courses of streams. Their plotting presents no special difficulty.

(2) Vegetation:

(a) Grass: The area and extent of grass land is determined and plotted with the proper conventional symbol. Where the grass is low, as in a pasture, all topographic operations are easy, but where the grass is very high control work is exceedingly difficult.

(b) Forests: The limits of forest lands are determined and plotted, but the conformation of the ground in such areas is plotted only in a broad generalization. Usually, and especially in forests on level ground; the control will have to be made by traverses. Where a few high and open hills overlook the woods, triangulation can be carried on to a considerable extent. Critical points throughout the woods may be marked by fastening a flag pole and streamer to a high tree at such points, so that the streamers can be seen from the high knolls where such streamers can be located by intersection. Often, too, from an open space or a high tree, in such woods, the topographer can locate himself by resection. Topographic details of the ground which are very essential in the open, are unimportant in a map of the woods.

(c) Cultivated Fields: Cultivated fields are plotted as such, but the character of vegetation is not shown unless the map is for immediate use, or the vegetation is permanent as in rice fields, cane fields, orchards, etc.

(3) Lines of Communication:

(a) Roads and Trails: Roads are determined by traverses or by triangulation at their crossings, forks, bends, etc. Im-

portant trails are likewise determined. The width of roads is conventional except on plots of large scale.

(b) Railroads and Canals: Railroads and canals are determined in the same manner as roads. Side tracks, canal locks, shops, etc., are also very important on military maps.

(c) Bridges, Ferries and Fords: The kind, width, length and height above water of bridges; kinds and number of piers and abutments; kind, depth and length of ferries; and the width, depth and kind of bottom of fords, are determined and plotted.

(4) Buildings:

(a) Farm Buildings: Dwelling houses on farms are determined and plotted with the conventional sign; outbuildings are not plotted; detached barns are. The name of the owner is also plotted.

(b) Churches and School Houses: Churches and school houses are always very important in map reading as points of reference, and should be plotted with their name.

(c) Towns and Cities: The solid built sections of cities are plotted in solid blocks on map, dwelling houses in the thickly settled sections are plotted conventionally, scattered dwelling houses are each plotted. The streets of cities and towns are plotted.

In small scale maps, cities are plotted by shaded areas while small towns are represented by a circle (°).

Applied Sketching. In the diagram, Fig. 33, is shown a portion of a field sheet. The field sheet on the plane table would be about the same size as the board, as 22′x28′, and on it would be plotted all primary and secondary triangulation stations within the area which the field sheet represented. In that portion of the field sheet shown in Fig. 33, only one triangulation station happens to lie.

Designation of Stations: Some system of designation should be used in which the forms suggest the character of the stations. In extended surveys primary stations should be designated by proper names—the local name of the hill on which the station is located; if there is no local name, a name can be supplied. In limited surveys, the primary stations can be designated by

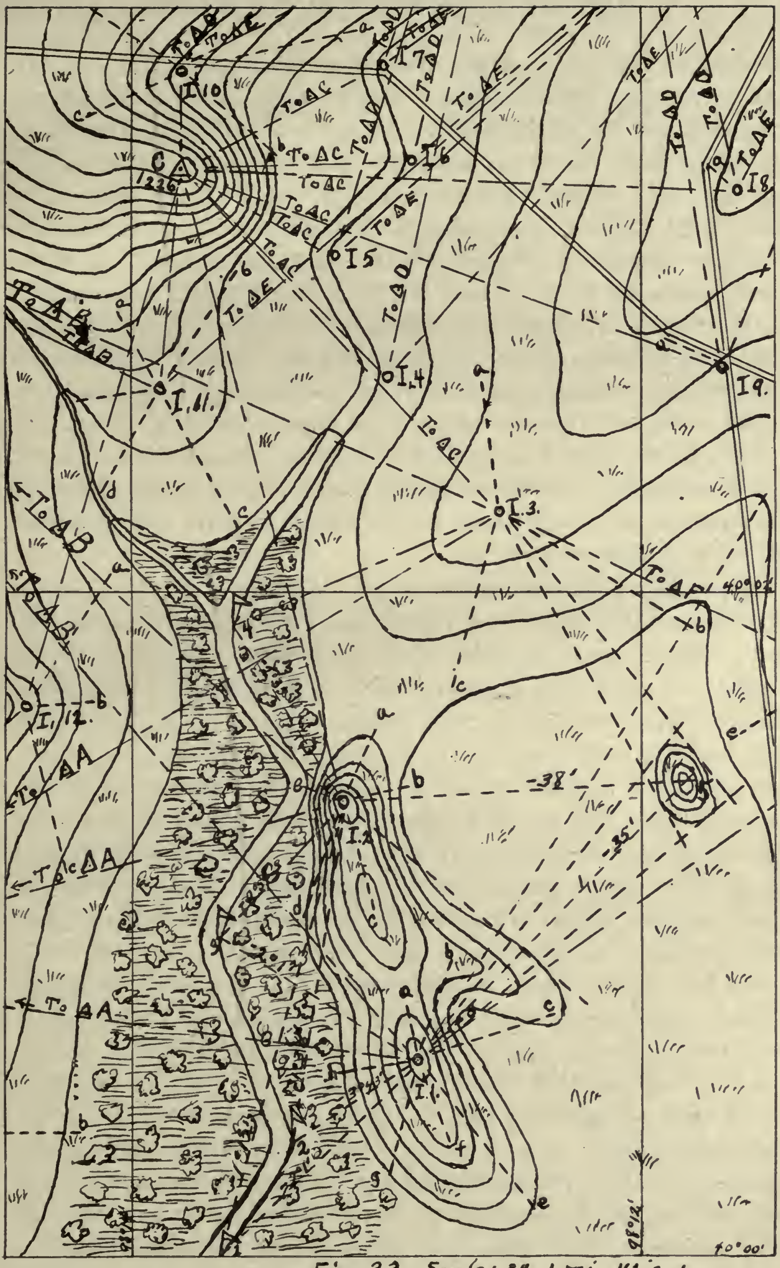


Fig. 33. Scale: 3" = 1 mi. V.1. 20'.

capital letters in the order of their establishment; as, ΔA, ΔB, ΔC, etc. Secondary stations can be designated numerically in the order of their establishment; as, Δ1, Δ2, Δ3, etc. Tertiary, or plane table resection, stations can be designated numerically in the order of their establishment preceded by the letter "I"; as, I1, I2, I3, etc. The instrument stations of a control traverse can be designated numerically in the order of their establishment preceded by the letter "T"; as, T0, T1, T2, etc.; should a traverse start from a triangulation station, the designation of such station will be used in lieu of "T-O." Intersected points can be designated numerically in order of their establishment without reference to the instrument station from which they are intersected; as, 1, 2, 3, etc. The critical points around an instrument station, established by a stadia reading, can be designated by small letter in the order of their establishment at each instrument station.

For convenience of reference, the elevation of triangulation stations should be shown in figures, either near each station or in order on the margin of the field sheet.

Procedure: In Fig. 33, the field sheet having been prepared with coördinate lines and all primary and secondary stations plotted, the sketcher is ready to proceed to the sketching. Arriving at the south central portion of the field he selects the southern knoll as the first instrument station, and locates it by resecting on ΔA, ΔB, and ΔF; the elevations of these triangulation stations are known; the vertical angles to them from the instrument station (I1) are read; the ground distances to them are obtained by applying a graphic reading scale to the map distances—from which the difference in elevations are obtained. These differences subtracted from the respective elevations of the triangulation station should all give the elevation of I1, which results should check within a few feet. The elevation of I1 is thus found to be 125′. Stadia readings are taken to the critical points *a*, *b*, *c*, *d*, *e*, *f*, *g*, and *h*. By the use of a stadia reduction table or stadia computer, the horizontal distances of and differences in elevation to these critical points are obtained and plotted. With this data the sketcher can plot the hill as far north as the top of the spur to the northeast. The sketcher in his preliminary reconnaissance observed that the river here flowed through an impenetrable swamp, and the vegetation was so high that the bends of the river through the swamp could not be located by resection from those bends for the triangulation stations could not be seen, so he had a detail in a boat to establish flags on poles 20 feet long at these bends. At I1, the sketcher draws pencil rays to such flags as he can see with the expectation of intersecting on the same flags from some subsequently located station; he thus draws rays to flags 1, 2, 3, *(on all intersecting rays the vertical angle should be written with pencil on the field sheet).* To the northeast there is a ravine about a mile away whose general direction he can determine by a single ray. There is also a knoll about three-quarters of a mile away that he can locate by intersection, and he therefore takes a sight at its top using a rock or tree or other easily recognizable object, if there is none the center of the top of the hill will do. This ray he designates *5;* the vertical angle is written along the ray. He also takes rays to the north and south at the foot of the hill, but does not determine the vertical angles, for he can see that the ground from the foot of the hill he is on to the foot of this knoll is practically level.

For the next instrument station he selects the northern knoll of this same ridge, and locates it by resecting on ΔA, ΔB, and ΔC; the central knoll can be located by stadia from it. The critical points *a*, *b*, *c*, *d*, *e*, are determined by stadia readings and after reduction are plotted; a sighting ray is taken along the north foot of the spur to the southeast. From this data the whole ridge as far north as I2*a* can be plotted. I2*e* is also a bend of the river. Rays are taken on *1*, *2*, *3*, *4*, and *5*, which with those from I1 locates points *1*, *2*, *3*, and *6*. 20 feet must be subtracted from the elevations of the flags as obtained in order to get the elevation of the river at these bends.

From I3 the southern slope of the low ridge is determined and plotted, while rays to the east and west of the 1090 foot hill determined from I1 and I2 enables that hill to be plotted. A ray to *4* with the one from I2 determines the bend of the river at that point.

Instrument stations I4, I5, I6, and I7, all determined by resection, locate the critical points of the river through that section, and the elevation of the river at those points.

From I8 the location and elevation of that point is determined, and the bend of the road near there. From this point all the slope to the west can now be plotted. From I9 the road crossing and the road bend to the west are determined. Rays from this point along the roads will determine the map direction of these roads from their plotted intersection. From I7, the direction of the road to the southeast and to the west can be determined.

In reference to that portion shown west of the river, the immediate vicinity of △C would have been plotted when that station was occupied for determination. From I10 the slope to the north can be obtained; from I11 the slope to the south and also the stream from the northwest; from I12, the slope from that point to the edge of the swamp can be determined and plotted.

In this illustration very few details have been shown. This in order to make the fundamental principles of contouring the clearer. The topographer having determined the location and elevation of the critical points, has the slope of the ground between right before him from which he should be able to plot his contour lines. In actual sketching when a critical point is determined, the lines may be erased, which leaves the field sheet free for other work without a multitude of lines in which to lose determined data. In the diagram resection lines are represented by dot-dash lines; intersection lines and stadia readings by dot lines. The critical points of vegetation areas, location of houses, etc., etc., are determined by any of the methods explained heretofore: intermediate points are estimated.

Field notes, if kept, should be systematic and legible. The following shows a specimen of a field note page.

Title and By Whom Executed: Every completed field sheet, map or sketch should have included on it (1) the kind of map, (2) by whom executed, (3) date of execution, (4) scale, (5) contour interval, (6) a simple graphic scale in yards or feet, and (7) a simple slope scale; as,

TOPOGRAPHICAL SURVEY

NEAR

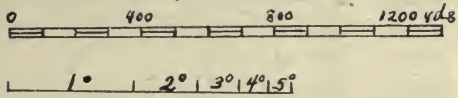
EAGLE PASS, TEXAS

BY

LT. JOHN DOE, 40th Inf.

Scale: 3″ = 1 mile.

V. I. = 20′.



The title should also include the purpose for which the survey is for if this is not apparent from the map itself; as, "Proposed Military Reservation," Etc. The map should also have both a true and magnetic arrow. Should meridians of latitude be plotted a true north arrow will not be necessary.

FIELD NOTES, TOPOGRAPHICAL SURVEY

Fm.	To	Hor. Dis.	Azimuth Control	Azimuth Check	Ver. Ang.		Elev.
I1	Δ*A*	6200	97°30′	277°30′	+	28′	1125
	Δ*B*	11320	139°33′	319°33′	+	28′	1125
	Δ*F*	5560	234°15′	54°15′		0	1123
	a	520	167°56′		—	3°51′	1090
	b	960	198°06′		—	3°17′	1070
	c	1320	251°30′		—	4°25′	1023
	d	560	227°20′		—	10°45′	1019
	e	1720	322°12′		—	3°30′	1020
	f	820	340°00′		—	45′	1100
	g	1080	13°40′		—	5°33′	1020
	h	760	80°30′		—	7°58′	1020
	1	2560	44°35′		—	2°01′	1015
	2	1380	56°45′		—	3°43′	1015
	3	2160	121°55′		—	2°19′	1017
	5	3530	223°20′		—	35′	1090
I2	Δ*A*	5720	74°00′	254°00′	+	30′	1125
	Δ*B*	9080	133°02′	313°02′	+	54′	1124
	Δ*C*	6000	165°58′	345°58′	+	58′	1125
	a	730	205°05′		—	7°14′	1032
	b	600	257°14′		—	10°06′	1018
	c	1000	344°12′		—	0	1124
	d	1130	17°28′		—	5°19′	1020
	e	360	112°26′		—	16°33′	1018
	2	3160	8°10′		—	1°36′	1015
	1	4310	15°00′		—	1°12′	1015
	3	1700	42°57′		—	2°54′	1017
	4	1900	148°35′		—	2°35′	1019
	5	3140	265°10′		—	38′	1090
I3	Δ*A*	8100	58°00′	238°00′	+	45′	1068

Sketcher ....Date ....

Instr. Man ....Inst. ....

Recorder ....Stadia Cons. ....

Needle	Remarks
N82°30′W	*Elev.* $\Delta A=1175$
N40°30′W	*Elev.* $\Delta B=1268$
N54°15′E	*Elev.* $\Delta F=1123$
N12°00′W	*Slope even to col.*
N18°00′E	*Back of spur to N. E.*
N71°30′E	*Foot of spur to N. E.*
N47°15′E	*Slope uniform*
S37°45′E	*Slope uniform*
S20°00′E	*Slope uniform*
S13°45′W	*Slightly convex near sta.*
S80°30′W	*Slope uniform*
S44°30′W	*Flag at bend of river—20′*
S56°45′W	*Flag at bend of river—20′*
N58°00′W	*Flag at bend of river—20′*
N43°15′E	*Knoll to northeast*
S74°00′W	*Elev.* $\Delta A=1175$
N47°00′W	*Elev.* $\Delta B=1268$
N14°00′W	*Elev.* $\Delta C=1226$
N25°00′E	*Slope concave to col.*
N77°15′E	*Slope uniform*
S15°45′E	*To knoll with col. between*
S17°30′W	*Slightly concave*
N67°30′W	*Slope uniform to river*
S 8°15′W	*See 2 from I1.—20′*
S15°00′W	*See 1 from I1.—20′*
S43°00′W	*See 3 from I1.—20′*
N31°30′W	*Flag at bend of river—20′*
N85°15′E	*See 5 from I1*
S58°00′W	*Elev.* $\Delta A=1175$

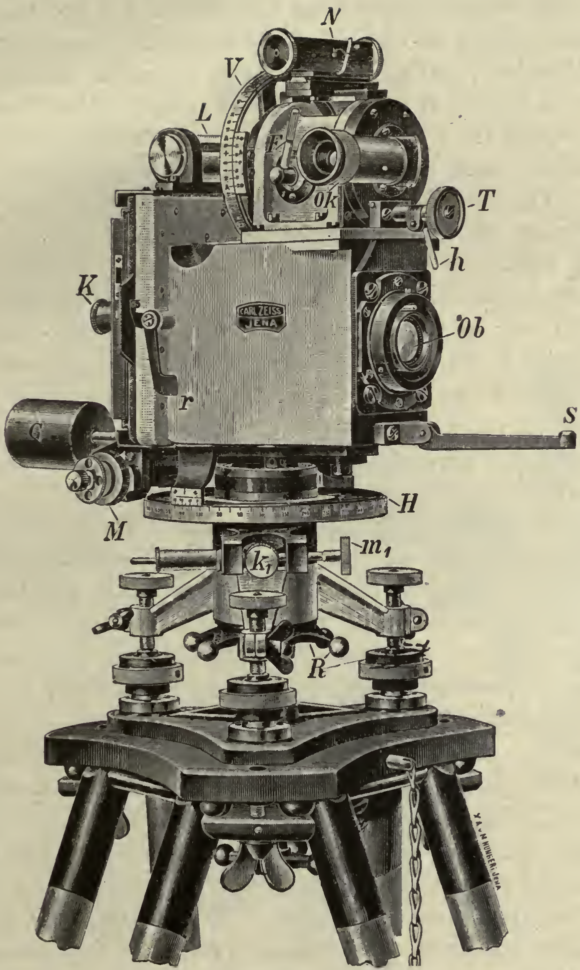
Photo-Topographic Operations

General Principles. In photo-topographic surveys photographs of the terrain are taken from triangulation stations, from which the critical points of the terrain are determined by graphic methods and the terrain plotted in the office. The sketcher does not see the terrain and the work is only suitable where wide generalization is permissible. Such will usually be the case in the survey of mountains where the difficulty of field work will make photo-topographic methods of double value. Although the U. S. Government surveys have employed photo-topographic methods only to a small extent, some European Governments and Canada have done so quite extensively and with very great success. In the future topographic surveys of mountains 2,000 feet in height and over will generally be made by photo-topographic methods.

Photo-Topographic Instruments. The principle instrument used in photo-topographic surveys is the camera, which is of fixed focal length and is mounted on a tripod much the same as a transit is. There are a number of different kinds of survey cameras now manufactured, some of these are very good while others are not; the author would recommend the "photo-theodolite" as the most efficient and best adapted instrument for the work on the market. It can be used not only for the topographic work but also the triangulation work.

The photo-theodolite should consist of a camera of fixed focal length mounted on a tripod the same as a transit. There should be leveling screws and level bubbles; a vertical axis and horizontal scale and vernier, so that the camera can be revolved in azimuth and set at any angle; also a horizontal axis with scale and vernier, so that the camera can be plunged and set at any vertical angle; and in addition, there may be a telescope with either horizontal, or vertical, or better both, axis, with the corresponding scales and verniers. This telescope is very handy in measuring angles in triangulation work and dispenses with the use of a transit.

The camera should contain a solid rectangular recticle of the same size as the ground glass, which has two cross wires defining the vertical and horizontal medians of the same. These



FIELD PHOTO-THEODOLITE
Courtesy of Carl Zeiss

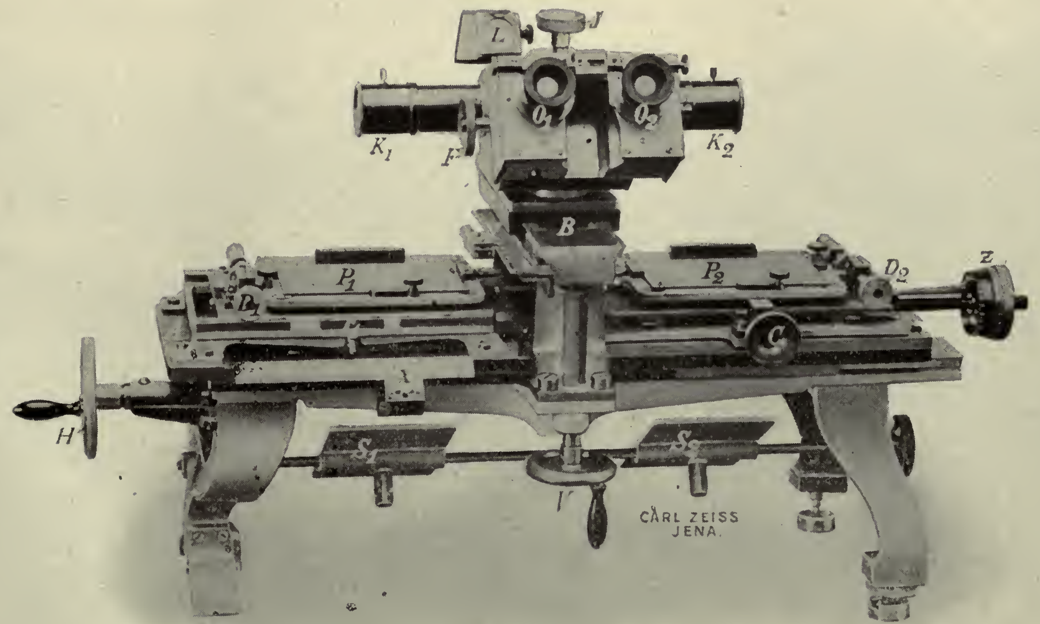
wires should be sufficiently near the ground glass to cast a well-defined line on the negative during exposure, the photographic lines on the negative furnishing the control for plotting. The cross wires should be vertical and horizontal, respectively with the level bubbles, and their intersection should be on the optical axis of the lense. When the vertical vernier reads "zero" the optical axis of the lense should be parallel with the plane of the level bubbles, and perpendicular to the vertical axis of the camera. The plane of the ground glass should always be perpendicular to the optical axis of the lenses.

Either plates or films may be used. Films are much more easily transported in the field and are also more easily loaded; either film rolls or film packs may be used. If plates are used, the magazine plate holder will be found much more convenient.

The Stereo-Comparator: If two views of the same terrain are taken in which the camera in both cases had the optical axis of its lense perpendicular to the same base line and was a short distance apart on that base line, then the distance to any object in the terrain can be computed from the base line and the amount of parallax to that object as shown from the two views. Parallax as shown on photographic negatives is of very small magnitude, and where it is measured a measuring instrument of great precision is required. Such an instrument, known as the Stereo-Comparator, has been invented by Dr. C. Pulfrich of Jena.

The Stereo-Autograph: Oberleutnant Ed. Ritter von Orels of the *Militargeographischen Institut* in Wien has invented an instrument, known as a "Stereo-autograph" which mechanically determines the horizontal and vertical position of points from a picture and plots them on a plane surface to any desired scale.

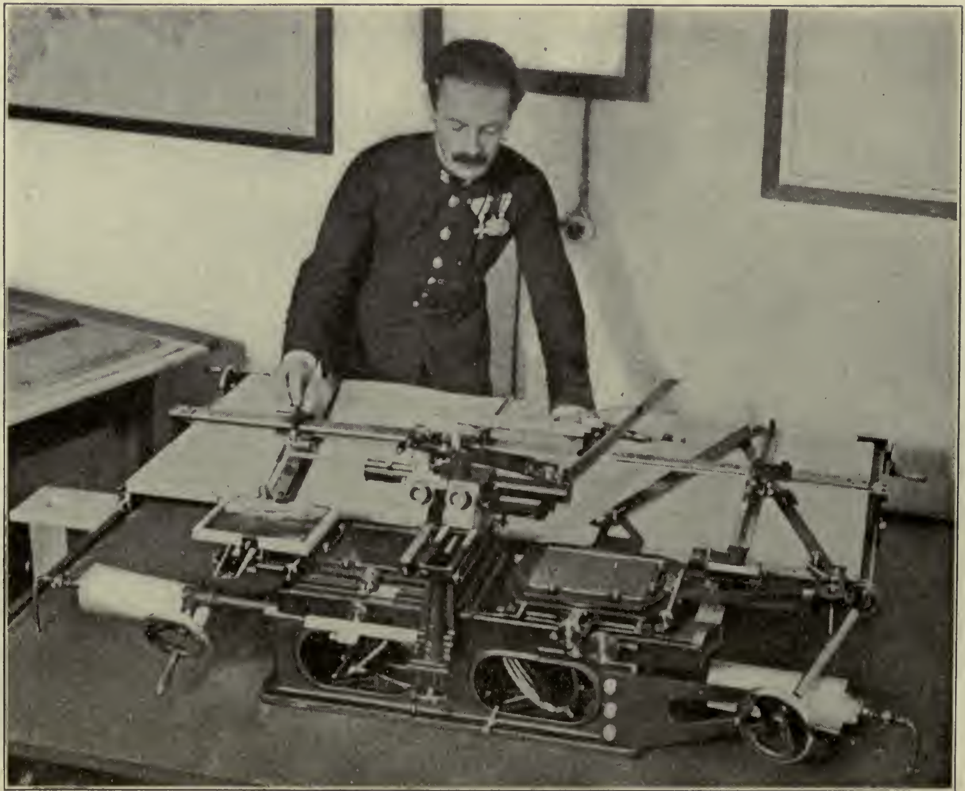
Photo-Topographic Control. The control for a photo-topographic survey is an elaborate system of triangulation: the same as that of a regular topographic survey. If there is no existing triangulation of the territory to be surveyed, it will be necessary to first measure a base line and establish a triangulation system upon it in the territory. If there exists a triangulation system, such as the Geological or Coast & Geodetic Survey, it will have to be reduced to a system of smaller triangles,



STEREO-COMPARATOR ($x\frac{1}{5}$)
Courtesy of Carl Zeiss, Jena

View of Terrain Mapped by the Stereo-Autograph; Map on Following Page
Courtesy of Carl Zeiss, Jena

CONTOUR MAP MADE BY THE STEREO-AUTOGRAPH; VIEW OF TERRAIN ON PRECEDING PAGE
Courtesy of Carl Zeiss, Jena



Stereo-Autograph

as for sketching, so that the terrain can be effectively covered with photographs. If a photo-theodolite be used, the triangulation and the photographing of the terrain can all be done with one instrument and with one set-up at each station; otherwise it will be necessary to have a regular transit to execute the triangulation work. Instrument stations will usually be primary and secondary triangulation stations, but tertiary stations established by either photographic or transit resection will also be frequently used. Where the photo-theodolite is used resection can be made then as with a transit or plane table. At each instrument station a series of photographs are taken covering the whole horizon; by photographic intersection, graphically determined from two or more negatives taken from different known stations, critical points are plotted, their elevations determined, and the terrain plotted therefrom.

Photographic Intersection. If a negative be placed in the same position with respect to the terrain as when it was exposed in the camera, the rays of light connecting points on the terrain and their images on the negative will all meet in the same point. This point is just as far back of the negative as the optical center of the lense was in front of the dry plate during exposure: in other words, this point is just the focal length of the lense used, away from the negative. From Fig. 34 it can be easily seen that when two negatives of the same object taken from different positions, are plotted to point in the same direction as when exposed, the lines connecting the focal points, a and b, and the critical point x, form a triangle which is exactly similar to the natural triangle ABX. If, therefore, ab is plotted to scale, then ax and bx will also be to scale, and the map position of X can be plotted by producing the photographic rays ax and bx to the point x where they intersect. See Fig. 35.

(1) Photographic Intersection Without Orientation: Having given two triangulation or instrument stations, A and B, and an unknown critical point X, to determine the map position x from two photographs of X—one taken from A and including in its field B and X, and the other from B and including in its field A and X. See Fig. 35.

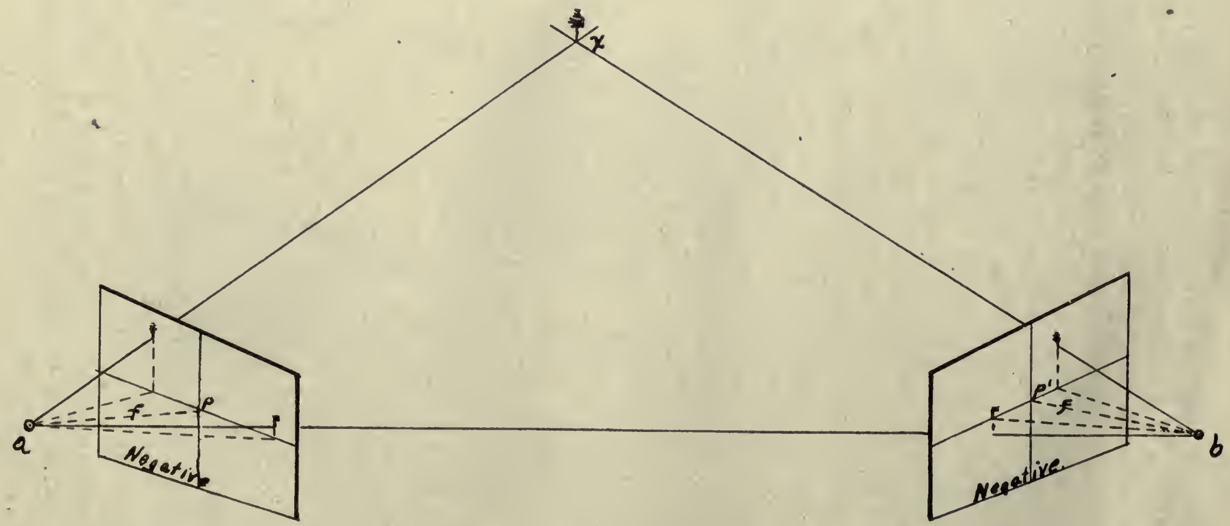


Fig. 34.

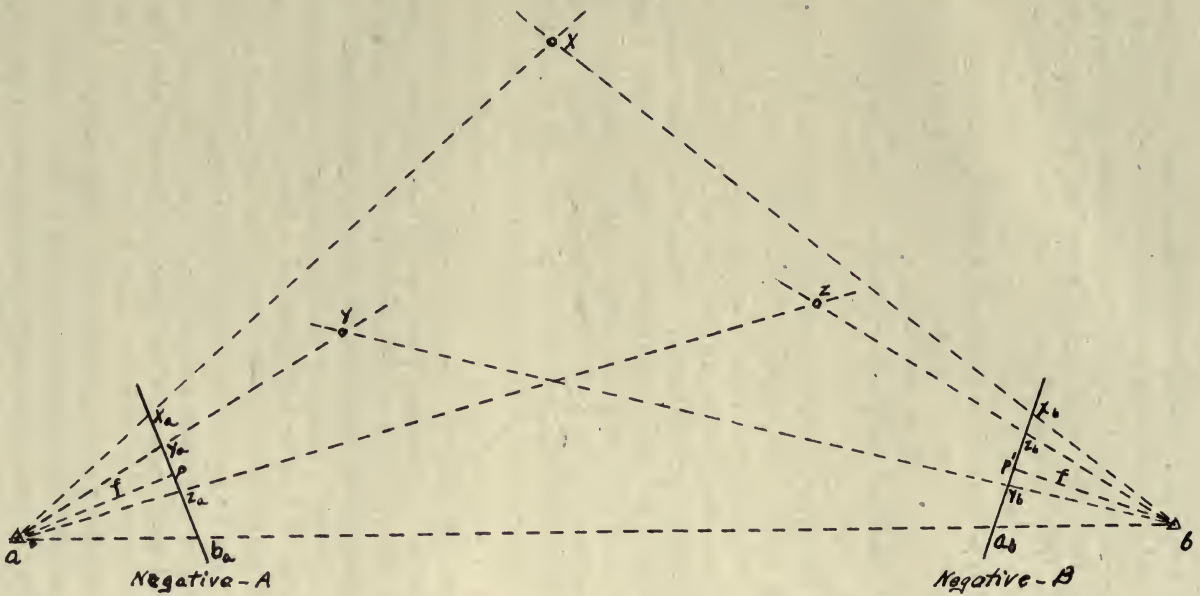


Fig. 35.

Procedure: (1) From the triangulation data plot the points a and b on the map to scale, and draw a pencil ray ab; (2) with dividers and reading scale measure the distance on plate "A" from the image b_a to the vertical median P^p, and on plate "B" from the image a_b to the vertical median p^1; (3) construct at a an angle pab whose tangent equals $\frac{pb_a}{f}$, and at b an angle p^1ba whose tangent equals $\frac{pa_b}{f}$, in which f is the focal length of the lense of the camera used; (4) measure off on the lines ap and bp^1 the distance of f in inches; (5) at p and p^1 construct perpendicular lines to ap and bp^1, respectively (these lines represent the horizontal positions of the negatives at the time the exposures were made); (6) with dividers measure on Negative "A" the distance from the image point x_a to the vertical median p and lay this distance off on the perpendicular pb_a from point p to x_a, similarly measure the distance on Negative "B" from the image point x_b to the vertical medium p^1 and lay this distance off on the perpendicular p^1a_b from point p^1 to x_b; (7) now plot the lines ax_a and bx_b through point a and x_a and b and x_b, respectively, producing them until they intersect at a point x, the map position of the unknown point X. Where the scale is large and the distance to the critical point is small, the plotted triangle axb will not be large enough to contain a perpendicular x_ab_a, nor the actual length of the negative. In such cases it will be better to use a blank piece of tracing paper plotting the line ab long enough to contain the lengths ab_a and ba_b, respectively. This triangle can be very easily reduced to scale by drawing a line parallel to bx intersecting the side ab at a point from a equal to the map distance of AB then this line will intersect side ax at the map position of X. The distances of f, b_ap, px_a, etc., could also be proportionally reduced by dividing the same by some factor, as 2, 3, or 5, etc.

(2) Photographic Intersection With Orientation—Fleemer's Three-Point Orientation: Having given two triangulation stations, A and B, with a series of photographs at each, to de-

termine the map position of an unknown point X visible to both A and B.

In this method the camera is correctly oriented at each station and a series of photographs taken at each to include the whole horizon. Thus if the camera lense included a field of 60°, it would take six photographs at each station and the camera could be set at the following azimuths—0°, 60°, 120°, 180° 240°, and 300°. For orienting the camera at the first station, the same methods as explained for the plane table can be used, preferably a sun azimuth; at the second and succeeding stations orientation should be made by back-sighting. We will assume that the photograph at A which includes X was set at 240°, and the one at B which includes X, at 120°, as shown in Fig. 36.

Procedure: (1) Plot the points a and b to scale and at each point construct polygons (hexagons) in which the perpendicular distance from the center points to the sides is equal to f; (2) measure off the distances $x_a p$ and $x_b p^1$ from the negatives ("A"240° and "B"120°) and plot the distances on the proper side of the proper polygons; (3) now draw the lines ax_a and bx_b until they intersect in a point x, which is the map position of X.

Photographic Resection. It will occasionally be desirable to occupy an unknown point as an instrument station, from which to take a series of photographs for topographic purposes. In such cases where the photo-theodolite is used, the azimuths to visible triangulation stations can be read, recorded, and then plotted. The intersection of these azimuth rays is the map position of the unknown station. Where a camera is used with which horizontal angles cannot be read, the map position of the unknown station can be determined if a photograph taken from that station contains at least three visible plotted triangulation stations.

(1) The Three-Point Problem: Having given a photographic negative containing three triangulation stations, A, B, and C, taken from an unknown station X, to determine the map position of X.

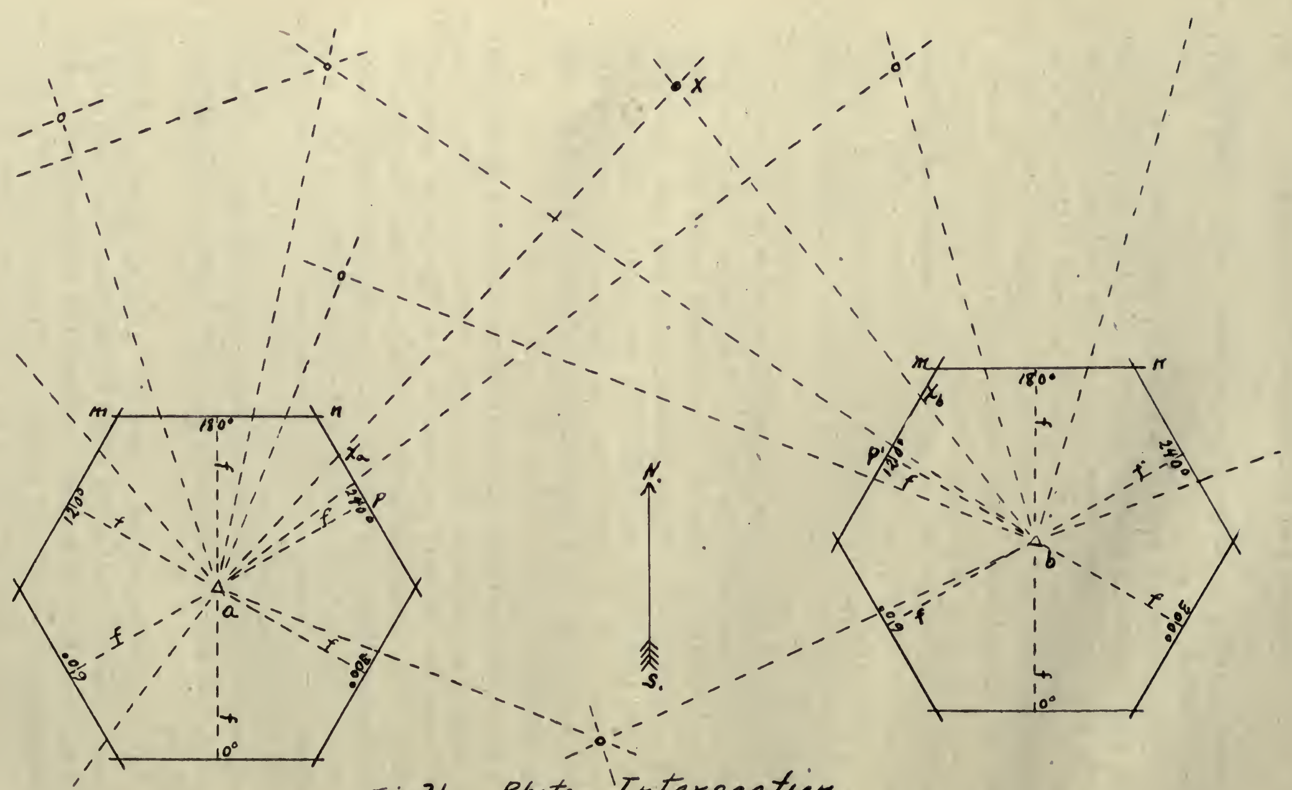


Fig. 36. Photo-Intersection.

Procedure: (1) Draw a line mn on a piece of tracing paper and upon it construct a perpendicular vp equal to the focal length of the camera lense (Fig. 37); (2) lay off on the line mn the distances va^1, vb^1 and vc^1, equal, respectively, to the distances on the negative MN of the image points a, b, and c, from the vertical mediam vv^1; (3) from point p draw lines through points, a^1, b^1 and c^1; (4) now adjust the tracing paper over the map so that the lines pa^1, pb^1 and pc^1 pass through the

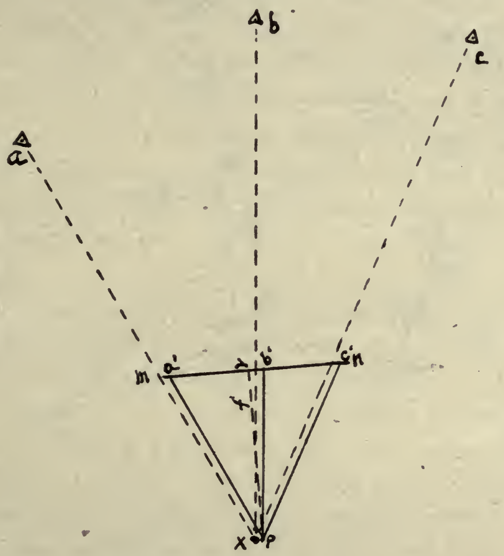


Fig. 37. Photo-Resection.

plotted points, Δa, Δb, and Δc, and the point p will then be over the map position of the unknown station X. Prick p so as to mark the position of x on the map.

(2) The Five-Point Problem—Prof. Schiffner's Simplified Graphic Construction: Having given a photographic negative containing five triangulation stations, A, B, C, D, and E, taken from an unknown station X, to determine the map position of X.

Procedure: (1) from a draw lines through the plotted points b, c, d and e (Fig. 38); (2) from the negative mark the horizontal positions of the images of A, B, C, D and E on a straight edge of blank paper, labeling them a_x, b_x, c_x, d_x and e_x; (3) apply this straight edge to the blank paper so

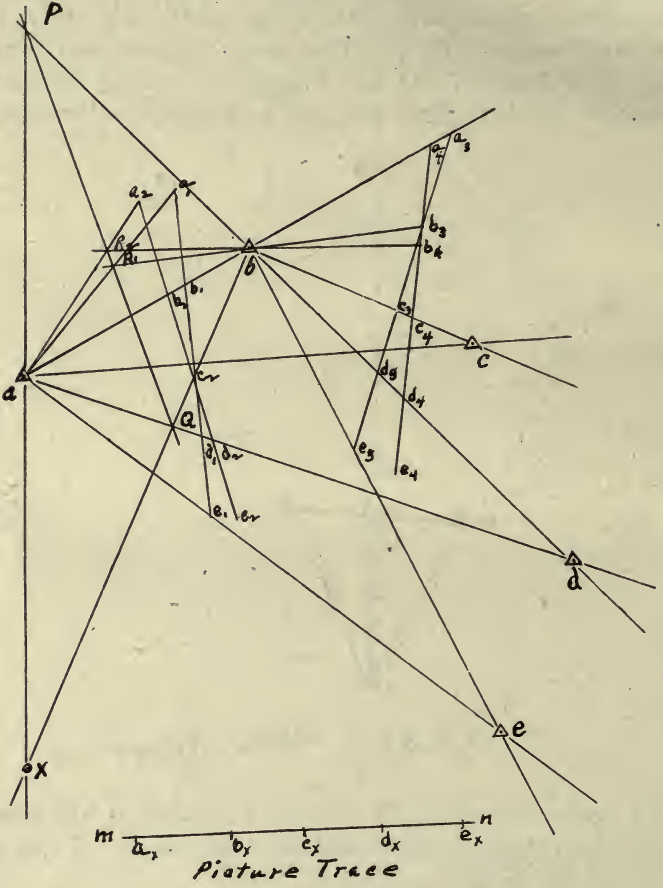


Fig. 38. 5-Point Photo-Resection.

that points b_x, d_x and e_x, coincide with the lines ab, ad and ae, respectively, mark the position of a and draw then line aa_1; (4) similarly apply the straight edge so that the points b_x,

c_x and d_x, coincide with the lines ab, ac and ad, respectively, mark a_2 and draw the line aa_2; (5) similarly apply the straight edge so that points a_x, d_x and e_x, coincide with lines ba, bd and be, respectively, mark b_3 and draw the line bb_3; (6) similarly apply the straight edge so that points a_x, c_x and d_x, coincide with lines ba, bc and bd, respectively, mark b_4 and draw the line bb_4; (7) lines aa_1 and bb_3 will intersect at a point R_1, and aa_2 and bb_4 at R_2—now through points R_1 and R_2 draw a straight line intersecting bd produced at some point P, and line ad at some point Q; (8) from P draw a line through a, and from Q a line through b: their point of intersection is the map position x of the unknown station X.

ORIENTATION OF PICTURE TRACE BY THREE-POINT METHOD. *Having given a photographic negative containing three triangulation stations, A, B and C, taken from a known station S, to orient the picture trace on the map—Prof. Schniffer's Method.*

It is usually better to orient the picture trace by the tangent method explained above, but it may occasionally be desirable to use the method explained in this section.

Procedure: (1) Draw radials from s through the plotted points a, b and c (Fig. 39); (2) at a convenient point a_1 on the radial sa, draw a line parallel with radial sc; (3) upon this line lay off distances a_1b_1 and b_1c_1 equal respectively to the horizontal distances of the images of A and B and B and C on the negative; (4) at b_1 and c_1 draw lines parallel with radial sa, producing them so as to intersect radials sb and sc, respectively, and then through these intersections draw a line hh^1—this line is parallel with the desired position of the picture trace; (5) on line hh^1 lay off distances hb_2 and b_2c^1 equal respectively to a_1b_1 and b_1c_1, and through points b_2 and c_2, draw parallels to radials sa intersecting the radials sb and sc respectively at b^1 and c^1; (6) through b^1 and c^1 draw a line intersecting the radial sa at a^1; this line $a^1b^1c^1$ is the required position of the picture trace.

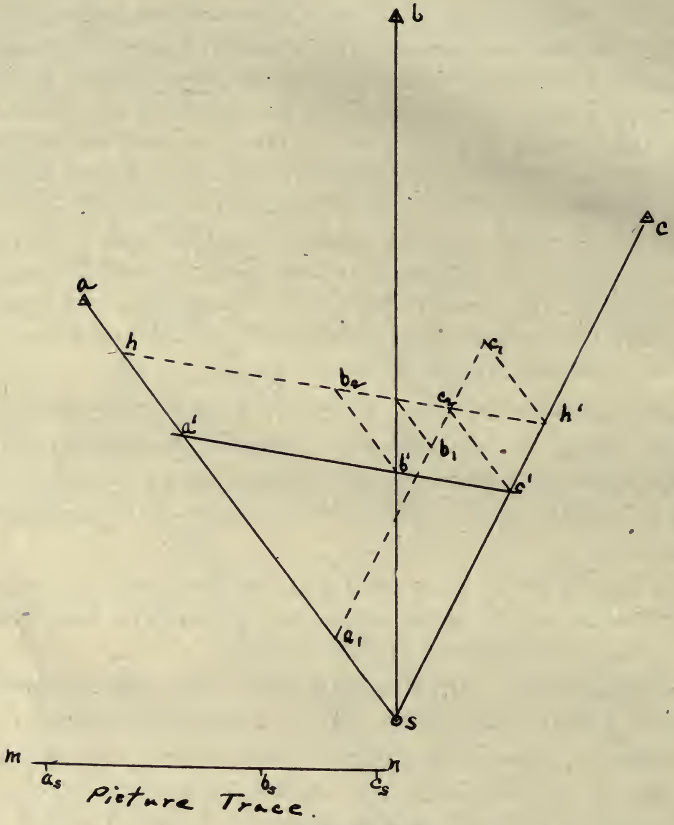


Fig. 39

Determination of Distance With the Stereo-Comparator. *Having given two photographs of the same object, taken with the optical axis parallel in the two exposures.*

When two photographs of the terrain are taken from two different stations, as O_1 and O_2 in Fig. 40, with the optical axes parallel, the distance to any critical point can be found from the following formula: $e = \frac{f \cdot b}{d}$.

In Fig. 40, let O_1 and O_2 represent the instrument stations; $M_1$and M_2 the terrain photographed in each case; m_1 and m_2 the negatives; and B a distant critical point. The optical axes O_1M_1 and O_2M_2 are parallel and the distance apart is measured. All the rays passing through a lense meet in a point, from which it is evident that the lines joining B to O_1 and O_2 pass through the image points B_1 and B_2 of B on plates m_1 and m_2. First as-

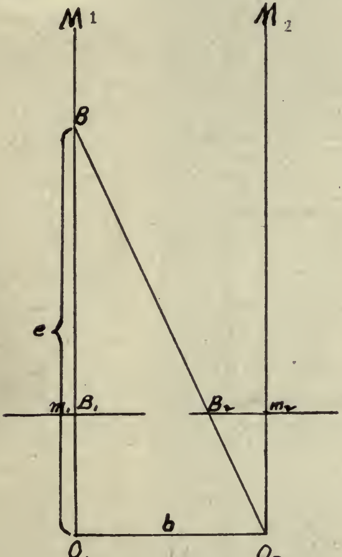


Fig. 40.

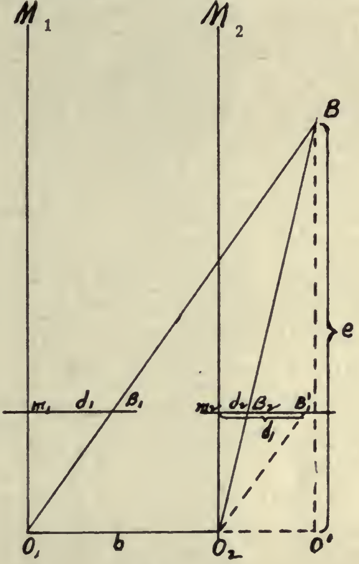


Fig. 41.

sume that B falls along the line O_1M_1, then the triangle O_1BO_2 is similar to triangle $m_2O_2B_2$ and e is to f as b is to d. This is true for all positions of B within the field of the camera lense. Thus in Fig. 41, triangle O_1BO_2 is similar to triangle BO_2B_2, and b is to d_1-d_2 as O_1B is to $B:O_2$; Triangle O_1BO^1 is similar to triangle O_2m_2B:, and $e:f::O_1B:B_1O_2$, from which the following proportion and equation are true: $e:f::b:d_1-d_2$, or

$$e=\frac{f \cdot b}{d_1-d_2}.$$

In this equation f is the focal length of the camera lense and b is measured, and both are thus known; the distance d_1-d_2 can

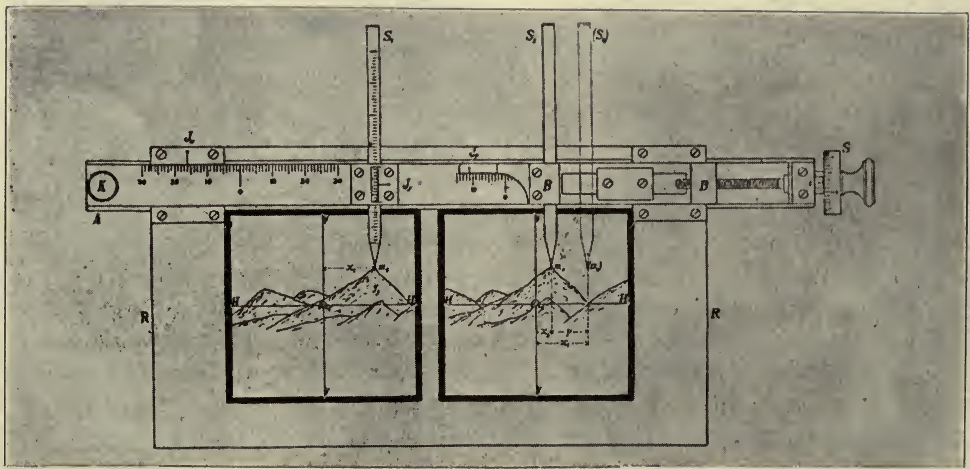


Fig. 42. Pulfrich's Stereo-Micrometer
Courtesy of Carl Zeiss

be measured on the negative; and e can be solved from the equation.

To measure this small distance, d_1-d_2, accurately, the stereo-comparator is used. The principle of this instrument is shown in Fig. 42, in which two vertical pointers S_1 and S_2 are brought over the image points m_1 and m_2 by means of a horizontal micrometer screw S. The small distance d_1-d_2 (or x_1-x_2) is read from the scales. The distance y of the image point above or below the horizontal mediam HH_1, can also be accurately measured on the stereo-comparator.

Determination of Elevation. When the camera is level the horizontal mediam hh_1 (Fig. 43) on the negative mark points which are of the same elevation as the instrument station, and since the size of an image varies inversely with the distance, the difference in elevation between the instrument station and any photographed point can be determined if the distance between them and the distance of the photographed point above or below the horizontal mediam hh_1 on the negative are known. In Fig. 43, a represents one of the foci of the camera lense, x_a the image point, x the critical point, hh^1 the horizontal mediam of the negative, and o a point directly below x and of the same elevation as a. $x_a h$ and xo are parallel to each other and the triangle ax_1h and axo are proportional. Therefore, $ax_a : ax :: x_a h : xo$, or $f : l :: d : e$, in which f is the focal length of the camera lense, l the distance from the instrument station to the critical point, d is the distance above or below the horizontal median, and e the difference in elevation between the instrument station and the critical point. Then $e = \pm \frac{l \cdot d}{f}$.

e and l are given in feet, while d and f are given in inches. d is plus or minus according as to whether it is above or below the horizontal median. Where the critical point is several miles distance, a correction should be made for the earth's curvature, which makes the equation: $e = \pm \frac{l \cdot d}{f} - \frac{7.92 \cdot L^2}{12}$,

where L is the distance in miles.

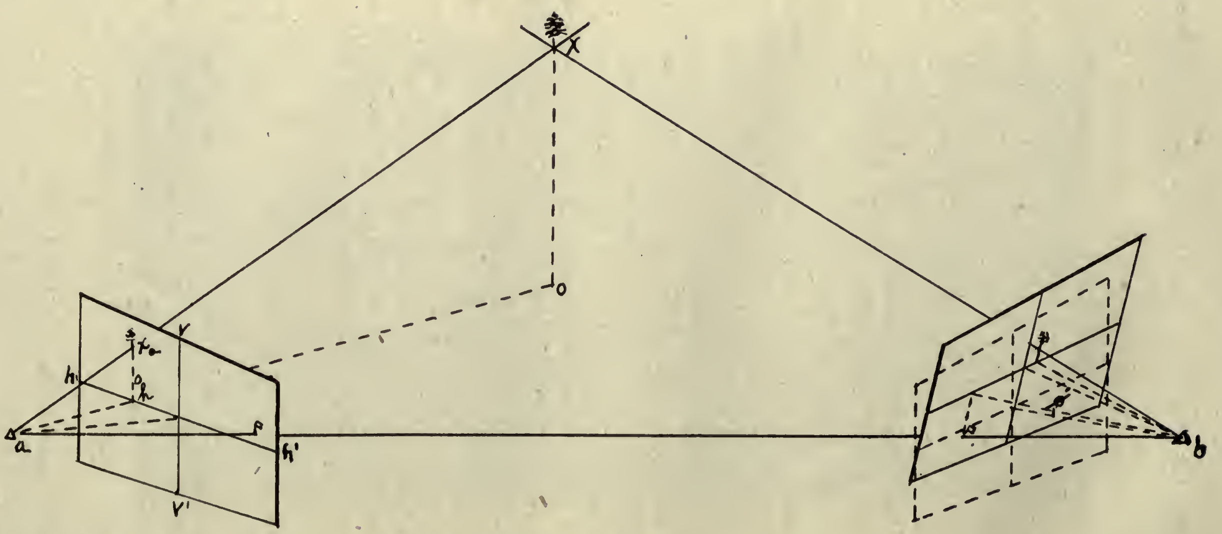


Fig. 43.

When the camera is plunged, or inclined to a plus or minus vertical angle, the following equation must be used:

$$e = \pm \frac{l \cdot d}{f \cos^2 \phi} - \frac{7.92 \cdot L^2}{12} \pm l \tan \phi,$$

where ϕ is the vertical angle of the optical axis (camera). Where E is the elevation of the instrument station and E^1 that of the critical point, then the complete equation is: $E^1 = E \pm e$.

When the camera is plunged the horizontal axis must be level so that no matter what the vertical angle at which the camera is set the optical axis is in the same vertical plane. In photographic intersection and resection work it makes no difference whether the camera's optical axis is horizontal or plunged providing the camera's horizontal axis is level.

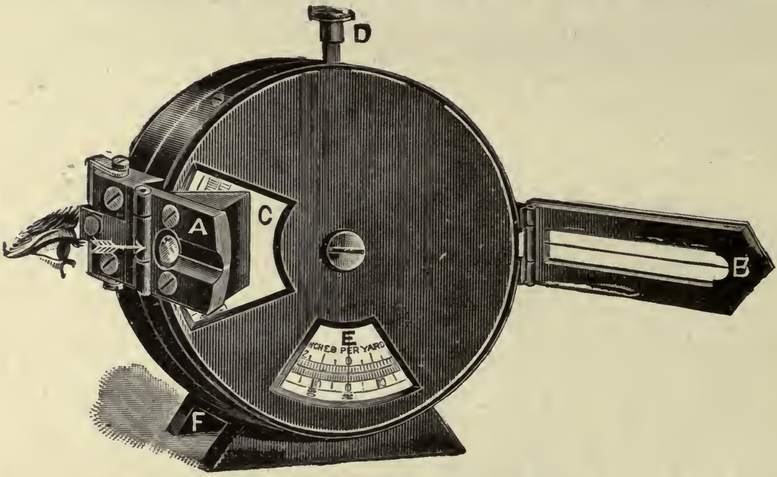
CHAPTER III

MILITARY SKETCHING

By "military sketching" rapid field topographical sketching is usually meant—where simple instruments are used and the control work is rather rudimentary as distinguished from topographical surveying where instruments of precision are used and the control work is very accurate. It is so considered and used in this book.

Measuring and Plotting Direction

(1) With Prismatic Compass. When the prismatic compass is used for determining direction, the field sheet is usually



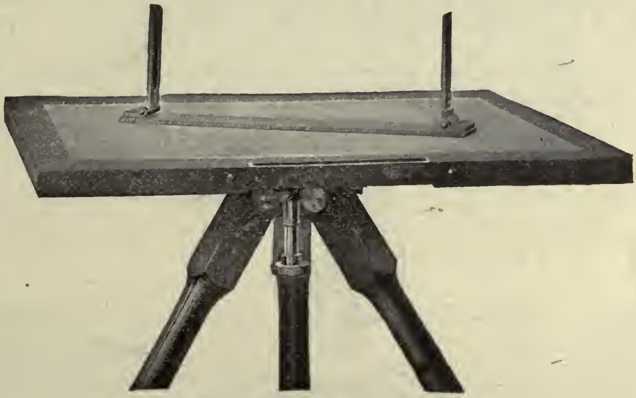
*Prismatic Compass and Clinometer

a transparent tracing paper placed over a paper protractor. This paper protractor should be rectangular in shape and about the same size as the sketching board. The circular scale, or protractor scale, should be 8, 10, or 12 inches in diameter and graduated into degrees. The prismatic compass is held level in the hand at the height of the eye and the vertical wire of the sighting vane is brought in line with the object whose

*Courtesy of W. & L. E. Gurley.

direction is to be determined. While looking through the eye piece the scale of the prismatic compass is also visible from which the *magnetic azimuth* to the unknown point is read directly. This azimuth, it should be remembered, has the north instead of the south, as the point of reference, and should the zero on the protractor be south a correction of 180° must be made to it. Having determined the azimuth with the prismatic compass, the direction (line) is plotted with triangles as explained in Chapter II, page ε5.

When opaque paper is used for the field sheet, a T-square and semiprotractor are used for the plotting. The azimuths are read with the prismatic compass after which they are plotted as explained in Chapter II, page 84.



*SKETCHING BOARD AND TRIPOD

(2) WITH SKETCHING BOARD ORIENTED. This method is used where the sketching board contains a compass, usually a trough compass, by means of which it can be oriented. After the board has been oriented a pin is stuck in the plotted instrument station, and around this pin a ruler is pivoted to such a position that the edge of the ruler is brought into line with the unknown critical point. A pencil ray now drawn along the ruler's edge will mark the direction line to the unknown critical point. This is very simple method, dispenses with the carrying of a detached compass, and is the method generally used in the field for rapid sketching.

*Courtesy of W. & L. E. Gurley.

Measuring and Plotting Distance

(1) By Pacing or Timing. If the sketcher knows the length of his regular pace, by pacing the distance between two points their distance apart can be easily computed or plotted from the number of paces required to be taken to walk from one to the other. The distance so paced is quite accurately determined providing the ground is fairly open, level and solid. If it be up or down grade a reduction must be made, and also, if the ground be muddy, heavy, or otherwise have a retarding effect on one's gait.

Reduction For Grades:

	5°	10°	15°	20°
Up Grades:	10%	20%	25%	30%
Down Grades:	4%	8%	10%	12%

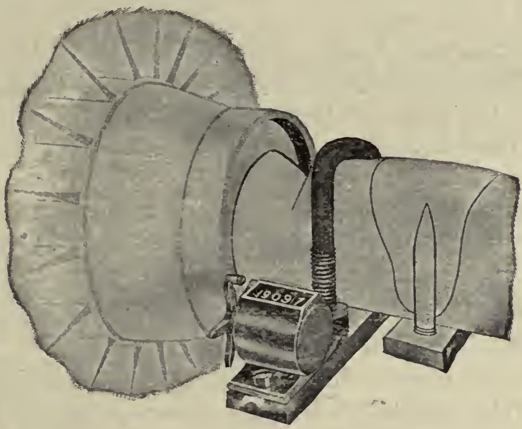
The distance between two points can also be equally accurately computed from the time necessary to walk from one point

*Tally

to the other, allowing for the same factors as in pacing. Timing is much more accurate than pacing where mistakes in count-

*Courtesy of W. & L. E. Gurley.

ing are very easily made, although the pace tally and pedometer will eliminate this objection. Distance is also determined by observing the time it takes a horse to travel the distance at established gaits. Bicycles and carriage wheels can also be used, the number of revolutions of a wheel times its circumference giving the distance. The revolutions are recorded on an odometer, but if the sketcher has no odometer a white rag tied



*Odometer

on a spoke or a felloe will enable the revolutions of the wheel to be easily counted.

(2) By Intersection. Intersection gives directly the map distance to any intersected point, from which the ground distance can be found by applying a reading scale to it.

(3) By Resection. Resection also gives directly the map distance to any resected point, from which the ground distance can be found by applying a reading scale to it.

(4) By Estimation. If the sketcher has had much experience in topographical surveying and has cultivated an "eye" for ground distances, he should be able to estimate distances about as accurately as they can be paced. No inexperienced sketcher, if it can be avoided, should attempt to estimate distances, for such estimating is nothing more than mere guessing. The beginner should always measure distances at first by stadia,

*Courtesy of W. & L. E. Gurley.

intersection, and other accurate means in order to cultivate a good "eye" for distances. Topographical surveying is an excellent preliminary training for rapid military sketching, and all officers that can should do some topographical surveying.

The following facts in regard to the appearance of objects under different conditions, given in the Small Arms Firing Manual (1913), should be tested and verified:

Objects seem nearer—

(a) When the object is in a bright light.

(b) When the color of the object contrasts sharply with the color of the background.

(c) When looking over water, snow, or a uniform surface like a wheat field.

(d) When looking from a height downward.

(e) In the clear atmosphere of high altitudes.

Objects seem more distant—

(a) When looking over a depression in the ground.

(b) When there is a poor light or a fog.

(c) When only a small part of the object can be seen.

(d) When looking from low ground upward toward higher ground.

Construction of Working Scale. For plotting distances a working scale should be constructed with units corresponding to the units in which the ground distances are to be measured. The unit used may be the pace, stride, wheel-revolutions, time, etc.

To Construct a Pace-Working Scale

Measure off with a steel tape or chain a distance of 800 to 1000 yards. Pace this distance forward and back at least six times. It is better to pace this distance on different days, than to do the pacing all on one day. Record the number of paces each time, discarding any obvious mistakes in counting, divide the sum of these paces by the number of times paced, the quotient is the average number of paces for the distance; divide the distance by the average number of paces and this quotient will give the average length of pace. For example:

Distance = 1000 yards.

Date:	No. of paces:
April 5	1146
" 5	1149
" 6	1145
" 6	1147
" 7	1146
" 7	1149

6882 ÷ 6 = 1147 = Average number of paces.

1000 yards ÷ 1147 = .875 yards =31.5 inches = Length of pace.

It is desired to construct a scale about three inches long, to be used in road sketching. The scale of road sketches is three inches to one mile. Divide the denominator of the R.F. of the road sketch by the length of the pace in inches. The R.F. of three inches to one mile is 1/21,120. Therefore:

21,120 ÷ 31.5 = 670.5 = number of paces to one inch on map.

A scale about three inches long would contain (670.5 × 3) 2011.5 paces. We shall therefore select 2000 paces as the length of our working scale, as this number is also one that can be easily subdivided.

2000 ÷ 670.5 = 2.98 inches = Length of scale.

Measure off 2.98 inches and divide the length into five equal parts, as explained in the case of the construction of a reading scale, p. 21. Equal parts will then represent 400 paces, a very convenient number for subdividing. Construct a scale as shown in the diagram. Fig. 44.

Construct working scales from the following data:

(1) Working Scale of Strides:

Scale of map = Six inches to one mile.
Distance paced = 880 yards.
Average number of strides = 500.

(2) Time Working Scale:

Scale of sketch = Three inches to one mile.
Distance paced = 880 yards.
Average time = 10 minutes.

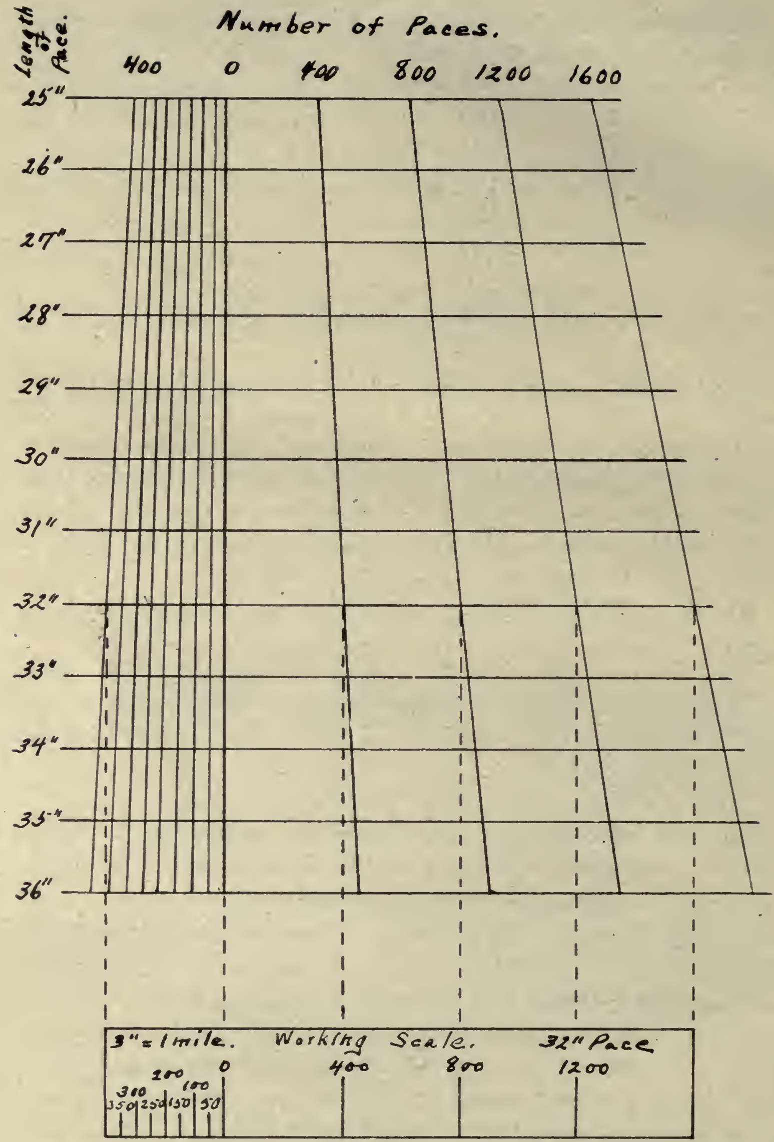

Number of Paces.
Length of Pace.
400
0
400
800
1200
1600
25"
26"
27"
28"
29"
30"
31"
32"
33"
34"
35"
36"
3" = 1 mile.
Working Scale.
32" Pace
0
400
800
1200
300
200
100
350
250
150
50

Fig. 44.

(3) Working Scale of Wheel-revolutions:
Scale of sketch = Three inches to one mile.
Distance traveled = one mile.
Number of revolutions = 674.

(4) Working Scale for Horse Walking:
Scale of sketch = Three inches to one mile.
Distance traveled = One mile.
Average time = 15 minutes.

When sketching with a board that is oriented at each set-up, it is more convenient to have the working scale right on the alidade ruler; but where a prismatic compass is used, it is more convenient to have the working scale on a cardboard attached to the sketching board, plotting distances therefrom by means of a pair of dividers.

Measuring and Plotting Slopes

Vertical Angle Measurement. *(1) With Slope Board:* For diagram of a board see Fig. 45. The slope (sketching)

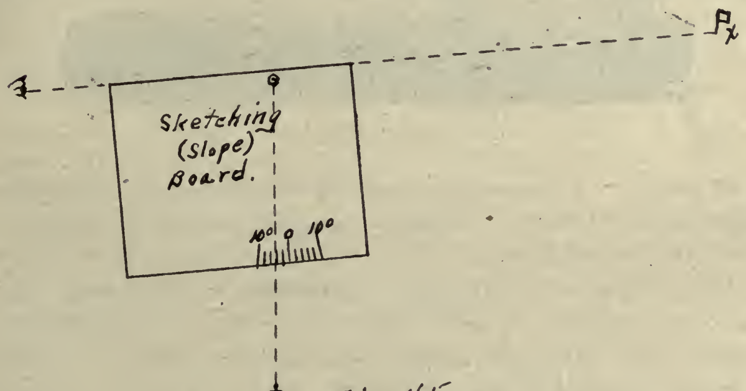


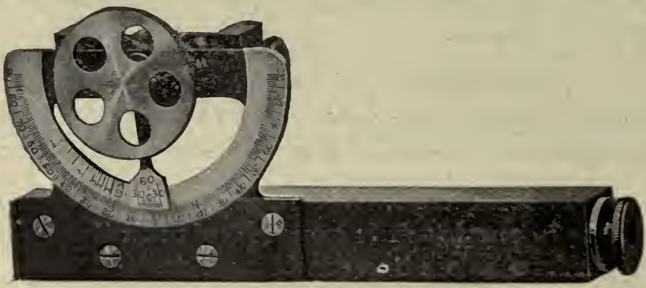
Fig. 45.

board is held in a vertical plane and at such an angle that by sighting along the top edge of the board, the object whose vertical angle is desired is just seen. When that position is attained the plumb-bob string should be held firmly in position by pressing the finger against it. The intersection of the string with the circular scale is the vertical angle required.

In a slope board it is obvious that a line passing through the center and the zero of the circular scale should be exactly perpendicular to the top edge of the board.

(2) With the Clinometer: The service clinometer is held in such a vertical position that the object is sighted on the cross wire. The vertical angle is read at the same time the sight is taken. The service clinometer is based on a very sound principle—that of gravity. The gravity scale oscillates very much, yet with a fairly steady hand and good eye, vertical angles within one-fifth of a degree should be read.

In the Abney Clinometer the telescope is sighted on the object and held in that position while the scale is brought to a



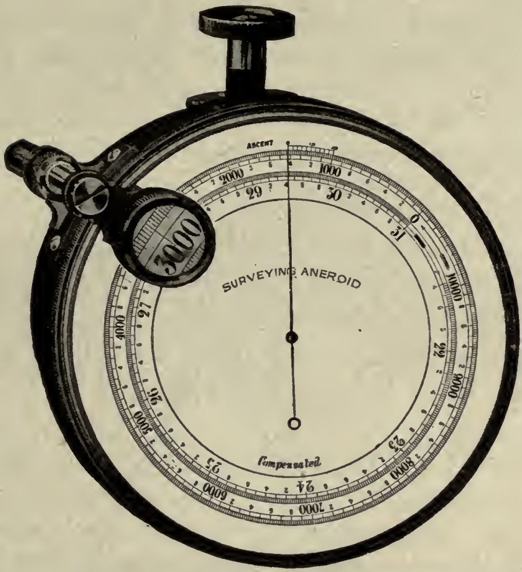
*Abney Clinometer

level position by means of an attached spirit level, visible while sighting through the telescope. In that position the scale is clamped and read.

Elevation with Aneroid Barometer. The use of the Aneroid barometer in determining differences in elevations has already been discussed (Chapter I, page 6). Its use is quite extensive in rapid military sketching.

Stadia Reduction. When the distance and vertical angle are known, the difference in elevation in feet can be obtained by multiplying the tangent of the vertical angle by the ground distance. To solve such problems, a stadia table or stadia computer can be used. The use of Cox's Stadia Computer has already been explained (Chapter I, page 81).

*Courtesy of W. & L. E. Gurley.



*Surveying Aneroid Barometer

Use of Slope Scales. Where two points are plotted and the vertical angle between them is known, the difference in elevation between them can be found by applying directly to them a slope scale for the known angle and counting the number of contour intervals included by the two points.

Plotting Slopes. The same general principles governing the plotting of slopes, as explained in topographical survey are here applicable. Not so high a degree of precision, however, is expected.

Plotting Character of Terrain

While the conformation of the terrain is being plotted by means of contour lines, the features of the terrain are at the same time represented by means of conventional signs which are usually suggestive of the thing represented.

Streams, Lakes, etc. In sketching, the courses of streams, and the shores of lakes will usually be plotted by determining a sufficient number of points along them to control their plot-

*Courtesy of W. & L. E. Gurley.

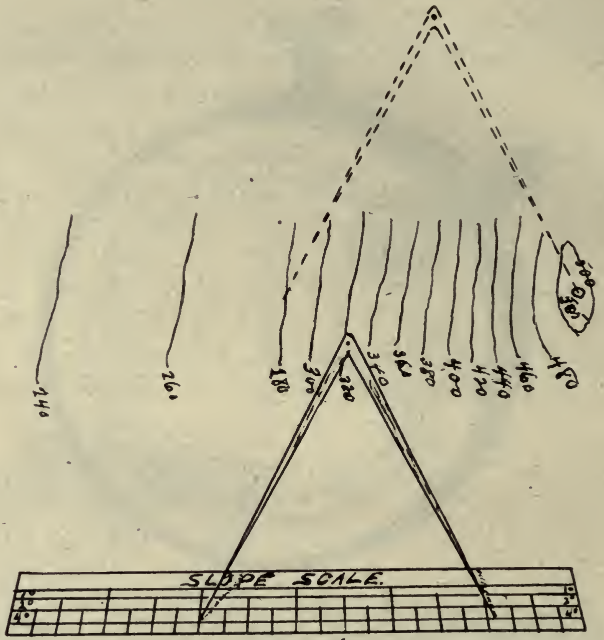


Fig. 46

ting within the degree of accuracy required. These points are determined by either resection, intersection, or other methods of determining the location of critical points. Where a stream or shore line is hid in underbrush, various means will have to be devised for their survey as explained in the chapter on Topographical Surveying.

Contour lines follow the banks of streams up-stream before crossing until they intersect the water surface of the stream where they cross the river in a straight line. They do not as is frequently supposed, follow the conformation of the bottom of the stream. The reason for this is quite evident: contour lines along the banks would coincide for long distances and make plotting and map reading unnecessarily difficult; on the other hand, to make the necessary soundings of rivers to determine their depth would be so laborious and expensive as to justify the same only in Engineering Surveys. In military surveys, streams are classified as fordable and unfordable. Only the depths of fords along unfordable streams are determined.

Vegetation. See Chapter II, page 93.

Lines of Communications. See Chapter II, page 93.

Towns and Buildings. See Chapter II, page 94.

Classes of Sketches

Military sketches are divided into two general classes—road sketches and area sketches. Area sketches are further divided into—position sketches, outpost sketches, and place sketches. All these have already been described.

Kinds of Sketching

Sketching may be done either by working alone or in conjunction with others. Where sketching is done by several working in conjunction, they all of course must use the same primary control; otherwise it will be almost impossible to join their sketches to form a single map of the area.

Individual Sketching. *(1) Individual Road Sketching:* Road sketching is usually executed by making a traverse of the road. This traverse is the control work of the sketch. Distances along the road can be measured by pacing, timing, number of wheel revolutions, etc. By making proper allowances for climatic conditions, grades, etc., a surprising degree of accuracy can be attained.

The sketching board at each instrument station can be oriented either by compass or by back sight. The latter method is more accurate, but takes much more time. Every change of direction and of slope is a critical point. The sketching board may be set up at every change of direction in the road or at every other change. In the latter method only the compass method of orientation can be used. The procedure in both methods will be described.

Back-Sight Method: First, set up the sketching board at A (first instrument station); orient by compass or other method; select an arbitrary point a to represent A on the sketch; stick a pin at a and pivot the alidade ruler so as to sight B; draw an indefinite pencil ray ab′; pace the distance AB and mark it off on the line ab′ by means of the working scale: this point on ab′ is the map position of B.

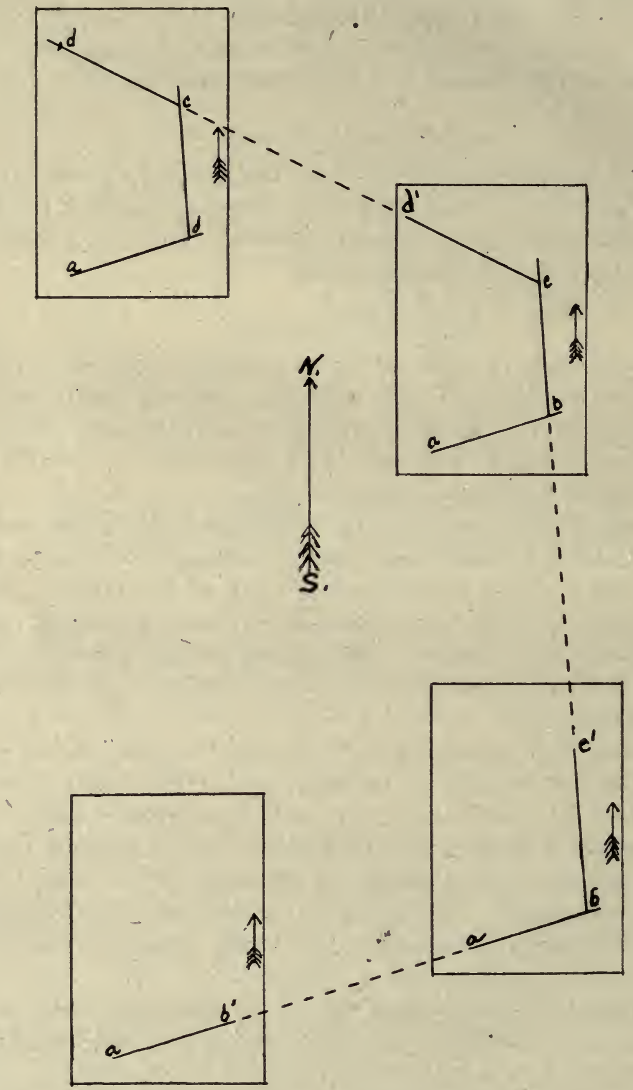


Fig. 47. Back-sight Traverse.

Second: Set up the sketching board at B; stick a pin at b and place alidade ruler along line ab; turn sketching board, without moving alidade ruler, until A is sighted; the sketching board is then oriented.

Third: With sketching board clamped, pivot alidade ruler around pin stuck at b until C is sighted; draw an indefinite pencil ray bc′; draw a parallel line along ab to represent the road. Repeat these operations at each change of direction.

Compass Method: First: Set up at A; orient sketching board by compass; select an arbitrary point a to represent A on the sketch; stick a pin at a, and pivot working ruler on it until B is sighted; draw an indefinite ray ab′ along the edge of the ruler.

Second: Pace the distance to B, and mark it off along the line ab′; then pace the distance from B to C, making a note of it.

Third: Set up at C and orient sketching board by compass; stick a pin at b and pivot the working ruler on it until B is sighted; draw an indefinite line bc′; now mark the distance BC off along bc′: this line bc will represent the section BC of the road.

The compass method can also be used in setting up at every station. Cross roads, road junctions, etc., are also critical points, and the direction of each intersecting road should also be plotted.

The terrain is sketched ¼ mile, or 440 yards, to either side; at each station the vertical angles to lateral critical points, and of points within the distance of the next change of direction along the road are read by means of the clinometer, or slope board; the distance to such critical points are estimated, from which the contours are plotted by means of a slope scale, or the difference in elevation is found by means of a stadia computer or table and the contours so spaced as to show the character of the slope. It is quite evident that the slope scale method is the much more rapid one. The vertical angle to the next change of direction in the road is read, the distance between paced, or timed, which gives all the data necessary to determine the elevation of the next instrument station. The elevations of instrument stations are thus carried forward.

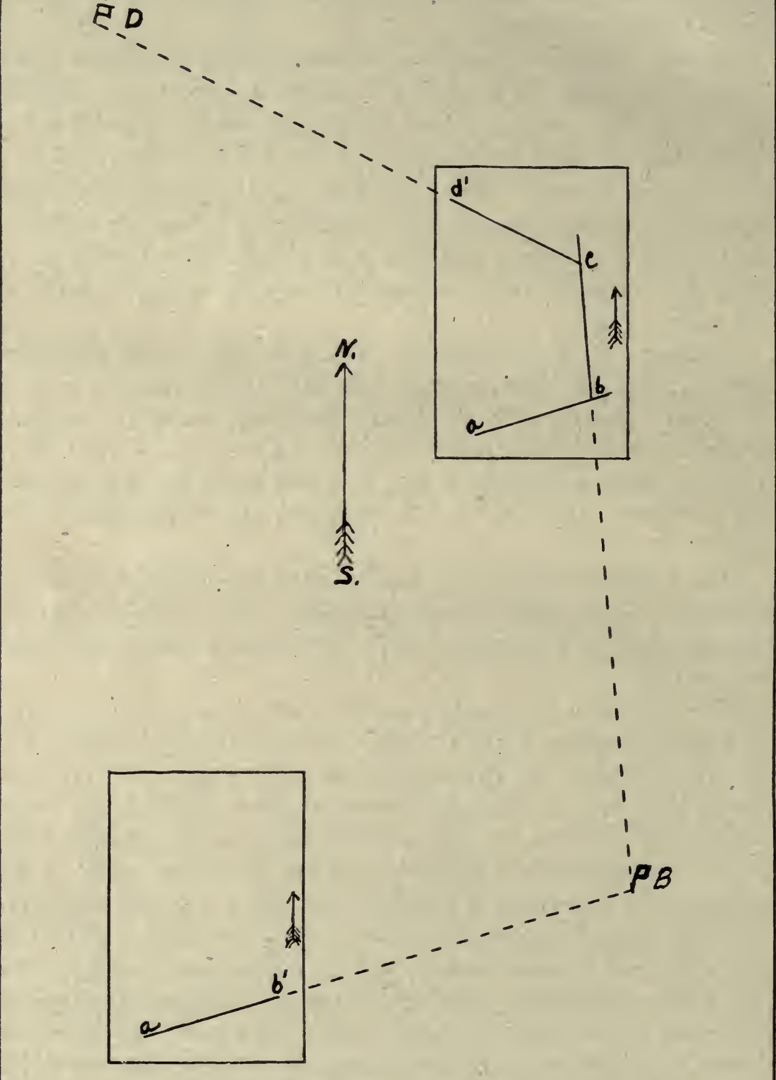


Fig. 48. Compass Traverse

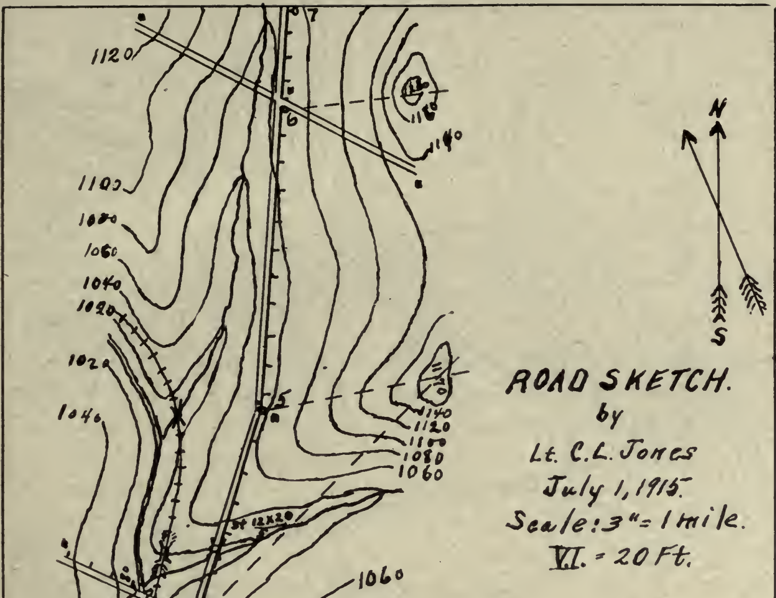


Fig. 49, Road Sketching

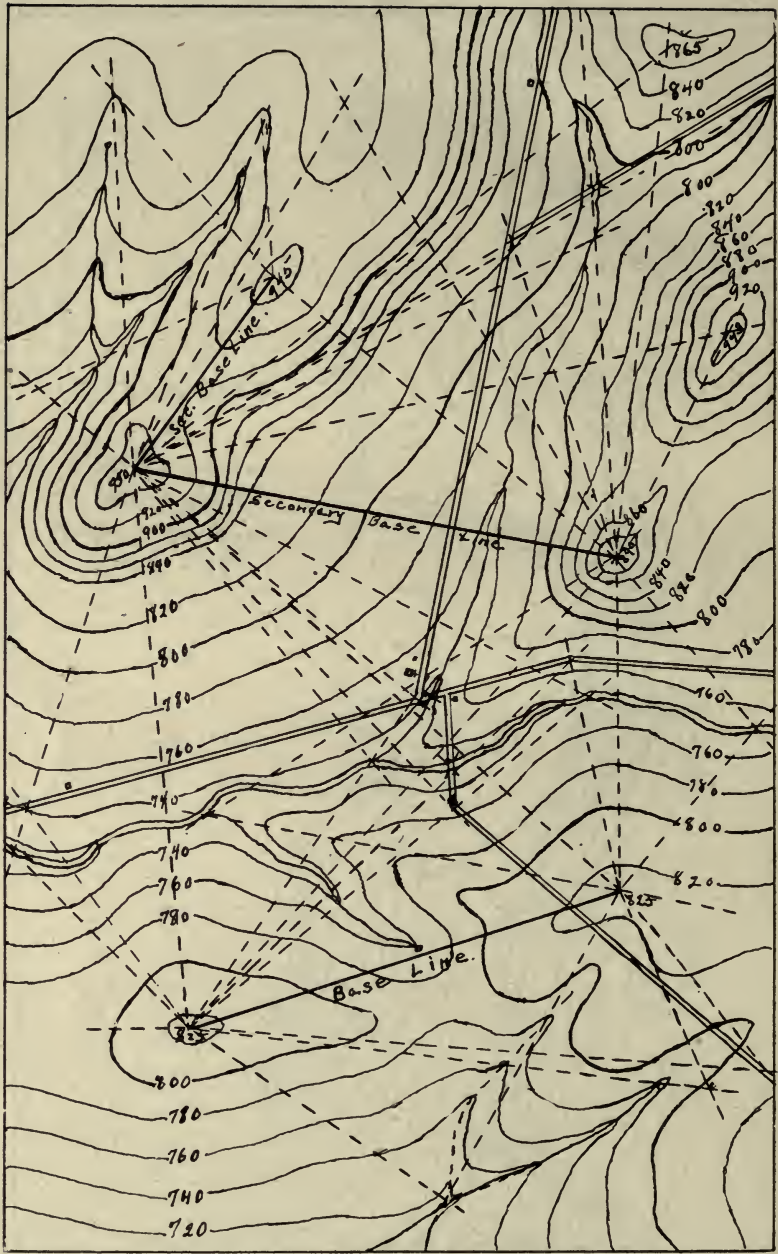


Fig. 50, Position Sketching.

(2) Individual Position Sketching: In any kind of sketching the sketcher must use some kind of a control, or his work will be inconsistent. While this fact is quite evident to the skillful sketcher, the beginner does not think of a base of control; he usually tries to reproduce each feature of the terrain independently and without reference to other features; but the impossibility of this is soon demonstrated to him by a warped sketch and a confused idea as to the real requirements for successful sketching.

When given a position to sketch, the sketcher should select two prominent points, visible and accessible to each other; the distance between them may be determined by pacing, timing, estimation, or any other method of distance determination used in rapid sketching. Even where this distance is estimated, the sketch will be consistent within itself, and all points determined from them will be in proper relation with one another: should the distance be determined more accurately later on, the scale can be changed to show it. (Fig. 50.)

These two points will determine a base line. The sketching board is set up at each of these points in term, orienting the board in each case—at the first station by compass, at the second by back-sight on the first; radiating lines are drawn towards all critical points within the area, the vertical angles determined and recorded, at each of the two stations. The radiating lines drawn from these two stations towards the same critical points will intersect and determine the map position of such critical points. The vertical angle from both stations to the same critical point, and the elevation of that point as determined from the two stations should check within a few feet. The elevation of one end of the base line will usually be assumed and the elevation of the other end determined from it.

Where the area is large, auxiliary base lines may be established by intersection from the primary one, so that the whole area will be covered by prominent critical points determined by triangulation. The location of minor critical points and points between are determined by estimations based on the adjacent intersected points. The whole area should be covered by the sketcher to detect all features that might be omitted or unseen by occupying only the high points.

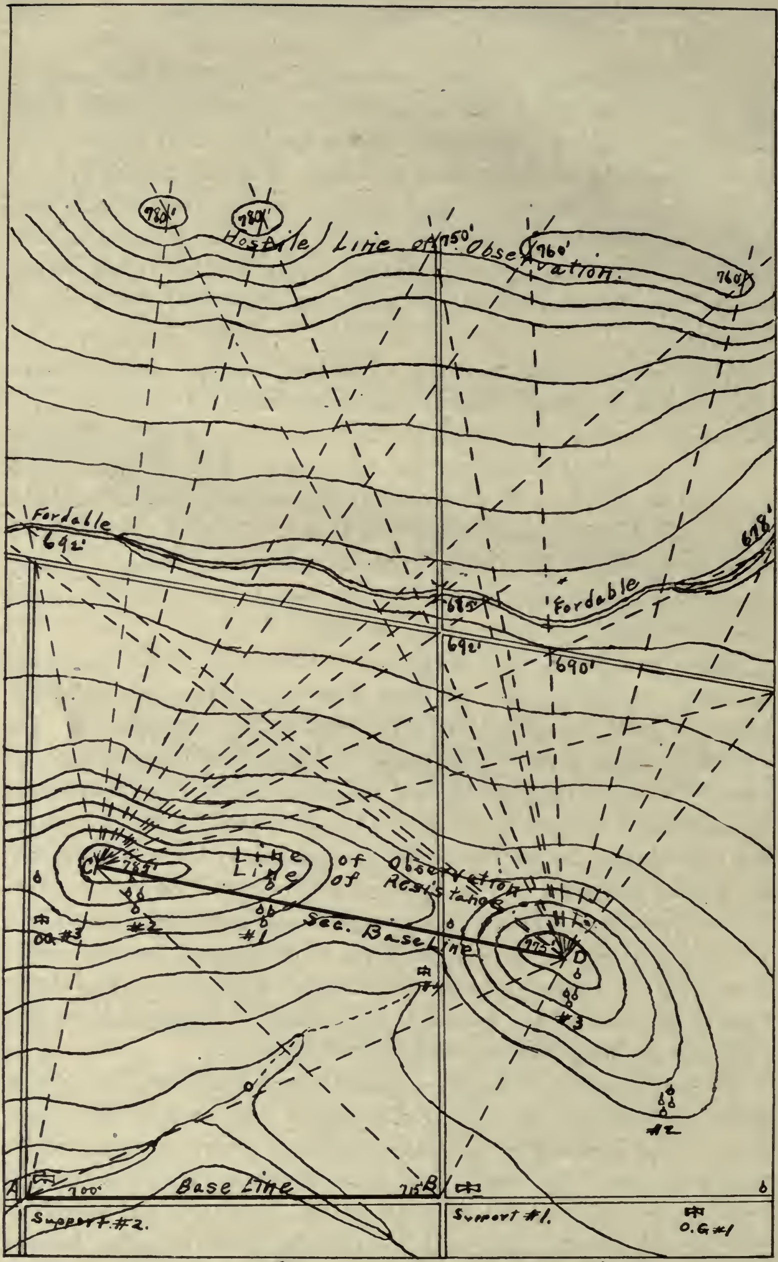


Fig. 51. Outpost Sketching

It should be remembered that rapid position sketches are not extended topographical surveys, and hence the degree of control is not nearly so great.

(3) Individual Outpost Sketching: The control work for an outpost sketch will generally be a Base Line along the line of observation. From the extremities of this Base Line, intersections can generally be taken on a sufficient number of critical points in the foreground to control the sketching. If it is impracticable to measure the distance between two suitable points on the line of observation directly, as where some impassible or difficult ground lies between them, their distance apart may be determined in the same manner as for passing impassible objects in plane surveying, or their distance apart may be determined from an auxiliary base line in rear, say on the line of resistance. The diagram in Fig. 51, in which C and D are two prominent points on the line of observation, and A and B, two points on a line to the rear, illustrates this method.

The sketching of the terrain up to the line of observation and a short distance beyond will usually be comparatively easy, but the sketching of the terrain to the front towards the enemy will depend upon tactical conditions: otherwise the sketching of outpost positions present no special problems.

(4). Place Sketching: Place sketching, or *Eye Sketching,* as it is sometimes called, is, as its name indicates, the sketching of a portion of the visible terrain from a single point of observation. This problem will often be met with in scouting, as where reconnoitering the enemy's outpost position, entrenchments, camp, etc. Where such a sketch can be supplemented with a photograph of the terrain, it should be done. In sketching from a single point of observation, no base of control can be secured. The sketching board, or pad, should be oriented as correctly as possible; an arbitrary point selected on the paper to represent the point of observation; from this point, using and sighting with a working ruler if possible, radiating lines should be drawn towards prominent or critical points in the foreground; the distance to these points are estimated and measured off on the sketch with a working ruler; the vertical angle to these points should also be measured, or estimated, and recorded.

With the location and elevation of these selected points, thus determined, used for control, an experienced sketcher will be able to produce a fairly accurate representation of the ground. Such sketches will usually have to be executed with rapidity, and all elaborate methods are eliminated.

(5) Memory Sketching: Memory sketching is the representation, in the form of a sketch, produced entirely from the memory. They are usually of trails and roads. For control the sketcher should estimate and plot first the most important road or trail, and then estimate and plot all other roads, trails, and other objects with respect to and based upon it.

In such sketches, the conformation of the ground is rarely shown and then only in a very general way. Contour lines will seldom, if ever, be used. The relief method can be most successively employed. The general conformation can be indicated by writing "hills," "planes," etc., at their estimated locations. The character of the terrain should be shown as remembered.

Any person can make a memory sketch of the terrain with which they are familiar. The author has often had uneducated Filipinos to sketch the roads and trails of the terrain for considerable distances on the ground, by means of which he was able to traverse unknown ground with ease. Memory sketches of roads and trails, on paper or sketched on the ground is the common method of showing the way to strangers, both in civilized and semi-civilized countries. Such sketches present no difficulty in execution: they are of course only approximately to scale, and points may be considerably out of proper relation with one another, but this is realized and allowed for by the reader.

Combined Sketching. Where the sketching of an area is executed by several sketchers working in conjunction, the area should be divided into sections and a section assigned to each sketcher or sub-party. A base line or traverse will be used for the control of each section, but in order that the sections may be compiled and a consistent map of the whole produced, the relation of the control, both horizontal and vertical, of the several sections to each other must be known. This may be obtained by using a base line or traverse common to all, or the sections using for their control parts of a single base line running clear across the whole area.

(1) Combined Road Sketching: Where the roads of an area are to be sketched, each road running towards the front should have a sub-party assigned to it. Each sub-party, except the left (or right) one should have at least one chief and one assistant—the left (or right) sub-party will usually need only one sketcher. Over the whole there should be a chief sketcher and such assistants as necessary. Where the parallel roads to the front are far apart, or the cross roads numerous, each sub-party should be increased with the necessary assistants. Combined road sketching will usually be done by mounted sketchers.

If possible the sketching should start from a road traversing the entire front, in which case a base line or traverse can be made of this road, and each sub-party use that portion running through its section as its primary control. Beginning at the left end, the whole party will follow the chief, sketching this traverse road. At each road running to the front this sketcher will give the necessary data (usually a carbon copy of the sketching throughout the section) to the sub-party assigned to that road, in order that he may proceed at once to its sketching. The carbon copy will show the traverse road throughout the section, the initial portion of the road to the front, the contours, and in addition, the elevation in feet of the road's juncture with the road to the front.

Should a lack of time render this procedure impossible, each sub-party will go to its initial point at once and begin sketching. In such cases, a mounted sketcher should ride rapidly from one initial point to another, and give each sub-party the elevation of its initial point. For this purpose the aneroid barometer is used. Each sub-party must plot the line of direction of the cross road at the first set-up, so that its road sketch can be applied to the primary control traverse (cross road) which will be made simultaneously with the sketching to the front.

Each sub-party traverses the road assigned to it. The sketching of the road is usually done by the chief of the sub-party. Whenever a cross road is met, one of the assistants of the sub-party is assigned by its chief to traverse and sketch it

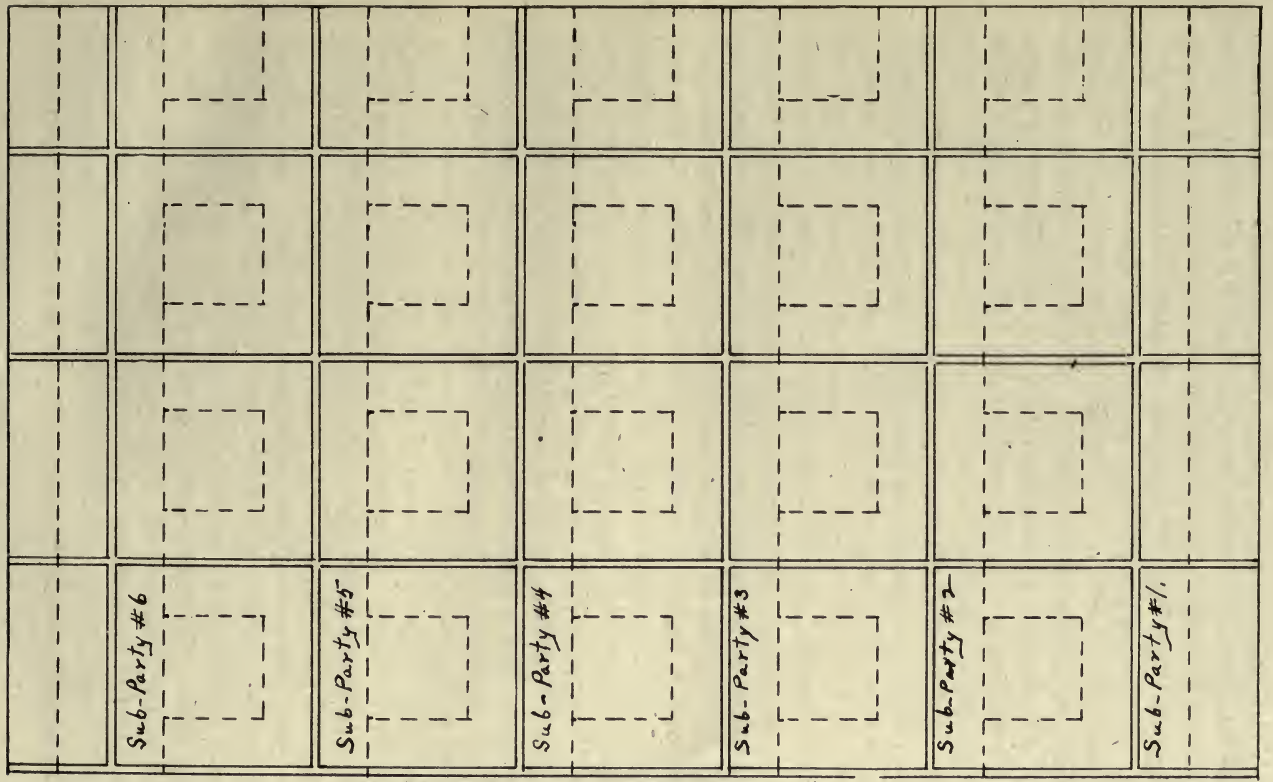


Fig. 52. Combined Road Sketching.

Courtesy of W. & L. E. Gurley

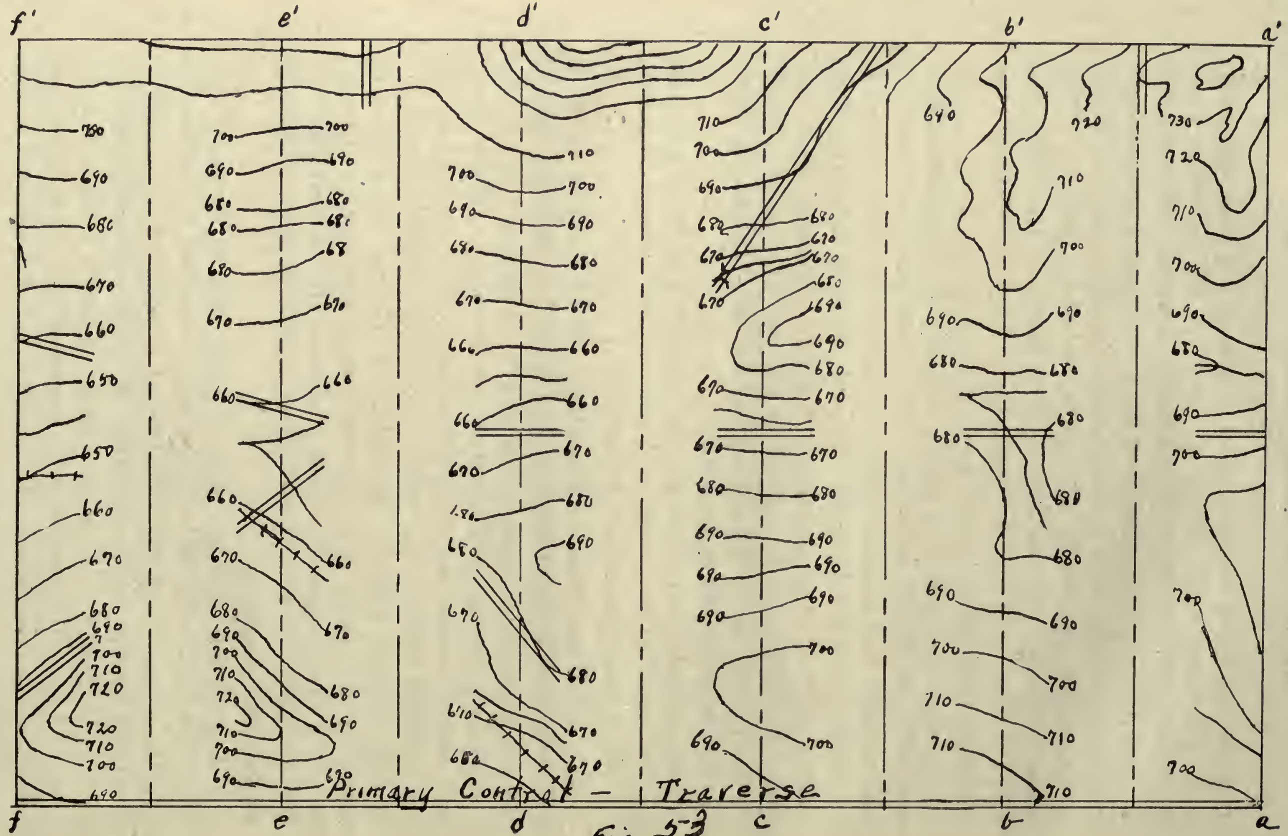
from the road junction to within $1/4$ mile of the road belonging to the sub-party to the left of it: the chief will sketch the cross roads for $1/4$ mile to the right of the main road. At a distance of $1/4$ mile from the main road each cross road to the right should be marked with a conspicuously posted piece of paper or cardboard containing the number of the sub-party. This poster will show the sketcher of the party to the right just where to stop, otherwise he would sketch clear to the main road running to the front.

It is very desirable that each sub-party on the left should be even with or slightly in advance of the sub-party on its right, and to make this probable the sub-parties should be started in succession from left to right. Should the right sub-party have started off first, the procedure would be reversed: each sub-party sketching just $1/4$ mile to its left and to within $1/4$ mile of the road to its right. The party last starting sketches to within $1/4$ mile on both sides of its road.

The conformation of the ground, character of the vegetation, etc., will be filled in to within $1/4$ mile on both sides of all roads: the intervening ground is not sketched.

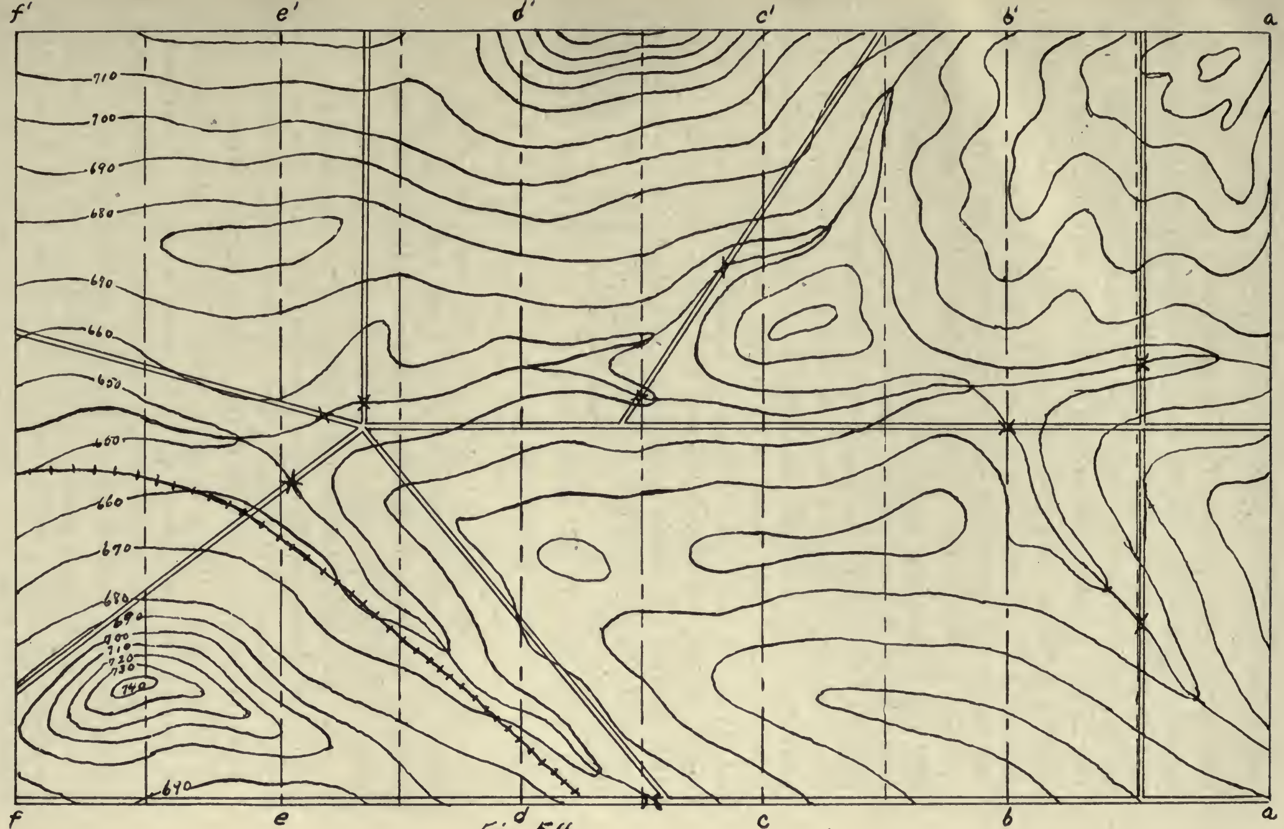
(2) Combined Position Sketching: The area to be sketched will be divided into sections and a sub-party consisting of a chief and one assistant assigned to each; over the whole there will be a chief sketcher and such assistants as necessary. The width of each section should not as a rule exceed $1/2$ mile. It may extend any distance towards the front; for a day's work it should not extend over two miles. For control, a traverse along the near side of the area may be run, or the near side of each section determined by triangulation from a conveniently located base line. The principle of the latter is shown in the diagram in Fig. 55 for outpost sketching.

If there is not sufficient time to make either of the above controls, the widths of the sections are determined by estimation and the elevation of the initial point in each section is determined by occupying these points in rapid succession with an aneroid barometer. As soon as each sub-party receives the elevation of its initial station it begins sketching. The procedure will be about as follows: Initial points (a, b, c, d, and e, Fig.



Primary Control — Traverse

Fig. 52

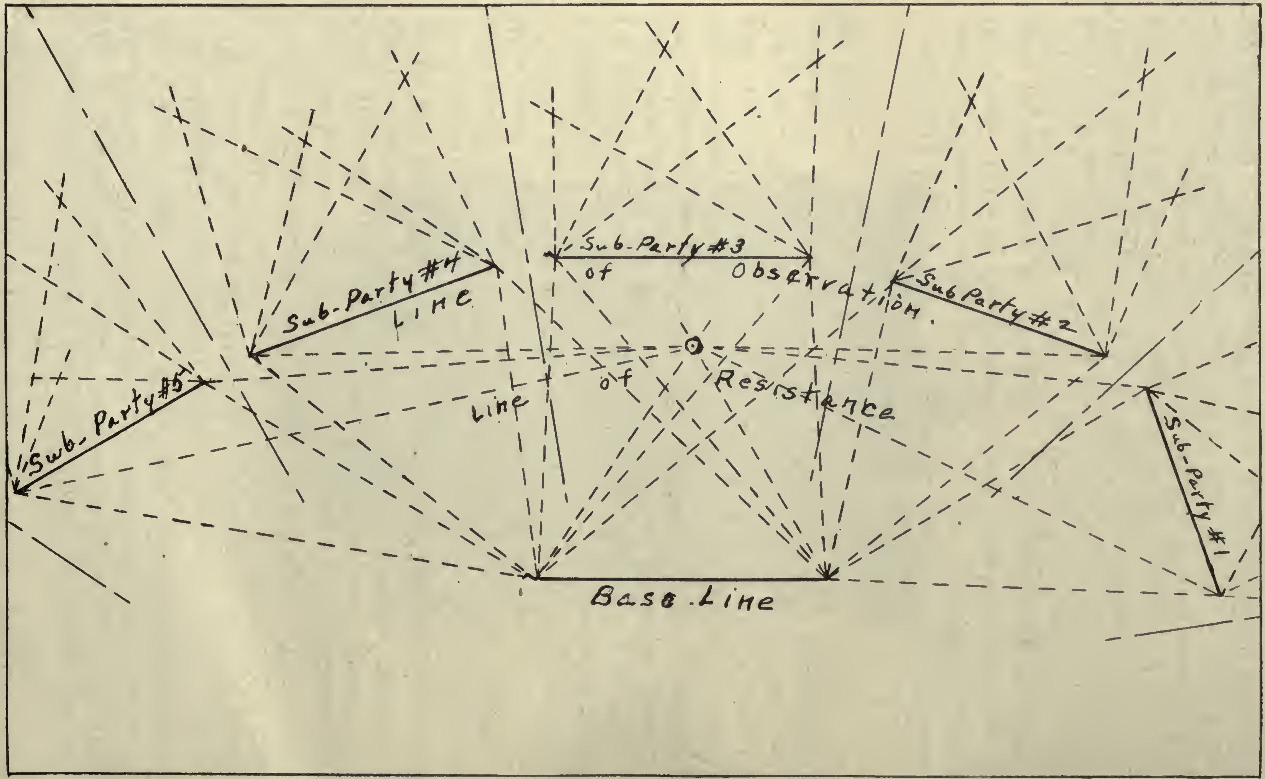


f'
e'
d'
c'
b'
a
710
700
690
680
670
660
650
660
660
670
680
690
700
710
720
730
740
670
f
e
d
c
b
a

Fig. 54.

53), marking the points of divisions between sections are established on the near side or base line, which points should be marked with streamers or stakes. The chief of sub-party No. 1 will set up at a; orient; mark off a line aa′ at 90° to the base line ae; he will then sketch a strip 200 or 300 yds. wide to the limiting point a′, and then along the front a′b′. The chief of sub-party No. 2 and the assistant of sub-party No. 1, the former doing the sketching, will set up at b; orient; strike off a line bb′ at 90° to BE. They will then sketch a strip 200 or 300 yds. wide along the line bb′ to b′. At b′, the chief of sub-party No. 2, will cut his field sheet in two along the line bb′, and give its left half to the assistant of sub-party No. 1, who will sketch along the line b′a′ until he meets his own chief. At this point the chief will take the sketch his assistant has and fasten it on his own field sheet in its proper map position. If the length of the base line ab has been measured, this can be easily done; if not, the sketches along a′b′ will be placed in contact with the lines aa′ and bb′ parallel to each other. The sub-party, having its border sketched, in returning to the base line, sketches the area within the sketched borders. The chief of sub-party No. 2 sketches to the right along b′c′ to the point where he meets his own assistant, and so on. When the sketch is completed, each section is trimmed to its limiting lines and the several sections pasted together to represent the whole area. This method will insure contour lines matching when the sketches are brought together, and make adjustments unnecessary. See Fig. 54.

(3) Combined Outpost Sketching: The organization, control, and procedure in outpost sketching is much the same as that in position sketching, except the ground to the front will not be traversed in sketching, the same being done from the line of observation. The sketchers will be divided into sub-parties of one or more sketchers each, all under a chief. Each party will be assigned a section, designated not only by limiting points along the line of observations, but also by limiting points to the front. The outpost position will generally be in a convex line, so that the sections will be much wider to the front than at the line of observation.



ig. 55. Combined Outpost Sketching - Control.

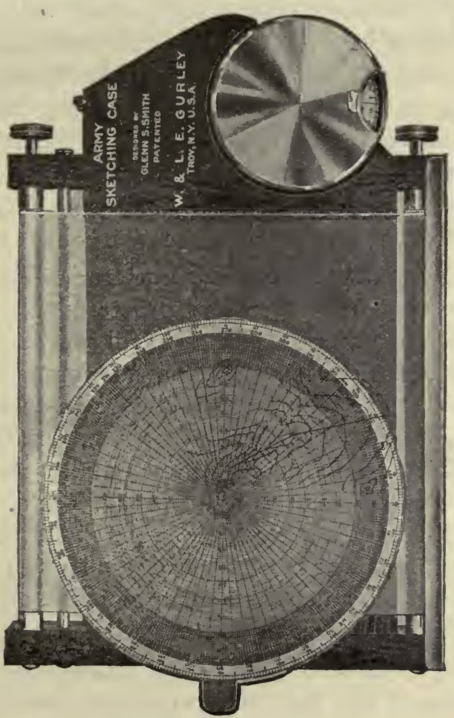
For control, a traverse may be made of the line of observation, or the limiting points of sections along the line of observation determined by triangulation from a primary base line to the rear. The diagram in Fig. 55 will illustrate the general principle of the latter method of control.

Using the limiting points of their sections on the line of observation, the sub-parties will all begin at the same side of their sections, which should be designated by the chief. The sketching boards are set up on these initial points, oriented, and rays taken from this point to all the prominent points in their respective sections. The sketchers then go to their other base points and from there take rays on these same critical points of their sections, the intersection of these rays determining the map position of these critical points. The vertical angles to these points should be taken from both base points.

The horizontal and vertical locations of the critical points of a section are thus determined from which the conformation of the ground can be sketched. If the sub-parties begin at their right base point, each sketcher should begin to sketch from the left, and when he has completed a strip 200 or 300 yards wide, he should make a tracing or carbon copy of it and send it to the sub-party on his left. This tracing or copy should have the elevation of contours marked on it. This will enable each sub-party to the left to connect his work on that of the sub-party to the right.

Rapid Sketching

General Principles. There is no art to which the statement: "Practice makes perfect," is more applicable than to sketching. Only by much practice and experience can any degree of perfection be attained. Some are naturally better adapted to sketching—learn it more quickly—and do it more accurately and neatly. This does not, however, prevent anyone from learning the art. The average non-commissioned officer and scout will learn sketching more in the manner of a trade: without thoroughly understanding the theory and principles involved; sketching operations can be executed by a mere knowledge of how to do them, and a fairly accurately map produced. Before any high standard of sketching can be attained, the sketcher must acquire a keen sense of ground distance, direction, and degree of slopes, and also a correct appreciation of map distances. The beginner should therefore make haste by working slowly at first, until he has acquired an "eye" for map elements. Even secondary critical points should at first be determined by measuring them: estimates in the beginning will be



*ARMY SKETCHING CASE

nothing more than guesses, and all "guesses" should be eliminated in sketching. With practice the number of secondary critical points whose determination may be made by estimation will gradually increase until it will be necessary to measure only the controlling critical points.

KNOWLEDGE OF MAP DISTANCES. The sketcher should acquire an accurate conception of small lineal units. He should be

*Courtesy of W. & L. E. Gurley.

able to estimate an inch within 1/20 of an inch—to divide an inch into 2, 3, 4, 5, 8, and 10 equal parts by estimation. Given a map of a given scale, he should be able after a short inspection of it, to estimate the distances of 100 yards, 500 yards, 1000 yards, and other multiples of 100 yards. Given a map of given scale and contour interval, he should after short inspection, tell the degree of all slopes by observing the spacing of the contours. To him a topographical map should stand out as a real model would. These are prerequisites to rapid sketching.

Knowledge of Ground Distance. The sketcher must have an accurate conception of 100 yards and multiples of it to 1000 yards—of 1200 yards, 1500 yards and 2000 yards. The effect of light, slopes, and intervening objects in making objects appear to be nearer, or farther away must be known.

Knowledge of Direction. The determination of direction is perhaps the easiest map element to determine, yet from that mere fact it is sometimes the most fruitful source of error. The determination of the cardinal points of the compass has already been considered. The sketcher should have an accurate conception of 90°, and be able to divide a right angle (90°) into two equal parts of 45° each, also, into three equal parts of 30° each, and also into nine equal parts of 10° each. The directions from one point to other points on the terrain should be plotted by sighting along a working ruler to such points, keeping the ruler in contact with a pin stuck at the map position of station from which the directions are being taken.

Knowledge of Slopes. A sketcher should be able to estimate the degree of any slope with accuracy, and he must know just how far apart to space the contours to represent the slope without using a slope scale or counting the number of contour intervals. This requires much practice in measuring slopes and in the use of slope scales in plotting them. He must also acquire the ability of estimating elevations directly and know the effect of intervening slopes upon the appearance of elevations. The beginner will usually guess the degree of a slope, either from the top or bottom, at about twice or more its actual amount.

Accuracy and Neatness. The learner of any trade or profession must have good tools to begin with, and it is especially necessary for sketchers to have good sketching instruments in the beginning. They cause him to do his work more carefully and accurately, and enable him to acquire a truer appreciation of map and ground elements. The commander or instructor who furnishes his men with sawed-off fence boards, soft-lead pencils, etc., for sketching, in order to simulate war conditions, will not produce sketchers whose work can be depended upon; but after a man has once acquired the art of sketching by learning with good instruments, he will be able to produce a good map or sketch whatever the materials at hand.

CHAPTER IV

PHOTOGRAPHY*

The Camera. Cameras may be divided into: first, those using plates and those using films; and second, those in which the focus is fixed and those in which the focus is not fixed. Both fixed-focus and focusing cameras can be used either for plates or for films, or for both according to their construction.

The Box. In fixed-focus cameras, the box is light tight and covered with leather; at the front of the camera there are the lense and shutter; at the back, some arrangement for loading the camera either with plates or films; on top there is a view

†Brownie Camera—Fixed Focus

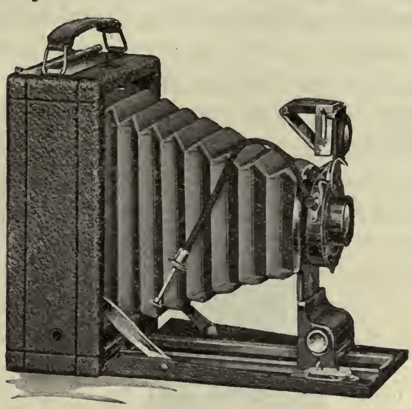
finder. The box of the fixed-focus camera has no ground glass and it is unnecessary to estimate the distance to the object, the camera being in focus for all distances. Such cameras are necessarily much more bulky than the focusing camera which telescopes to a small size when closed.

In the focusing cameras, the front side drops down to form the base for the focusing of the camera. On this side, or base, is a track upon which the lense frame may be run back and forth to any position desired. The lense frame is attached to the box of the camera by means of a light-tight telescopic bellows. At the back there is some arrangement by means of which the camera may be loaded either with plates or films, or both. Some focusing cameras have a ground glass at the back upon which

*For a complete treatise on amateur photography, the reader is referred to *How to Make Good Pictures*, published by the Eastman Kodak Co., Rochester, N. Y.

†Courtesy of Eastman Kodak Co.

the image of an object can be focused; others do not, and with them it is necessary to estimate the distance to the object. The



*Premo Camera—Focusing

latter will always have a view finder attached to the lense frame. For distances of 100 feet or more, the focus of the camera is

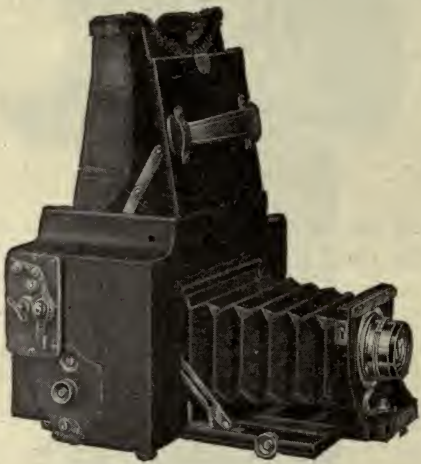
*3A. Autographic Kodak

practically the same, so that for such distances the lense may be set at the 100 foot mark on the scale. For less than 100 feet,

*Courtesy of Eastman Kodak Co.

the distance must be accurately estimated, and the nearer the object to the camera, the more accurate the estimate must be.

The scale on the base board of all cameras is accurately adjusted by the makers for the latitude of their factory, but the focus of lenses for considerable differences in latitude will be found to be quite different. Thus, for cameras made for use in Northern United States, the focus, when used in the Philippine Islands will be found to be out of focus by from 20 to 30 feet, as indicated by the scale. For such differences in latitude,



*3A. Graflex

the camera should be tested for this variance and the scale readjusted. For this purpose, in a camera without a ground glass, a detached ground glass may be held on the back of the camera in the position which the plate or film occupies during exposure, and the image of an object focused upon it.

The Lense. With the modification that the camera box, must, of course, be light tight, of good construction, and the shutter a good one, the statement that, "The lense is the camera," is true. Standard lenses, however, are made of different capacities, and any such lense will do just as good work as any other such lense within the limits of its capacity.

*Courtesy of Eastman Kodak Co.

Optics of Lenses

Focal Length. The *focal length* of a lense is the distance between the optical center of a lense and the vertical plane of the image which it forms of a distant object. This vertical plane of the image will be the surface of the film or plate in, or the ground glass of, the camera when it is focused on a distant object. In cases of simple lenses, this distance can be measured directly from the mechanical center of the lense: but in case of most hand cameras in which double combination lenses are used, of which the optical center is not the mechanical center, the equivalent focus must be determined, by which is meant, the distance also between the optical center of the double combination and the ground glass when the camera is focused on a distant object.

To measure the focal length of a simple lense: The diagram in Fig. 56 explains itself—C is a candle; L, the lense; and S,

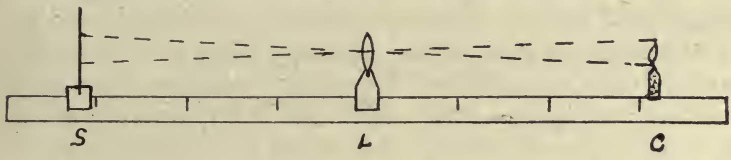


Fig. 56.

a white cardboard, or screen. L is placed in the center of a yard stick, while C and S are so adjusted with respect to each other that the image of the candle flame on the screen is exactly the same size as the flame itself. In such a position, the candle and screen should be exactly the same distance from the lense, and one-half of either distance is the focal length of the lense. If it is desired to check this result, the following method is used: The candle and lense are placed at a convenient distance apart on the yard stick, and the screen is brought to such a position that the image is most distinct. Then the focal length of the lense is found from the following formula: $F = CL \times LS \div (CL + LS)$. This operation should be carried out for several positions of the lense, and the mean value of the F's obtained, taken as the most probable value of F.

To determine the equivalent focus of a double combination lense: The camera is focused on a distant object and the position of the lense on the base board (position of scale pointer) is marked on the base. A ruler with well-defined division marks is then tacked on the wall at the height of the camera when placed on a tripod or table, and the camera is brought to such a distance from the ruler on the wall, that the image of the ruler on the ground glass, when the camera is focused, is exactly the same size as the ruler itself. To determine this, a pair of dividers may be set for exactly one inch on the ruler, and the dividers so set, applied to the image on the ground glass. When the camera is so adjusted that the image in focus is exactly the same size as the ruler, as indicated by the dividers, the position of the pointer is again marked on the base. The distance between these two marks is the equivalent focus of the double combination lense being tested.

Speed of Lenses. There is a common but fallacious idea, that the speed of a lense depends upon the glass of the lense. It is true that glass of different densities have different indices of refraction, and light travels through them with different rates of speed. But those differences are so small, the lense being so thin, that variations in speed due to the material of the lense must be entirely omitted. It must be admitted that speed as used in the statement, "speed of lenses," is not correctly used according to the definition of that word. By *speed of lenses* is meant the "amount" of light which enters a lense within a given time: this is independent of the rate at which light travels, since that rate is constant; it is dependent only upon the size of the lense—the size of the opening through which the light passes. Since the areas of two circles are proportional to the square of their diameters, a lense which has a diameter twice as great as another lense will have a speed (capacity) four times greater than the other lense.

The value of lenses of large diameter, or light capacity, or speed as it is commonly called, is quite evident in photographing moving objects. In such cases an image is desired only at one position during the motion, which requires an exposure of very short duration; as, 1/100, 1/500, or 1/1000 of a second, or an instantaneous exposure as all exposures of over 1/25 of a second are called. If such an exposure is to be transmitted to the sensitive plate, sufficient light must have entered through the lense during that time to effect the proper chemical change in the sensitive solution of the dry plate emulsion. Here a large lense would permit sufficient light to enter while a smaller one would not.

The speed of a lense is always listed or expressed in the quotient of its focal length divided by the diameter of its largest stop (largest diameter at which it may be used). Thus, if the focal length of a lense were 4.75″ and the diameter of its largest stop, .75″, its speed is f.6.3. If the stop of this same lense is reduced so that the quotient of its focal length divided by the size of stop used, is f.8, then the speed of this lense at that stop is no greater than the speed of a smaller lense whose largest opening gives f.8. The speed of lenses of hand cameras are given in the following quotients—f.4.5; f.6.3; f.8; f.16; f.32; f.64; f.128. f.64 is just twice as fast as f.128 and so on.

Depth of Focus. By the *depth of focus* is meant the range within the maximum and minimum limits with respect to distance in which all objects in the field will be in focus on the ground glass at the same time. This depth increases with the distance from the lense; it varies inversely with the size of the stop; and it varies inversely with the focal length of the lense. A fast lense closed down to f.128 will have the greatest depth of focus. An exposure at this stop will take a proportionally longer time to let in sufficient light to produce the proper chemical effect on the sensitive plate.

A great depth of focus is desired in photographing the terrain. f.16 or f.32, will usually be found sufficient in such work. Fixed support must of course be used in time exposures.

Definition. The *definition* of a lense is the sharpness, and clearness of the image which it produces of an object. This depends entirely upon the quality, purity, and perfection in curvature of the lense. A lense will therefore give good definition only within the limits in which it is ground in perfect curvature. Should there be imperfection in curvature, in the lense, there will be different images of the same object which will produce a haze instead of a well-defined image. The diagram in Fig. 57 will illustrate this. A perfect lense produces only a single image of the same object.

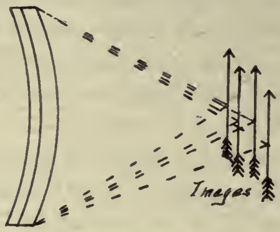


Fig. 57. Lack of Definition

ASTIGMATISM. By *astigmatism* is meant a defect in a lense in which the arcs of curvature through all meridians are not of the same degree. Such lenses do not render horizontal and vertical lines equally sharp. Non-astigmat lenses are free from astigmatism.

STYLE OF LENSES

SINGLE LENSES. Single lenses are made in two forms, *meniscus* and *plano-convex*. The meniscus form, giving the greater

*FIG. 58. PLANO-CONVEX LENSE

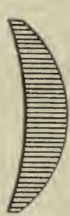


*FIG. 59. MENISCUS LENSE

definition, is always employed in the best cameras. The single lenses, are made of two different kinds of glass—crown and flint, cemented together, called *combinations,* in order to make them *achromatic.*

NONACHROMATIC LENSES. When light passes through a glass prism, the light will be dispersed into its primary colors upon leaving the prism. Light passing through a simple lense,

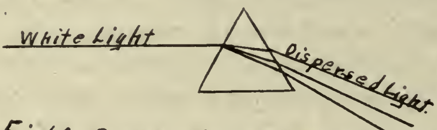
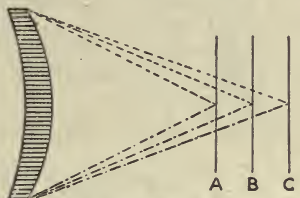


Fig. 60. Single Prism (Non-Achromatic)

*Courtesy of Eastman Kodak Co.

made of one kind of glass, will do the same. Such lenses are called *nonachromatic*, and are not used in standard cameras.

ACHROMATIC SINGLE LENSES. If however another prism of the same kind, or another prism with a different index of refraction of proper shape be used in conjunction with the first prism, the primary colors will be reassembled into one white ray upon leaving the second prism. This principle is followed in the con-



NON-ACHROMATIC.
*FIG. 61

struction of *achromatic single lenses*, so called, out of crown and flint glass, cemented together.

The effect of nonachromatic lenses is to produce a number of different sized images of the same object, one for each primary light color. Only one of these images can be in focus at the same time and the combined image will have neither definition nor clearness, being a blur of several images. This is illustrated

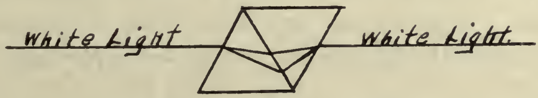


Fig. 62. Double Prism (Achromatic).

in the diagram in Fig. 61, where C is the visual focus, while A and B are images of different colored light rays.

RAPID RECTILINEAR LENSES. Rapid rectilinear lenses are double combination lenses of two single achromatic meniscus lenses. Each combination is composed of two kinds of glass, crown and flint, cemented together with a transparent cement, called balsam. The combinations are denoted as front and rear combinations, respectively, and are mounted in the ends of a brass tube, which in the common hand camera forms part of the

*Courtesy of Eastman Kodak Co.

shutter; the leaves of the shutter being between the two combinations. The focal length of either the front or rear combination is much greater than that of both combinations together and from this fact, the rear combination may be used

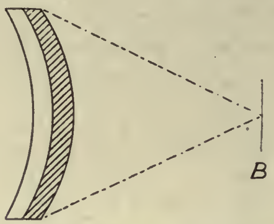


*Fig. 63. Achromatic Lense

alone with success in telo-photographic work, as where a picture of a single distant object is desired.

This double combination lense is called *rapid rectilinear* from the fact that it renders the straight lines of a picture without distortion. It is also called *symmetrical* or *convertible*, according as to whether the focal lengths of the combinations are equal or not. With the convertible rapid rectilenear lense, the photographer has in fact three distinct lenses of different focal lengths—the double combination, the rear combination alone, and the front combination alone.

The rapid rectilinear lense is the kind with which most hand cameras are equipped, and it will be found sufficient for most work. It is next to the anastigmat lense in quality.

*Fig. 64. Double Combination Lense

Anastigmat Lenses. Anastigmat lenses are the best lenses made. They have the highest speed, the best definition, and are entirely free from astigmatism. The anastigmat lenses are

*Courtesy of Eastman Kodak Co.

much more highly corrected, the surface being ground in perfect curvature; they are calculated up on formulæ that permit them to be worked at much greater openings, and they thus permit more light to enter within a given time and are therefore much more rapid. The definition even at the larger stops is as great as that for inferior lenses at smaller stops. The

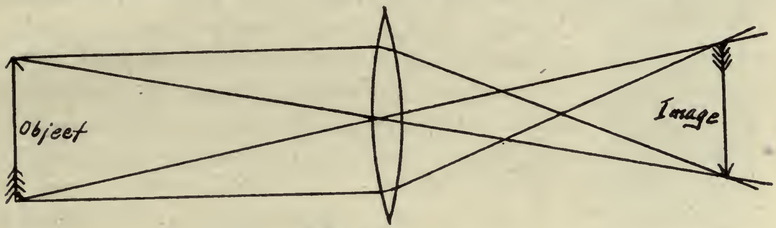


Fig. 64.

superiority of this lense in taking moving objects is at once apparent. Used with a focal plane shutter, exposure of 1/1000 of a second, or even faster, may be made.

The Shutter

General Principles. The shutter is the mechanism by which the duration of the admittance of light into the camera is controlled. The requisites of a good shutter are—1st, the mechanism should work with precision, remaining open during the period for which it is set; 2nd, the diaphram leaves should be light tight when the shutter is closed; and 3rd, all parts of the dry plate should be exposed to the light an equal time. The focal plane shutter is the only one that absolutely fulfills the last conditions. The present automatic shutter, however, reduces the inequalities of time to such an extent as to eliminate all noticeable effects in the picture.

In addition to the shutter diaphram, there is an adjustable stop, by means of which the size of the light aperture is controlled. At the bottom of the front of the shutter is a lever containing a pointer—by moving this pointer to the right or left, the size of the stop is changed. The stop scale contains the numbers, f.6.3. . . . f.128, and by setting the pointer opposite the proper number, the exact size of stop desired is secured.

The *speed* of shutters ranges from "time" exposure down to 1/100, and even faster than 1/1000 of a second, according to the kind of shutter. When the time pointer is set on "T" (Time), one pressure of the air bulb opens the shutter, while a second pressure is required to close it: the shutter, therefore, can be kept opened any length of time on "T." If the indicator is set on "B" (Bulb), the shutter is opened on the pressure of the bulb and closes when that pressure is released. The other speeds on the common automatic shutter are generally, 1 second, 1/5, 1/25, 1/50 and 1/100 of a second. These speeds work automatically, the shutter opening at the pressure on the bulb and closing at the indicated time without the control of the release. Focal plane shutters work as fast as 1/1500 of a second. Exposures faster than 1/25 of a second are called instantaneous exposures.

Styles of Shutters

There are a large number of different kinds of shutters, but all may be grouped into three general classes—simple, automatic and focal plane shutters. The *simple shutter* is used mostly in box, or fixed focus cameras. It consists of disk wheel which has a series of different sized holes, or stops, with their centers on the same inner circumference of that disk. The center of this disk is so attached to the camera front that when the disc is revolved, the center of each hole, or stop, coincides with the optical axis of the camera lense. With this disk there is a simple control mechanism by means of which time and instantaneous exposures can be made.

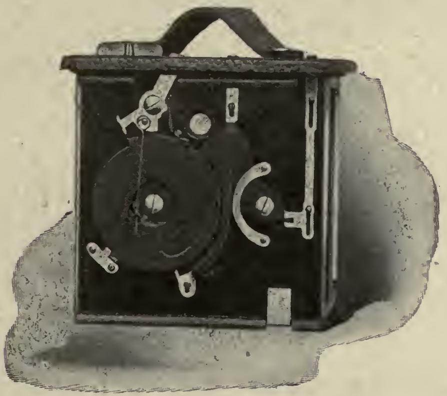
*Compound Automatic Shutter

The *automatic shutter* with which most focusing cameras are equipped, consists of a series of blades which close to and open

*Courtesy of Eastman Kodak Co.

from the center. This center coincides with the optical axis of the lense, and when the blades are closed they are light tight. The blades are controlled by a delicate mechanism by means of which the length of exposure, or opening at which set, is made very accurate. In double combination lenses, the shutter blades are between the combinations. The adjustable stop is close to the shutter blades.

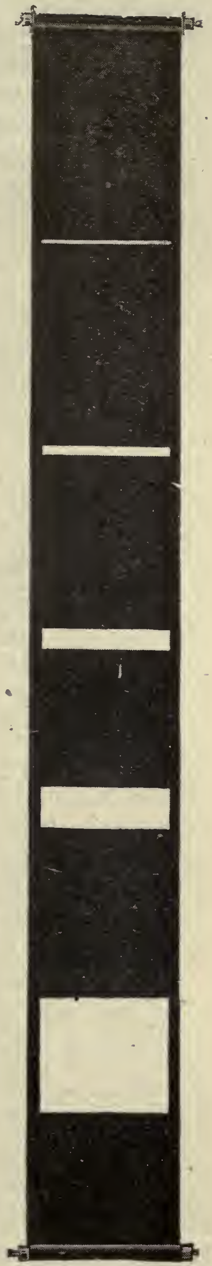
The *focal-plane shutter* consists of a curtain containing slits of different widths. The ends



*Focal Plane Shutter

of this curtain are attached to automatic revolving cylinders. The different sized slits in combination with different speeds of the cylinders, give a large number of different length exposures—from time to as low as 1/1500 of a second. The curtain works in front of and in close proximity to the dry plate or film.

Control of Shutters. The simple shutter is usually controlled by a button or lever which releases a spring that works the disk. The automatic shutter is controlled by air or by a bead, a pressure on which pushes in a plunger



*Focal Plane Curtain

*Courtesy of Eastman Kodak Co.

that releases the mechanism working the shutter blades. Except when working on "T" and "B," the blades close automatically at the period for which set.

The mechanism of an automatic shutter is very delicate and *it should never be oiled.* The metal of which it is made will not rust and oil will destroy the accuracy of its automatic action.

The Dry Plate (Film)

The *dry plate* consists of a very perfect glass upon one side of which is a thin emulsion. This emulsion consists of a silver salt and certain other chemical compounds held in a thin gelatin film. The silver salt in this emulsion is sensitive to light; i. e., this silver salt when struck with light is changed to another form of a different chemical composition. This affected form of the silver salt when treated with a *Developer* is reduced to metallic silver, but this developer has no effect on the original silver salt and of course those portions of the dry plate which have not been exposed to light. The amount, or the depth, of the silver salt that is changed into this other form at any point on the dry plate is directly proportional to the amount, or intensity, of the light striking the dry plate at that point. More light travels from bright objects than from dark objects; therefore, the position of bright images on the dry plate will have more of the silver salt changed than the position of dark images. The plate, therefore, after it shall have had the unchanged silver salt dissolved out of it by the *Hypo-solution,* will appear of varying degrees of blackness, according to the intensity of the metallic silver at the different points of the plate. Should any portion of the dry plate be unexposed to light, the silver salt in that portion will be entirely dissolved and washed out, and that proportion will be represented only by a transparent gelatin film. The bright images on the dry plate will appear dark in the *negative,* while dark images will appear light—just the contrast of the scene photographed. To get a corrected view we must take a photograph of the negative, which is usually done by placing a paper holding on one surface a sensitive silver salt, in contact with negative, causing the light to pass through the negative before striking the silver salt on the paper and thus regulating the intensity of the light and the amount of silver salt on the paper changed to the other form. This process is called "Printing" and is exactly similar to "Blue Printing." The image or picture developed on the paper is called a positive.

Colors are not reproduced in a negative or print; in fact some colors have no more effect on the dry plate than black objects. Thus, a blue flower appears white while a yellow one appears black. Certain dyes dissolved into the sensitive emulsion render certain colors sensitive to the silver salt, so that when these colors are photographed, they appear as "lights" of varying degrees. Dry plates when so treated are called orthochromatic plates, and such plates are rapidly replacing the common dry plate on the market.

Plates are made with emulsions of varying degrees of sensitiveness; some plates being much faster—requiring less exposure to light to have the same effect produced on them. Manufactured dry plates are far superior in quality and far cheaper in price than home made plates; they are made under secret processes: so that their preparation need not be considered further.

It should be observed that a negative or photograph is not a reproduction of colors, but of lights and shadows which to the eye presents a likeness of the thing photographed. It is similar to a pencil sketch executed in one color.

Plate Holders. A plate holder is a light-tight box in which plates may be carried in day light while not in the camera or original package. It contains an opaque partition so that one plate holder may hold two dry plates at the same time. On either side of the holder is an opaque slide, which is removed while loading, unloading, or making an exposure. One side of the slide is marked "Exposed," and when the dry plate has been exposed the slide is inserted with this side out.

To load the plate holder, the original box containing the plates is opened in the dark room which contains a greatly reduced red light. The slides are removed from the holder and a plate inserted in each side. The emulsion side of the plate (does not reflect light), faces out and its surface should be brushed with a soft camel's hair brush to remove any dust that might be there. The slides are then inserted with the plain side out, denoting the plates to be "unexposed."

ROLL FILMS. A roll film is a strip of transparent film on one side of which there is a sensitive emulsion just the same as in case of a dry plate. This film is long enough to contain from six to twelve exposures and is wound on a spool. To each end of the film is attached a strip of opaque paper which makes the roll light tight when entirely wound from either end. These rolls when entirely wound can be loaded into and removed from the camera in broad daylight. Roll films are the handiest for field work, not only for the ease with which they can be inserted into and removed from the camera in daylight, but also from the ease with which they can be carried on the person.

FILM PACKS. Film packs are composed of 12 films of single exposure each, held in a light tight pasteboard box. This box is used just the same as a plate holder. The films can be exposed in succession and the box in daylight. It is superior

*FILM PACK ADAPTER

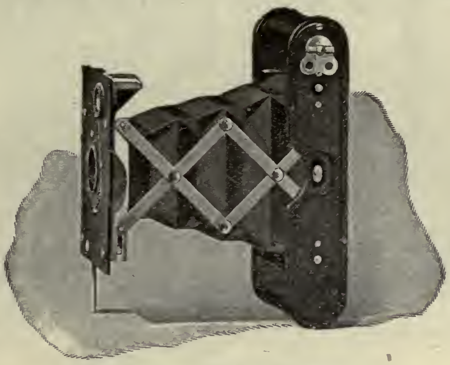
to a roll film in that the portion of exposed film may be removed at any time in a dark room and the box be used again for the unexposed films, while a roll film must have all of its exposures made before being removed from the camera if it is desired to use each exposure.

STYLES OF CAMERAS

The different styles of cameras that might be used in military operations are—the box camera, the folding camera, the view

*Courtesy of Eastman Kodak Co.

camera, the graflex camera, and the enlarging camera. No description of these cameras is necessary for all are familiar with them in a general way.



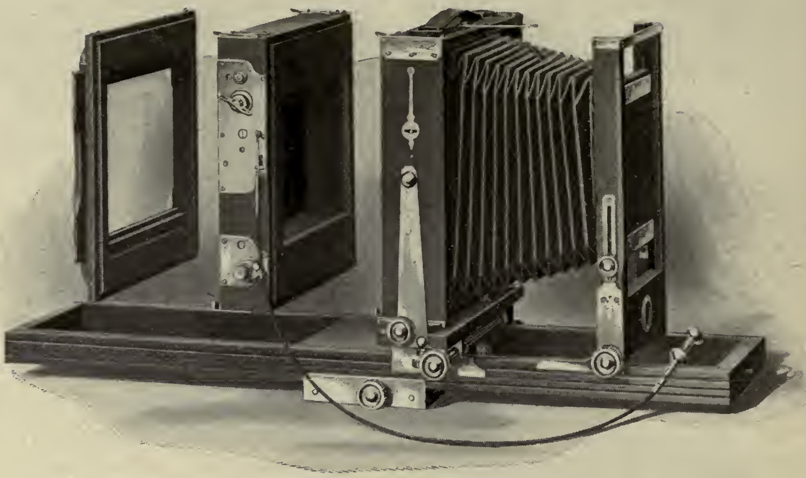
*Vest Pocket Kodak

For reconnaissance work the "Vest Pocket Kodak" and the "No. O Graphic Camera," manufactured by the Eastman Kodak Co., are the most compact and easily carried. They are susceptible of excellent work, but when used an enlarging camera must also be employed to enlarge the print to a proper size.

*No. O Graphic Camera

If it is practicable to carry a larger camera, the 3A Kodak equipped with the Zeiss Kodak Lense; or a 3A Graflex with a B. & L. Zeiss Tessar, Ser. Ic. lense (manufactured by the East-

*Courtesy of Eastman Kodak Co.



*View Camera

man Kodak Co.) should be used. Where position views are desired near the vicinity of troops, a larger camera can be used, such as the view or panoramic camera.

*Principle of Enlargement

Using the Camera

Position For Exposure. No matter what the vertical angle of the optical axis, or position of the lense, the camera should be so held or placed that the ground glass is exactly parallel with the plane of the perspective. If the camera is held so that the ground glass is not parallel with the plane of the perspective, the object photographed will be distorted in the picture according to the degree which the background is out of the parallel.

*Courtesy of Eastman Kodak Co.

*Distorted Picture

Support For Exposure. For instantaneous exposures the camera may be held in the hand, but for timed exposures the camera must be supported on a tripod, table, or other solid support.

Adjustments For Exposures. Bearing in mind that the plane of the background must be vertical as explained above, the optical axis of the camera must be brought into the azimuth of the object to be photographed. When it is brought into the proper horizontal position on the ground glass, as indicated by the view finder, or as shown on the ground glass itself, the camera box should be held in place and other adjustments used to bring the image into the proper vertical position on the ground glass. If the object to be photographed is high, such as a near building, and the photographer cannot get far enough away on account of surrounding buildings, etc., the camera base should be tilted upward so that the object falls entirely on the ground glass, the camera back being kept vertical. If it is desired to make only a small change in the vertical position of the image on the ground glass, it can be accomplished by raising or lowering the lense on its support, the required amount.

*Courtesy of Eastman Kodak Co.

FOCUSING—*Judging the Distance.* When an object is less than 100 feet away, and the camera used has no ground glass on which the image can be focused, the distances must be estimated and the closer the object to the camera the more accurate the estimate must be. The photographer should, therefore, have a good idea of distances—ten, fifteen, twenty-five, fifty, seventy-five, and one hundred feet, should be definite conceptions in his mind. Knowing these distances, he can bisect them to obtain other ranges. Thus, an object might be half way between 15 and 25 feet, or just twice ten feet away, from which the photographer could make an intelligent estimate of 20 feet.

TIMING THE EXPOSURE. The time of the exposure will depend upon the intensity of the light and the size of stop used. In order to make accurate estimates of the time required, the photographer must learn from experience. Between three hours after sunrise and three hours before sunset, the following are given for the northern United States, when using the f.128 stop:

With Sunshine ....1/100 of a second
With Light Clouds ....1/2 to 1 second
With Heavy Clouds ....2 to 5 seconds

With a good lense, a f.16, or f.32 stop is recommended. If in a given condition of light, one second is the proper time for the f.16 stop, then two seconds is the proper time if the shutter is closed to f.32.

DEVELOPING

THE DARK ROOM. The dark room should be a light-tight room of sufficient size to carry on the work of developing properly. It is best to paper the walls with black paper. The room should be provided with a light-tight ventilating flue. In the field, in the theater of operations, where a dark room cannot be improvised, a tent can be made into a dark room. Such a tent should be painted black, or otherwise rendered entirely opaque.

LIGHTING THE DARK ROOM. The dark room may be illuminated with a dark room lantern or a small colored window. The dark lantern should be provided with two or more red colored glass slides to control the intensity of the light, and a cover or lid to shut the light off entirely. The intensity of the light from a red colored window glass can be controlled by placing one or more covers of red paper over it. It should also be provided with a door or black curtain to shut the light out entirely.

WATER SUPPLY. If possible the dark room should be plumbed for running water. A water supply or pressure tank can be used to great advantage where a city supply is not available. If neither of these sources is available, the water will have to be carried from a well—clear rain water should be used if available. Two galvanized iron tubs will suffice for washing plates and prints, transferring frequently from one tub to the other.

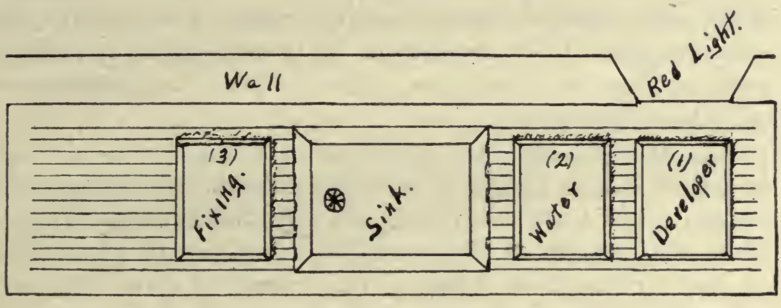


Fig. 66.

ARRANGEMENT OF APPARATUS. The developing bench should be somewhat similar to the sink in a kitchen. In the center there should be a basin with drain and a water supply spigot above it; on either side there should be corrugated surfaces on which to place the developing and fixing trays. The ridges of this surface should be level; the troughs should slope towards the basin to furnish drainage. For developing there should always be three trays arranged in series: first, the tray containing the developer; second, a tray with pure water; and third, a tray containing the fixing bath, or hypo. Opposite the developing tray there should be a small red colored window, or a dark lantern, in order to see the progress and the completion of the development. See Fig. 66.

Above and below the developing bench, there should be shelves so that any apparatus or supplies that may be required during the developing shall be easily available and be out of the way when not in use. The developing bench should of course be next to the wall, and in northern latitudes against the north wall. The door to the dark room should be within the building, and when closed light tight.

Cleanliness. The trays, the developing bench, and the whole dark room should be absolutely clean. Care must always be taken that not a trace of hypo ever gets into the developer. Whenever the fingers are put in the hypo, they should be immediately rinsed off in pure water and wiped. No dirt or foreign chemicals should ever get into the developer and fixing bath, and when it does, the solution should be thrown away and a new one prepared. Good negatives and pictures cannot be produced where there are dirty or impure developing and fixing solutions, and too much care cannot be taken to prevent any and all uncleanliness.

The Developer. The developer is a solution of several chemicals used to develop a dry plate after it has been exposed to light. The development of a plate is the reduction to metallic silver of that portion of the sensitive silver salt that has been changed by the effect of light. The amount of silver salt that is capable of being reduced to metallic silver at any place on the plate depends upon the amount of light that struck that place during exposure; and the reduction of the affected silver salt may be stopped at any time by removing the plate from the developer. The photographer is thus able to develop an exposed dry plate to any density that he may wish, provided of course the plate has not been underexposed. The chemical which reduces the affected silver salt is called the *active* or *developing agent.* There are many developing agents on the market, but the Pyro and Hydrochinon-Metol Developers are the best known to amateurs.

The developing agent alone reduces the affected silver salt very slowly, but when an alkali is mixed with it, the developing agent has a greater affinity for oxygen and therefore becomes quite energetic in its reduction of the affected silver salt. The alkalies most commonly used are Sodium Carbonate and Potassium Carbonate. The alkali is called an *accelerator.*

Often the development of a particular exposed plate is too energetic. In such cases the development can be retarded by the addition of Potassium Bromide, or other *restrainer.* The action of the Potassium Bromide is to dissolve some of the silver salt (Silver Bromide) out of the emulsion, thereby forming a double salt of silver which is less easily reduced to metallic silver by the developing agent.

When it is desired to keep the developer from discoloring and oxidizing a *preservative* is added to it. The preservative most commonly used is Sodium Sulphite. In addition to its qualities as a preservative, Sodium Sulphite has much to do with the color of the negative. If only a small amount is used the negative will be brown in color and the quality harsh and hard, while a greater portion will give a gray, soft negative with more detail.

The developer may be in the form of prepared powder, in which case it is only necessary to dissolve it in the amount of water prescribed in the directions accompanying it. If in a concentrated liquid form, it must be diluted. If one makes one's own developer, the chemicals should be accurately weighed and used in the proportion prescribed in the formula.

PYRO DEVELOPING FORMULA*

Pyrogallic Acid Solution

"A"	Avoirdupois	Metric System
Pyrogallic Acid	1 oz.	30 grams
Sulphuric Acid	20 minims.	1 c. c.
Water	28 ozs.	900 c. c.
("B") Soda Solution		
Carbonate Soda (desiccated†)	2 ozs.	60 grams
Sulphite Soda (desiccated†)	3 ozs.	90 grams
Water	28 ozs.	900 c. c.

For Dark-Room Development Take

"A"	½ oz.	15 c. c.
"B"	½ oz.	15 c. c.
Water	4 ozs.	120 c. c.

This developer will then contain 1.56 grains Pyro per oz.

*Page 97, *How To Make Good Pictures*, Eastman Kodak Co.
†If crystals are used, double the quantity.

ELON-HYDROCHINON OR METOL-HYDROCHINON*

Solution A

Elon or Metol	60 grains	4 grams
Hydrochinon	30 grains	2 grams
Sulphite Soda (desiccated)	¾ oz.	22.5 grams
Water	20 ozs.	600 c. c.

Solution B

Carbonate Soda (desiccated)	½ oz.	15 grams
Water	20 ozs.	600 c. c.

For Dark-Room Development Take

Solution "B"	1 oz.	30 c. c.
Solution "B"	1 oz.	30 c. c.
Water	2 ozs.	60 c. c.
Potassium Bromide, 10%	*4 to 8 drops*	

DEVELOPING. *Normal Procedure:* The plate to be developed is removed from the plate holder after exposure in the dark room. Its emulsion surface is brushed off with a fine camel hair brush to remove any traces of dust that may be adhering to it. The plate is then immersed into the developing solution, emulsion side up. The solution should cover the plate as evenly and quickly as possible; all air bubbles forming on the surface should be removed at once with a light brush of the fingers. The tray should be rocked back and forth so as to keep the

†PREMO FILM PACK TANK

developer in contact with the plate in constant motion. The developer should be from 65° to 70° F. If the red light (should be greatly reduced) from the dark lantern be cast upon the plate, the high lights will be seen to appear first and then a well defined image. The development is not yet complete: it

*Page 97, *How To Make Good Pictures,* Eastman Kodak Co.
†Courtesy of Eastman Kodak Co.

must be carried on until the negative is very dense. The fixing of the plate will greatly reduce this density, and the resulting image after the fixing will be clear and distinct. When the development has proceeded to the proper point as explained, the negative is removed from the developer, rinsed off in a tray of pure water, and then immersed in the hypo, or fixing tray.

Overexposed Plates: Should the image come out very quickly instead of slowly and regularly, the plate has been overexposed. In such cases remove the plate from the developer at once and place it in the tray containing the pure water; add a few drops, according to the degree of overexposure, of Potassium Bromide Solution (45 grains of KBr to one ounce of water) to the developer. Put the plate back into the developer and proceed as before.

Underexposed Plates: If the plate developes slowly, no details appear in the shadows, but high lights come up quickly, the plate has been underexposed. In such cases, remove the plate from the developer and put it into the tray containing the pure water; dilute the developer with an equal amount of pure water (of the same temperature); put the plate back into the developer and proceed as before.

The developer should never be diluted or have a chemical added to it while the plate is in it, as the resulting solution will not be of uniform strength quickly enough. Such changes in the strength of the developer should be made only after the plate has been removed from it, and the plate should not be put back until the added chemical has had time to mix thoroughly.

Daylight Development. By the use of the film tank developer roll films can be developed in broad daylight. The tank is loaded with the film much the same as a roll film camera is. In the use of these tanks, the kind and strength of developer recommended by the makers, should always be used, and the time specified for the developing rigidly followed. The film tank developer permits developing in the field without other accessories, where a dark room is not usually available, and its use commends itself for military purposes.

For field purposes prepared developing powders should be used. They eliminate the necessity of weighing and mixing, and besides are more conveniently transported.

THE FOLLOWING INSTRUCTIONS ARE GIVEN BY THE EASTMAN KODAK CO., FOR THE USE OF THEIR KODAK FILM TANK*

"The Kodak Film Tank consists of a wooden box, a light proof apron, a 'Transferring Reel,' a metal 'solution cup,' in which the film is developed, and a hooked rod for removing film from solution. There is also a dummy film cartridge with which one should experiment before using an exposed cartridge. The various parts of the outfit come packed in the box itself.

Setting up the Film Tank:

"1. Take everything out of the box. Take the apron and Transferring Reel out of the solution cup.

"2. The axles marked C and D in the cut (Fig. 67) are to be inserted in the holes in the front of the box. The front will be toward you when the spool carrier in end of box is at your right. These axles are interchangeable. The axle 'C' must be pushed through the hollow spindle which will be found loose in the box. The spindle has a lug at each end to which the hooks of the apron are to be attached.

"3. The axle 'D' must be pushed through the hollow rod of the Transferring Reel in position as indicated in the illustration. The flanges at each end of the Transferring Reel are marked 'Y' in the illustration (Fig. 67). Both axles 'C' and 'D' must be pushed clear through into the holes on the opposite side of the box.

†FIG. 67

"4. Attach one end of the apron to spindle, through which axle 'C' passes, by means of the metal hooks which are to be engaged with lugs on the spindle (Fig. 68). The corrugated side of the rubber bands is to be beneath the apron when it is attached. Turn to the left on axle 'C' and wind entire apron onto axle, maintaining a slight tension on apron, in so doing, by resting one hand on it.

"5. Insert film cartridge in spool carrier (Fig. 69), and close up the movable arm tight against end of spool. Have the duplex paper ('B' in Fig. 67) lead from the top.

Important:

"Film to be used in the Kodak Film Tank must be fastened to the duplex paper at both ends. All Kodak films are fastened at one end in the factory. The other end is fastened in the following manner. *Just before you are ready to develop* (holding spool with the black side of the duplex paper up) unroll the duplex paper carefully until you uncover the piece of gummed paper which is fastened to

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* *How To Make Good Pictures*, Eastman Kodak Co.

†Courtesy of Eastman Kodak Co.

*Fig. 68

*Fig. 69

*Courtesy of Eastman Kodak Co.

end of film and is to be used as a means of fastening film to duplex paper. Moisten the gummed side of sticker evenly for about an inch across the end and stick it down to duplex paper, rubbing thoroughly to secure perfect adhesion. Wind end of duplex paper on spool again and the cartridge is ready to insert in machine.

*Fig. 70

"6. Break the sticker that holds down the end of duplex paper, thread the paper underneath wire guard on Transferring Reel—through which axle 'D' passes (Fig. 70), and turn axle slowly to right until the word 'stop' appears on duplex paper.

*Fig. 71

*Courtesy of Eastman Kodak Co.

"7. Now hook apron to lugs on Transferring Reel (Fig. 71), in precisely the same manner that you hooked the opposite end in lugs on spindle, except that axle 'D' turns to the right.

"8. Turn handle half a revolution so that apron becomes firmly attached and put cover on box. Turn axle 'D' slowly and steadily until duplex paper, film and apron are rolled up together on Reel. As soon as this is completed the handle will turn very freely."

9. Put four or five ounces of lukewarm water into the Solution Cup and dissolve in it the following chemicals in the order named (for 5″ and 7″ tanks):

30 grains Pyro
60 grains Sulphite of Soda (desiccated)
60 grains Carbonate of Soda (desiccated)

or better, in place of these chemicals, "dissolve in it the contents of the large package of the Kodak Tank Developer Powders, and fill the cup with cold water to the embossed ring—not to the top. In the latter case, dissolve the contents of the small package in the solution and the developer will be ready: in the former, fill the tank to the embossed ring—not to the top, with cold water. The temperature of the developer should be 65° Fahr." "For Brownie Tanks use $\frac{1}{3}$ the amounts above specified: for the 3½″ Tank use 11/15."

*Fig. 72

"10. Now remove cover from box and draw out axle 'D' (Fig. 72), holding apron and duplex paper with other hand to keep end of apron from loosening.

"11. Remove entire Transferring Reel (now containing apron, duplex paper, and film) which is freed by pulling out axle D, and insert immediately in the previously prepared developer.

"In removing Reel do not squeeze the apron, but hold it loosely or slip a rubber band around it to keep from unrolling.

"12. * * * Lower Transferring Reel into Cup (Fig. 73), with the end containing crossbar up. Let Reel slide down slowly. The operation of removing reel from box can be done in the light of an ordinary room,

*Courtesy of Eastman Kodak Co.

*Fig. 73

*Fig. 74

but for safety it is well that the light should not be too bright. *The total length of time for development is 20 minutes.*

"Note. Immediately after lowering Reel into solution cup, catch it with wire hook and move slowly up and down two or three times, taking care, however, not to raise any part of Reel above the surface of the solution. This is to expel air bubbles.

"13. Then place the cover on the cup (Fig. 74) putting lugs on cover into the grooves and tighten cover down by turning to right. Now turn the entire cup end for end, and place in a tray or saucer to catch any slight leak in the cup. At the end of three minutes reverse the cup, and, thereafter, reverse every three minutes until the time of development (20 minutes) has elapsed. Turning the solution cup in this manner allows the developer to act evenly and adds brilliancy and snap to the negatives. The wire hook is to be used for lifting the reel out of cup. Hook on to cross-bar in one end of reel (Fig. 75).

*Fig. 75

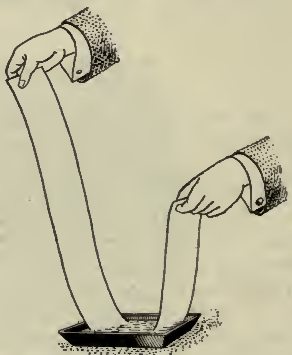

*Fig. 76

*Courtesy of Eastman Kodak Co.

"14. When development is completed pour out developer and fill cup with clear, cold water and pour off, repeating this operation three times to wash the film. Then remove Transferring Reel; separate film from duplex paper and place immediately in the Fixing Bath, which should be in readiness as explained in 15.*

"*The film may be separated from duplex paper in light of an ordinary room if the developer is thoroughly washed out.* The operation of separating film and duplex paper should be done over a bowl, bath tub, or sink. When the duplex paper does not free itself readily from back of film, split the paper where possible, this will remove the hard outer surface of the paper, the remaining portion will soon become soaked and then can be removed easily by rubbing gently, while immersed, with the ball of the finger. This adhering of the duplex paper to the film is almost invariably caused by the use of too warm developer."

FIXING

"15. Provide a box of Kodak Acid Fixing Powder which should be prepared as per instructions on the package. Put this into a tray or wash bowl. When the powder is thoroughly dissolved add to the solution as much of the Acidifier, which you will find in a small box inside the large one, as directions call for. As soon as this has dissolved the Fixing Bath is ready for use. Any quantity of the bath may be prepared in the above proportions. The Fixing Bath given on the next page may be used."

The Fixing Bath:

"16. Pass the film face down (the face is the dull side) through the fixing solution as shown in the cut (Fig. 76), holding one end in each hand. Do this three or four times and then place one end of the film in the tray, (8″ × 10″ is a good size) still face down, and lower the strip into the solution in folds. Gently press the film where the folds occur, not tightly enough to crack it, down into the solution during the course of fixing. This insures the fixing solution reaching every part of the film. Allow the film to remain in the solution two or three minutes after it has cleared, or the milky appearance has disappeared. Then remove for washing.

Fixing:

"NOTE. If preferred, negatives may be cut apart and fixed separately."

"After developing a roll of film the apron must be wiped dry before developing another roll. The apron will dry almost instantly if immersed for a moment in very hot water. Keep apron wound on axle 'D' when not in use. Never leave apron soaking in water."

"Several rolls of film may be developed at the same time if the operator wishes. To do this it is necessary to have a 'Duplicating Outfit' consisting of 1 Solution Cup and cover, 1 Transferring Reel and 1 Apron for each additional roll of film to be developed. The extra rolls of film may then be wound on to Transferring Reels as previously described and immersed into the Solution Cups."*

If it is desired to develop twice as fast double strength developer is used. Should the normal of 65° Fahr. be impossible to maintain, the following

* The liberty of slightly rearranging the above instructions has been taken in order to avoid the cross references of the text.

table* may be used for obtaining the time of development, interpolating the intermediate values.

Temperature			Time One Powder	Time Two Powders
70°	—	—	15 minutes	8 minutes
65°	NORMAL		20 minutes	10 minutes
60°	—	—	25 minutes	11 minutes
55°	—	—	30 minutes	13 minutes
50°	—	—	35 minutes	15 minutes
45°	—	—	40 minutes	17 minutes

THE FIXING BATH AND FIXING. After the negative has been developed to the point desired, removed from the developer, and rinsed off in pure water, it is then immersed into a solution of Hyposulphite of Soda which dissolves out of the film all the silver salt that has not been affected by light. Until the negative has been immersed into the Hyposulphite solution, it is sensitive to light and all the operations up to this point must be carried on in the dark room; from now on the negative is insensitive to light. The negative, however, is kept in the Hyposulphite, or Hypo Solution, as it is commonly called, until after all the silver salt has been dissolved out. When the silver salt is completely dissolved out of the negative, all the creamy appearance will have left the back of the negative: it is then "fixed." This "fixing" must be complete to preserve permanently the negative. In order to make the film surface of the negative hard and tough to withstand handling, a *hardening solution* is added to the Hypo.

FIXING BATH[1]

Water	16 ozs.	480 c. c.
Hyposulphite of Soda	4 ozs.	120 grams
Sulphite of Soda (desiccated)	¼ oz.	7.5 grams
When *fully dissolved*, add the following hardener:		
Powdered Alum	⅛ oz.	3.75 grams
Citric Acid	⅛ oz.	3.75 c. c.

This bath may be made up at any time in advance and be used so long as it retains its strength, or is not sufficiently discolored by developer carried into it to stain the negatives.

For the same reason as in case of developers, it is recommended that prepared fixing powders be used, and especially so in field operations.

*Extract from page 86, *How To Make Good Pictures.*

[1] Page 86, *How To Make Good Pictures,* Eastman Kodak Co.

Washing and Drying. In order to preserve the negative, all the hypo must be thoroughly washed out of it. After having been thoroughly fixed, the plate should be rinsed off in water, placed in a zinc washing box, and immersed in running water for about thirty minutes. They may be placed, standing on edge, in a bucket of water, and have the water on them changed ten or twelve times, allowing each change of water to remain on them for about five minutes.

After the negative has been thoroughly washed, it should be rinsed off in fresh water and placed in a drying rack to dry. Where several plates are developed consecutively, the fixing and drying can be carried on simultaneously and at a great saving of labor.

Printing

Printing Papers. There are many different kinds of printing papers on the market, but all may be grouped into two general classes—(1) "printing out" papers, and (2) "developing out" papers. In the former, the picture is printed on the paper as it is exposed through the negative to light; in the latter, the paper is also exposed to light through the negative, but the picture does not show until it is developed out. Of the latter papers, Velox and Azo are the best. The great advantage of these papers are, they may be handled in subdued daylight, take only a short timed exposure, and develop quickly. Velox is furnished in two grades, Regular and Special, and of different surfaces. Regular Velox develops quickly, and should be used with thin or weak negatives. Special Velox develops slowly and is intended for contrasty or dense negatives. For views of the terrain, etc., either Velox or Azo, or any other good developing out paper is recommended.

For military passes, safe-guards, etc., the photo of the person or building whose identity is essential should be printed directly on the printed blank form. For this purpose, that portion of the blank form that is to contain the photo should be covered with a film of emulsion containing a sensitive silver salt; the unexposed blank forms should of course be kept in light tight packages. Passes and safe-guards with the photo printed directly upon them are much more difficult to forge than those on which a photo print is pasted or mounted.

In case such forms are not furnished, and it is desired to improvise some, the following method of preparation may be used. The blank form should be printed on a good quality note paper, not too rough. The following solutions are made:

	Solution A	
Sodium Phosphate	16 grams	4 grams
Distilled Water	¼ oz.	7 cu. cm.
	Solution B	
Silver Nitrate	20 grams	4.5 grams
Distilled Water	¼ oz.	7 cu. cm.
	Solution C	
Citric Acid	1 oz.	30 cu. cm.
Distilled Water	4 ozs.	120 cu. cm.

Mix solutions A and B together, in a dark room with artificial light (red); add solution C by degrees until all the yellow silver phosphate dissolves. Using a fine camel hair brush, brush the resulting solution over that portion of the form devoted to the picture and hang it up in the dark to dry. When dry, this makes a printing out paper, which when exposed through the negative gives a rich reddish brown image. The image thus produced is fixed in the following hypo bath:

Hyposulphite of Soda	1 oz.
Water	16 ozs.

After having been fixed, thoroughly wash and dry.

Much better results can be obtained by using "developing out" printed blank forms, prepared by manufacturers of printing papers.

Printing Light and Exposure. For exposing prints when Velox or Azo paper is used, either daylight or artificial light may be used. If daylight is used, the exposing window should be on the north side of the dark room, as the light on that side will be more uniform. To subdue this light, several thicknesses of white tissue paper may be put over this window, the number depending upon the intensity of the light desired.

Artificial light is to be preferred as it is much more uniform. The following table[1] will show approximately the time needed for exposure:

[1] From *How To Make Good Pictures*, Eastman Kodak Co.

Size of Negative.	Distance from light.	Welsbach Burner.	32c.p. Electric or 6 ft. gas Burner.	16c.p. Electric or 4 ft. gas Burner.	Average Oil Lamp.
4x5, or smaller	7 inches	10 sec.	20 sec.	30 sec.	40 sec.

Regular Velox should be developed to the proper depth in from 15 to 20 seconds; Special Velox, 30 seconds. If the development is faster or slower, the length of succeeding exposures should be accordingly regulated.[1]

Developing and Fixing. Prints should be developed in the solution recommended by their manufacturers. For Velox paper Nepera Solution should be used. Should the photographer desire to mix his own solution, the following M. Q. Developer[1] should be used:

(Dissolve chemicals in the order named)

Water	10 ozs.	300 c. c.
Elon or Metol	7 grains	½ gram
Hydroquinone	30 grains	2 grams
Sulphite of Soda (desiccated)	110 grains	7 grams
Carbonate of Soda (desiccated)	200 grains	13 grams
Potassium Bromide (10% *Sol.*)	40 drops	40 drops

The developing is carried on in the same manner as for plates. The prints are put in the developer with the emulsion side up, several at a time; the developer should cover the emulsion quickly and all air bubbles removed at once with a brush of the fingers. The trays should be arranged as for plate developing. The temperature of the developer should be from 65° to 70° F.

Where there are a large number of prints, porcelain lined dish pans can be used to advantage for both developing and fixing. After prints are developed, they should be rinsed off in pure water before being placed in the fixing bath. In order that the prints may be thoroughly fixed, they should be frequently changed about in the Hypo in order to bring the face of all prints in contact with the Hypo. The following Hypo

[1] From *How To Make Good Pictures,* Eastman Kodak Co.

Formula[1] is recommended where prepared powders are not used:

Water	64 ozs.	1920 c. c.
Hyposulphite of Soda (Crystal)	16 ozs.	480 grams

When thoroughly dissolved, add the following hardening solution, dissolving the chemical separately and in the order named:

Water	5 ozs.	150 c. c.
Sulphite of Soda (desiccated)	½ oz.	15 grams
Acetic Acid No. 8 (25%)	3 ozs.	90 c. c.
Powdered Alum	1 oz.	30 grams

Washing and Drying. Prints must be thoroughly washed in water to remove all traces of Hypo. This is especially difficult where a large number of prints must be washed at the same time. In such cases it is best to have two washing trays or tubs, changing the prints from one tub to the other several times, and using fresh water at each change.

After they have been thoroughly washed, the prints are ready to be dried. They should be placed face down in a pile on a clean piece of glass, and pressed with the hands to remove the surplus water, after which they should be laid out singly, and face down on cheese cloth stretchers—frames, 3 or 4 feet square, on which cheese cloth has been stretched and fastened.

Mounting. If it is desired to place or mount the print on a cardboard, mounting tissue or library paste is applied to the back of the print. To apply the mounting tissue, the print is placed face down on a clean surface and a piece of mounting tissue of the same size is fastened to its back by touching the tissue at several places with the point of a hot iron (not too hot) ; if it is desired to trim the print it is now done, using a trimming board—a knife or scissors should never be used; the print is then placed on the mount with the tissue next to it at the position desired, and the surface of the print pressed with a hot iron—not rubbed. Prints so mounted will not curl even on the thinnest mounts; two prints may even be placed back to back with the mounting tissue.

Prints for military purposes will seldom be mounted. To remove the curl formed in drying, each print is placed face down on a piece of clean white paper, and a hot iron is run over its surface.

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[1] Page 107, *How To Make Good Pictures,* Eastman Kodak Co.

Intensification and Reduction

Intensification. When negatives are underdeveloped, they may be intensified as follows: If the negative has been allowed to dry it should be soaked in clean water about 20 minutes. It is then put face up in an empty tray and the *intensifier* solution poured over it. The intensifier is allowed to act until the negative is all of one even color; the solution is then poured off and the negative is washed in four or five changes of clean water for fifteen minutes and put out to dry.

It is recommended that prepared intensifiers be used. The following intensifiers,[1] however, may be prepared:

Sol. A:	Bi-chloride of Mercury (poison)	75 grains
	Water	5 ozs.
Sol. B:	Iodide of Potassium	112 grains
	Water	2½ ozs.
Sol. C:	Hyposulphite of Soda	150 grains
	Water	2½ ozs.

Reduction. When the negative is overdeveloped its density may be reduced in the following manner: If the negative has been allowed to dry, it is soaked in clean water for 20 minutes, and then immersed in a reducing solution. The tray is gently rocked back and forth until the negative has been reduced to the desired density. It is then washed in running water for 10 minutes, or in four changes of water. The following reduction formula[2] is recommended:

Water	6 ozs.
Hyposulphite of Soda	½ oz.
Ferri-Cyanide of Potassium (saturated solution), poison	20 drops

Photographic Terms

"High Lights." Those portions of a negative which are most dense, or represent the bright or light portions of the picture, are called the "High Lights."

"Shadows." Those portions of a negative which are most transparent, or represent the dark portions of the picture, are called the "Shadows."

"Thin." When a negative has little density in the "High Lights" it is said to be "Thin."

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[1] Page 89, *How To Make Good Pictures*, Eastman Kodak Co.
[2] Page 88, *How To Make Good Pictures*, Eastman Kodak Co.

"Dense." When a negative is dark all over it is said to be "Dense."

"Flat." When there is very little contrast between the "High Lights" and the "Shadows" of a negative, it is said to be "Flat."

"Fogged." When a negative shows no clear or transparent places, even in the "Shadows," it is said to be "Fogged."

Defects in Negatives

Too "Thin." Negatives which are too "thin," have usually been underdeveloped. The beginner seeing a well-defined image on the plate generally stops the developing too soon and a thin negative results after the plate has been "fixed." With experience the photographer will learn when the plate has been developed to the proper point: thin negatives can be intensified as heretofore explained.

Too "Dense." Negatives which are too "dense," have usually been overdeveloped, the plate having been left in the developer too long. Dense negatives can be reduced as heretofore explained.

Much Contrast But Little Detail in Shadows. If the "high lights" of a negative are too dense and the "shadows" too transparent, the plate has usually been underexposed. Judging the light and time is a matter of experience. The beginner should keep a record of exposures in order to overcome errors in the judging of the light and time.

Little Contrast But Much Detail in Shadows. If the "high lights" of a negative are not dense enough and the "shadows" not transparent enough, the plate has usually been overexposed. The same procedure should be followed as in the preceding section.

"Fogged Negatives." If a negative is "fogged" all over, including the margins which were hid by the plate holder during exposure and which should be perfectly clear, the trouble has usually been in the dark room or in the dark room lamp. If in the dark room, it is not light tight: if in the dark room lamp, the lamp either emits white light or the red light is too bright.

Lack of Sharpness. If the picture or negative lacks sharpness and definition, either the camera was out of focus or was jarred during exposure. The remedy in the first case is the proper estimation of distance, or proper focusing. In the second case the camera may have been jarred by the wind during exposure, or when the bulb was pressed. A timed exposure can never be made while holding the camera in the hands.

Spreading of High Lights. In photographing objects in which there is a great contrast of light and shade, such as interiors where a window is included in the view, the intensity of the light from the bright portions will illuminate the images of the dark portions and thus blot out the detail from the black portions. The remedy here is to use a non-halation plate which overcomes this illumination, or "halation" effect.

Black Streaks or Blotches. A negative which has black streaks or blotches on it, has been light struck either before or after exposure; that is, direct light has struck the plate. This may result from a vast number of causes—leaky plate holders, non-light-tight dark room, dark-room lamp emitting white light, mistakes by the photographer, etc.

Frosty Appearance. Should the negative a few days after drying, show a white appearance or deposit on the film, it has not been thoroughly washed, this appearance being caused by the Hypo still remaining in the film. The negative must be thoroughly washed: *Hypo remaining in the negative will affect the prints made from it, even before it shows on the negative itself.*

Finger Prints. Finger marks on the negative are caused by touching the emulsion side of a dry plate, or allowing the plain side of a dry plate that has been touched with the fingers to come in contact with the emulsion side of another dry plate, before exposure. Dry plates should always be picked up by the edges, and when packed placed emulsion sides together. Finger marks cannot be removed from the negative. In removing plates from plate holders after exposure, they should be similarly handled by their edges only.

Stains. Yellow or brown stains are generally caused by using a developer that has been allowed to spoil from age or uncleanliness. They are also caused by using water containing iron, or a rusty developing, fixing, or washing tray. The "whites" (or "high lights") of prints will have a yellowish tone or small red spots should water containing iron be used. This may be prevented by filtering the water through several thicknesses of flannel, or one of canton flannel, before using it in solutions. Iron rust stains can be removed by soaking the negative for a few moments in diluted Sulphuric Acid (1:20).

PIN HOLES. Pin holes are caused by particles of dust adhering to the emulsion surface of the dry plate during exposure. Before dry plates are loaded, this emulsion surface should be lightly brushed with a soft camel hair brush to remove all traces of dust.

TRANSPARENT SPOTS. Transparent spots are caused by bubbles forming and remaining on the dry plate during the developing. As soon as a bubble forms on the plate during the developing, it should be immediately removed by a light brush of the finger.

OPAQUE SPOTS. Opaque spots on the negative are caused by dust adhering to the plate while immersed in the developer, or from dirt in the developer, or in the fixing solution, or in the washing water. The plate before being immersed into the developer, should have its emulsion surface lightly brushed with a soft camel bair brush to remove any trace of dust that may be on it. The chemicals used and their solutions should not only be pure, but the dark room should also be scrupulously clean so that no loose dirt or dust will fall in the trays during the developing, fixing, and washing processes.

TRANSPARENT LINES. Transparent lines on the negative are caused by brushing the emulsion surface of the dry plate too hard, or by using a stiff brush. The brush should be a soft camel hair brush, and the emulsion surface should be brushed very lightly and carefully. This brush should be used for no other purposes.

OPAQUE LINES. Opaque lines are generally caused by chemicals getting on the hairs of the brush used to dust the emulsion surface of the dry plate. This brush should never be laid down on the work bench, but should have a special place on the shelf above assigned to it where there is no probability of its coming in contact with chemicals, either dry or in solution.

Mottled Appearance. The negative will present a mottled appearance if the developer does not uniformly and quickly cover the whole plate, and also if the developer is not kept in constant motion over the emulsion surface by the tray being slowly and continuously rocked back and forth during the developing.

Defects in Prints[1]

Having given a good negative from which the prints are made, the following defects may result:

Prints are too black: Overexposure; overdevelopment; insufficient Bromide of Potassium; wrong grade of paper used.

Prints too light: Underexposure; underdevelopment; wrong grade of paper.

Not enough, or too much, contrast: Usually happens where whites develop too quickly for shadows to develop proper definition, or shadows develop too quickly for whites. Expose shadows longer or shorter than high lights to the light.

Grayish whites throughout entire print: Chemical or light fog; insufficient Bromide of Potassium.

Grayish mottled or granulated appearance of edges or of entire print: Underexposure; forced-development; old paper; paper kept in damp place; moisture; chemical fumes.

Brown or red stains: Old or oxidized developer; developer too warm; imperfect fixing; fixing bath lacks sufficient acid and prints are not kept moving in it to allow even fixing.

Round white or black spots: Air bells on surface of emulsion; develop prints face up; remove air-bells when formed.

White deposit all over surface of prints: Milky Hypo bath; insufficient acetic acid in Hypo bath.

Picture good, but surface covered with black marks: Abrasion marks. For glossy surface paper use N. A. (Non-abrasive) Velox Liquid Developer.

Blisters: Prints creased or broken while washing; water from tap falling directly on prints; too strong acetic acid used in hardener; too great difference between temperature of fixing solution and wash water; fixing bath lacks sufficient hardener. Never use a plain Hypo fixing bath without a hardener.

[1] From *How To Make Good Pictures*, Eastman Kodak Co.

MILITARY PHOTOGRAPHY

POSITION AND OUTPOST VIEWS. There will often not be sufficient time to make sketches of position and outpost areas. In such cases photographs of the areas, until the proper sketching can be done, will be invaluable. Photographs of sketched areas will also be valuable supplements to the maps thereof. In photographing an area, views should be taken from several positions if possible. Where a photograph of a wide front is desired, a panoramic camera can be used to great advantage.

PLACE AND RECONNAISSANCE VIEWS. Place views will usually be taken while out on reconnaissance work, and may or may not be supplemental to a sketch of the terrain included by the photograph. The scout will find a Pocket Kodak or No. 0 Graflex, or other similar cameras, best adapted to reconnaissance work. These cameras are small and can be easily carried on the person and will not incumber his movements.

TOPO-PHOTOGRAPHY. This subject has been fully treated under Photo-Topographic Operations in the chapter on Military Topography.

AERO-PHOTOGRAPHY. Whenever a photograph of the terrain is taken with a single camera, as a Graflex, from an aëroplane, the camera will usually be held at an inclined angle, and an oblique view of the plane of the objective (in this case, the ground) will be obtained. This view will be distorted, for the ground glass of the camera will not be parallel with the plane of the objective. Thus, in Fig. 77, a and a^1 are equal angles, and the intercepts m_1m_2 and m_2m_3 on the ground glass are also equal to each other, but the intercept M_1M_2 is much less than the intercept M_2M_3 on the ground. Now M_1M_2 occupies as much space (m_1m_2) on the negative, or ground glass, as M_2M_3, (m_2m_3) does, and thus m_2m_3 is distorted with respect to m_1m_2, as well as the whole outer field with respect to the inner field of the view. If the ground glass were parallel with the plane of the objective, as the line rp_2 in Fig. 77, the view would not be distorted, but it is impossible to adjust the ground glass for each exposure in aëro work.

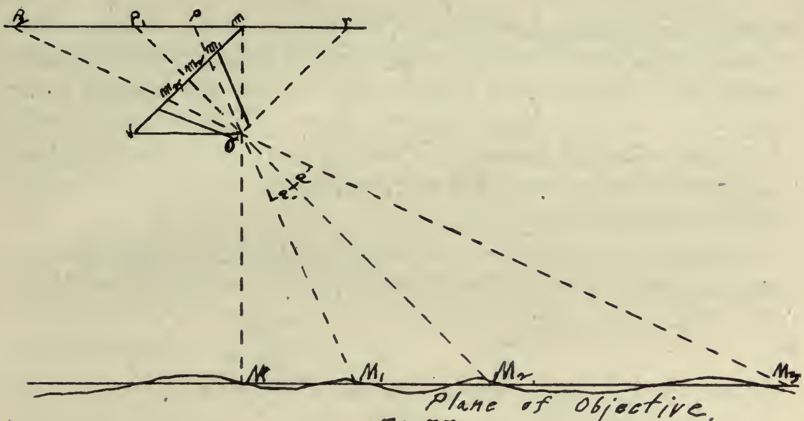

Fig. 77.

Rectification of Distortion. It is obvious that the distorted view thus obtained should be rectified into a true view. If a distorted negative be placed in front of a camera so as to make the same angle with the optical axis of the camera as the optical axis made with the plane of the objective when the negative was taken, and a photograph of that negative taken, the resulting positive image on the dry plate will be a corrected view. Such a simple procedure in the rectification of distorted negatives cannot be followed, for it will not be known just at what angle the optical axis made with the plane of the objective, and the true scale of the image cannot be thus reproduced, or rather produced.

If in Fig. 77, the camera lense O be imagined wide angled enough to permit a vertical ray from M to pass through to intersect the ground glass, m_3m_1 produced, at point m, then the hypothetical image point m is the only point on the negative where the view is not distorted. From zero at point m (M) this distortion increases directly in magnitude toward m_3 (M_3), so that even image m_1 on the near edge of the view will be out of scale (distorted) where the altitude of the camera is considered the distance to the plane of the objective. When an object is twice the focal distance from one side of a lense, the image of it is twice the focal distance on the other side of the lense and is of the same magnitude. Therefore, to take a photograph of a negative so that it will be produced to scale, the hypothetical point m on the negative and its hypothetical image point m′ on the positive must be on opposite sides of the lense and both twice the focal distance away. Then m and m′ will be of the same magnitude. The angles at which the negative and positive must be placed with respect to each other is shown in the diagram in Fig. 78.

This diagram shows the principle of the Scheimpflug Perspectograph. In this diagram the parallel lines are a focal dis-

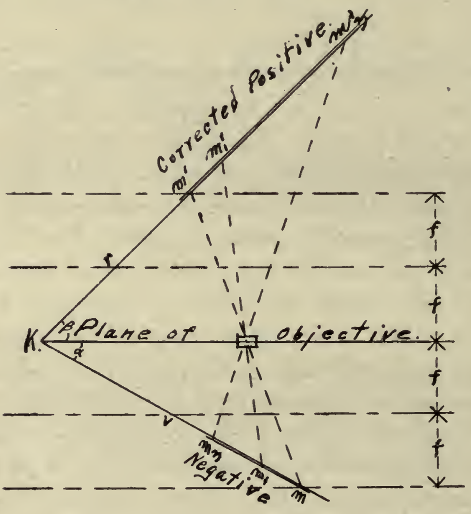

Fig. 78.

tance apart: the lines KA and KB form the angles α and β with the central line, designated "Plane of Objective." α and β are found from the following formula:

$$mv \sin \alpha = f = m^1 r \sin \beta$$

in which mv and m^1r (or, mr) can be found from Fig. 77. $m^1{}_1m^1{}_3$ is the corrected positive of negative m_1m_3, and it will be noticed that $m^1m^1{}_1 : m^1{}_1m^1{}_3 :: MM_1 : M_1M_3$, so that the intercepts on the corrected positive are proportional to the corresponding intercepts on the ground throughout.

THE SCHEIMPFLUG CAMERA. A vertical photograph of the terrain taken from a point above, such as from a balloon, will include only a small field even when taken from a comparatively high altitude and a wide angle lense is used. Thus, with a 60° angle lense at an altitude of one mile, the field will be a circle whose diameter is only about 6,000 feet. Most aëro-photographs, however, are taken at altitudes much less than one mile and the field is proportionally smaller. For successful aëro-photography, therefore, a special camera with large field must be used. For such work, Captain *Theodore Scheimpflug* of the Austrian Army, has devised a compound camera which has met with the greatest success, and the general principles of it will be discussed.

The *Scheimpflug Camera* consists of one central vertical camera surrounded by seven other cameras inclined at an angle of 45° to it. The shutters of all these cameras work simultaneously and are controlled by one release. The combined exposures include an angle of 140° and cover a field over 25 times as large as a single camera. Fig. 79 (a) shows the general principle of the Scheimpflug Camera, while Fig. 79(b) shows its photographic field. Since there are seven inclined cameras evenly spaced around the central vertical one, no two cameras are directly opposite each other. In Fig. 79(a) however, the liberty is taken of representing two inclined cameras in the same vertical plane as the central camera, so as to show more clearly the vertical intercepts on the ground.

The intercept or field of the central camera is a circle determined by the intersection of a vertical cone with the ground: the apex of this cone is the lense of this camera and angle of the apex of this cone is equal to the angle of the lense. The cones of light from the inclined cameras intercept the ground at an angle of 45°. Fig. 79(b) shows the photographic field of the compound camera. The intersection of fields of the inclined cameras are shown only within the working limits of the combined cameras. It will be noticed that the field of each camera must overlap the adjacent fields so that the entire field is covered.

The combined photographic field is thus made up of one central vertical view and seven surrounding oblique views. The distortion of the oblique views are corrected by means of the

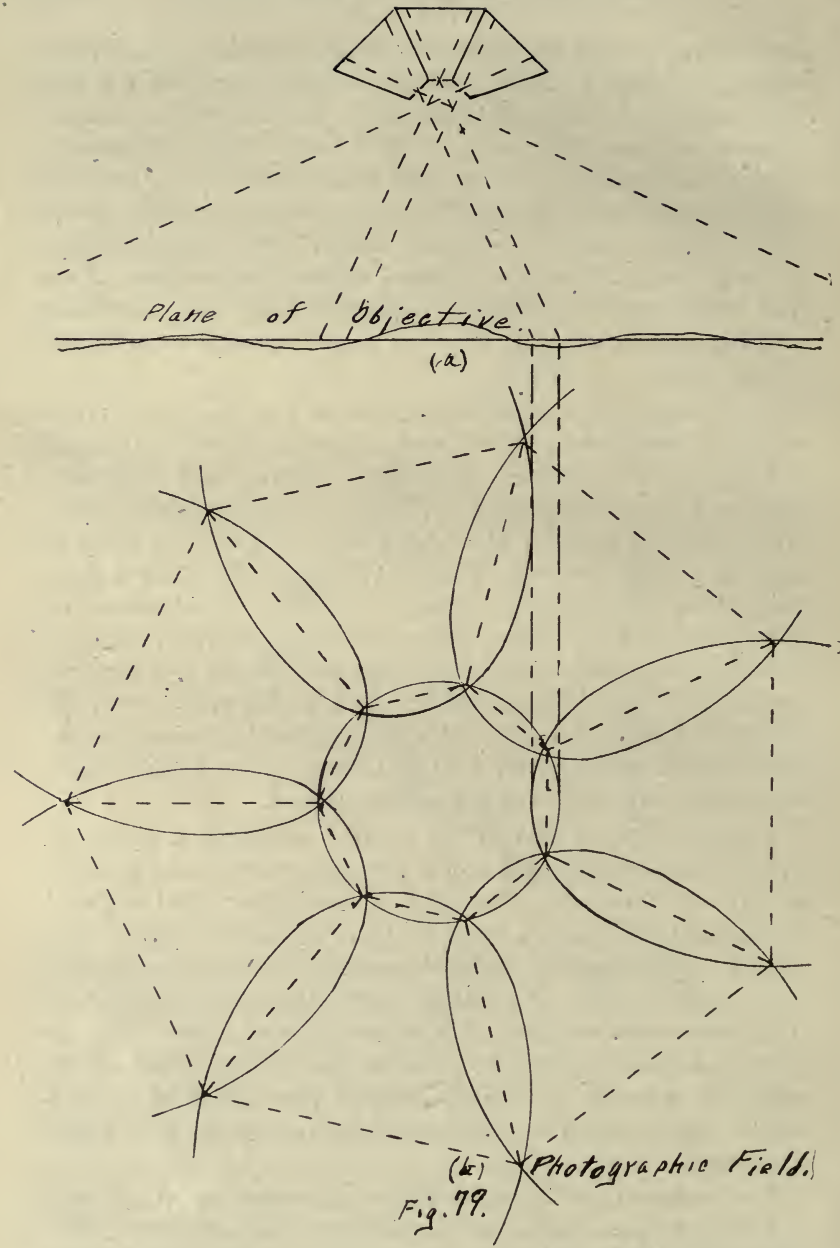

Fig. 79.

Fig. 23. — Appareil à 8 chambres, en position pour le déclenchement.

SCHEIMPFLUG CAMERA ATTACHED TO BALOON BASKET
Courtesy of Scheimpflug Institute

*View of Scheimpflug Camera from Below

perspectograph, the same as explained for an oblique view from a single camera, and these corrected views are assembled photographical to the central view with microscopic precision by means of a special camera.

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*Courtesy of Scheimpflug Institute.

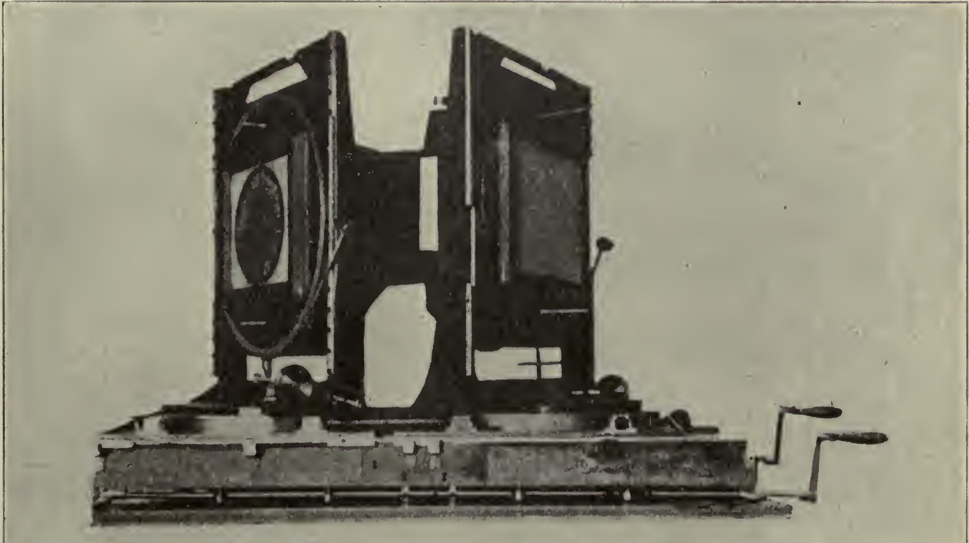
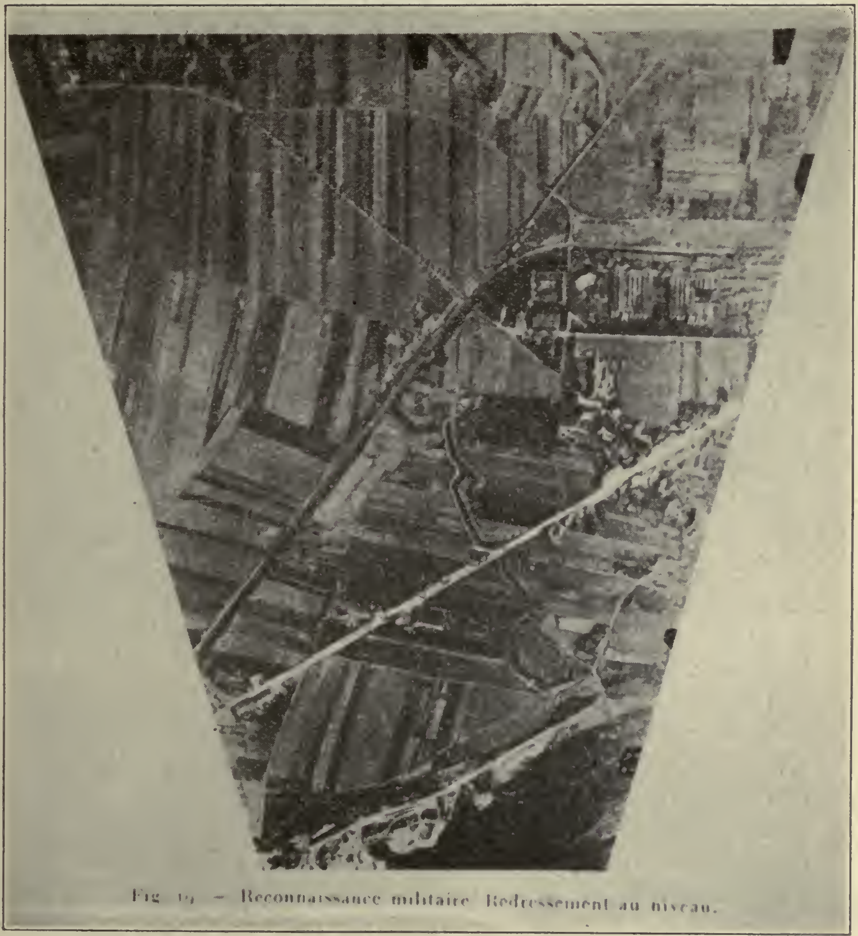


Fig. 3. — Perspectographe Scheimpflug-Kammerer.

Scheimpflug-Kammerer Perspectograph for Rectifying Distorted Views

Courtesy of Scheimpflug Institute.

Aereo-Reconnaissance View Distorted
Courtesy of Scheimpflug Institute.



Aereo-Reconnaissance View Corrected
Courtesy of Scheimpflug Institute.

CHAPTER V

SPECIAL PROBLEMS

Chaining

In chaining the distance between two points four things must be kept in mind: (1) the straight distance between the two points is to be obtained; (2) the horizontal distance between the two points is to be obtained; (3) the point where the end of the chain or tape comes each time must be marked; and (4) the chain or tape must be stretched straight and tight each time.

Reading the Chain or Tape. The Gunter's Chain is 66 feet (4 rods) long and has 100 links. Each link is therefore 1/100 of a chain, and the number of links are written decimally. Thus, a distance containing five chains and seven links would be written, 5.07 chains. The Surveyor's Chain is 100 feet long and has 100 links each 1 foot long. Chains usually have every tenth link numbered with a tag from the ends towards the center; as, 0-10-20-30-40-50-40-30-20-10-0. In reading, two very easy errors must be avoided: 60 feet, etc., must not be read as 40 feet, etc., and 42 feet, etc., for 38 feet, etc. The latter can be avoided by reading the tags on each side.

The tape is usually 100 feet long, and is divided into feet with the last foot on each end divided into tenths and hundredths of a foot. Some tapes are numbered to correspond to chains, and such tapes posses all the difficulties of a chain in reading. Most chains, however, have their divisions numbered consecutively from "0" to "100." When the distance between two points is less than the length of the tape, the tape is stretched from one stake to beyond the second stake; the head chainman goes to the second point, put the next greater foot division opposite the second point while the rear chainman pulls the tape straight and tight, and notes the subdivision in tenths and hundredths which is opposite the first point. The head chainman announces the number of the division opposite the second point, and the distance is read by the rear chainman mentally subtracting from that number 1 foot and adding the fraction of a foot from the first point to the "1-ft." division.

Chaining. A chaining party will usually consist of a front and rear chainman, designated as No. 1 and No. 2, respectively, equipped with a 100 foot tape, two markers and 11 pins. Procedure:

When the two points are intervisible and directly accessible: Both points are marked with rods or markers so that they can be easily seen. The tape having been stretched out on the ground with all bends and kinks removed, No. 1 who has the 11 pins sticks one at the initial point; he then picks up the 100 foot end of the tape and walks directly towards the far point; when the "0" end of the tape nears the initial point, No. 2 calls out "*Chain!*", at which No. 1 halts, faces No. 2, and pulls the tape fairly taut; at this instant No. 2 clasps the "0" end of the tape, kneels directly in rear of the initial point, with the left foot in such a position that it forms a prop for the hands when the "0" division of the tape is opposite the far end of the pin; No. 2 then motions No. 1 to the right or left in alignment with the far point, after which No. 1 pulls the tape straight and tight, taking the kneeling position facing No. 2; No. 2, observing that the "0" division is opposite its proper place, calls out, "*Stick!*"; No. 1 then sticks a pin with its far side opposite the 100 foot division and calls out, "*Stuck!*"; No. 2 then lets loose of the tape and pulls up the pin at the initial point and follows the end of the tape which is being pulled forward by No. 1. As the second pin is approached, the same procedure is followed, and so on, throughout the distance. When No. 1 has stuck his last pin, he calls out "*Pins!*", and No. 2 goes forward to him with the pins which he has pulled up, and as a check counts them for there should be 10 (one is always left in the ground). It is evident that each time No. 1, calls for pins, he will have gone 1000 feet. If, therefore, at the far point, No. 2 has six pins in his hands No. 1 has called for "pins" three times, and from the last pin stuck to the far point is 43 feet, the distance measured between the two points is 3643 feet.

When the two points are not intervisible, but directly accessible: This condition will occur where a ridge or other high ground is between the two points. In such a case the two points

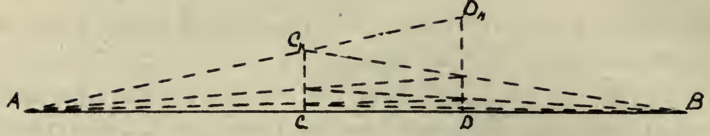


Fig. 85.

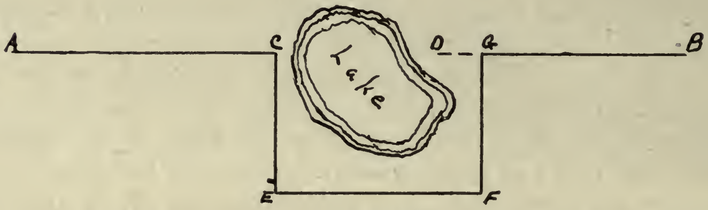


Fig. 86.

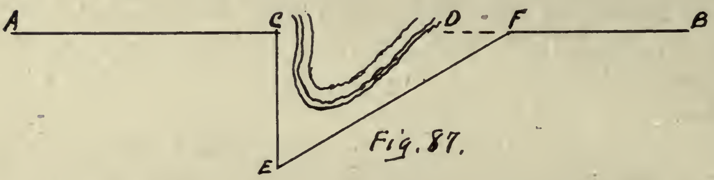


Fig. 87.

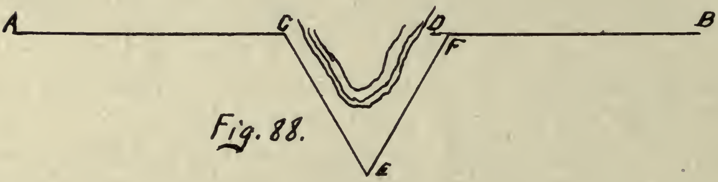


Fig. 88.

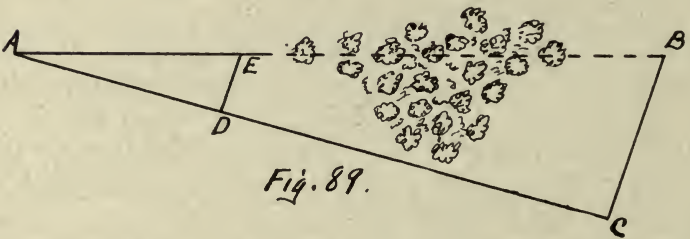


Fig. 89.

are first marked with visible rod, after which the two chainmen proceed to the intervening ridge or hill, No. 1 placing himself on the far side of the hill so that he can just see the near point, while No. 2 places himself on the near side of the ridge just so he can see the far point. No. 1 then aligns No. 2 to the right or left on the near point, after which No. 2 aligns No. 1 to the right or left on the far point. They then alternately align each other until they are both on the line, as shown in Fig. 85. They mark their position with rods, and then commence chaining, using these intermediate rods first for aligning, and after the high ground is reached the visible rod marking the far point.

When the points are intervisible, but not directly accessible: This condition will occur where a lake or swamp intervenes. In such a case, the chainmen, one on the near side of the lake and the other on the far, align themselves on the straight line joining the two points, as in the preceding case, and mark their position with visible rods. The distance from the first point to the near rod is first chained; a line at right angle to this line is then chained far enough to clear the lake; then a line at right angle to this last line is then chained, in the original direction, far enough to pass the point on the far point of the lake; a line is then chained at right angle to the last line until it intersects the straight line joining the two points whose distance apart is being measured. Fig. 86 shows this method graphically. From the figure it is evident that if A and B are the two points, their distance apart is equal to AC+EF+GB. Local conditions might make an equilateral or right triangle offset better than a rectangle offset, as shown in Figs. 87 and 88, the side CE being obtained by calculation.

When the two points are neither intervisible nor directly accessible: This condition will occur where a woods or underbrush intervenes. When the intervening vegetation is not too large, select a point C which is intervisible and directly accessible to both A and B, Fig. 89. Chain the distances AC and CB; at a convenient known point D on the line AC, measure off a line DE parallel to CB, and equal to $\frac{AB \times CB}{AC}$. If the foregoing has been carefully done, the line AE produced will mark the line to be cleared through the woods in order to make A and B intervisible and accessible. Should the woods be of any extent it will be far more economical to run a transit traverse to determine their distance apart.

Care of Steel Tape and Chain. The steel tape is easily broken in two if pulled when kinked, and before pulling it along on the ground or stretching it to make straight and tight, the front chainmen should look along the length of the chain each time to see that there are neither kinks nor bends. Both tape and chain easily rust, so that each time before putting the same away they should be wiped dry; if stored away they should have a good coating of cosmoline or other heavy grease. Instead of carrying a steel tape on a closely wound reel, it is better to carry it looped. This is done as follows: The near end of the tape is clasped in the right hand palm up, and the right hand is swung to the rear pulling the chain with it; the chain is then clasped by the left hand palm down at the first five foot division and placed in the palm of the right hand without allowing the tape to turn; each five foot division is similarly placed over the palm of the right hand, and the tape is thus gathered in concentric folds which can be crossed and tied at the center. The chain is first doubled in the middle, after which each two links are folded together across the two preceding links so that the whole chain when folded presents the appearance of an hour glass. To undo a tape or chain so done up, reverse the above processes.

Telemetric Measurement of Distances

Theory of the Stadia. In the measurement of distance with the stadia, the intercept which two horizontal stadia wires in the telescopic field makes on a graduated rod held on the distant point is observed. This intercept is directly proportional to the distance. Fig. 90 show the stadia rod as seen through the telescope.

From the theory of lenses, it will be noticed from Fig. 91 that all the rays of light, such as, A and B pass through the common point O, one of the foci of the lense, and after passing through the lense become parallel rays aa^1, bb^1, and so on. In the similar

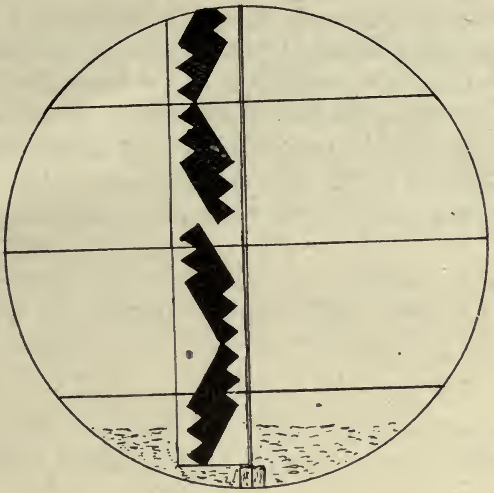


Fig. 90.

triangle, Oa^1b^1 and OAB, $f:S::a^1b^1:AB$, but $ab = a^1b^1$; therefore $S = \dfrac{f \times AB}{ab}$. The recticle containing the horizontal cross wires is placed at the focal distance of the lense in rear of it,

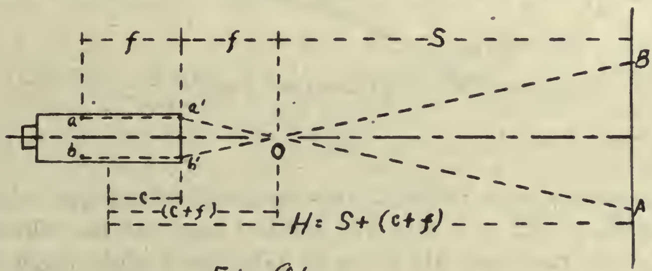


Fig. 91.

and the distance apart of the two horizontal wires a and b is usually fixed and of such amount that the focal distance divided by ab (usually designated as $\dfrac{f}{i}$) equals 100. In such cases $S = 100 \times AB$. S is the distance from O to the stadia rod, so that if the distance from the center of the telescope is desired, as in more accurate work, the constant $f + c$ (focal length of lense plus distance from center of transit to lense) must be added to each stadia reading made on the stadia rod. *This "$c + f$" is the same for all distances.*

Inclined Readings. If in Fig. 92, the stadia rod AB were held perpendicular to the line of collimation, then the stadia reading obtained would be the slope distance; but the stadia

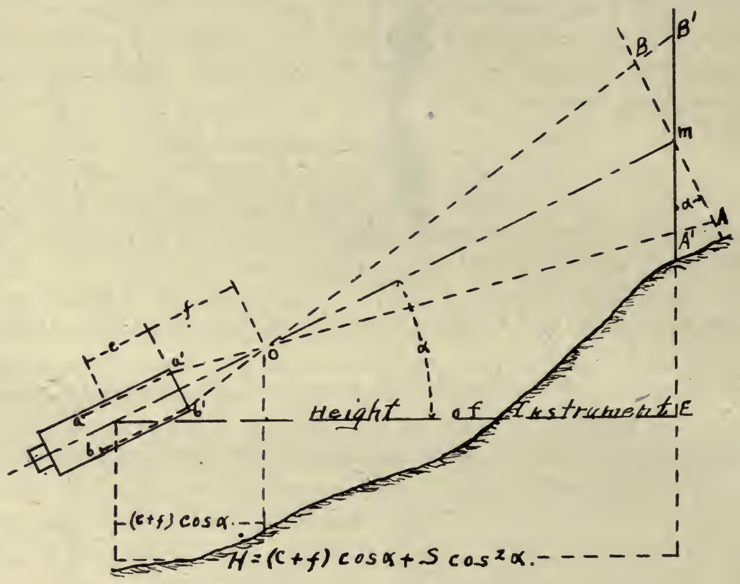


Fig. 92.

rod is always held vertical, and the actual intercept A^1B^1 is larger than AB. Let α be the vertical angle of the telescope. In Fig. 92, the angle at A can be taken as a right angle, and the angle A^1mA equals angle α, from which $100AB = 100A^1B^1\cos\alpha$ = the slope distance Om. The slope distance, OM, times $\cos\alpha$ equals the horizontal distance S, therefore:

$$H = (c + f)\cos\alpha + (100A^1B^1\cos\alpha)\cos\alpha, \text{ or}$$
$$= (c + f)\cos\alpha + S\cos^2\alpha.$$

To get the difference in elevation it is only necessary to multiply the slope distance ($A^1B^1\cos\alpha$) by the sine of the vertical angle, or:

$$Em = (c + f) \sin \alpha + (A^1B^1 \cos \alpha) \sin \alpha, \text{ and since,}$$
$$\cos \alpha \sin \alpha = \tfrac{1}{2} \sin 2\alpha, \text{ and } S = 100A^1B^1;$$
$$Em = (c + f) \sin \alpha + S \tfrac{1}{2} \sin 2\alpha.$$

The value for H and Em for vertical angles up to 30° for stadia reading of 100 are given in Table IV.

The value $\frac{f}{i}$ is seldom exactly 100, but slightly less or more, so it is necessary to multiply the stadia reading read by a small factor, called the stadia constant. The method of obtaining this stadia constant is explained later on.

Verniers

A *vernier* is an auxiliary scale by which in conjunction with the main scale the latter can be read more closely than can be shown by actual subdivision.

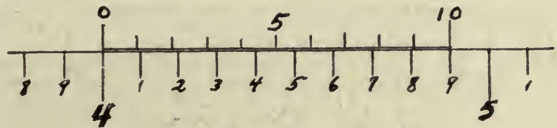


Fig. 93, Direct Vernier

Direct Verniers. In Fig. 93 the upper scale is the vernier scale, while the lower scale is part of a main scale to which the former belongs. It will be noticed that ten divisions are equal to just nine of the divisions on the main scale, from which it can be easily seen that each division on the vernier is just one-tenth smaller than the division on the main scale. If, therefore, the vernier scale be moved just one-tenth of a division to the right, the first line of the vernier; i. e. the first line to the right of the "O," will coincide with a line on the main scale; if moved two-tenths of a division to the right the second line on the vernier will coincide with a line on the main scale, and so on. It will be seen that, except when the "O" line coincides, only one line on the vernier can coincide with a line on the main scale at the same time.

Where a vernier is used in conjunction with lineal scale, such as a level rod, the main scale will be subdivided decimally as, feet, tenths of a foot, and hundreds of a foot, while the vernier will read one-tenth smaller than the smallest division of the main scale, or thousandths of a foot.

To read a vernier: In Fig. 93 assume that the fifth line of the vernier coincides, then the "O" of the vernier will be between the "4" and "1." Look along the main scale in the direction in which it is numbered to the first division immediately opposite and to the left of the "O" of the vernier: this will give the reading to the lowest subdivision on the main scale: then look along the vernier in the direction in which it is numbered to the line which coincides, which will give the next lower digit of the reading. Under the above supposition the reading in Fig. 93 would be 4.05, but as actually shown is 4.00.

Retrograde Verniers. In Fig. 94 it will be noticed that ten divisions on the vernier are equal to eleven divisions on the

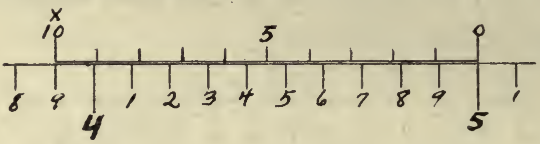


Fig. 94. Retrograde.

main scale. Each division on the vernier is therefore one-tenth larger than the smallest division of the main scale. If, therefore, the vernier be moved one-tenth of a division to the right, the first division line to the left on the vernier will coincide, and so on. For this reason the vernier must be numbered in the direction opposite to which the main scale is numbered. Such verniers are called *retrograde verniers.*

To read a retrograde vernier: Look along the main scale to the first division immediately opposite and to the left of the "O" of the vernier, which will give the lowest reading on the main scale: then look back along the vernier, in the direction in which it is numbered to the line that coincides, which will give the vernier reading.

Retrograde verniers are little used, being employed in level rods numbered from the center downwards; for declination correction scales in the compasses of some transits where an economy of space is desired; and in a few other special cases.

LEAST COUNT OF THE VERNIER. The value obtained by dividing the smallest division of the main scale by the number of divisions on the vernier is called the least count of the vernier. This is merely the reading of the vernier as explained in the preceding paragraphs, and may be denoted by $l \div n$, where l equals the length of the smallest division on the main scale and n, the number of divisions on the vernier. If, in case of a level rod, l equals one-hundredth of a foot, and n equals 10, then the least count on the vernier will be one-thousandth of a foot. In a transit reading directly to 30′, and n equals 30, the least count on the vernier will be 1′. In all direct verniers, where n is the number of divisions on the vernier, n — 1 will be the number of divisions on the main scale which are equal to n divisions of the vernier.

DOUBLE VERNIERS. In case of the horizontal scale of a transit, which is used to measure angles in either direction, two direct verniers numbered in opposite directions and having a common "O" are used. These verniers so used together are called *Double Verniers.* Each part of the double vernier will equal n — 1 divisions on the main scale, and there will be one

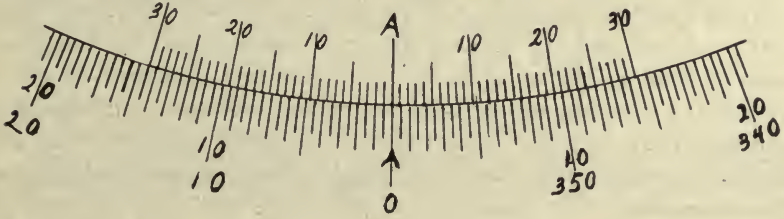


Fig. 95.

line in each part that will coincide. Fig. 95 shows a double vernier.

To read a Double Vernier: The "O" on the vernier will give the smallest reading of the main scale the same as in a single direct vernier: to get the vernier reading, look along that part of the double vernier which is numbered in the same direction as the main scale which is being used is numbered, for the line that coincides. *Do not use that part of the vernier which is num-*

bered in the direction opposite to which the main scale being used is numbered.

Folded Verniers. *A Folded Vernier* is a single direct vernier that may be read in either direction. This is accomplished by numbering the center division line "O" and numbering in both directions from the "O." Fig. 96 shows a folded vernier.

Fig. 96.

Folded verniers are commonly used on the vertical scales of transits, where an economy of space is desired and both plus and minus vertical angles are read.

To read a Folded Vernier: The "O" of the vernier shows the least reading of the main scale as in all other cases: to get the vernier reading, look along the vernier from the "O" in the same direction as the main scale being used is numbered for the vernier line that coincides. If no such line is found between the "O" and that end of the scale, glance to other end of the vernier and look along the same in the same direction as before to the line that coincides, the division lines being considered numbered consecutively upward until the "O" is again reached. *In a folded vernier, as in case of a single direct vernier, only one line coincides.*

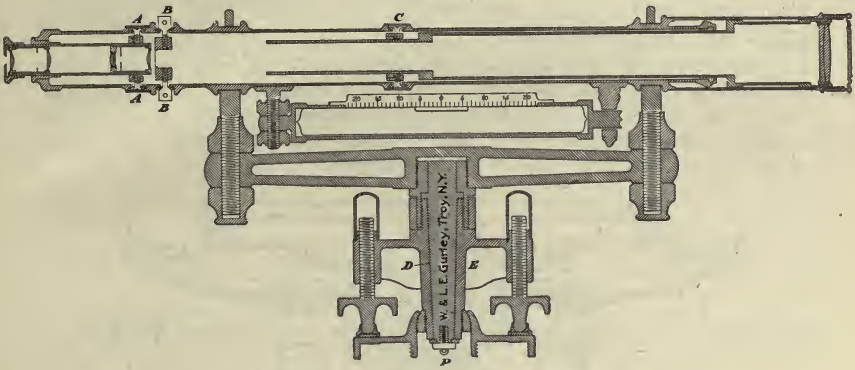
ADJUSTMENTS OF THE LEVEL

1ST ADJUSTMENT. TO MAKE THE LINE OF SIGHT DETERMINED BY THE INTERSECTION OF THE CROSS WIRES TO COINCIDE WITH THE OPTICAL AXIS OF THE TELESCOPE.

Test: Fix the intersection of the cross wires on some definite point such as a nail head on the side of a house about 50 feet away. Revolve the telescope in its wyes until the attached level is on top. Should the intersection of the cross wires remain on the nail head, the line of sight and optical axis coincides: if it does not, the two do not coincide.

Adjustment: Bring the intersection of the cross wire half way to point selected by means of the bottom and top cross-wire recticle screws, and the other half by means of the leveling screws. Repeat test and adjustment until intersection of the cross wire remains on point. The vertical cross wire can be similarly adjusted by first turning telescope on one side in its wyes and then on the other.

2ND ADJUSTMENT. TO MAKE THE AXIS OF THE ATTACHED LEVEL PARALLEL WITH THE OPTICAL AXIS OF THE TELESCOPE.



*SECTIONAL VIEW OF WYE LEVEL

Test: Clamp vertical axis of level and bring level bubble to center of level tube. Now lift the telescope out of its wyes, and place it back with ends reversed. Should the bubble not be in the center of level tube, the axis of the level is not parallel with the optical axis of the telescope.

Adjustment: Bring the bubble half way back to center by means of the capsan screws that hold it to the telescope barrel and the other half by means of the main leveling screws. Repeat test and adjustment until bubble remains in the center upon reversing telescope end for end in its wyes.

3RD ADJUSTMENT. TO MAKE THE AXIS OF THE WYES PERPENDICULAR TO THE VERTICAL AXIS OF THE TELESCOPE.

Test: Bring the telescope over two opposite leveling screws and bring bubble to center by means of the main leveling screws: do the same with the telescope over the other pair of leveling screws. With the bubble in the exact center in the latter operation, revolve the level on its vertical axis 180°. Should the bubble leave the center, the wyes axis and the vertical axis are not perpendicular to each other.

Adjustment: Bring the bubble half way back to center by means of the wyes capsan screws which attach them to the horizontal arm, and the other half by means of the main leveling screws.

ADJUSTMENTS OF THE TRANSIT

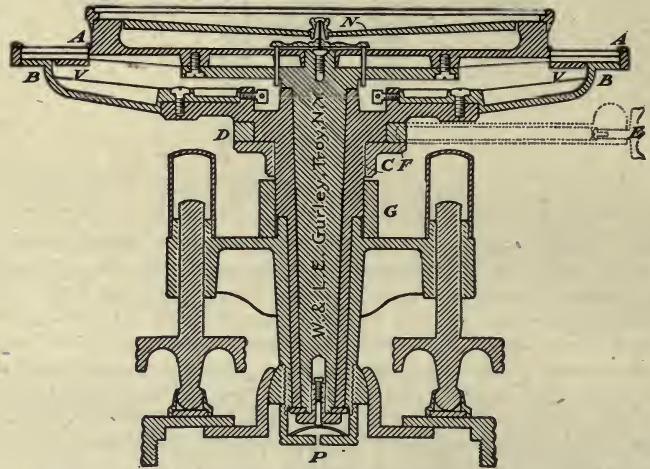
The adjustments of the plane table is practically the same as those for the transit. Where the transit is revolved in azimuth 180°, a line is first drawn entirely around the alidade ruler, and the alidade telescope revolved 180° in azimuth, by picking it up and reversing end for end, putting it back in the rectangle previously drawn around the alidade ruler. In all adjustments of the plane table the alidade should be in the center of the

*Courtesy of W. & L. E. Gurley.

board and the length of the alidade ruler over a pair of opposite leveling screws.

1ST ADJUSTMENT. TO MAKE THE HORIZONTAL PLANE OF THE PLATE LEVELS PERPENDICULAR TO THE VERTICAL AXIS OF THE TRANSIT.

Test: Bring a plate level directly parallel with the plane of two opposite leveling screws, and bring the level bubble to the center; bring the bubble of the other plate level to the center by means of the other pair of leveling screws; revolve transit 180°. Should the bubble leave the center of the latter plate level it is out of adjustment.



*Sectional View of Transit Sockets and Circular Plates

Adjustment: Bring the bubble half way back to center of level tube by means of the capsan nuts at its ends, and the other half by means of the main leveling screws. Make same test and adjustment for the other plate level; repeat test and adjustment on each plate level alternately until the bubbles remain in the center with the transit revolved to any position.

2ND ADJUSTMENT. TO MAKE THE LINE OF SIGHT PERPENDICULAR TO THE HORIZONTAL AXIS OF THE TRANSIT TELESCOPE.

Test: The transit having been set up and leveled, drive a stake in the ground 200 or 300 feet away and in the stake drive a pin; set the intersection of the cross wires on this pin; clamp both upper and lower limbs and plunge the telescope on its horizontal axis; sighting through the telescope inverted, have a stake driven the same distance away as before, the center of the stake being at about the intersection of the cross wires; have a man to stick a pin in this stake at the exact intersection of the cross wires; loosen upper limb and revolve transit until the cross wires are

*Courtesy of W. & L. E. Gurley.

again exactly on the first pin; clamp upper limb and plunge the telescope. If the cross wires do not fall exactly upon the second pin again, the cross wires are out of adjustment. See Fig. 97.

Adjustment: By means of the side cross wire recticle screws bring the intersection of the cross wires one fourth of the way back to the second pin. Repeat test and adjustment until instrument is in adjustment. If the telescope is an erecting one, the recticle will be moved in the same direction in which the correction is to be made.

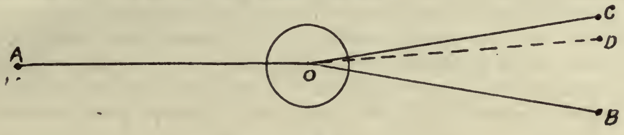


Fig. 97.

3RD ADJUSTMENT. TO MAKE THE HORIZONTAL AXIS OF THE TRANSIT TELESCOPE PERPENDICULAR TO THE VERTICAL AXIS OF THE TRANSIT.

Test: The preceding adjustment having been made, center the cross wires on a point, as a nail head, at the top of a house; depress telescope on its horizontal axis until the bottom line of the house is seen, such as the water table; have a man to mark the point where the intersection of the cross wires falls; plunge telescope and revolve transit about 180° and sight the same point at the top of the house with the telescope inverted; depress

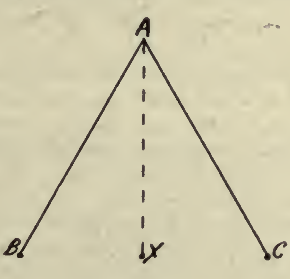


Fig. 98.

the telescope until the same bottom line of the house is sighted. If the intersection of the cross wires does not fall on the same point at the bottom of the house, the horizontal axis of the telescope is not perpendicular to the vertical axis of the transit. See Fig. 98.

Adjustment: Lower or raise the movable support of the telescope axle at one end by means of the proper screws until one half the difference is corrected. Repeat test and adjustment until instrument is in this adjustment.

4TH ADJUSTMENT. TO MAKE THE AXIS OF THE LEVEL ATTACHED TO TELESCOPE PARALLEL WITH LINE OF SIGHT.

Test: The preceding adjustment having been made, select a nearly level piece of ground, and drive a stake on each side of the transit and the same distance from it—about 200 or 300 feet; depress telescope by means of vertical tangent screw until bubble is in center of level tube; read the elevation on the level rod held on the stake towards which the telescope is sighted and record; revolve telescope and sight other stake; bring bubble of telescope level to center again by means of the vertical tangent screw and read the elevation on the level rod held on the second stake, and record. Note difference in elevation between the two stakes. Remove transit to a slight distance beyond one stake in prolongation with both stakes; sight the stakes and bring bubble of telescope level to the center by means of the vertical tangent screw; read the elevation of both stakes. If the difference in elevation is not the same as when the transit was between the stakes, the axis of the level tube is not parallel with the line of sight. In Fig. 99, ac-bd=ae-bf, when the axis of the telescope level is parallel with the line of sight.

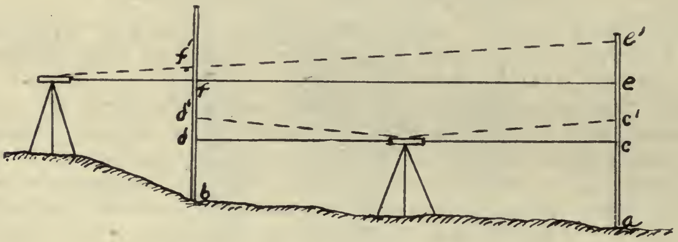


Fig. 99.

Adjustment: Set the target on the level rod at "a" to read bf′ + (ac′—bd′); sight the intersection of the cross wires on the level target at "a," and clamp the vertical scale; with telescope clamped, bring bubble of telescope level to the center by raising or lowering on end of the level tube by means of the capsan nuts at that end. Repeat test and adjustment from 2nd position until ac — bd = ae — bf.

5TH ADJUSTMENT. TO MAKE THE "O" OF THE VERNIER OF THE VERTICAL SCALE TO COINCIDE WITH "O" OF THE VERTICAL SCALE WHEN THE BUBBLE OF THE TELESCOPE LEVEL IS IN THE CENTER.

Test: The preceding adjustments having been made, the bubble of the telescope level is brought to the center by means of the vertical tangent screw. Should the "O" of the vernier not coincide with the "O" of the vertical scale, the vernier is out of adjustment.

Adjustment: With the bubble of the telescope level in the center and the telescope clamped, loosen the screw at one end of the vernier and tighten the screw at the other end in the direction in which it is desired to move the vernier, until the "O's" coincide.

The adjustments of both the level and transit are given in the order in which they must be made. This order is very logical and if the reasons for the same, which are very apparent, be thoroughly understood, the sequence will seem natural and the adjustments made as a matter of habit, rather than trying to remember them arbitrarily from the numerical designations.

In addition to the above adjustments, there are a few others, which must be made.

PARALLAX. This must be eliminated every time an angle is read.

Test: With the cross wires and object in focus, move the position of the eye to the right and left; should there also be a movement of the image, the image is not in the same plane as the cross wires, and there is parallax, as it is called.

Adjustment: Point the telescope towards the sky and bring the cross wires in as perfect focus (definition) as possible by moving the eye piece in or out. Now sight the object, focus by moving object glass in or out, and observe if there is any parallax. If so, slightly change position of object glass by moving in or out. If this does not eliminate the parallax, repeat entire test and adjustment until it is eliminated. The telescope must be adjusted for parallax for each person.

TO MAKE THE VERTICAL CROSS WIRE PERPENDICULAR TO THE HORIZONTAL AXIS OF THE TELESCOPE. This adjustment also makes the horizontal cross wire parallel with the horizontal axis of the telescope. *This adjustment should be made in conjunction with the 2nd adjustment above.*

Test: Bring the top of the vertical wire on a point about 50 feet away, and clamp the upper and lower limbs of the transit; raise telescope by means of the vertical tangent screw, at the same time looking through the telescope to see if the vertical wire remains on the point while the telescope is being raised. If not, the vertical wire is not perpendicular to the horizontal axis of the telescope.

Adjustment: Loosen two adjacent cross-wire recticle screws, and tap one of the recticle screws in the direction in which it is desired to turn the recticle (for erecting telescope). By looking through the telescope the amount can be closely judged. Repeat test and adjustment, until the vertical wire remains on the point throughout its length during the raising or lowering of the telescope.

Should there be play in the bearings, the transit can not of course do accurate work, should such faults appear it would be better for the average instrument man to send his instrument into the shops. Also if it is desired to straighten a magnetic needle or center the pivot support of a magnetic needle.

The brass capsan adjusting screws and nuts should not be tightened too much, the general rule being that the pressure applied to them by means of the wire pin should be felt, and there should be no play. These things should be learned by the beginner from an experienced man.

A topographer must know how to take care and adjust all surveying instruments, the subject will not, however, be further treated in this book for it is thoroughly covered in all manuals on plane surveying.

SPIRIT LEVELING

As it is presumed that the reader has a knowledge of surveying, the procedure in leveling will similarly be taken up only in a general way. If a more thorough discussion of its theory be desired, a standard textbook on plane surveying, or the *Engineer's Field Manual*, should be consulted.

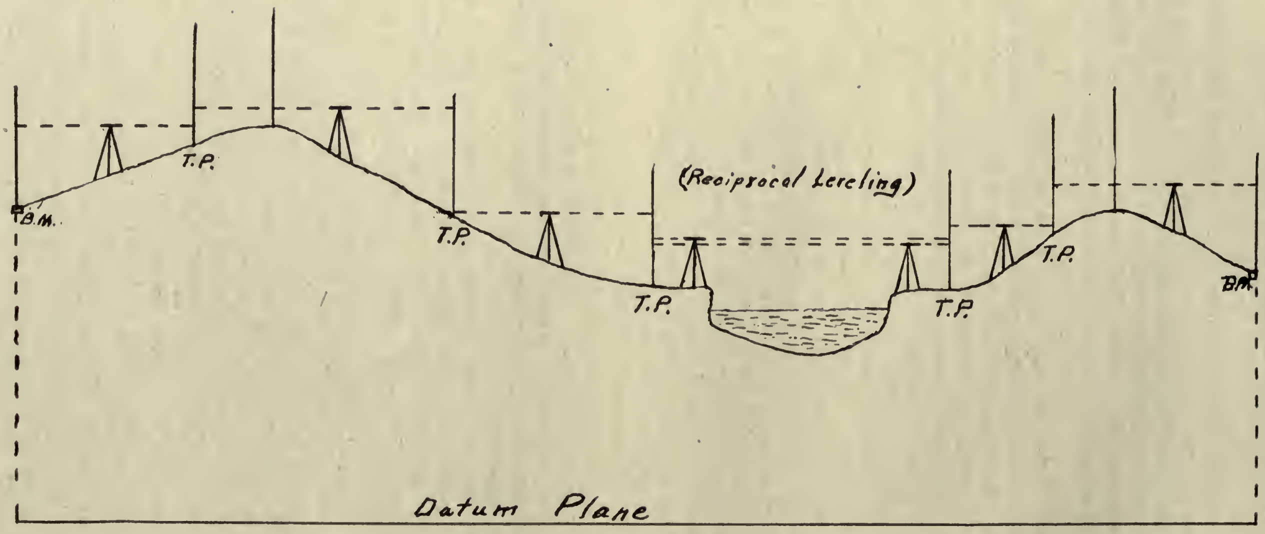
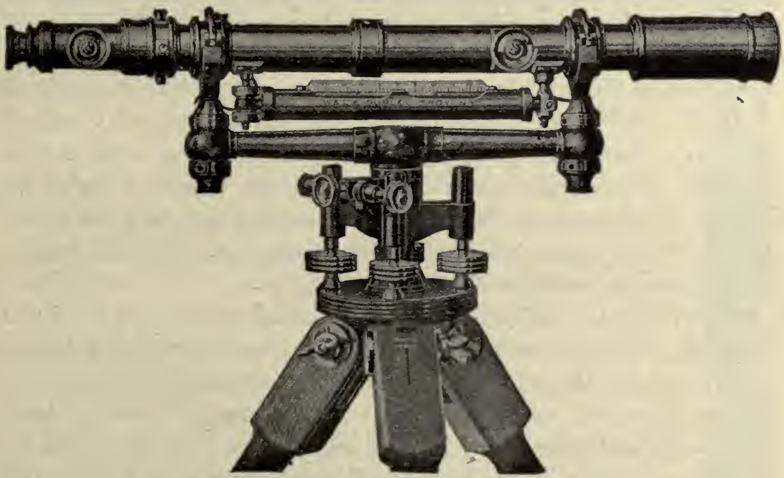


Fig. 100. Line of Levels.

General Discussion. A line of levels are run to determine either the difference in elevation between two distant points, or the elevations of a series of points along a line. The former is called *differential leveling;* the latter, *profile leveling.* In addition to these two kinds of leveling, there is a third, called *reciprocal leveling,* in which between the same two points the level is set up (1) near one of these points, and then set up (2) about the same distance from the other point, sights being taken on the two points at both set-ups; the mean of the two set-ups is taken as the difference in elevation between the two points.

In precise leveling the distance to any back sight and to any front sight at any set-up should be about equal. If the terrain at any place prevents such equal distances being taken—such as, sights across rivers, etc., reciprocal leveling should be employed between the turning points on the border of such places.

Leveling Terms. *Datum:* In all leveling, the elevations of all points are referred to some base level line or plane, com-



*Wye Level

monly called, *datum line* or *datum plane,* whose elevation is assumed to be "O." The datum plane is usually sea level when it is known. When the elevation above sea level of a point on

*Courtesy of W. & L. E. Gurley.

or near a line of levels is unknown, the assumed datum or elevation of the initial point will be such that no point along the line of levels will be below the assumed datum plane. For a line of levels run to any distance the datum plane will really be a spheroid of revolution determined by the sea level, and similarly a datum line, a great circle. For very short distances, the datum may be considered an absolute level plane or straight line.

Plane of Sight: When the level is in adjustment, and is set-up and leveled, the optical axis of the level telescope will determine an imaginary horizontal plane when the level is revolved around its vertical axis. This horizontal plane is called the plane of sight.

Height of Instrument: The elevation of the plane of sight above the datum plane or line, is called the *height of instrument.* It should be observed that the height of instrument is not the elevation of any station; in fact, the level is never set up over a station whose elevation is to be determined. The *height of instrument* less the distance from the ground to the plane of sight, however, would give the elevation of the ground at the point where the level is set up.

Back Sight: A back sight is a reading taken on a level rod held on a station or point of known elevation above the datum in order to determine the elevation of the plane of sight, or height of instrument. Thus, if the elevation of the known station is 900 feet, and the back-sight reading is 5 feet, the height of instrument would be 905 feet.

Front Sight: A front sight is a reading taken on a level rod held on a station or point of unknown elevation, in order to determine the elevation of such station or point, the elevation of the plane of sight, or height of instrument, having been previously determined by a back sight on a station of known elevation. Thus, if the height of instrument is 905 feet, and the front-sight reading is 10 feet, the elevation of the unknown station would be 895 feet. A *front sight* reading may be taken on stations both in front of and behind the instrument station.

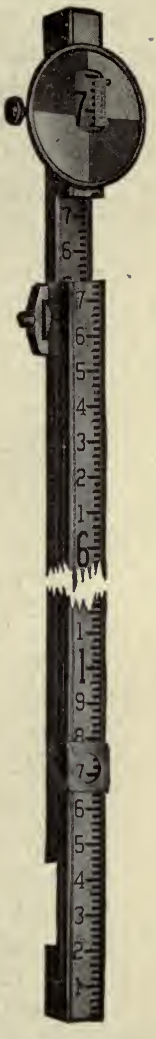
Turning Point (T. P.): A station upon which a front sight has been taken to determine its elevation from one set-up, and a back sight from the succeeding set-up is taken to determine the height of instrument at that set-up, is called a turning point. *Bench Marks (B. M.)* are stations whose elevations have been accurately determined and are marked by monuments or plates.

Intermediate Stations: A station upon which only a front sight is taken to determine its elevation, and upon which no back sight is taken to determine height of instrument, is called an intermediate station. In profile leveling front sights are taken on all critical points along the line of levels to determine their elevation, and all such stations not used as turning points are called intermediate stations.

Signaling: The instrument man must prearrange proper suggestive signaling with the rodmen so that he can control the target setting of the level rod. The following are in general use: the hand above the shoulder, raise the target; the hand below the shoulder, lower the target; waving the hand slowly above the shoulder, raise the target slowly; waving it slowly below the shoulder, lower the target slowly; holding the right arm straight out, plumb the rod to the right; the left arm straight out, plumb to the left; the rod and target correct, bring both hands together over the head and let them fall to the side.

Leveling. *Organization:* A level party will usually consist of at least three men—one instrument man, one front rodman and one rear rodman. If much cutting of underbrush, etc., is necessary, the level party should be increased by the necessary axemen.

Procedure: The level is set up and leveled, at a convenient point with reference to the first station, or bench mark. This set-up should be about midway between the first station, or bench mark, and the first turning point. Thereafter the instrument should be set up about midway between each two turning points. A back sight is taken at each set-up to determine



*Leveling Rod

*Courtesy of W. & L. E. Gurley.

the "H. I.," and a front sight on the next turning point "T. P." to determine its elevation, and the procedure thus continued to the end. If the elevations of intermediate stations are to be determined, front sights on such stations are taken from the nearest set-up. Should the terrain make it necessary to set up near a "T. P.," a reciprocal level between it and the next station should be made. All readings are carefully recorded in the level note book.

FIELD NOTES.

Differential Leveling

Sta.	B.S.	H.I.	F.S.	Elev.	Elev.
B.M.#1	*5.*	*1005.*			*1000.*
T.P.#1	*3.6*	*1003.9*	*4.7*		*1000.3*
#2	*2.1*	*997.4*	*8.6*		*995.3*
#3	*6.2*	*994.3*	*9.3*		*988.1*
#4	*7.4*	*998.5*	*3.2*		*991.1*
	(Reciprocal Leveling between #4 & #5)				
#4	*6.0*	*997.1*	*5.7*	*992.8*	
#5	*11.2*	*1003.9*	*4.5*	*992.6*	*992.7*
#6	*9.6*	*1008.3*	*5.2*		*998.7*
B.M.#2			*3.1*		*1005.2*

Profile Leveling

Sta.	B.S.	H.I.	F.S.	Elev.	Elev.
B.M.#1	*4.*	*929.*			*925.*
Ia			*6.2*	*922.8*	
Ib			*2.1*	*926.9*	
T.P.#1	*2.8*	*921.5*	*10.3*		*918.7*
Ia			*4.6*	*916.9*	
Ib			*12.9*	*908.6*	
Ic			*7.2*	*914.3*	
T.P.#2	*6.3*	*913.7*	*14.1*		*907.4*
B.M.#2			*2.6*		*911.1*

LIMIT OF ERROR. The limit of error in leveling is given by the formula, $E = C \sqrt{M}$, in which E is the error, M the distance in miles, and C a constant depending upon the character and requirement of the work. The value of C, used by the U. S. Geological Survey is .05 for ordinary spirit leveling, and .02, for precise spirit leveling.

STANDARDIZING OF TAPE OR CHAIN

A topographer in the field will seldom have to test a tape or chain unless an accurate base line is to be measured. A tape can be standardized by sending it to the Bureau of Standards, Washington, D. C. Upon the return of this standardized tape, a permanent base line should be at once established for standardizing other tapes, and for testing them from time to time.

Among other things the data from the Bureau of Standards will give (1) the temperature at which the test was made, (2) the tension at which the comparison was made, and (3) the length of the tape corrected for a temperature of 62°.

To Construct a Base of Standardization. A level floor should be selected if possible of the length of the tapes to be tested—100 feet, or 100 yards long. If not, a level concrete side walk may be used. A floor within a building is the best as the temperature can be regulated to 62° F. more easily; while out of doors it is necessary to take advantage of a cloudy or overcast day, and make corrections for temperature. A level surface eliminates the necessity of correcting for sag.

A distance equal to the length of the tape is measured off as accurately as possible. Over the ends of this distance zinc plates 3 or 4 inches square are securely fastened on the floor, with nails or screws, the center of the plates being placed over the end marks. About six inches from one plate, in prolongation to the distance, a L-shaped iron bar is securely bolted onto the floor. The upper arm of this L-shaped iron should be about 1 to 1½ inches high and have a quarter inch hole in it about half way up. Through this hole is placed an iron rod with a hook to catch the end of the tape; the other end of this iron rod (which passes through the hole of the L-iron) is threaded and has a nut by means of which the zero of the tape can be brought into exact coincidence with a scratch on the near zinc plate.

At about 1½ to 2 feet from the other end of the measured distance and in prolongation to it, is fastened another L-iron bar. The hook of the iron rod used here catches the handle of a spring balance and this in turn the handle of the tape. The nut is tightened until the spring balance reads the tension at which the tape was standardized at the Bureau of Standards. A reading glass should be used in bringing the zero of the tape into coincidence with the mark on the first zinc plate. A scratch is then made on the second zinc plate in coincidence with the

100 foot mark on the tape. If it is desired to make this scratch just 100 feet, or yards from the scratch on the first zinc plate, a steel ruler marked in 50ths or 100ths of an inch should be used to make the correction. Two thermometers are attached to the tape, one fourth the distance from both ends, and these thermometers should read 62° F., or correction must be made for contraction or expansion due to difference in temperature from 62° F. The 25 and 50 foot or yard divisions may at the same time be marked on zinc plates fastened to the floor at such places.

By a similar procedure unstandardized tapes may be standardized by using this permanently standardized base. It can be similarly used in testing standardized tapes from time to time.

Determination of Constants of a Tape

The constants of a tape or chain used for making corrections in measuring distances are—(1) the error due to difference in temperatures, (2) the error due to difference in pull, and (3) the error due to sag.

To determine the constant of expansion due to temperature: The tension is kept constant while the length of the tape is measured on a standardized base at different temperatures and recorded, from which the expansion per foot for an increase in temperature for one degree can be calculated. A tape 100 feet long will change about ½ inch in length for a change of sixty degrees F. in temperature.

To determine the constant of expansion due to tension: The temperature of the tape is kept constant while the tape is subject to different tensions (amount of pull), and the length of the tape is measured and recorded at each change in tension, the measurement being made on a standardized base, from which the expansion per foot per pound tension may be computed. A tape 100 feet long will stretch slightly less than 1/100 of an inch per pound pull.

Constant due to sag: The equation commonly used for error due to sag is, $C = \frac{d}{24}\left(\frac{wd^2}{P}\right)$, in which C is the excess in inches in length of sagged tape over the true distance between supporting stakes; d is the distance in inches between supporting stakes; w is the weight in pounds of one inch of the tape; and P is the pull in pounds.

Determination of Stadia Constant

In view of the facts that stadia rods are often broken, and transits are sometimes exchanged while in the field, it is best to make all stadia rods alike and to have the instrument man to determine the stadia constant for the transit which he uses, rather than constructing a stadia rod especially for a transit.

A distance of about 1000 feet is measured off and divided into sections of about 100 feet each. The length of these sections need not be exactly 100 feet, and in fact should not be, but their exact length should be known and recorded.

The transit is set up over an end stake and the transit shifted so that the plumb bob is exactly over the center of stake. The stadia rod is held plumb over each stake, the stadia read and the reading recorded. From these readings and the true distance the stadia constant for the particular transit and stadia rod is obtained. The following table will show the method of determining the constant:

Inst. Sta.	*True Dist.*	*Stadia Reading* — (c + f)	*Difference*	*Per Cent*
2	100	101	1	1.
3	198	199	1	.5
4	299	300.5	1.5	.5
5	402	404	2	.5
6	500	502	2	.4
7	601	604	3	.5
8	699	702	3	.45
9	803	807	4	.5
10	890	894	4	.44
11	1010	1015	5	.5

Stadia Constant = 10)5.29
—.5%

From this constant the following table can be constructed to correct stadia readings:

	0	10	20	30	40	50	60	70	80	90
0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0
100	99.5	109.5	119.4	129.4	139.3	149.3	159.2	169.2	179.1	189.1
200	199.0	209.0	218.9	228.9	238.8	248.8	258.7	268.7	278.6	288.6
300	298.5	308.5	318.4	328.4	338.3	348.8	358.2	368.2	378.1	388.1
400	398.0	408.0	417.9	427.9	437.8	447.8	457.7	467.7	477.6	487.6
500	497.5	507.5	517.4	527.4	537.3	547.3	556.2	566.2	576.1	586.1
600	597.0	607.0	616.9	626.9	636.8	646.8	656.7	666.7	676.6	686.6
700	696.5	706.5	716.4	726.4	736.3	746.3	756.2	766.2	776.1	786.1
800	796.0	806.0	815.9	825.9	835.8	845.8	855.7	865.7	875.6	885.6
900	895.5	905.5	915.4	925.4	935.3	945.3	955.2	965.2	975.1	985.1

Control Traverses

A control traverse is as its name indicates a traverse in which the work done is so accurate that it may be used as the control of other work that may be based upon it.

The transit having been tested for adjustments, and adjusted if found necessary, is set up over the first instrument station, which is usually numbered "O." The set-ups must be very accurately done at each station—the plumb bob brought exactly over the center of the stake marking each instrument station and the bubbles of the level tubes brought exactly to the center of their tubes. The center of the stake can be marked by a tack head or with a cross made with a lead pencil.

The A-vernier of the transit is made to read 0° 00′, and the reading of the B-vernier should be 180° 00′, but due to eccentricity of the scale, or a slight play in the vertical axis this reading may be off one or two minutes, which must be allowed for, as will be explained later on. With the upper limb clamped and the lower limb unclamped the transit is oriented, either by using the magnetic needle or by taking a sun azimuth. The taking of a sun azimuth will also be considered later on.

Now clamp the lower limb, unclamp the upper limb, and sight on the center of the stake of station No. 1. To do this, station No. 1 is occupied by the rodman with a stadia rod. The stadia rod is first held with its edge towards the transit, the left front corner edge being held exactly over the center of the stake; the rodman standing directly behind the rod so as to be in a position to hold it as plumb as possible. When the rod is in the center of the telescopic field of the transit, the upper limb is clamped and by means of the upper tangent screw the vertical cross wire is brought into coincidence with the left edge of the rod—the right edge as the transit man faces. If the stadia rod neither leans to the right nor to the left, the vertical cross wire will be in contact with the rod throughout its length. If it is not, motion the rodman to plumb to the right or left, and then turn the upper tangent screw to bring the vertical wire into coincidence with the stadia rod again, repeating until the vertical wire coincides throughout its length. The top of the stake should be visible in the bottom of the telescopic field when the vertical wire is brought into contact with the stadia rod.

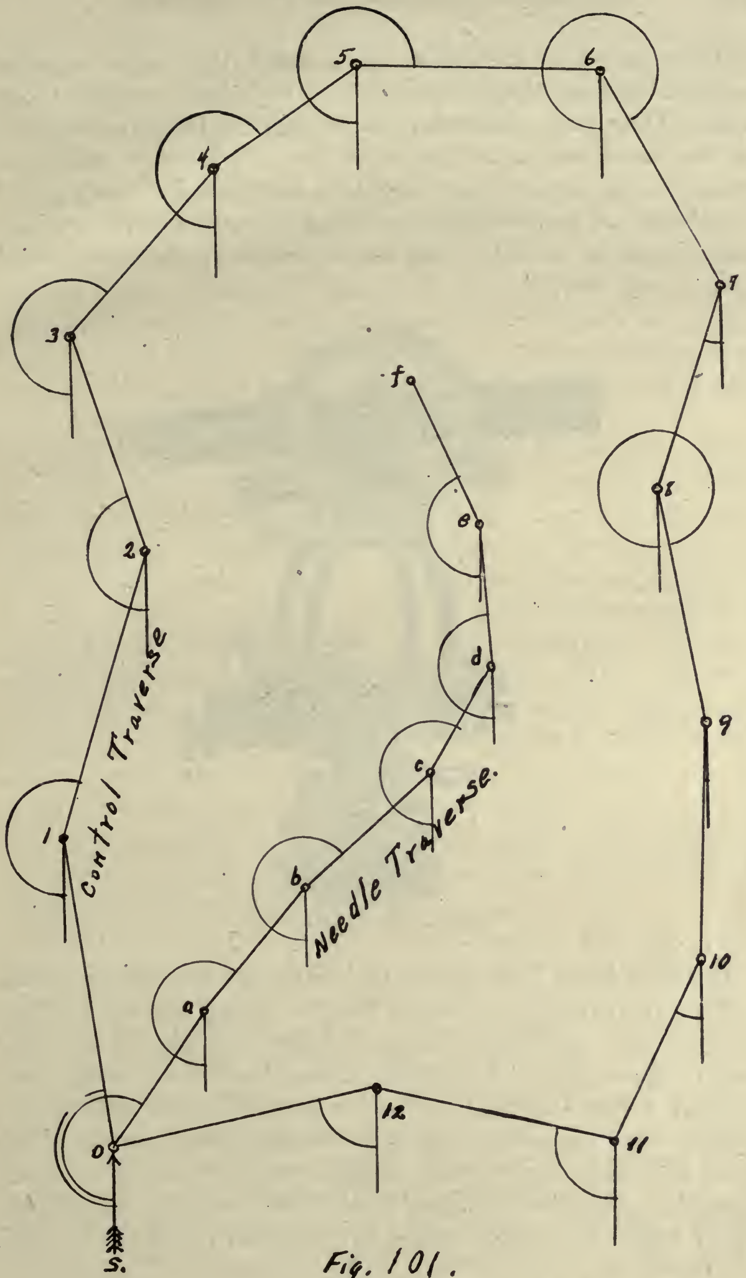
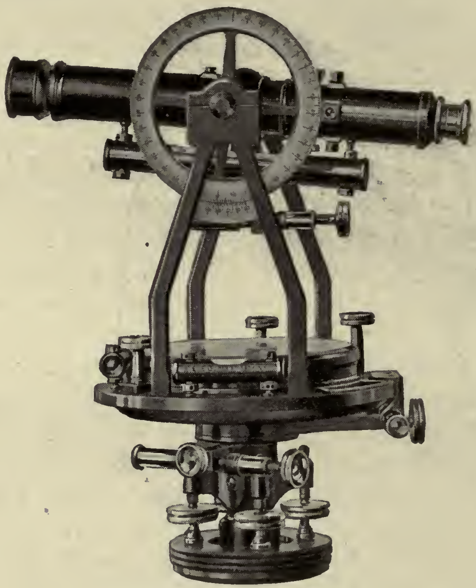


Fig. 101.

The verniers are then read and recorded; the rodman signaled to turn the face of his stadia rod to the front, and the stadia read. The center horizontal line brought to the same elevation on the stadia rod as the height of the transit above the No. O stake, and the vertical angle is read. To determine the height of the transit, a small rod six feet long is carried by the transit man. Read the needle, which should always be done as a check against mistakes.



*Reconnaissance Transit

Unclamp lower limb, loosen the tripod screws, lift the needle, and set up transit over station No. 1. Center the vertical wire on stake No. O, the rear rodman holding the right front corner edge on the center of the stake. Clamp lower limb, using lower tangent screw to bring vertical wire into exact coincidence. *Do not touch upper limb clamp or the upper limb tangent screw.* Read the stadia and vertical angle as a check on the readings from the previous station, and read the B-vernier to see that the upper limb and tangent screw have not been touched through

*Courtesy of W. & L. E. Gurley.

mistake. If the B-vernier does not read the same as when at station No. O, make it do so, and bring the vertical wire into coincidence by using the lower limb and tangent screw. Record readings.

Unclamp upper limb and sight on stake No. 2, read and record both verniers, the vertical angle and the stadia reading and record them. *Do not touch lower limb or the lower limb tangent screw.* Unclamp upper limb and take side shots, reading only the control vernier, the vertical angle and the stadia. Sight back on station No. 2, to see if the verniers read the same as when first sighted on No. 2. If it does not, the lower limb or its tangent screw has been touched.

It will be noticed that the A-vernier at station No. O was the control vernier, and the B-vernier at station No. 1. When the transit is set up at station No. 2 the A-vernier will be in control again, and so on alternately; the A-vernier being in control at even numbered and the B-Vernier at the odd numbered stations. In the record, the vernier in control may be indicated by the proper letter in each case. This alteration of control verniers eliminates errors due to eccentricity of the scale limb.

The following signs can be conveniently used: Right hand straight out to the right, plumb to the right; left hand straight out to left, plumb to the left; hands waved once above the head, turn face of stadia rod towards transit; hands waved twice over head, put rod down; to come in, signal assembly. Other signals may be improvised. A plumb bob and line attached to the stadia rod, is very useful to plumb by.

When the A- and B-verniers are not exactly 180° 00′ apart, there is a constant error that must be corrected; if there is an eccentricity in the horizontal scale this error will be variable. In either case take one half the error and add it to the vernier in control (see record). The stadia reading and vertical angle are read in both directions between two stations, and the mean taken as the most probable true value. It may seem unnecessary to observe all these details in a control traverse, but a traverse of only 20 to 30 stations, will bring home to one the need of the most accurate work at all times. The needle should be read at each set-up to furnish a check on the reading of the verniers.

FIELD NOTES, CONTROL TRAVERSE

			Azimuth			
Fm.	To	Hor. D.	Control	Check	Ver. Ang.	Elev.
0	1	823	A171°12′	350°12′	+ 1°15′	710
1	0	823	B350°12′		— 1°15′	728
1	2	780	196°45′	16°45′	+ 40′	737
2	1	780	A 16°45′		— 40′	
	a	615	75°16′		+ 5°18′	793.8
	b	937	261°43′		+ 1°32′	739.5
2	3	600	160°40′	340°40′	— 15′	735.4
3	2	600	B340°40′		+ 15′	
3	4	580	221°45′	41°43′	— 5′	734.5
4	3	580	A 41°44′		+ 5′	
4	5	464	235°30′	75°30′	— 12′	732.9
5	4	464	B 75°30′		+ 12′	
5	6	650	271°45′	19°45′	— 55′	722.5
6	5	650	A 91°45′		+ 55′	
6	7	650	331°15′	151°15′	— 1°10′	709.3
7	6	650	B151°15′		+ 1°10′	
7	8	560	17°50′	197°50′	+ 4′	710
8	7	560	A197°50′		— 4′	
8	9	630	348°55′	168°55′	+ 9′	711.6
9	8	630	B168°55′		— 9′	
9	10	620	1°32′	181°32′	+ 14′	714.1
10	9	620	A181°32′		— 14′	
10	11	520	27°55′	207°55′	+ 22′	717.4
11	10	520	B207°55′		— 22′	
11	12	636	103°00′	283°00′	— 33′	711.3
12	11	636	A283°00′		+ 33′	
12	0	708	78°45′	258°45′	— 15′	708.2
0	12	708	B258°45′		+ 15′	
0	1		171°11′	351°11′		

Sketcher..Date..
Inst. Man..Transit..
Recorder..Sta. Con..

Bearing.	Remarks.
N 8°45′W	*"O"=710 Elev.*
N16°45′E	
	Side Shot.
	Side Shot.
N19°15′W	
N41°45′E	
N55°30′E	
S 88°15′E	
S 28°45′E	
S 17°45′W	
S 11°00′E	
S 1°30′W	
S 28°99′W	
N77°00′W	
S 78°45′W	

(Control Traverses are plotted from the coördinates of its stations. To do this a base point is so selected that the coordinates of no station will be "O." For Northern Latitudes and Western Longitude, this will be the lower right-hand corner of the plotting sheet. All stations are plotted with reference to this base point. The coördinates of the traverse stations are computed out and adjusted on a Traverse Sheet. The traverse sheet on the following page is of these notes. Coördinates of Base Point, 40°00′ N. Lat., and 100°00′ W. Long.; of Sta. "O," 40°02′ 1518 ft. N. Lat., and 100°03′ 3113 ft. W. Long.; or "Nothing," 17117 ft.—"Westing," 13622 ft.

The difference between North and South Latitudes, which should not be greater than 1 in 300, is divided in two and each half proportioned equally to its respective stations.

The Latitude of a course is equal to its length times the cosine of its bearing; the departure, the length times the sine of its bearing.)

Traverse Sheet

Fm.	To	Azimuth; Distance; Bearing.	Latitude + North	Latitude — South	Departure — East	Departure + West	Coördinates North'gs	Coördinates West'gs
0	*1*	*171°12'*	**(+.3)*	*(—.2)*	*(—.5)*	*(+.5)*	*17117.0*	*13662.0*
		823					*813.6*	*126.4*
		N 8°48'W	*813.3*			*126.4*	*17930.6*	*13788.4*
1	*2*	*196°45'*						
		780					*747.2*	*224.3*
		N16°45'E	*746.9*		*224.8*		*18677.8*	*13564.1*
2	*3*	*160°40'*						
		600					*556.5*	*199.2*
		N19°20'W	*556.2*			*198.7*	*19234.3*	*13763.3*
3	*4*	*221°45'*						
		580					*433.1*	*385.7*
		N41°45'E	*432.8*		*386.2*		*19667.4*	*13377.6*
4	*5*	*235°30'*						
		464					*263.1*	*381.9*
		N55°30'E	*262.8*		*382.4*		*19930.5*	*12995.7*
5	*6*	*271°45'*						
		650					*19.7*	*649.2*
		S88°15'E		*19.9*	*649.7*		*19910.8*	*12346.5*
6	*7*	*331°15'*						
		650					*569.7*	*312.1*
		S28°45'E		*569.9*	*312.6*		*19341.1*	*12034.4*
7	*8*	*17°50'*						
		560					*532.9*	*172.0*
		S17°50'W		*533.1*		*171.5*	*18808.2*	*12206.4*
8	*9*	*348°55'*						
		630					*618.0*	*120.6*
		S11°05'E		*618.2*	*121.1*		*18190.2*	*12085.8*
9	*10*	*1°32'*						
		620					*619.6*	*17.1*
		S 1°32'W		*619.8*		*16.6*	*17570.6*	*12102.9*
10	*11*	*27°55'*						
		520					*459.2*	*244.0*
		S27°55'W		*459.4*		*243.5*	*17111.4*	*12346.9*
11	*12*	*103°00'*						
		636					*143.4*	*620.2*
		N77°00'W	*143.1*			*619.7*	*17254.8*	*12967.1*
12	*0*	*78°45'*						
		708					*137.9*	*694.9*
		S78°45'W		*138.1*		*694.4*	*17116.9*	*12662.0*
			2955.1	*2958.4*	*2076.8*	*2070.3*		
				2955.1	*2079.3*			
Difference by ½				*3.3*	*6.5*			
				1.7	*3.3*			

**1.7 ÷ 6 = .3 = Plus correction for each North Latitude.*
1.7 ÷ 7 = .2 = Minus correction for each South Latitude.
3.3 ÷ 6 = .5 = Minus correction for each East Departure.
3.3 ÷ 7 = .5 = Plus correction for each West Departure.

Back Sight Traverses

Back sight traverses are executed in the same manner as control traverses, except that it is not closed on itself for check. The orientation of the transit is carried forward in the same manner as in control traverses. Back sight traverses are much more accurate than needle traverses, but require more time. Back sight traverses are not corrected for probable errors, and generally plotted directly on the sketching board. The record is kept in the same manner as for control traverses.

Needle Traverses

In needle traverses, the transit is oriented at each set-up by means of the magnetic needle. When oriented, the lower limb is clamped and remains clamped throughout the rest of the set-up. If there is a magnetic declination, the magnetic declination correction scale is so adjusted that when the needle points at its "O," the horizontal scale of the transit is in true azimuth. In passing from one station to another the magnetic needle should always be lifted from its support. Needle traverses are rarely closed and adjusted, and in topographical surveying are used mainly for filing-in work.

To orient with needle: The A-vernier is set at 180° 00′ and the upper limb clamped; the needle is lowered onto its support; the lower limb is unclamped and the transit turned to a position where the needle points at "O," using the lower tangent screw for fine adjustment. A transit so oriented, where there is no local magnetic disturbances, should be within five minutes of the true north, or within a total error range of not more than 10 minutes.

Field Notes of a Needle Traverse

Fm.	To	Hor. Dist.	Azimuth Control	Azimuth Check	V. A.	Elev.	Bearing
						0=710	
0	*a*	*430*	*214°35′*		+ *1°00′*	*717.5*	*N34°30′E*
b	*a*	*420*	*220°00′*		+ *45′*	*723*	*N40°00′E*
b	*c*	*446*	*228°30′*		+ *30′*	*727*	*N48°30′E*
d	*c*	*320*	*210°33′*		— *15′*	*725.7*	*N30°30′E*
d	*e*	*360*	*175°30′*		— *13′*	*724.4*	*N 4°30′W*
f	*e*	*420*	*155°10′*		— *58′*	*719*	*N24°45′W*

Measurement of Base Line (1:100,000)

The selection of a sight for a base line has already been discussed. (See page 54.)

The two ends of a precisely measured base line should be marked by concrete hubs placed sufficiently deep to prevent movement by probable agencies. Having marked the ends, a transit is set up over one of them; the transit is sighted on the distant hub and both upper and lower limbs of the transit are clamped. Stakes are now driven 20 feet apart, "shooting" them in line by means of the transit telescope, and measuring the distance apart by stadia. This operation can be carried on for about 1000 feet, when it will be necessary to move the transit forward, to a stake that has been accurately centered in the line of sight at the preceding set-up. The center of all stakes should, in fact, be in the line of sight.

In using a 100-foot tape, which will usually be the tape used in military surveys, every 100 feet along the base line should be marked by a large stake, about 2″x4″, while the 20-foot stakes between may be about 1″x2″. The top of all these stakes should be of the same elevation, which can be secured by using the transit as a level, while shooting in and measuring distances. To secure this, the stakes are driven to such a depth that the tops are all on the same level; or if it is impossible to do this on account of hard ground, rocks, etc., the stakes may be sawed off at the proper place. It is usually necessary to divide the Base Line into sections of different elevations. In such cases the top of the stakes of each section are all on the same level. The division between adjacent sections of different elevations is determined by a plumb bob and line.

Two small lath nails are driven into each of the smaller stakes, sufficiently apart to allow the tape to have free play when stretched between them. Zinc plates are nailed on the tops of the large 100-foot stakes. For holding the "O" and 100-foot ends of the tape, the same kinds of holders as used in standardizing of tape are used, except they are fastened on heavy planks several feet long, and firmly anchored into the ground at each set-up. At about one-fourth the distance from each end of the steel tape are attached two small thermometers for observing the temperature of the tape at each reading.

The "O" of the steel tape is first brought over the center of the hub of the near end of the base line, using a reading glass to get it there. The tape is then pulled to a uniform tension of 12 pounds, or of any other standard tension; the distance from the 100-foot mark on the tape to the center scratch on the zinc plate of the 100-foot stake, is measured by means of a short steel ruler divided into 50ths of an inch, using a reading glass. The distance between the 100-foot stakes, the tension, and the temperature are of course recorded as announced, and are sufficient for all corrections.

Overcast days are the best for base-line measurements, but such days cannot be waited for. If the above method be carried out carefully and precisely, the Base Line should be within a maximum limit of error of one part in 100,000. Should so accurate a base line not be desired, the degree of precision may be reduced: stakes may be driven only every 50 feet, or 100 feet—the "O" and 100 foot ends, including the spring balance, may be held directly in the hands—the center of the 100 foot stakes may be marked with a pencil, reading glass dispensed with, etc., according to the kind of base line desired.

RECORD OF BASE LINE MEASUREMENTS

Length of Tape Used: *99.935* feet at *15* lbs. tension and *62°* F. Tension used = *12* lbs. Weight of tape per inch = *.003* lbs. Distance between stakes = *20* ft. Cross section of tape = *.01* sq. in.

				Temperature	
Fm.	To	Correction	Minus	Ther. No. 1	Ther. No. 2
ΔA	*1*	*.253*		*70.0°*	*70.0°*
1	*2*		*.346*	*70.2°*	*70.2°*
2	*3*		*.117*	*70.3°*	*70.5°*
3	*4*	*.342*		*70.5°*	*70.6°*
*	*	* *	* *	* *	* *
99	ΔB		*.715*	*65.2°*	*65.1°*
Totals:		*21.214*	*43.186*	*6958.3°*	*6965.5°*
Average:				*69.58°*	*69.66°*
Mean:				*69.62°*	

BASE LINE COMPUTATIONS. The computations of the Base Line whose measurements are given in the preceding paragraph will now be made. This Base Line contains one hundred 100-foot sections, or five hundred 20-foot sections:

Length of Base Lines:		
A 99.935-foot tape used 100 times =	9993.500	Ft.
Plus Corrections =	21.214	"
	10014.714	"
Minus Corrections =	43.186	"
	9971.528	"
Temperature Correction = CL(t-t′), in which C, the coefficient of expansion is taken at .0000065; L, the entire length of tape applied, 9993.5 feet; and (t-t′), (69.62°- 62°) 7.62° =	+ .495	"
	9972.023	"
Tension Correction = Pl ÷ ES, in which P equals the difference in pull used and that at which tape was standardized; l, the length of the tape in inches; E, the modulus of elacticity, 28000000; and S, the cross-sectional area of tape: or (3 × 1200 ÷ 28000000 × .01. This correction is in inches, and the correction for one tape length must be multiplied by 100. =	— .107	"
	9971.916	"
Sag Correction (in inches) $= \frac{d}{24}\left(\frac{wd}{P}\right)^2$, in which d equals the distance between supporting stakes in inches; w, the weight of tape per inch in pounds, and P, the pull in pounds. This correction must be multiplied by 500 to get entire sag in inches, and divided by 12 to reduce to feet, or $\left(\frac{240}{24}\right)\left(\frac{.003 \times 240}{12}\right) \times 500 \div 12 =$	— 1.500	"
True length of Base Line =	9970.416	"

Elevation Correction. If the Base Line has an altitude above sea and it is desired to reduce it to its length or projection at sea level, the following equation is used: $X = \frac{L \times R}{R + A}$, in which X equals the projected length at sea level; L, the length of the Base Line as actually measured and corrected; R, the radius of the earth in feet; and A, the altitude of the Base Line above sea level in feet. Where a Base Line consists of sections of different altitudes their lengths must all be adjusted for sea level, or for a common altitude. R may be taken as 6,378,000 meters.

Base Lines are generally measured at least twice, and if the accuracy required is 1:100000, the above base line upon remeasurement should not vary from 9970.416 feet by more than .1 feet; if 1:10000, then by not more than one foot.

Measurement of Angles in Series

Where it is desired to determine the azimuths to several points from one instrument station, and it is desired to have a check against mistakes, etc., the following method is used. The transit is set up and oriented in true azimuth. With the lower limb clamped throughout, the azimuths to the several points are read in succession, the azimuth to the first point being read again immediately after reading the azimuth to the last point. If the second reading of the azimuth to the first point is the same as the first reading to that point, it can be safely presumed that the lower limb screw and tangent screw have neither been touched throughout the determinations. If they do not read the same, the whole procedure should be repeated until they do. To make the readings more accurate, the telescope may be plunged and the azimuths read in the reverse direction. This latter method is used when reading the azimuths of the adjacent secondary triangulation stations from a primary triangulation station.

Record of Angles Measured in Series

From	To	Dist.	Azimuth Control	Check	V. A.	Elev.
Tel. Direct						
ΔC	*Δ1*		*190° 45′*	*10° 45′*	*—2° 10′*	
	Δ2		*275° 53′*	*95° 53′*	*—1° 41′*	
	Δ3		*356° 17′*	*176° 17′*	*—2° 25′*	
	Δ4		*88° 30′*	*268° 30′*	*—3° 15′*	
	Δ1		*190° 45′*	*10° 45′*	*—2° 10′*	
Tel. Plunged						
ΔC	*Δ1*		*190° 45′*	*10° 45′*	*—2° 10′*	
	Δ4		*88° 30′*	*268° 30′*	*—3° 15′*	
	Δ3		*356° 17′*	*176° 17′*	*—2° 25′*	
	Δ2		*275° 53′*	*95° 53′*	*—1° 41′*	
	Δ1		*190° 45′*	*10° 45′*	*—2° 10′*	

Measurement of Angle by Repetition

In triangulation work, the angles of each primary triangle are required to be measured more accurately than can be done in a single reading with the common transit. In such cases each angle is measured by the method of repetition.

Assuming the transit to be set up at ΔA of a triangle whose other vertices are ΔB and ΔC; ΔB being to the left and ΔC to the right. The A-vernier is set at 0° 00′ with the upper limb clamped; the transit is then sighted on ΔB, clamping the lower limb as soon as sighted and using the lower tangent screw for fine adjustment; with the lower limb clamped, unclamp the upper limb and sight ΔC, using the upper tangent screw for fine adjustment; read the verniers and record, the reading of the control vernier (A-vernier) is the size of the angle ΔAΔBΔC.

Now unclamp the upper limb and sight again on ΔB: if the A-vernier reads 0° 00′, the lower limb has not been moved and the size of the angle is correct for a single reading.

Unclamp upper limb, sight on ΔC again; clamp the upper limb, unclamp the lower limb, and sight on ΔB; clamp the lower limb, unclamp the upper limb and sight ΔC. Repeat this operation five times, and on the last sight on ΔC, read the vernier and record. By this procedure the horizontal scale of the transit has been moved through five times the angle ΔBΔAΔC, and on the last sight, the control vernier (A-vernier) will read five times the angle BAC. Should the angle BAC be greater than 72°, it will be necessary to add 360° to the reading of the control vernier; for the scale reads only to 360°.

Now plunge the telescope and read the angle CAB, and then five times angle CAB, as was explained in the preceding paragraphs. With the telescope plunged the B-vernier will be in control; ΔC will be the first sighted on, and ΔB second. The size of the angle will be 360° minus the reading of the control vernier (B-vernier).

In using a transit reading to minutes, the limit of error will be one minute whether a single reading is taken or an angle five times as great is measured. By reading an angle by multiplying its size by five, therefore, the limit of error is reduced one fifth, or to 12 seconds in this case. The mean of the values thus obtained, is taken as the most probable value of the angle BAC.

In triangulation work, all the angles of a triangle must be measured by repetition and their sum should not vary from 180° 00′ 00″ by 15″. If so, the measurement of the angles must be repeated. The error when less than 15 seconds is distributed equally to the three angles of the triangles.

RECORD OF ANGLES OF TRIANGLE MEASURED BY REPETITION

Fm.	To	Dist.	V. A.	Control	Check
Telescope Direct—Angle ABC:					
ΔB	ΔA		+2° 10′	0° 00′	180° 00′
	ΔC		+3° 36′	48° 10′	228° 10′
	5ABC			240° 49′	60° 49′
Telescope Inverted—Angle CBA:					
ΔB	ΔC		+3° 36′	0° 00′	180° 00′
	ΔA		+2° 10′	311° 50′	131° 50′
	5CBA			119° 11′	299° 11′
Telescope Direct—Angle CAB:					
ΔA	ΔC		+1° 42′	0° 00′	180° 00′
	ΔB		—2° 10′	75° 19′	255° 19′
	5CAB			16° 32′	196° 32′
Telescope Inverted—Angle BAC:					
ΔA	ΔB		—2° 10′	0° 00′	180° 00′
	ΔC		+1° 42′	224° 41′	44° 41′
	5BAC			343° 28′	163° 18′
Telescope Direct—Angle BCA:					
ΔC	ΔB		—3° 36′	0° 00′	180° 00′
	ΔA		—1° 42′	56° 32′	236° 32′
	5BCA			282° 38′	102° 38′
Telescope Inverted—Angle ACB:					
ΔC	ΔA		—1° 42′	0° 00′	180° 00′
	ΔB		—3° 36′	303° 28′	123° 28′
	5ACB			77° 22′	257° 22′

Angle	Mean	Correction		Adjusted Angle
48° 9′ 48″				
48° 9′ 48″	*48° 9′ 48″*	+ 4″	=	48° 9′ 52″
75° 18′ 24″				
75° 18′ 24″	*75° 18′ 24″*	+ *4″*	=	*75° 18′ 28″*
56° 31′ 36″				
56° 31′ 36″	*56° 31′ 36″*	+ *4″*	=	*56° 31′ 40″*
Sum	*179° 59 48″*			*180° 00′ 00″*
Error	*12″*			

Azimuth by Polaris

Procedure. The transit is set up over a stake, leveled, sighted on a second stake at 200 or 300 feet distance, and the lower limb clamped. The A-vernier may be set at 0°00′, or at the estimated azimuth to that stake. When Polaris becomes visible in the evening, the telescope of that transit is sighted on it, the intersection of the cross wires being brought exactly on Polaris. To make the cross wires visible, a light is held at a proper position in front of the object glass to illuminate them. If the intersection is made at the culmination of Polaris, no correction is necessary for the azimuth of Polaris, but if taken

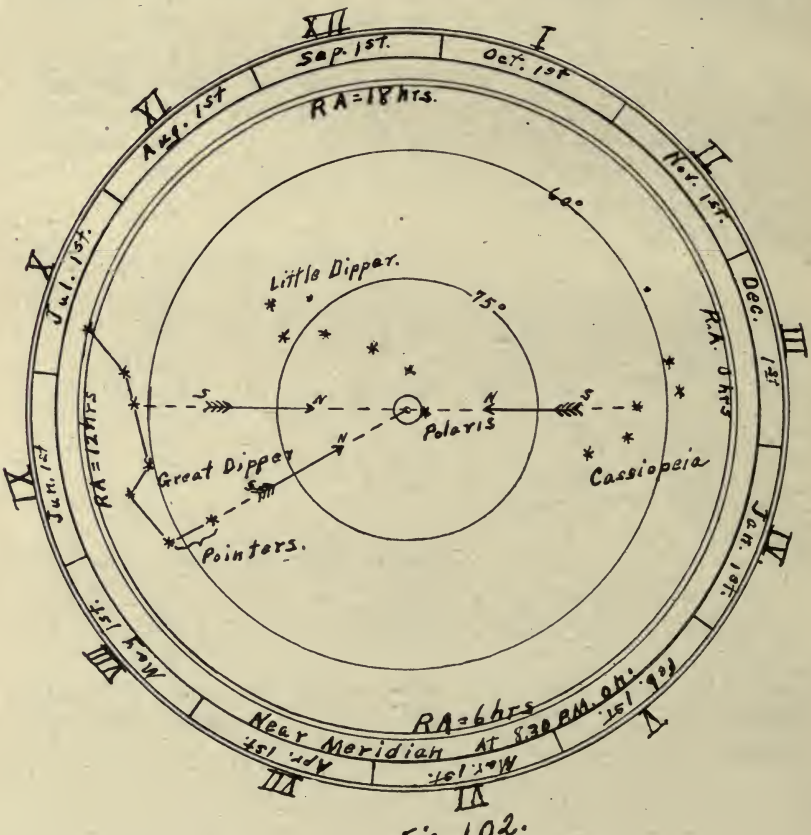


Fig. 102.

Turn circle until current month is on top: the Great Dipper is then shown in its relative position at 8:30 P. M.

at any other time a correction is necessary. Intersection on Polaris taken at elongation, corrected for the azimuth of Polaris at that time, is perhaps the more accurate; for the lateral movement of Polaris is not so rapid and the cross wires can be more easily centered on it.

Throughout the entire procedure the lower limb remains clamped. To sight Polaris, the upper limb is unclamped and the telescope directed on it, the upper limb is then clamped using the upper tangent screw for fine adjustment. The angle at the transit between the distant stake and Polaris, corrected for the azimuth of Polaris at the time of observation, added to or subtracted from 180°00′ according as to whether the distant stake is to the east or west of Polaris, gives the true azimuth between the two stakes.

AZIMUTH OF POLARIS

Clock reading of:			Clock reading of:		
Cass. δ	Ursae Major. z	Azimuth of Polaris.	Cass. δ	Ursae Major. z	Azimuth of Polaris.
12.30	6.30	18′	6.30	12.30	359°42′
1.00	7.00	35′	7.00	1.00	359°25′
1.30	7.30	49′	7.30	1.30	359°11′
2.00	8.00	61′	8.00	2.00	358°59′
3.00	9.00	70′	9.00	3.00	358°50′
4.00	10.00	61′	10.00	4.00	358°59′
4.30	10.30	49′	10.30	4.30	359°11′
5.00	11.00	35′	11.00	5.00	359°25′
5.30	11.30	18′	11.30	5.30	359°42′

In this table the azimuth of Polaris at culmination is considered 0°00′. In most survey work, the azimuth of true north is considered 180°00′, and where so used the azimuths of Polaris as given in this table must be corrected by adding 180°00′ to each of them.

The above table is for the epoch of 1911, but may be used until 1930. The table is good for latitudes 0°-18°, for other latitudes the following corrections must be made, adding the same to azimuths of the left hand column and subtracting from azimuths of the right hand column:

Lat. 19°-30°, 1/10	Lat. 43°-46°, 4/10	Lat. 54°-57°, 7/10
Lat. 31°-37°, 2/10	Lat. 47°-50°, 5/10	Lat. 58°-59°, 8/10
Lat. 38°-42°, 3/10	Lat. 51°-53°, 6/10	Lat. 59°-60°, 9/10

Azimuth by Sun Observation*

Astronomical Terms. For the purpose of astronomical locations of heavenly bodies, the universe is represented by an imaginary sphere whose center is the earth and whose radius is equal to the distance from the earth to the sun. Similar to those of the earth, Great Circles of the celestial sphere are those circles of that sphere whose plane passes through the center of the celestial sphere, or what amounts to the same thing,

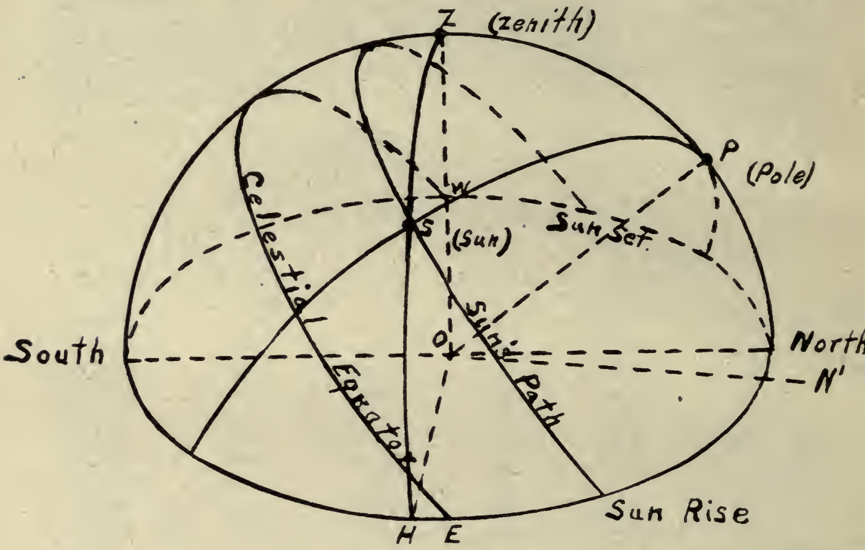


Fig. 103.

those circles of the celestial sphere whose planes pass through the center of the earth. A *Vertical Circle* is a great celestial circle which passes through both the zenith and nadir. The *Equi-Noctial Circle* (ED) is the celestial equator. *Hour Circles* are great celestial circles which pass through the celestial poles; the hour circles correspond to the terrestial meridians of longitude; they are, however, numbered counterclockwise, from "0" to "23," inclusive. The *Vernal Equinox* is the hour circle that is numbered "0"; it is the celestial Greenwich—the meridian on which the sun crosses the equator on March 20;

* In the text North is referred to as N; and South, as S.

the vernal equinox passes through the First of Aries (constellation). The *Meridian* (NZS″) is the great circle which passes through the celestial poles and the zenith. The *Prime Vertical* (HZO) is the great celestial circle which passes through the zenith and nadir perpendicular to the Meridian.

The *Altitude* of a star is its angular elevation above the horizon; the *Zenith Distance* of a star is the angular distance between it and the zenith; altitude + zenith distance = 90°. The *Declination* of a star is its angular distance north or south of the celestial equator, measured along its hour circles; the *Polar Distance* of a start is its angular distance from a celestial pole, measured along its hour circle; declination + polar distance = 90°. The *Hour-Angle* of a star is the angle between the meridian and the hour circle of that star, measured from the meridian eastward to the hour circle. The *Right Ascension* of a star is the angle between the vernal equinox and the hour circle of that star, measured counterclockwise. The *Azimuth* of a star is the angle at the zenith between the meridian and the vertical circle of that star measured clockwise from the true south; it is also the angle between the plane of the meridian and the plane of the vertical circle, which is of course the same. The *Amplitude* of a star is the angle at the zenith between the prime vertical and the vertical circle of that star; azimuth ± amplitude = 90° or 270°.

Time. The *Solar Day* at any place is determined by the two successive transits of the meridian at that place by the Sun. Since the motion of the sun in right ascension is not the same throughout the year, but varies constantly, the length of the solar day throughout the year is not constant. The *Apparent Solar Time* is the time shown by a sun dial: *Greenwich Apparent Noon* is the exact moment at which the Sun transits the Greenwich meridian. The *Mean Solar Day* is the average length of the solar days of the year. The difference in time between the apparent solar day and the mean solar day is called the *Equation of Time* for that day, and this equation of time for each day is given in the Solar Ephemeris Tables. In taking sun observations for azimuths, mean solar time must be changed to apparent solar time.

General Principles. If in Fig. 103, we know the azimuth of a star, or the sun, which is S″OH, or its equal S″ZH, and at O measure this angle, or azimuth, from S, we shall have a true north and south line, ON, which is the projection of the celestial meridian on the earth. In practice this cannot be done accurately, for the azimuth of the stars and the sun are constantly changing throughout the day. An auxiliary point N′ is selected as near the north as can be estimated: the angle N′OH is taken at a particular moment, at which moment the altitude of the star is also taken. From this data the spherical triangle SZP is solved for the angle PZS, or its equal NOH, the true azimuth of the sun at the instant the observation was taken. It is evident that N′OH — NOH is the angular difference between the estimated and the true north. By subtracting or adding this angular difference N′OH, according as to whether N′ is to the west or east of true north, the true position of ON, or true north, is obtained. Corrections must be made for refraction, etc., which will be taken up later.

Solution of the Astronomical Triangle. The astronomical triangle, SZP, can be solved by any of the several proper trigonometric formulæ. The following formulæ are recommended.

$$\text{Tan } \tfrac{1}{2}Z = \sqrt{\frac{\sin (s - PN) \sin (S - HS)}{\cos s \cos (s - SP)}} \text{ ; or,}$$

$$\text{Cos } \tfrac{1}{2}Z = \sqrt{\frac{\cos s \cos (s - SP)}{\cos PN \cos HS}} \text{ ; or,}$$

$$\text{Cos } A = \frac{+ \cos PS}{\cos PN \cos HS} - \tan PN \tan HS\text{; or,}$$

$$\text{Cot } \tfrac{1}{2}A = \sqrt{\sec s \sec (s - SP) \sin (s - HS) \sin (s - PN)}.$$

Z is the angle SZP, or angle HON, or the azimuth of the star or sun from the true north.

A is the angle between the south and the sun, measured counterclockwise.

PN is the latitude of the station of observation, and for any station is constant.

HS is the altitude of the sun, and is measured directly by the vertical scale of the transit: it must, however, be corrected for refraction.

SP is the north polar distance of the sun at the moment of observation: it is obtained by adding or subtracting the declination of the sun to or from 90°. The declination of the sun for Greenwich apparent noon is obtained from ephemeris tables.

$s = \frac{1}{2}(HS + PN + SP)$.

PARALLAX AND REFRACTION. A line from a star to the center of the earth and a line from the same star to the station of observation forms a small angle, called the parallax of the star: the size of this angle depends upon the latitude of the station of observation, but since it is never more than 9 seconds, it may be disregarded.

Refraction is the divergence of the rays of light from the sun as they pass through air of increasing density in approaching the surface of the earth. Refraction is greater when the rays of light enter the air at an angle, as in the early morning or late afternoon, and is less when they enter perpendicularly, as at near noon. At noon, there is only meridional refraction. Observations for sun azimuth should not if it can be avoided be taken before 9 A.M. and after 3:00 P.M.

In the Nautical almanac and Ephemeris, published by the Naval Observatory, will be found tables giving the refraction for one, two, three, and four hours before and after noon for each day for the 40th latitude and factors of correction for other latitudes. This correction is negative and is subtracted from the altitude of the sun as observed and read from the transit.

DECLINATION. The declination of the sun at Greenwich apparent noon is given for each day of the year in the Nautical Almanac: the hourly change in declination for each day is also given. From the difference in time between Greenwich and the station of observation, the declination of the sun at the moment of observation can be computed. If the station of observation is on the 75th, 90th, 105th, or 120th meridian of longitude, the difference in time will be 5, 6, 7, or 8 hours, respectively, from Greenwich. Should the longitude be other than these meridians, it will be necessary to add or subtract the proper correction for difference in longitude, which is 4 minutes in time for each degree of longitude.

An example in the determination of declination will now be given. What was the declination of the sun at 9:00 A.M., June 15, 1913, at a point on the earth whose longitude is 100° West?

From the Ephemeris Table the declination of the Sun on this day at Greenwich apparent noon was 23°18′18.9″ North: the hourly difference in declination 6.75″. The 100th meridian will be transited by the sun 6 hours and 40 minutes after Greenwich shall have been transited ($100° \times 4' = 400'$, or 6 hours and 40 minutes). At 9:00 A.M., therefore, the sun will be 3 hours and 40 minutes past the Greenwich prime meridian. In 3 hours and 40 minutes, the change in declination will be $3\frac{2}{3} \times 6.75'' = 24.75''$. Since at this time of the year the Sun is traveling towards the north, this correction must be added to the declination of the Sun for Greenwich apparent noon on this date. $23°18'18.9'' + 24.75'' = 23°18'43.65''$, is therefore the declination of the Sun at 9:00 A.M. for the 100th meridian on this date. The apparent time for this date must be corrected by $+ 7.9''$ (from same table), which gives 23°18′51.55″, as the corrected declination.

METHOD OF OBSERVATION. The sun cannot be sighted through the telescope without injury to the eyes, unless the object glass is smoked, which is undesirable. If, however, the telescope is pointed at the sun, so that the sun rays will pass through the telescope, the image of the sun can be caught on a white screen or cardboard held five or six inches from the eyepiece of the telescope. Images of the cross wires will also show on the cardboard, and appearance of the cardboard with the images will be as shown in the diagrams in the "Record" below.

The transit must be in adjustment, and is set up at the point desired: an auxiliary point N′, such as a tree or fence post with a point marked on it can be selected as the estimated north point. The A-vernier is set to read 180°00′: the lower limb is unclamped and the transit is sighted on the point on N′, using the lower tangent screw for fine adjustment: read the A-vernier to see that it still reads 180°00′.

With another man holding the cardboard to catch the images from the telescope, bring the Sun's image into the first quadrant, the upper limb and vertical axis being unclamped: when near the intersection of the central cross wires, clamp both the upper limb and the horizontal axis, and bring the edge of the sun's image in contact with both wires simultaneously, using the upper tangent screw and the vertical tangent screw. The contact will be for a moment only, as the movement of the sun's image across the field is perceptible. Just before the contact, the instrument man should say, "Ready," and at the exact instant "Take." The recorder takes the time, observing the number of seconds, and records it. The instrument man reads the A and B verniers and the vertical angle, the recorder recording the readings as announced. Another observation is taken with the image of the sun in the 3rd quadrant. The transit should then be sighted back on N′ to see that the A-vernier still reads 180°00′, and this is done after every set of readings. It is very easy to touch the lower clamp or tangent screw by mistake, and if so, it is necessary only to repeat the work since the previous check: otherwise the whole work must be rejected. The telescope is then plunged and the image of the sun first brought into the 2nd quadrant and then into the 4th quadrant. When the telescope is plunged, the B-vernier will be in control. If, when the telescope is plunged and sighted on the point on N′, the B-vernier does not read 180°00′ exactly, it is better to note the difference from 180°00′ and apply it as a correction to the subsequent readings of the verniers while the telescope is plunged, rather than setting the B-vernier to read 180°00′ and bringing the telescope onto the point by using the lower tangent screw.

If it is desired four sets of readings may be taken. In the first set, the telescope is normal and the sun's image is brought in the 1st and 3rd quadrants: in the second set, the telescope is inverted and the sun's image is brought into the 2nd and 4th quadrants: in the third set, the telescope is inverted and the sun's image brought into the 1st and 3rd quadrants: in the fourth set, the telescope is normal and the sun's image is brought into the 2nd and 4th quadrants. Where a sun azimuth is taken in a control traverse all four readings will generally be taken in rapid succession. In triangulation work, however, the first two sets of readings will generally be taken in the morning, while the second two will be taken in the afternoon, at about an equal time from noon.

FIELD NOTES OF SUN AZIMUTH

The Field Notes of a Sun Azimuth should be kept in the following manner: (Assumed azimuth from Sta. O to Sta. N′, 180°00′).

Quadrant		Time	Azimuth to Sun		Altitude	Bearing
			Control	Check		
		hr. m. s.				
			Set I, Direct			
	1st:	*10.45.15*	*321°30′*	*141°30′*	*27°56′*	*S46°30′E*
	3rd:	*10.47.41*	*322°45′*	*142°45′*	*27°25′*	*S45°15′E*
	Sums:	*21.32.56*	*644°15′*		*55°21′*	*90°45′*
	Means:	*10.46.28*	*322° 7′30″*		*27°40′30″*	*S45°22′E*
			Set II, Reversed			
	2nd:	*10.51.29*	*323°23′*	*143°23′*	*28°30′*	*S44°35′E*
	4th:	*10.53.33*	*323°10′*	*143°10′*	*28°15′*	*S44°10′E*
	Sums:	*21.44. 2*	*646°33′*		*56°45′*	*88°45′*
	Means:	*10.52.31*	*323°16′30″*		*28°22′30″*	*S44°22′E*
			Set III, Reversed			
	1st:	*10.55.15*	*323°32′*	*143°32′*	*28°58′*	*S44°30′E*
	3rd:	*10.58.16*	*325°00′*	*145°00′*	*28°58′*	*S43°00′E*
	Sums:	*21.53.31*	*648°32′*			*87°30′*
	Means:	*10.56.45*	*324°16′*		*28°58′*	*S43°45′E*
			Set IV, Direct			
	2nd:	*11.02.59*	*326°10′*	*146°10′*	*30° 5′*	*S41°50′E*
	4th:	*11.04.21*	*325°46′*	*145°46′*	*29°45′*	*S42°15′E*
	Sums:	*22.06.20*	*651°56′*		*59°50′*	*84° 5′*
	Means:	*11.03.40*	*325°58′*		*29°55′*	*S42° 2′E*

The "means" from the field note sheet are transferred to a Sun Azimuth Sheet and the computations made thereon.

Latitude:	*28° 40′ 00″* N.	From *Station "O"* to *Station "N′."*
Longitude:	*100° 30′ 00″* W.	Assumed Azimuth: *ON′, 180° 00′.*
Date:	*December 24, 1915*	Watch *5 min. fast* for *90th* Mer. T.

SUN AZIMUTH COMPUTATION

	Set I, Direct	Set II, Reversed	Set III, Reversed	Set IV, Direct
Altitude	*27°40′30″*	*28°22′30″*	*28°58′00″*	*29°55′00″*
Refraction[1]	— *1′24″*	— *1′23″*	— *1′22″*	— *1′21″*
True Altitude = SH	*27°39′ 6″*	*28°21′ 7″*	*28°56′38″*	*29°53′39″*
True 90th M. Time[2]	*10.41.28 A. M.*	*10.47.31 A. M.*	*10.52.45 A. M.*	*10.58.40 A. M.*
Diff. in Time[3]	— *.42*	— *.42*	— *.42*	— *.42*
Local M. Time[4]	*9.59.28 A. M.*	*10.05.31 A. M.*	*10.09.45 A. M.*	*10.16.40 A. M.*
Hours past G. N.[5]	4⅔ *hrs.*	4⅔ *hrs.*	4⅔ *hrs.*	5 *hrs.*
Hourly Difference[6]	*2.42″*	*2.42″*	*2.42″*	*2.42″*
Total Difference	*11″*	*11″*	*12″*	*12″*
SP — from table[7]	*113°26′11″*	*113°26′11″*	*113°26′11″*	*113°26′11″*
True SP	*113°26′22″*	*113°26′22″*	*113°26′23″*	*113°26′23″*
True SH	*27°39′ 6″*	*28°21′ 7″*	*28°56′38″*	*29°53′39″*
Latitude = PN	*28°40′00″*	*28°40′00″*	*28°40′00″*	*28°40′00″*
2s	*169°45′28″*	*170°27′29″*	*171° 3′ 1″*	*172°00′ 2″*
s	*84°52′44″*	*85°13′45″*	*85°31′31″*	*86°00′ 1″*
A[8]	*37° 1′46″*	*35°53′20″*	*34°52′20″*	*33° 9′ 6″*
Azimuth of Sun[9]	*322°58′14″*	*324° 6′40″*	*325° 7′40″*	*326°50′54″*
Angle N′ to Sun[10]	*142° 7′30″*	*143°16′30″*	*144°16′00″*	*145°58′00″*
Azimuth ON′	*180°50′44″*	*180°50′10″*	*180°51′40″*	*180°52′54″*
Avg. Azimuth ON′	*189°51′22″*	Data observed by		
True earing, ON′	*N 0°51′22″ E*	Data recorded by		
Mag. Bearing ON′	*N 8°50′00″ E*	Computed by		
Mag. Declination	*N 8° 1′00″ E*	Checked by		

[1] From the Ephemeris Tables, the refraction correction of the Sun's altitude for Latitude 40° is 2′20″ at two hours before noon, the time of observation. From the same tables, the Latitude Coefficient for 20°40′ is 61. The refraction correction is the product of the refraction correction for 40° N. Lat. times the latitude of the station of observation.

[2] True 90th Meridian Time, which is Central Standard Time, is 6 hours earlier than Greenwich time; i.e. the sun transits the Greenwich ("0") Meridian six hours before it transits the 90th Meridian. The watch used was 5 minutes fast: this amount was mentally subtracted from the time given in the field notes in transferring to Sun Azimuth Sheet.

[3] Difference in time in minutes is found by dividing difference in longitude in degrees by four.

[4] Local Mean time is obtained from Standard Time by adding or subtracting the difference in time as found from the difference in longitude; adding if east of Meridian of reference, subtracting if west.

[5] Hours past Greenwich noon means from the moment of observation.

[6] Hourly difference in declination of the Sun is found in the solar ephemeris tables for any day of the year; if on the date of observation the Sun is traveling towards the equator, this correction is subtracted; if away from equator, added.

[7] The declination of the Sun for every day at Greenwich Noon is given in the solar ephemeris tables. This declination plus or minus 90° gives the North Polar Distance of the Sun: plus if the Sun is south of the equator, minus, if north.

[8] A, the angle between the south and Sun measured counterlockwise, can be obtained from either of the two formulæ on page 250, but the one giving A in its cosine is recommended. If blank forms are used for the computation of sun azimuths, lines should be provided for the log of each factor of the equation used, etc.

[9] The azimuth of the Sun is here obtained by subtracting the angle A from 360°.

[10] The angle N′ to the Sun is obtained by subtracting 180° from the azimuth of the Sun as read from the Transit.

By subtracting the angle N′ to Sun from the true azimuth of the Sun, the true azimuth of O to N′ is obtained; take the average as the more probable value.

The Magnetic Declination can also be determined by reading and recording the Magnetic Bearings.

Latitude, Longitude, and Azimuth Determination by the Solar Attachment*

General Explanation of the Solar Attachment. There are two solar attachments, the Burt and the Telescopic. The former is attached to the telescopic axis, and the latter, to the telescopic standards, as shown in the illustrations of them. The solar attachment has three scales: the hour circle, the declination arc, and the latitude arc. In the Burt Solar attachment, while the attachment itself does not contain a latitude arc, the vertical limb of the transit is utilized as such. Vertical limbs which are made especially to be used in conjunction with the Burt Attachment have two rows of numbers: the lower set which are for vertical angle measurements represents the co-latitude of the instrument station; the upper, the latitude (90° minus latitude equals co-latitude). The theory of the Attachment depends upon the facts that when the Latitude Arc is set to read the co-latitude (or latitude, depending upon the vertical scale used) ; the Declination Arc set to read the declination of the Sun for the day and hour corrected for refraction; and the Hour Circle set to read the apparent time—then the ray of light from the Sun will pass along the optical axis of the Attachment. The Burt Attachment has a lense and silver plate, while the Telescopic Attachment has a lense and a prism, the silver plate or prism acting as a screen to catch the image of the sun formed by the lense. This silver plate and prism contain two vertical parallel lines and two horizontal lines which intersect and form a square which is just large enough to include a circular image of the Sun. When the circular image coincides with the four sides of this square at the same instant, then the ray of light from the Sun and the optical axis of the Attachment exactly coincide. When the sun is north of the equator, the Declination Arc of Attachment is towards the Sun, and when the Sun is south of the equator, the Declination Arc points away from the Sun. For these reasons, each end of the Burt Attachment is furnished with a lense and silver plate, in order that the Attachment can be used either way.

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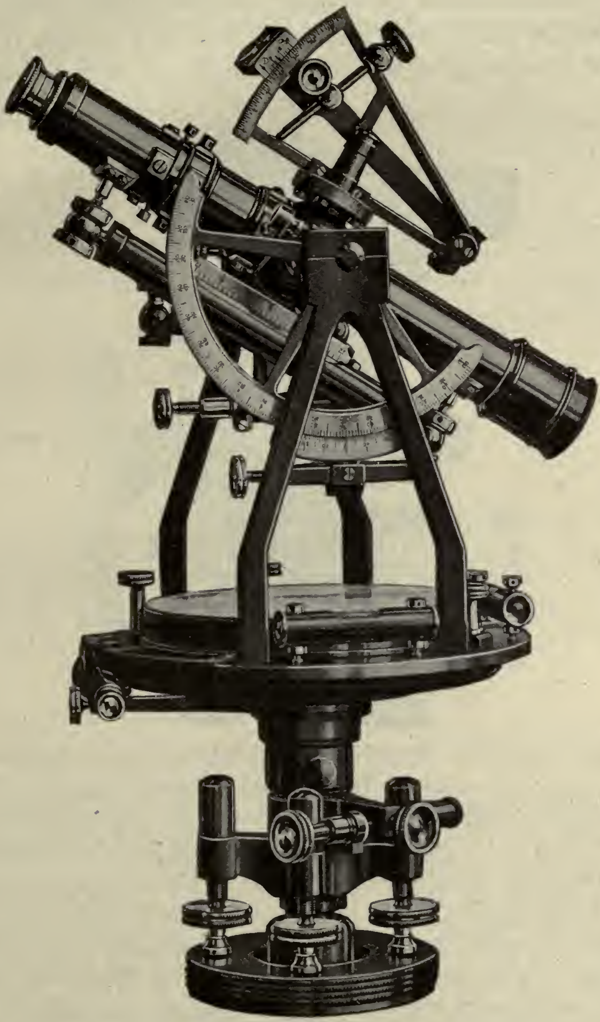
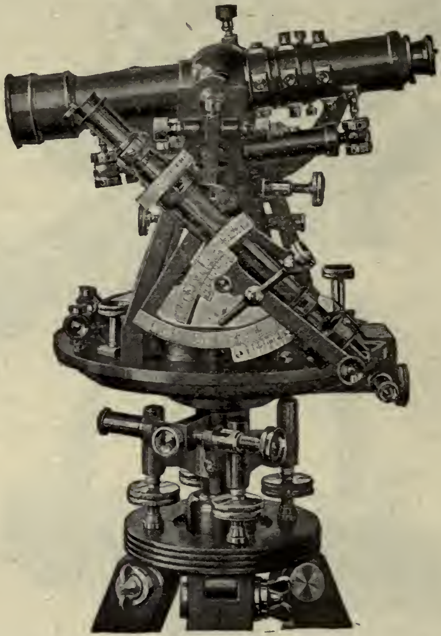
* For a more complete description of the solar attachment and its uses, see *Gurley's Manual*, published by W. & L. E. Gurley.



Surveyor's Transit with Burt Solar Attachment
Courtesy of W. & L. E. Gurley.

Under the above conditions, having one condition unknown, it may be determined by making the other adjustments, and adjusting the unknown condition until the ray of light from the Sun and the optical axis of the Solar Attachment coincide.



*Light Mountain Transit with Telescopic Solar Attachment

"When the telescope is set horizontal by its spirit level, the hour circle will be in the plane of the horizon, the polar axis will point to the zenith, and the zeros of the vertical arc and its vernier will coincide. If we incline the telescope, directed north, the polar axis will descend from the direction of the zenith. The angle through which it moves [when the polar axis is directed on the north pole of the heavens], being laid off on the vertical arc, will be the co-latitude of the place where the instrument is used, the latitude itself being found by subtracting this number from ninety degrees."†

To Find the Latitude. "Level the instrument very carefully, using the level of the telescope, until the bubble will

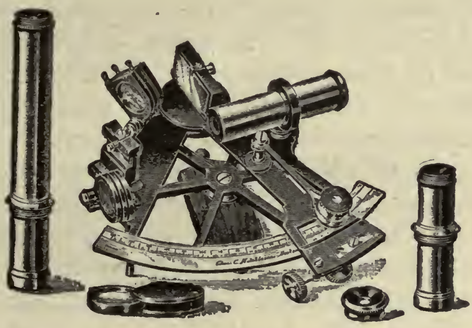
*Courtesy of W. & L. E. Gurley.

†Page 97, *Gurley's Manual.* Courtesy of W. & L. E. Gurley.

remain in the middle during a complete revolution of the instrument, the tangent movement of the telescope being used in connection with the leveling screws, and the axis of the telescope being firmly clamped.

"Clamp the vertical arc, so that its zero and the zero of its vernier coincide as near as may be, and bring them into exact line by the tangent screw of the vernier.

"Set off upon the proper arc the declination of the sun for noon of the given day, corrected for the meridional refraction, note the equation of time, and fifteen or twenty minutes before noon direct the telescope to the north and lower the objective



*Sextant

end until the sun's image can be brought nearly into position between the equatorial lines [the two horizontal lines on the silver plate or prism], by moving the instrument upon it, its spindle and the declination from side to side.

"The declination arc being brought directly in line with the telescope, clamp the axis, and with the tangent screw of the telescope axis bring the image precisely between the lines, following the sun's motion as the image runs below the lower equatorial line, or, in other words, as long as the sun continues to rise in the heavens.

"When the sun reaches the meridian the image will remain stationary in altitude for an instant, and will then begin to rise on the plate.

*Courtesy of W. & L. E. Gurley.

"The moment the image ceases to run below is apparent noon, when the index of the hour arc should indicate XII, and the latitude be determined by the reading of the vertical arc."*

To Find the Longitude. In order to use the Solar Attachment for determining longitude, it is necessary to have some standard meridian time. A good watch adjusted to all positions and climatic conditions carrying standard time will do. The Naval observatory time is sent out from Washington over the Western Union lines at 12 M. Eastern time: it reaches all points in the Central Time belt at 11.00 o'clock; in the Mountain Time belt at 10.00 o'clock; and in the Pacific Time belt at 9.00 o'clock, A.M. Standard (Solar) Time, by which the watch can be daily checked at a Western Union office. Should this be impracticable, as where a party is in the field, I would recommend the following procedure: Select an easily recognized star that transits the meridian near the zenith, and two solid objects that are at least 50 yards apart and that are in line with the selected star when it sets. Those objects may be a fence post and cone of a roof, or a distant sharp ridge. As soon as may be observe the time, which is perceptible, that the selected star falls below the line of sight determined by the two selected objects; record the date and the time in seconds. This star will set below this line of sight approximately 3′56″ later every night, and the watch can be daily checked by it. Thus, should the time of setting have been 8.13′22″ P.M. the first time, ten days later it will set 39′20″ later, or at 8.52′42″ P.M.

To find the longitude by means of the Solar Attachment, the same procedure is followed as in finding the latitude, as explained above, except that at "the moment the image ceases to run below," which is apparent noon at the place of observation, the time is recorded to seconds. The difference between this recorded time and XII o'clock, corrected for the equation of time for the day of observation as shown in the Solar Ephemeris tables, is the true difference in time between the place of observation and the meridian of reference. This difference in time can be changed to difference in longitude (one hour equals 15° of longitude), from which the longitude of the place of observation is easily computed.

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* Page 112, *Gurley's Manual*. Courtesy of W. & L. E. Gurley.

To Find the True Azimuth. When the latitude is determined as explained above, at the moment of apparent noon, the telescope will point either towards the true north or true south, depending upon whether the sun is north or south of the equator. Therefore, if the A-vernier is set to read 180° when the sun is north of the equator, and 0° when the sun is south, and at the moment of apparent noon, as determined, the lower horizontal limb of the transit is clamped, then the transit is exactly oriented in true azimuth.

Determinations of Latitude, Longitude, and Azimuth at other Times than at Apparent Noon. The same procedure is followed as above explained, except the following: The hour circle is set to read the apparent time at which the observation is to be made (this circle reads to five minutes); the declination is set for the declination at the hour of observation of the day corrected for the refraction for that time: the A-vernier is set to read 180° when the sun is north of the equator, and 0° when south: the lower limb is unclamped and the transit oriented by compass as near as may be, it is then clamped and the image of the sun is brought into the square of the silver plate by means of the lower limb tangent screw and the vertical tangent screw. At the moment the image of the sun is brought into the square, the transit will be oriented in true azimuth and the vertical scale will read the co-latitude of the place of observation. If either the true azimuth or latitude be known the procedure is much simplified, for the transit can be at once oriented in true azimuth, or the co-latitude set on the vertical scale, requiring the motion of only one screw of the transit to bring the image into the square on the silver plate of the Solar Attachment.

The declination of the sun for Greenwich or Washington apparent noon only for each day is given in the Ephemeris Tables. The hourly difference in declination, however, for each day is also given, from which the declination for other hours than at apparent noon can be computed.

*To Compute the Declination. "Suppose the corrected declination is desired for the different hours of October 15, 1912, at Troy, N. Y. The latitude is 42° 44′. The longitude is

Gurley's Manual.

practically five hours: so that the declination given in the Ephemeris for apparent noon of that day at Greenwich would be that for 7 A.M. at Troy, or five hours earlier. Note carefully the algebraic signs. The declination is south or minus. Its hourly difference is minus. The refraction always plus. Hence we use the algebraic sum, thus:

S 8°28′56″.5 is the tabular declination for 7.00 A. M.
55″.6 = hr. diff.
8°29′52″.1 + ref. (4 hrs.) 2′29″ = — 8°27′23″, 8.00 A. M.
55″.6
8°30′47″.7 + ref. (3 hrs.) 1′39″ = — 8°29′09″, 9.00 A. M.
55″.6
8°31′43″.3 + ref. (2 hrs.) 1′19″ = — 8°30′24″, 10.00 A. M.
55″.6
8°32′38″.9 + ref. (1 hr.) 1′07″ = — 8°31′32″, 11.00 A. M.
55″.6
8°33′34″.5 + ref. (0 hr.) 1′07″ = — 8°32′27″, 12 M.
55″.6
8°34′30″.1 + ref. (1 hr.) 1′07″ = — 8°33′23″, 1.00 P. M.
55″.6
8°35′25″.7 + ref. (2 hrs.) 1′19″ = — 8°34′07″, 2.00 P. M.
55″.6
8°36′21″.3 + ref. (3 hrs.) 1′39″ = — 8°34′42″, 3.00 P. M.
55″.6
8°37′16″.9 + ref. (4 hrs.) 2′29″ = — 8°34′48″, 4.00 P. M."

To know whether to add or subtract the hourly difference in declination it is only necessary to observe whether the daily declination is increasing or decreasing. The abbreviation "ref" above means "refraction." A tabular table can be made in which the columns represent the hours—VIII, IX, X, XI, XII, I, II, III, IV; and the lines, the days of the month; and the declination for each hour placed in the proper square. These tabular tables, a complete month on each sheet, can be mimeographed or printed in the office and furnished to the field parties. The Ephemeris Table includes the following for each day of the year: the date, the Sun's apparent declination, the hourly difference in declination, the equation of time to be added or subtracted from the apparent time, and the refraction correction for Lat. 40° for each hour of the day time. The refraction correction for other latitudes is found by multiplying its latitude coefficient by the refraction correction for 40°. The Ephemeris Table also includes a table of latitude coefficients.

ACCURACY AND USE OF THE SOLAR ATTACHMENT. Latitude and longitude determined at the apparent noon are, of course, the more accurate. By using a magnifier to observe the sun's image an error of one quarter of a minute in azimuth or latitude has been detected.* This for Lat. 40° gives the true latitude within about 1500 feet; and a like error for longitude, within about 1100 feet. These maximum limits of errors are too great for geodetic work, but is sufficient for reconnaissance and exploratory surveys.

Where the topographer uses a transit equipped with the Solar attachment and a sketching board, and is furnished with a table of computed declinations, he can, with a little practice, more quickly and accurately determine true azimuths for the orientation of his transit, than orientating by compass aided by "three-point solutions"; the oscillations of the compass and trials to reduce the triangle of error to a point, always consuming considerable time. Azimuths determined by the solar attachment any hour of the day are sufficient for all topographical operations.

†ADJUSTMENTS OF THE SOLAR ATTACHMENT. *Solar Lenses and Lines:* "Detach the declination arm by taking off the clamp and tangent screws, and removing the center by which the arm is pivoted on the arc.

"Substitute for the declination arm upon the attachment the adjusting bar furnished with every solar instrument, the center of the declination arm fitting into the hole at one end of the bar, and the bar being further secured to the attachment by the clamp screw passing through the hole in the declination arc left by the removal of the tangent screw, into the threaded hole at the other end of the adjusting bar, thus forming a support upon which the declination arm can be adjusted.

"Place the declination arm on the adjuster, turn one end to the sun, and bring it into such a position that the image of the

* Page 100, *Gurley's Manual*, which see.
†Pages 124-126, *Gurley's Manual.* Courtesy of W. & L. E. Gurley.

sun is made to appear precisely between the equatorial lines on the opposite plate.

"Carefully turn the arm over, until it rests upon the adjuster by the opposite faces of the rectangular blocks, and again observe the sun's image. If it remains between the lines as before, the arm is in adjustment. If not, loosen the three small screws and move the silver plate under their heads until one half the error in the position of the sun's image is removed.

"Bring the image again between the lines, and repeat the operation as above on both ends of the arm, until the image will remain between the lines of the plate in both positions of the arm, when it will be in proper adjustment, and the arm may be placed in its former position on the attachment. This adjustment is very rarely needed in our instruments, the lenses being cemented in their cells and the plates securely fastened.

"*To adjust the Vernier of the Declination Arc:* Set the vernier at zero, and raise or lower the telescope until the sun's image appears exactly between the equatorial lines.

"Having the telescope axis clamped, carefully revolve the arm until the image appears on the other plate. If precisely between the lines the adjustment is complete. If not, move the declination arm by its tangent screw until the image will come precisely between the lines on the two opposite plates. Clamp the arm and remove the index error by loosening two screws that fasten the vernier: place the zeros of the vernier and limb in exact coincidence, tighten the screws and the adjustment is complete.

"*To Adjust the Polar Axis:* Level the instrument carefully by the long level of the telescope, using the tangent movement of the telescope axis in connection with the leveling screws, until the bubble will remain in the middle during a complete revolution of the instrument upon its axis.

"Place the solar attachment upon the axis and see that it moves easily around it. Bring the declination arm into the same vertical plane with the telescope, place the adjusting level, * * * , upon the top of the rectangular blocks, and bring the bubble of the level into the middle by the tangent screw of the declination arc.

"Turn the arc half way around, bringing it again parallel with the telescope, and note the position of the level. If in the middle, the polar axis is vertical in that direction. If not in the middle, correct one half the error by the capsan head adjusting screws under the base of the polar axis, moving each screw of the pair the same amount, but in an opposite direction. Bring the level to the middle again by the tangent screw of the declination arc, and repeat the operation as before, until the bubble will remain in the middle when the adjusting level is reversed.

"Pursue the same course in adjusting the arc in the second position, or over the telescope axis, and when completed the level will remain in the middle during an entire revolution of the arc, showing that the polar axis is at right angles with the level under the telescope, or truly vertical.

"As this is by far the most delicate and important adjustment of the solar attachment, it should be made with the greatest care, the bubble being kept precisely in the middle and frequently inspected in the course of the adjustment.

"The adjusting level is supposed to be itself in adjustment: but if not, it can be easily corrected by the screw shown at one end, when reversed upon a plane surface, exactly as a mason's level is adjusted.

"*To adjust the Hour Arc:* Whenever the instrument is set in the meridian, * * *, the index of the hour arc should read apparent time. If not, loosen the two flat head screws on the top of the hour circle, and with the hand turn the circle around until the proper reading is indicated, fasten the screws again, and the adjustment will be complete."

*ADJUSTMENTS OF THE TELESCOPIC SOLAR. "1. Unscrew the tangent screw of the declination arc from the nut and remove the reflector together with its axis, by unscrewing the caps at its bearings.

"2. Adjust the line of collimation by revolving the telescope in its bearings, using as distant a point as possible.

"3. Cause the telescope to trace a vertical line and align with the main telescope by adjustment of the four capsan head screws of the axis of the frame.

* Page 117, *Gurley's Manual.* Courtesy of W. & L. E. Gurley.

"4. With the main telescope leveled, its line and that of the solar telescope should agree: if not, adjust the solar telescope by moving the tangent screw of the latitude arc. When the two lines are coincidence, the latitude arc should read 0.

"5. Replace the reflector and tangent screw of the declination arc. Lay off two points ninety degrees apart, one should be in good illumination, a point projecting above the sky line is to be preferred. Set the main telescope on one point and get the reflected image of the other point through the solar telescope, moving it by means of the tangent screw of the declination arc. The declination arc should then read 0.

"6. Lay off the latitude and corrected declination on their respective arcs and bring the sun's image inscribed in the cross wires by revolving the transit about its vertical axis, and the solar telescope about its axis. The instrument is now on the meridian from which any angle may be taken. There is no further change except the hourly change of declination."

Map Reproduction and Enlargement

The subject of Map Reproduction and Enlargement will be outlined here only in a general way, for its principles have been otherwise sufficiently discussed, for field work in the operations of topographical surveying and rapid sketching.

Map Reproduction. *Tracing:* In this method of map reproduction, a sheet of transparent tracing paper is placed over the map to be traced and the lines of the map are marked on the tracing paper with pen or pencil.

Carbon Tracing: In this method a sheet of paper is placed under the map with a sheet of carbon paper between, and the lines of the map directly traced with pencil or graphic pen. The under sheet of paper must be so attached to the map that there can be no slipping out of position.

Free Hand: In this method the map is divided into blocks by drawing north and south, and east and west lines, one or two, or more inches apart; the sheet of paper upon which the reproduction is to be made is similarly divided. By the use of dividers sufficient control points within each block on the map may be determined and plotted on the blank sheet, so that all the lines within a block can be sketched in free hand.

Blue Printing: All are more or less familiar with this process. Blue print paper can be purchased either in sensitive or unsensitive form. The former is kept in light-tight rolls, and several rolls in a tin case. To sensitive paper in the field the following solutions are used:

Solution A:	Citrate of Iron and Ammonia	2 ozs.
	Water	8 ozs.
Solution B:	Red Prussiate of Potash	2 ozs.
	Water	8 ozs.

For immediate use mix 4 parts of "A" with 3 parts of "B." A sheet of paper of the desired size is cut from the roll and laid on a flat surface; the mixed solution is applied with a sponge, care being taken not to wet the paper clear through; the sheet is then hung up in a dark room to dry, after which it is ready for use.

The process of printing blue paper is much similar to printing "printing out" papers in photography. A plane glass is used in the printing frame against which a sheet of tracing linen containing the map is held in place, the tracing linen forming the negative; a sheet of sensitive blue paper is then inserted in the printing frame with the sensitive side next to the tracing linen; a board of the same size as the frame holds the tracing linen and blue paper tightly against the glass of the printing frame. The frame with the linen and blue paper is then exposed to the direct sunlight for from four to eight minutes, after which the blue-print paper is taken out of the frame and placed in clear water sufficient to cover the whole surface of the print. It should be rinsed until the lines stand out in clear white and then hung up to dry. The lines of the map on the tracing linen should of course have been drawn well defined.

Additions and alterations may be made by using a 10% solution of Oxalate of Potash as an ink, adding a little mucilage if the solution tends to run.

White Printing: By using either a blue or brown print as a negative, a positive print of white background and black lines may be obtained. In such cases the blue or brown-print used, must have especially well-defined lines developed on it.

Photographic Method: This method is seldom used. It is very useful, however, where a small photograph is desired of some large map, and especially where such large maps are in considerable numbers, and it is desired to transport copies to a distance. The map is placed on a wall and a picture taken of it; the only special precautions necessary are that the map be well stretched and perfectly flat on the wall.

Lithographic Methods: Map reproduction, or printing, in the field is generally limited to the blue print method. In time of peace where a large number of military maps are desided, the lithographic methods should be employed. The printing is done lithographically from either stone or metal plates. Stone and metal plates can be most easily made by photo-lithographic methods, in which either sensitized aluminum or zinc plates are printed on photographically through a negative of the map, or a photo-lithographic print of the map is made on transfer paper which is printed lithographically on stone or metal plates. The best map printing, however, is done by engraving the map on a copper plate, transferring the same from the plate to a stone lithographically, and printing from the stone.

Map Enlargement. *By Pantograph:* The pantograph is a common and well-known instrument to most people. It may be used to reduce, enlarge, or reproduce a map, but only one copy can be produced at a time.

Photographic Method: The camera may also be used to enlarge small maps. The map is first photographed on a dry plate, and then by allowing light to pass through the negative while in the camera (the slides and partition of a plate holder having been removed) an image is formed in front of the camera at the desired distance away which sensitizes a sheet of printing paper placed at that position. The arrangement of the apparatus is as shown in the diagram, Fig. 104, which explains itself; the operation is carried out in a dark room. M is a mirror placed at an angle of 45° to reflect the light uniformly through the negative which is held in the camera C; S is the screen upon which the printing paper is placed—it

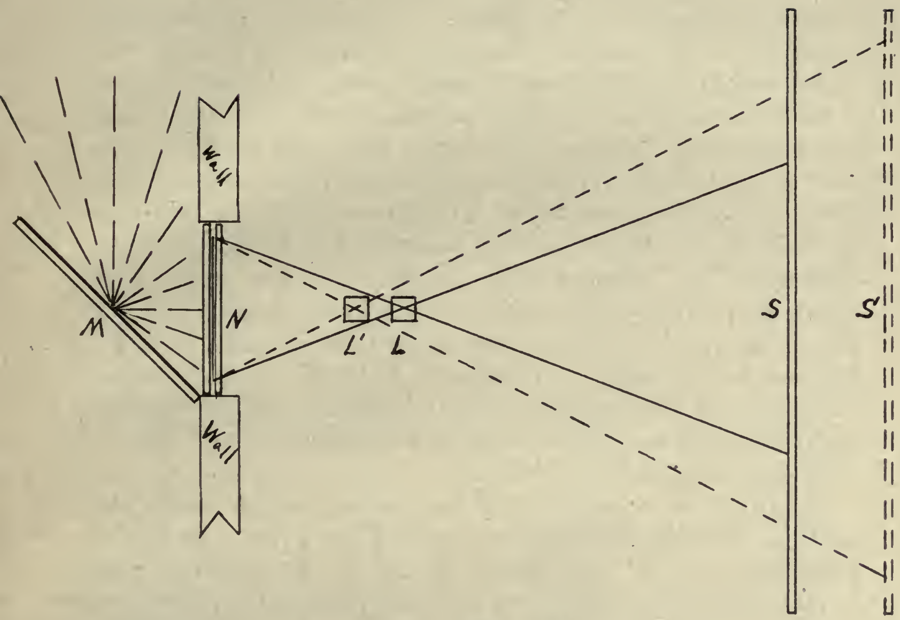

Fig. 104.

may be moved forward or backward to secure a map of the desired size.

By Coördinates: The map is divided into blocks by north-south lines and east-west lines, generally the same distance apart. Similar blocks are drawn on a blank sheet of drawing paper with the ratio between the lines and the corresponding ones on the map the same as the desired increase in size. By the aid of these lines the horizontal position of a sufficient number of controlling points of the map are estimated on the blank sheet to enable the map to be plotted free hand.

POLYCONIC PROJECTIONS. The polyconic projection shown in Fig. 105, was drawn in the following manner: A vertical line AA′ is drawn across the center of a sheet. This forms the central meridian, and it is divided into the divisions m_1m_2, m_2m_3, m_3m_4, which are equal to the differences in latitude between the parallels being shown. These differences in meters can be found from column 3 of TABLE V. For example, if every degree of latitude were being shown as a parallel, the amount as found in Col. 3, Table V, would have to be multiplied by 3600; for the amount given there is for 1″ of latitude.

A line BB′ is then drawn through point m_1 perpendicular to AA′, and similar lines through m_2, m_3, and m_4. On these lines are laid off the distances m_1n_1, m_2n_2, m_3n_3, and m_4n_4 from the central meridian, equal respectively to the values of longitudes for the respective parallel of latitude on which the distances are laid off, and which are found from Col. 4 of Table V (column headed "X"). Through these points, n_1, n_2, n_3, and n_4 are drawn curved lines, which lines are the other meridians of the sheet. At points n_1, n_2, n_3, and n_4, distances equal to Y_1, Y_2, Y_3, and Y_4, as found in Column 5, Table V (column headed "Y") are laid off along the meridians, and through these points and the points m_1, m_2, m_3, and m_4 are drawn curved lines to represent the parallels of latitude.

A projection so drawn will be precise enough where the limits of latitude and longitude are not too great. But more precisely, the "Y" coördinate should be the perpendicular distance from the intersection of a meridian and a parallel of longitude to the construction line BB^1. In Fig. 105, the distance from the construction line BB^1 if it were extended clear across the sheet, to the intersections of meridians with parallel, will be seen to be 3Y for the second meridian, 5Y for the third meridian (from the center meridian), etc. As a matter of fact they should be Y for the first meridian from the center, Y^2 for the second, Y^3 for the third, etc.; for the departure of an arc of a circle (which parallels are) vary with square of the distance. In very small scales both conditions above mentioned must be complied with for a perfect polyconic projection.

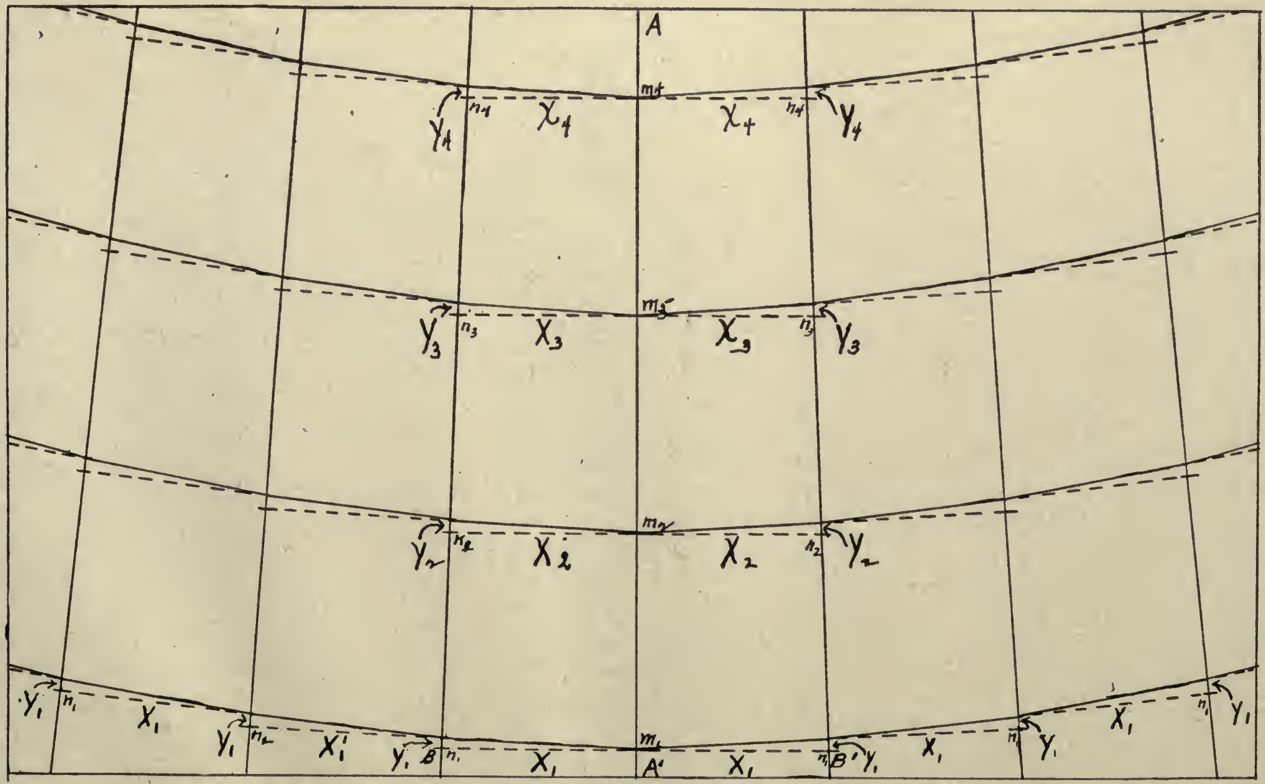

Fig. 105.

CONVENTIONAL SIGNS
UNITED STATES ARMY MAPS

Courtesy of United States Geological Survey

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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*

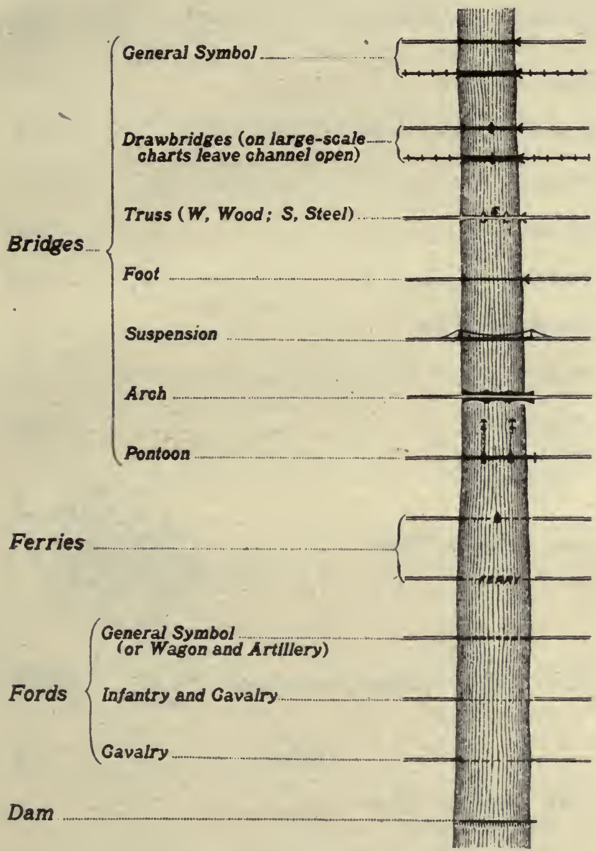
Tunnel

Railroad Station of any kind

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

Electric Power Transmission Line

WORKS AND STRUCTURES



WORKS AND STRUCTURES

Buildings in general ....


Ruins ....

Church .... or

Hospital .... HOS

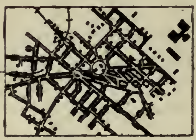
Schoolhouse .... or SH

Post Office .... PO

Telegraph Office .... or TO

Waterworks .... WW

Windmill .... or

City, Town, or Village ....


City, Town, or Village (generalized) ....


City, Town, or Village
(small-scale maps)

- *Capital* ....
- *County Seat* ....
- *Other Towns* ....

WORKS AND STRUCTURES

Cemetery .... CEM or

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

Prospect x

Shaft ....

Mine Tunnel — *Opening* ....

— *Showing direction* ....

Oil Wells ....

Oil Tanks (*abbreviation OT*) ....

Coke Ovens ....

Fences — *Fence of any kind (or board fence)* ....

— *Stone* ....

— *Worm* ....

— *Wire* .... *Barbed* x—x—x—x—x—x *Smooth* o—o—o—o—o

— *Hedge* ....

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

DRAINAGE

Streams in general 

Intermittent Streams 

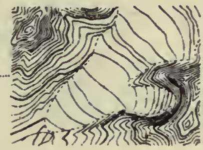
Lake or Pond in general
(*with or without tint, waterlining, etc.*) 

Salt Pond **(*broken shoreline if intermittent*)** 

Intermittent Lake or Pond 

Spring 

Falls and Rapids 

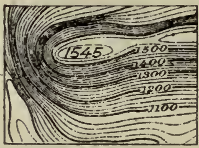
Glaciers
- *Contours*
  (*or as below*) 
- *Form Lines showing flow* 

RELIEF

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

Hill Shapes .... *Form lines, hachures, stipple, or other shading*

Contour System ....



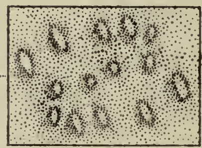
Depression Contours, if otherwise ambiguous, hachured thus ....

Bluffs

- *Rocky (or use contours)* ....

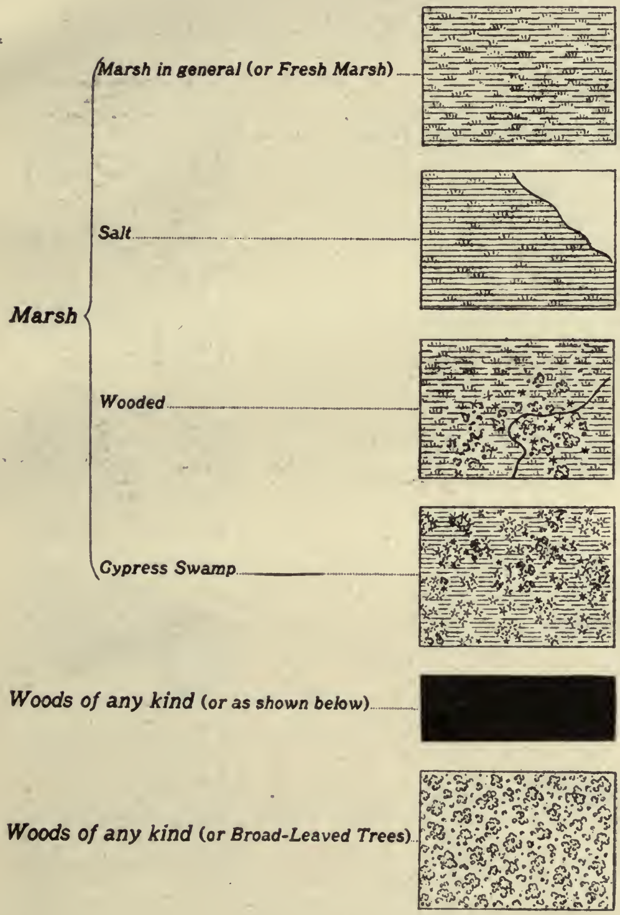
- *Other than rocky (or use contours)* ....

Sand Dunes ....



Levee ....

LAND CLASSIFICATION



LAND CLASSIFICATION

Pine ***(or Narrow-Leaved Trees)***

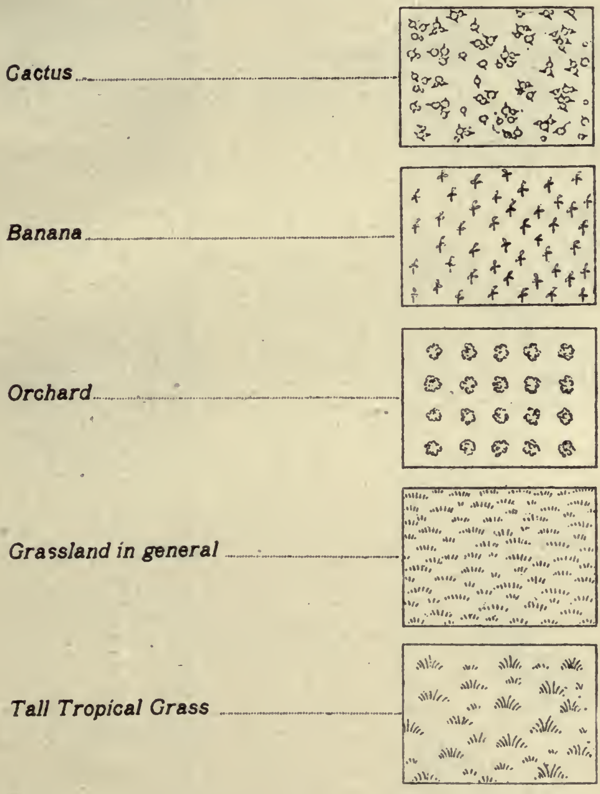
Palm

Palmetto

Mangrove

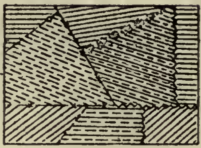
Bamboo

LAND CLASSIFICATION

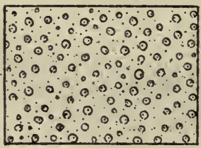


LAND CLASSIFICATION

Cultivated Fields in general

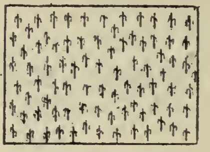


Cotton



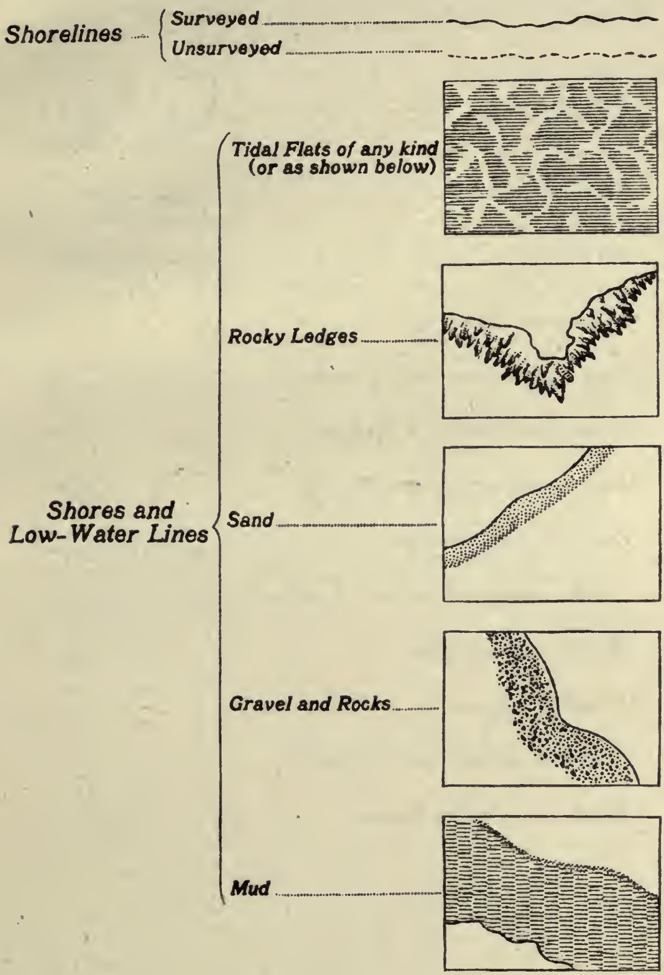
Rice

Sugar Cane



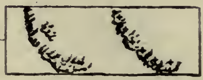
Corn

HYDROGRAPHY, DANGERS OBSTRUCTIONS

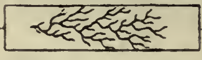


HYDROGRAPHY. DANGERS, OBSTRUCTIONS

Coral Reefs



Kelp



Eel Grass

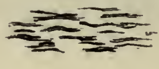
Rock under water .... + ⊛

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

Rock whose position is doubtful .... ⊛ *PD*

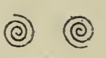
Rock whose existence is doubtful .... ⊕ *ED*

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) — — — — — — — —

HYDROGRAPHY, DANGERS, OBSTRUCTIONS

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

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.

HYDROGRAPHY, DANGERS, OBSTRUCTIONS

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

100 Fathom Line

200 Fathom Line

300 Fathom Line

500 Fathom Line

1000 Fathom Line

2000 Fathom Line

3000 Fathom Line

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 ....

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*.

AIDS TO NAVIGATION, ETC.

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, Ch. checkered.

Anchorage

- *Of any kind (or for large vessels)*
- *For small vessels*

Mooring Buoy

Range or Track Line

SPECIAL MILITARY SYMBOLS

Regimental Headquarters	23 I
Brigade Headquarters	2B 4D★3C
Division Headquarters	5D★3C
Corps Headquarters	8 A C ★
Infantry in line	
Infantry in column	
Cavalry in line	
Cavalry in column	
Mounted Infantry	
Artillery	
Sentry	
Vidette	
Picket, Cavalry and Infantry	
Support, Cavalry and Infantry	
Wagon Train	
Adjutant General	
Quartermaster	
Commissary	

SPECIAL MILITARY SYMBOLS

Medical Corps

Ordnance

Signal Corps

Engineer Corps

Gun Battery

Mortar Battery

Fort
Redoubt } *True plan to be shown if known*

Camp

Battle

Trench

When color is used execute the following in red

Abattis

Wire Entanglement

Palisades

Contact mines

Controlled mines

Demolitions

LETTERING

CIVIL DIVISIONS

States, Counties, Townships, Capitals and Principal Cities (all capital letters)

ABCDEFGHIJ
KLMNOPQRST
UVWXYZ

Towns and Villages (with Cap. initials)
abcdefghijklmnopqrstuvwxyz

HYDROGRAPHY

Lakes, Rivers and Bays (all capital letters)

ABCDEFGHIJ
KLMNOPQRST
UVWXYZ

Creeks, Brooks, Springs, small Lakes, Ponds, Marshes and Glaciers (with Cap. initials)
abcdefghijklmnopqrstuvwxyx

LETTERING

HYPSOGRAPHY

Mountains, Plateaus, Lines of Cliffs
and Canyons (all capital letters)

A B C D E F G H I J K L M N O P Q R S T U
V W X Y Z

Peaks, small Valleys, Canyons, Islands and Points.
(with Cap. initials)

abcdefghijklmnopqrstuvwxyz

PUBLIC WORKS

Railroads, Tunnels, Bridges, Ferries, Wagon-roads,
Trails, Fords and Dams (capitals only)

ABCDEFGHIJKLMNOPQRSTUVWXYZ

CONTOUR NUMBERS

1234567890 *1234567890*

MARGINAL LETTERING

ABCDEFGHIJKLMNOPQRSTU
VWXYZ

(with Cap. initials)

abcdefghijklmnopqrstuvwxyz
1234567890

LETTERING

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

Thickness of letter $\frac{1}{7}$ of height
Slope of letter 3 parts of base to 8 of height 

AUTHORIZED ABBREVIATIONS

A.	Arroyo	L.S S.	Life Saving Station
abut.	Abutment	L.H.	Lighthouse
A	Arch	Long	Longitude
b	Brick	Mt.	Mountain
B. S.	Blacksmith Shop	Mts.	Mountains
bot	Bottom	N.	North
Br.	Branch	n f	Not fordable
br.	Bridge	p.	Pier
C.	Cape	pk.	Plank
cem	Cemetery	P. O.	Post Office
con	Concrete	Pt.	Point
cov.	Covered	q.p.	Queen-post
Cr.	Creek	R.	River
cul.	Culvert	R. H.	Roundhouse
D. S	Drug Store	R. R	Railroad
E	East	S.	South
Est.	Estuary	s.	Steel
f.	Fordable	S H.	School House
Ft.	Fort	S M.	Saw Mill.
G S.	General Store	Sta.	Station
gir.	Girder	st.	Stone
G. M.	Grist Mill	str.	Stream
i.	Iron	T. G.	Toll Gate
I.	Island	Tres	Trestle
Jc.	Junction	tr.	Truss
k.p.	King-post	W. T.	Water Tank
L.	Lake	W. W.	Waterworks
Lat.	Latitude	W.	West
Ldg.	Landing	w.	Wood

TABLES

TABLE I

Conversions

Linear Measure—English=Metric

1 Inch	=	= 2.54 Centimeters
12 Inches	= 1 Foot	= 30.48 Centimeters
3 Feet	= 1 Yard	= .9144 Meters
5½ Yards	= 1 Rod	= 4.572 Meters
320 Rods	= 1 Mile	= 1.463 Kilometers

Linear Measure—Metric=English

1 Centimeter	=	= .3937 Inches
100 Centimeters	= 1 Meter	= 3.28 Feet
1000 Meters	= 1 Kilometer	= 1093.6 Yards

Square Measure—English=Metric

1 Square Rod	= 272.25 Sq. Feet	= 20.9 Sq. Meters
1 Acre	= 160 Sq. Rods	= .405 Hectares
1 Sq. Mile	= 640 Acres	= 2.14 Sq. Kilometers

Square Measure—Metric=English

1 Sq. Meter	=	= 10.76 Sq. Feet
10,000 Sq. Meters	= 1 Hectare	= 2.47 Acres
100 Hectares	= 1 Sq. Kilometer	= 247 Acres

Weights—English

Avoirdupois	= 1 Pound	= 16 Ounces	= 256 Drams	= 7,000 Grains
Apothecaries	= 1 Pound	= 12 Ounces	= 96 Drams	= 5,760 Grains
Troy	= 1 Pound	= 12 Ounces	= 240 Pwts.	= 5,760 Grains

The GRAIN is of the same weight in all three tables. Photographic formulæ are compounded by AVOIRDUPOIS.

Weights—English=Metric

27.34 Grains	= 1 Dram	= 1.77 Grams
16 Drams	= 1 Ounce	= 28.3 Grams
16 Ounces	= 1 Pound	= 453 Grams

Weights—Metric=English

1 Gram	= .035 Ounces	= 15.4 Grains
1 Kilogram	= 2.2046 Pounds	= 15,432 Grains

Liquid Measure—English=Metric

60 Minins	= 1 Dram	= 3.7 Cubic cm.
8 Drams	= 1 Ounce	= 29.6 Cu. cm.
16 Ounces	= 1 Pint	= .473 Liters

Liquid Measure—Metric=English

1 Cu. cm.	=	= .27 Drams
1,000 Cu. cm.	= 1 Liter	= 33.8 Ounces
1 Liter, also	=	= 1.056 Quarts

Land Measure

7.92 Inches = 1 Link
25 Links = 1 Pole
4 Poles = 1 Chain
10 Chains = 1 Furlong
8 Furlongs = 1 Mile

Nautical Measure

6 Feet = 1 Fathom
120 Fathoms = 1 Cable length
7⅓ Cable Lengths = 1 Mile
6088 Feet = 1 Knot
5280 Feet = 1 Statue Mile

Miscellaneous

$\pi = 3.1416 =$ Log .499715
$\pi r^2 =$ The area of a circle
$4\pi r^2 =$ The surface of a sphere.
$\frac{4}{3}\pi r^3 =$ The volume of a sphere.

TABLE II

Trigonometric Formulæ

Solution of Right Triangles—

$$\text{Sin A} = \frac{a}{c} = \frac{1}{\text{csc A.}} \qquad \text{Sin B} = \frac{b}{c} = \frac{1}{\text{csc B.}}$$

$$\text{Cos A} = \frac{b}{c} = \frac{1}{\text{sec A.}} \qquad \text{Cos B} = \frac{a}{c} = \frac{1}{\text{sec B.}}$$

$$\text{Tan A} = \frac{a}{b} = \frac{1}{\text{cot A.}} \qquad \text{Tan B} = \frac{b}{a} = \frac{1}{\text{cot B.}}$$

$$\text{K (area)} = \frac{1}{2}\ ab.$$

$$= \frac{c^2 \sin 2A}{4} = \frac{c^2 \sin 2B}{4}$$

$$= \frac{a^2 \cot A}{2} = \frac{b^2 \cot B}{2}$$

$$= \frac{a^2 \tan B}{2} = \frac{b^2 \tan A}{2}$$

$$= a\sqrt{\frac{(c+a)\ (c-a)}{2}} = b\sqrt{\frac{(c+b)\ c-b)}{2}}$$

Solution of Oblique Triangles—

(1) Given a side and any two angles:

$$a = \frac{b \sin A}{\sin B} = \frac{c \sin A}{\sin C}$$

$$b = \frac{a \sin B}{\sin A} = \frac{c \sin B}{\sin C}$$

$$c = \frac{a \sin C}{\sin A} = \frac{b \sin C}{\sin B}$$

(2) Given two sides and their included angle:

$$\frac{\text{Tan } \frac{1}{2}\ (A+B)}{\text{Tan } \frac{1}{2}\ (A-B)} = \frac{a+b}{a-b}$$

$$\frac{\text{Tan } \frac{1}{2}\ (A+C)}{\text{Tan } \frac{1}{2}\ (A-C)} = \frac{a+c}{a-c}$$

$$\frac{\text{Tan } \frac{1}{2}\ (B+C)}{\text{Tan } \frac{1}{2}\ (B-C)} = \frac{b+c}{b-c}$$

(3) Given the three sides:

$$\text{Tan } \tfrac{1}{2}A = \frac{1}{s-a}\sqrt{\frac{(s-a)\ (s-b)\ (s-c)}{s}}$$

$$\text{Tan } \tfrac{1}{2}B = \frac{1}{s-b}\sqrt{\frac{(s-a)\ (s-b)\ (s-c)}{s}}$$

$$\text{Tan } \tfrac{1}{2}C = \frac{1}{s-c}\sqrt{\frac{(s-a)\ (s-b)\ (s-c)}{s}}$$

(4) Given two sides and the angle opposite one of them:

$$\text{Sin A} = \frac{\text{a sin B}}{\text{b}} = \frac{\text{a sin C}}{\text{c}}$$

$$\text{Sin B} = \frac{\text{b sin A}}{\text{a}} = \frac{\text{b sin C}}{\text{c}}$$

$$\text{Sin C} = \frac{\text{c sin A}}{\text{a}} = \frac{\text{c sin B}}{\text{b}}$$

(5) Area:

$$K = \frac{bh}{2} \text{(Where b = base and h = altitude).}$$

$$= \frac{\text{bc sin A}}{2} = \frac{\text{ca sin B}}{2} = \frac{\text{ab sin C}}{2}$$

$$= \frac{a^2 \text{ sin B sin C}}{2 \text{ sin A}} = \frac{b^2 \text{ sin C sin A}}{2 \text{ sin B}} = \frac{c^2 \text{ sin A sin B}}{2 \text{ sin C}}$$

$$= \sqrt{s\ (s - a)\ (s - b)\ (s - c)}.$$

The following Trigonometric Formulæ will be found convenient in the solution of Oblique Triangles where one of the angles is greater than 90°:

Sin (90° + A) = Cos A
Tan (90° + A) = — Cot A
Sec (90° + A) = — Csc A
Cos (90° + A) = — Sin A
Cot (90° + A) = — Tan A
Csc (90° + A) = Sec A

The following natural trigonometric function of common angles are very useful in chaining where it is desired to lay off a simple angle for an offset to pass an obstructing point or area. In expressing the trigonometric function of any angle fractionally, the numerator is always taken as unity while the proper value as given below is taken as the denominator.

	Sin	Cos	Tan	Cot	Sec	Csc
30°	.500	.866	.577	1.732	2.000	1.155
45°	.707	1.000	1.000	1.000	1.414	1.414
60°	.866	.500	1.732	.577	1.155	2.000
90°	1.000	000	∞	000	∞	1.000
120°	.866	— .500	—1.732	— .577	—2.000	—1.155
135°	.707	— .707	—1.000	—1.000	1.414	1.414
150°	.500	— .866	— .577	—1.732	1.155	2.000
180°	000	—1.000	000	∞	—1.000	∞

TABLE III

Logarithms of Numbers

N.	0	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0211	0253	0293	0334	0374
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765
19	2786	2810	2833	2856	2878	2900	2923	2945	2967	2989
20	3010	3032	3053	3075	3096	3118	3139	3160	3181	3201
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900
31	4914	4928	4942	4956	4969	4983	4997	5011	5024	5038
32	5052	5065	5079	5092	5105	5119	5132	5145	5159	5172
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302
34	5315	5328	5349	5353	5366	5378	5391	5403	5416	5428
35	5441	5453	5465	5478	5490	5502	5515	5527	5539	5551
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5900
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222
42	6232	6243	6353	6263	6274	6284	6294	6304	6314	6325
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067
51	7076	7084	7093	7101	7110	7118	7127	7135	7143	7152
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316
54	7324	7332	7340	7348	7360	7364	7372	7380	7388	7396
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627

LOGARITHMS OF NUMBERS—*Continued*

N.	0	1	2	3	4	5	6	7	8	9
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701
59	7708	7716	7723	7731	7738	7745	7752	7760	7767	7774
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	2025
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633
92	9638	9643	9647	9652	9657	9661	9666	9671	8675	9680
93	9685	9690	9694	9699	9703	9708	9713	9717	9722	9727
94	9731	9736	9741	9745	9750	9754	9759	9764	9768	9773
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863
97	9868	9872	9877	9881	9886	9890	9895	9899	9903	9908
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9995

TABLE IV

Stadia Reductions For 100

		0′	10′	20′	30′	40′	50′
0°	H	100.00	100.00	100.00	99.99	99.99	99.98
	V	.00	.29	.58	.87	1.16	1.45
1°	H	99.97	99.96	99.95	99.93	99.92	99.90
	V	1.74	2.04	2.33	2.62	2.91	3.20
2°	H	99.88	99.86	99.83	99.81	99.78	99.76
	V	3.49	3.78	4.07	4.36	4.65	4.94
3°	H	99.73	99.69	99.66	99.63	99.59	99.56
	V	5.23	5.52	5.80	6.09	6.38	6.67
4°	H	99.51	99.47	99.43	99.38	99.34	99.29
	V	6.96	7.25	7.53	7.82	8.11	8.40
5°	H	99.24	99.19	99.14	99.08	99.03	98.97
	V	8.68	8.97	9.25	9.54	9.83	10.11
6°	H	98.91	98.85	98.78	98.72	98.65	98.58
	V	10.40	10.68	10.96	11.25	11.53	11.81
7°	H	98.51	98.44	98.37	98.29	98.22	98.14
	V	12.10	12.38	12.66	12.94	13.22	13.50
8°	H	98.06	97.98	97.90	97.82	97.73	97.64
	V	13.78	14.06	14.34	14.62	14.90	15.17
9°	H	97.55	97.46	97.37	97.28	97.18	97.08
	V	15.45	15.73	16.00	16.28	16.55	16.83
10°	H	96.98	96.88	96.78	96.68	96.57	96.47
	V	17.10	17.37	17.65	17.92	18.19	18.46
11°	H	96.36	96.25	96.14	96.03	95.91	95.79
	V	18.73	19.00	19.27	19.54	19.80	20.07
12°	H	95.68	95.56	95.44	95.32	95.19	95.07
	V	20.34	20.60	20.87	21.13	21.39	21.66
13°	H	94.94	94.81	94.68	94.55	94.42	94.28
	V	21.92	22.18	22.44	22.70	22.96	23.22
14°	H	94.15	94.01	93.87	93.73	93.59	93.45
	V	23.47	23.73	23.99	24.24	24.49	24.75

		3°	6°	9°	12°	15°
$c + f = .75$	H	.75	.75	.74	.73	.72
	V	.05	.08	.12	.16	.20
$c + f = 1.00$	H	1.00	.99	.99	.98	.96
	V	.06	.11	.16	.22	.27
$c + f = 1.25$	H	1.25	1.24	1.23	1.22	1.20
	V	.08	.14	.21	.27	.34

Stadia Reductions for 100—*Continued*

		0′	10′	20′	30′	40′	50′
15°	H	93.30	93.16	93.01	92.86	92.71	92.56
	V	25.00	25.25	25.50	25.75	26.00	26.25
16°	H	92.40	92.25	92.09	91.93	91.77	91.61
	V	26.50	26.74	26.99	27.23	27.48	27.72
17°	H	91.45	91.29	91.12	90.96	90.79	90.62
	V	27.96	28.20	28.44	28.68	28.92	29.15
18°	H	90.45	90.28	90.11	89.93	89.76	89.58
	V	29.39	29.62	29.86	30.09	30.32	30.55
19°	H	89.40	89.22	89.04	88.86	88.67	88.49
	V	30.78	31.01	31.24	31.47	31.69	31.92
20°	H	88.30	88.11	87.93	87.74	87.54	87.35
	V	32.14	32.36	32.58	32.80	33.02	33.24
21°	H	87.16	86.96	86.77	86.57	86.37	86.17
	V	33.46	33.67	33.89	34.10	34.31	34.52
22°	H	85.97	85.76	85.56	85.36	85.15	84.94
	V	34.73	34.94	35.15	35.36	35.56	35.76
23°	H	84.73	84.52	84.31	84.10	83.84	83.63
	V	35.97	36.17	36.37	36.57	36.77	36.96
24°	H	83.46	83.24	83.02	82.80	82.58	82.36
	V	37.16	37.35	37.54	37.74	37.93	38.11
25°	H	82.14	81.92	81.69	81.47	81.24	81.01
	V	38.30	38.49	38.67	38.86	39.04	39.22
26°	H	80.78	80.55	80.32	80.09	79.86	79.62
	V	39.40	39.58	39.76	39.93	40.11	40.28
27°	H	79.39	79.15	78.92	78.68	78.44	78.20
	V	40.45	40.62	40.79	40.96	41.12	41.29
28°	H	77.96	77.72	77.47	77.23	76.98	76.74
	V	41.45	41.60	41.76	41.91	42.07	42.23
29°	H	76.49	76.25	76.00	75.76	75.51	75.25
	V	42.38	42.54	42.69	42.85	43.00	43.16

		18°	21°	24°	27°	30°
$c + f = .75$	H	.71	.70	.68	.66	.64
	V	.24	.27	.31	.35	.39
$c + f = 1.00$	H	.95	.93	.91	.89	.87
	V	.32	.37	.41	.45	.49

		18°	21°	24°	27°	30°
$c + f = 1.25$	H	1.19	1.16	1.14	1.11	1.08
	V	.38	.46	.52	.58	.64

Horizontal Distance $= (c + f) \cos \alpha + S \cos^2 \alpha$.
Difference in Elevation $= (c + f) \sin \alpha + \frac{1}{2} S \sin 2\alpha$.

TABLE V

POLYCONIC PROJECTIONS

Lat.	1″ of Long. in Meters	1″ of Lat. in Meters	Coördinates of Curvature For 1° of Long. in Meters "X"	"Y"
1°	30.92	30.713	111,303.7	16.09
2°	30.90	30.714	111,253.4	33.9
3°	30.88	30.714	111,169.3	50.8
4°	30.85	30.715	111,051.4	67.6
5°	30.81	30.715	110,899.9	84.4
6°	30.75	30.716	110,714.9	101.0
7°	30.69	30.718	110,496.4	117.5
8°	30.62	30.719	110,244.5	133.9
9°	30.54	30.721	109,959.2	150.1
10°	30.46	30.723	109,640.5	166.1
11°	30.36	30.724	109,288.7	182.0
12°	30.25	30.727	108,903.8	197.6
13°	30.14	30.729	108,485.9	213.0
14°	30.01	30.731	108,035.1	228.1
15°	29.88	30.734	107,551.6	242.9
16°	29.73	30.737	107,035.4	257.5
17°	29.58	30.740	106,486.9	271.7
18°	29.42	30.743	105,906.0	285.6
19°	29.25	30.746	105,293.0	299.2
20°	29.07	30.750	104,648.0	312.3
21°	28.88	30.753	103,971.3	325.2
22°	28.68	30.757	103,263.1	337.6
23°	28.48	30.761	102,523.4	349.6
24°	28.26	30.765	101,752.7	361.2
25°	28.04	30.769	100,950.9	372.3
26°	27.81	30.773	100,118.5	383.0
27°	27.57	30.777	99,255.7	393.2
28°	27.32	30.782	98,362.6	403.0
29°	27.07	30.787	97,439.6	412.2
30°	26.80	30.791	96,487.0	421.0
31°	26.53	30.796	95,505.0	429.3
32°	26.25	30.801	94,493.8	437.0
33°	25.96	30.806	93,453.8	444.2
34°	25.66	30.811	92,385.4	450.8
35°	25.36	30.816	91,288.8	456.9
36°	25.05	30.821	90,164.3	462.5
37°	24.73	30.826	89,012.2	467.5
38°	24.40	30.832	87,833.0	471.9
39°	24.06	30.837	86,626.9	475.8
40°	23.72	30.842	85,394.3	479.0
41°	23.37	30.848	84,153.6	481.7
42°	23.01	30.853	82,851.2	483.8
43°	22.65	30.859	81,541.3	485.3
44°	22.28	30.864	80,206.5	486.2
45°	21.90	30.870	78,847.1	486.5

Polyconic Projections—*Continued*

Lat.	1″ of Long. in Meters	1″ of Lat. in Meters	Coördinates of Curvature For 1° of Long. in Meters "X"	"Y"
46°	21.52	30.875	77,463.6	486.3
47°	21.13	30.881	76,056.3	485.4
48°	20.73	30.886	74,625.6	484.0
49°	20.33	30.892	73,172.0	481.9
50°	19.92	30.897	71,696.0	479.3
51°	19.50	30.902	70,197.9	476.1
52°	19.08	30.908	68,678.2	472.3
53°	18.65	30.913	67,137.4	467.9
54°	18.22	30.918	65,575.9	463.0
55°	17.78	30.924	63,994.2	457.5
56°	17.33	30.929	62,392.9	451.4
57°	16.88	30.934	60,772.3	444.8
58°	16.43	30.939	59,132.9	437.6
59°	15.97	30.944	57,475.4	429.9
60°	15.50	30.948	55,800.0	421.7
61°	15.03	30.953	54,107.5	413.0
62°	14.56	30.958	52,398.3	403.8
63°	14.08	30.962	50,672.8	394.0
64°	13.59	30.967	48,931.7	383.8
65°	13.10	30.971	47,175.5	373.1
66°	12.61	30.975	45,404.8	362.0
67°	12.12	30.979	43,619.9	350.4
68°	11.62	30.983	41,821.5	338.4
69°	11.11	30.987	40,010.2	325.9
70°	10.61	30.991	38,186.5	313.1
71°	10.10	30.994	36,351.0	299.9
72°	9.58	30.997	34,504.2	286.4
73°	9.07	31.001	32,646.7	272.4
74°	8.55	31.004	30,779.1	258.2
75°	8.03	31.006	28,902.0	243.6
76°	7.50	31.009	27,015.8	228.8
77°	6.98	31.012	25,121.4	213.6
78°	6.45	31.014	23,219.1	198.2
79°	5.92	31.016	21,309.6	182.5
80°	5.39	31.018	19,393.4	166.7
81°	4.85	31.020	17,471.3	150.6
82°	4.32	31.021	15,543.7	134.3
83°	3.78	31.023	13,611.4	117.9
84°	3.24	31.024	11,674.7	101.3
85°	2.70	31.025	9,734.5	84.6
86°	2.16	31.026	7,791.2	67.8
87°	1.62	31.027	5,845.5	50.9
88°	1.08	31.027	3,898.1	34.0
89°	.54	31.027	1,949.3	17.0
90°	.00	31.028	.0	.0

To reduce meters to feet: multiply by 3.2809 (Log. .51600).

From Clark's Ellipsoid of 1866.

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