INDIVIDUAL AND COMBINED

MILITARY SKETCHING

—BY— uttle

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PREFACE.

The methods now in use for instruction in individual sketching at the Army School of the Line are a new development in the subject of Topography, and differ widely from the methods laid down in any text book.

The methods of combined sketching have been developed in the topographical work in the course at the Army Staff College, and are entirely new.

A description of these methods is deemed of sufficient importance to warrant publication in book form.

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INTRODUCTORY.

Whether a position is one to be occupied by his own troops or by those of the enemy, it is absolutely essential that, as far as possible, the commanding general should know the configuration of the country. The heights of high points, the relative heights of the different commanding points, the depth and extent of ravines, defiles, etc., even the location and difference of level of small hollows and folds in the ground in which the enemy might locate and protect a firing line, or his own troops might occupy with telling effect, are all matters of such paramount importance to him that knowledge of them or its lack may mean the success or failure of a campaign or battle.

Even in maps used primarily for planning a march, the position, extent and depth of defiles, the location and height of hills or ridges which might be occupied by the enemy, as well as the location of heavy grades, difficult pieces of road which might act as an impediment to the march, and thus have an important effect on planning its rate, the time of arrival at particular points, and the junction of different forces, are all matters of the greatest importance.

Again, in a march near the enemy with the object of turning his flank or seizing some strong point, it may be possible, with a good map, to so lay out the line of march that the troops may never be in sight of the enemy, while without proper information the marching line might betray its presence at points which might have been avoided.

Finally, a map reduces the whole field of operations to such a size that its features may be studied comparatively, and the good and bad features of several positions or lines of march noted. Instead of the commander of a large army attempting to inspect personally each position, he sends out as many officers as necessary, who bring back as it were the actual country for the general's inspection. This they can do only by bringing back a contoured map, showing the configuration of the country; and with such maps the commander does not have to rely on any one's opinion as to the suitability of the territory involved, but can inspect it for himself.

Considering all these points, it will readily be seen that a map which shows the configuration of the ground is of the greatest importance in military matters, and it is hardly an exaggeration to say that a map which presents simply a flat plan of the country is practically valueless from a military point of view, and this statement is becoming more and more exact as the improvement in arms and engines of war make military operations more a matter of science than of brute force.

It is the business of the proper bureau of the military establishment in time of peace to secure maps as complete as possible of every portion of the world at large, which might by any possibility become the theatre of operations. As circumstances render any locality particularly likely to be of importance, special attention is paid to the accuracy, detail and completeness of the maps of that section.

However, the collection of maps of another country is limited largely to what they themselves publish. Certain information may be obtained and added to the published maps, but any attempt to make a survey in detail of a foreign country or of any part of it, would be apt to be resented and regarded as an unfriendly act even if it were permitted. So, as a rule, any maps secured in time of peace will be available for strategical study, but will be of too small a scale and too deficient in detail to be of value for tactical use.

Even when war with another nation becomes almost certain it is difficult to accomplish anything in the way of improving the maps. Future wars will usually be preceded by a period of diplomatic exchange, while all possible effort is made to settle the points at issue without resort to hostilities. While this period may be of considerable duration, all open attempts at map making, if not prevented officially, will be apt to subject the map maker to rough handling by the populace.

The bureau then having performed its duty up to the outbreak of the war with all due diligence, the maps of the enemy's country on hand will generally be very far from a state of perfection, and even those of its own country will be far from adequate, unless they have been made especially for military purposes. The maps available are likely to be of too small a scale and deficient in detail necessary for tactical use. Some of the work of extension might be done by civilians, but the greater part of it, especially of the ground between the opposing forces, would fall to a topographical corps organized from the army itself, working under protection of the cavalry screen or with patrols. This mapping is done by methods differing widely from those in ordinary use and usually described by the term "military sketching." It is most important that as large a number as possible of officers and enlisted men be made proficient in such work during time of peace. Secondarily the study of military sketching is important, as one cannot become proficient in sketching without acquiring a thorough knowledge of map reading.

PART I

INDIVIDUAL SKETCHING

The term "military sketching," used to describe such surveys with a large limit of error as are made at a high rate of speed, frequently at great risk of personal danger from the enemy, and often including ground inaccessible to the surveyor, is here retained only because it is so firmly established by usage and notwithstanding the fact that its meaning as above defined is at variance with the customary significance of the words.

A military sketch is a map; a projection to scale, on a horizontal plane of the surface represented. Though in some of the minor parts of the work much of the location of points in direction, distance, and elevation is a matter of estimation, still the map-maker locates each line by locating the points which limit it. Nowhere in the construction of the map is there any representation of distance or direction by the application of the principles of perspective.

There are consequently no mathematical principles applying to military sketching which are not common to the general science of surveying, and no better foundation can be laid by him who would become an expert sketcher than a thorough understanding of accurate instrumental surveying. The instruments generally used in sketching for horizontal locations are the plane table and the compass. While the plane table may in actual practice be nothing more elaborate than a pad of paper with ruler or card for the alidade, and the compass of the small pocket variety, the principles are neither more nor less difficult than those involved in the use of similar instruments of the standard make.

This discussion will deal principally with the methods used for measuring and representing the vertical relations of the surface of the ground. It will be assumed that the student knows thoroughly the methods for measuring and representing distance and direction. If he does not he will find in any work on surveying a full discussion of the methods of making surveys with the plane table and with the surveyor's compass. The instruments used in sketching are portable forms of one or the other of these instruments.

The following points are, in the beginning, worthy of notice. The two indispensable characteristics of the military sketch are rapidity and a fair degree of accuracy. Of so much importance is rapidity that he who can secure a sufficient degree of accuracy only by working slowly must serve his country in some other capacity than that of sketcher.

From the time work begins in the morning until the finished maps have been delivered, speed is the controlling factor with the sketching corps, particularly if it be in front of an advancing army or one about to fight a battle.

The success of military topographical work covering large areas is principally a matter of organization, and is treated in a later chapter, but the possibility of doing such work at all depends on the skill of the individual sketcher. The necessity for high speed constantly governs the work, and the sketcher generally has no control over the speed demanded of him. When the advance pushes forward very rapidly, he must keep up with it or lose touch with the troops that will protect him in his work. He has not the compensating advantage of being able to work ahead when the advance moves slowly on account of the risk, not of personal danger, but of capture of himself, and what is more important, his completed work. Under ordinary conditions, the sketchers can not move any considerable distance ahead of the most advanced body of the army. That is, if the march is to cover twenty miles, that distance can not be divided into say five mile sections and worked by four men simultaneously, but the whole distance is a problem for one man who can work neither faster nor slower than the advance of the troops which protect him, and the only advantage of a multiplicity of sketchers is in the width of the strip covered.

The problem is much like that which confronts a stenographer in court. At times the work is such that one of small ability could perform it. In fact the average number of words per hour may not be excessive, yet the expert cannot avail himself of an average, but must maintain, at times, a speed very great and on the degree of which he can exert no influence.

The pursuit of a defeated but not routed enemy in a country of which accurate maps are not available, presents an illustration of such conditions as well as one of the value of sketching to a military force.

If the sketchers can keep up with the cavalry force maintaining touch with the enemy, and keep the main body supplied with maps, the advantage thus derived may have a deciding influence upon the operations. The pursuing force can push on with confidence, always knowing the road; how best to arrange its march; where to go slowly; where it can afford to make an extra effort to reach the top of a hill because of the knowledge that it is succeeded by a long down hill slope; where water can be found, etc. In this way the main army may get in such close touch with the enemy as to deprive him of the rest and halt necessary for reorganization and complete his demoralization.

Absolute accuracy is not to be expected. If the map fulfills all the conditions as to the information necessary for marching an army or occupying or fortifying a position, it is of little importance that a direction is a few degrees out, or that a distance, horizontal or vertical, is not exact. The error, though, should be that due to imperfection of instruments and approximate methods and not to blunders. The error will then be gradually accumulated, and there will be no distortion or radical departure from the actual conditions at any point. Beginners are apt to worry about an error of closure in mapping a road between two points whose relative location has been established by more exact methods.

If all the error is that due to method, a compensated copy of the work should give results very close to real conditions. But such compensation would be necessary only in combined work. Though the final error might be considerable, judged by the standard of exact surveying, the map would be none the less valuable to a military commander for marching an army or for placing troops in position, because the error at any point would be of smaller degree in direction or distance than would receive consideration for the purposes for which he uses the map.

However, as in combined surveys considerable errors of closure are likely to cause delay in combination of different sketches, the most careful work should be along the main controlling line of the map. Time would not usually be available for compensation, and the maps as turned in would have to be pasted together at once for printing. It must be accepted as another controlling principle of this work that whatever has been done during the day will usually be of little value unless a number of copies of it can be distributed the same night, preferably before midnight.

In the succeeding pages much will be said of estimation of distance, direction and slope. Perhaps it is best to say in the beginning that except in filling in minor details, estimation cannot be justified except by the task being greater than can possibly be accomplished otherwise. While the beginner should endeavor to perfect himself in estimating along with his other work, so that he may secure as good results as possible at times when measurement is impossible, for him to form the opinion that he will never have time to use instruments, and to start out by discarding his instruments and guessing at everything, is fatal to all progress. The careful observation of four classes at the Leavenworth Service Schools, which have used substantially the methods herein described, has shown conclusively that the most rapid, as well as the most correct sketchers, were those who, from beginning to end of their work, used the prescribed instruments and measured the distances wherever possible. They easily maintained their superiority when the pace was so rapid as to admit of no instrumental work except for establishing directions and elevations along the main traverse.

Furthermore, the methods are at best crude. Much of the work is free-hand, and will increase in value as the control of direction, distance and elevation is the more accurate. To become proficient the sketcher must at all times do some estimating, and sometimes do a great deal of estimating, and he should, by the methods elsewhere described, make himself proficient in this work. But the officer or soldier who hands in maps less accurate than could have been made in the time at his disposal, simply because it was easier to estimate than to measure, is guilty of neglect of duty.

The greatest accuracy of method allowed by conditions must be expended on the main traverse, the crudest work being done on those parts of the map where the effect of errors will be local. In general the system found most effective may be described as follows:

The beginner should start with a very small area of ground and measure and plot the direction and length of some line included within its boundaries. He can then, working free-hand with this line as a basis, make a fair map of the designated area. If, however, the area is too large, he will soon become confused and find that to go further it is necessary to locate extensions of the controlling line. About each extension he can make a certain amount of free-hand map with a fair degree of accuracy. In the end his completed map is a number of small free-hand maps connected by a series of located lines. With practice he can constantly increase the areas he can map without instrumental aid, and as he becomes expert in estimation of distance, direction, and slope, he rapidly draws in free-hand a succession of quite extended areas bound together and placed in their proper relation to each other by one central traverse. He constantly introduces short cuts in his methods. The beginner estimates a distance as so many yards or paces and plots it to scale. The advanced sketcher estimates that a point on the ground is distant by a certain map length, and he estimates the steepness of a slope not in degrees, but by contours of a certain spacing. He knows how to pick out the inequalities which can be shown in forms of roads, streams and contours, and to recognize and omit from consideration those features which, while large to the eye, are too small to be shown by the working scale.

In the traverse, however, the same latitude is not possible, and its accuracy as to direction, slope and distance should be as great as circumstances will allow. In general, some method of measurement with a small and fairly uniform error should be used, as by counting the paces of the sketcher himself or by timing or counting the paces or strides of a carefully rated horse. The sketcher should constantly be on the lookout for points ahead which can be located by a single sight and measurement when the line he is traversing takes a much longer winding way, so that he may throw out accumulated errors when he reaches such point. He will almost invariably be accompanied by an assistant or an orderly, who can make the measurement on the direct line and then ride back at an increased gait and join him on the circuitous route which he is sketching. In the absence of such an assistant, he can at least draw a direction line, which will be better than no check. Valuable use may also be made of intersections on prominent points ahead as means of throwing out accumulated error. A little care and good judgment will enable the traverse to be made sufficiently accurate without unduly sacrificing time. Accuracy sufficient for the purpose of the work is all that is needed. This does not mean that accuracy is not important, but simply that the limit of error should be carefully considered, and when this is determined, the work should be kept well within it. The successful sketcher must work in a broad-minded way, without any fussy attention to unimportant details.

The sketcher should constantly keep time in view and not try to get a greater degree of accuracy than is consistent with the character and speed limit of his work. In general, for topographical work, there will be a certain time limit imposed by conditions not under control of the sketcher. If this limit is exceeded, the work may and usually will be useless. Therefore, the individual sketcher should bend his efforts to securing, in the area assigned to him, the most valuable topographical information possible in the time at his disposal. Accuracy and detail must yield to time if a choice must be made.

This advice, however, is not intended for the beginner. Many of the short cuts mentioned can only be acquired through laborious practice, and in the beginning accuracy must be given more attention than speed. One can learn to estimate distance and slope only by a careful study of measured distances and slopes; can learn to sketch large areas only by starting with small ones; and must especially learn where to be careful and where to carry estimation to the limit.

There is one kind of accuracy, however, which the importance of speed cannot outweigh, and that is the accuracy of the information to be conveyed by the map. The officer must always remember that a map is his official report and is useless to the commander unless he can accept the information conveyed by it. If certain military features are shown on the map, the absence of such features at other points must be absolute proof that they do not exist. The information as to the main roads, crossroads, and connecting roads must be accurate enough for use. The map is useless if the army cannot march by it. When the circumstances are such that information usually given must be omitted or that data as to roads, etc., must be guessed at, such facts should be clearly set forth on the face of the map so that it will be certain in what respect the map can be relied on and what information must be obtained or verified by other methods. Especially should an officer sign only so much of a map as he can vouch for. If it is pieced out by information obtained by others, the authority for such parts should be made clear, and, in general, there is no excuse for an officer handing in a map containing sections which he has not personally seen and mapped except when the area and detail given him are greater than he can cover in the allotted time. He should accept not only the official but the moral responsibility for what he submits, and should not feel excused for errors leading to disaster or even delay by the fact that he had confidence in a man who furnished information that he might have obtained himself. This does not, of course, apply to dividing up the work among authorized assistants, commissioned or enlisted, but to the use of assistants not especially detailed. Even when working with authorized assistants, each man's part of the work should be distinct and should be signed.

Modern military practice places little value on the map which does not show the conformation of the ground, and it is equally well settled that this can best be shown by contours. It is the principal purpose to explain here the methods of rapid contouring. It will be shown that contouring is so simple a matter that this very important addition to a military map need not be omitted even with the condition of high speed enforced.

To make contoured maps the student must thoroughly understand the underlying principles. Frequently the difficulty seems great because the method of instruction is not correct and too little time is devoted to preparatory study. The first essential is to have a thorough knowledge of the various forms of the ground itself and an equally thorough knowledge of how to represent these forms on paper.

If we examine a landscape drawing of a piece of diversified ground, we see hills and valleys, streams, and the spurs dividing them. We are conscious of the various forms as if we saw the ground, but not of the line or mass, shade or shadow used in representing them.

So the artist in making the drawing thinks of the various forms and their relation to each other and constantly has in mind the effect, the appearance, of the whole picture. He has learned how to get that effect by long practice, but is no longer conscious of the details of expression any more than one is conscious of the alphabet when reading or writing. To give an example, for this is important, he sees a small hollow in an otherwise smooth hillside, and he draws that hollow. He does not reason that it is so long and wide and deep, and that to show a hollow of those dimensions he must use certain combinations of lines of certain direction, spacing and thickness. He simply draws it, and yet, that all the elements of direction, spacing, etc., have unconsciously received consideration is evident because another who does not know how to draw, while equally conscious of the hollow, cannot show it on paper.

So is contouring a method of graphical expression. One skilled in map reading and map making sees on the contoured map the actual forms stand out as clearly apparent as they would appear on a perspective drawing. In the latter case the conditions as ordinarily apparent to the human eye are imitated, while in the former the actual ground conditions are made apparent to the mind by interpretation of what is seen on paper. Barring this mental process, which soon becomes an unconscious one, the expression of form by contours is a very simple matter.

It is possible, by following a set of rules in taking observations on the ground, to get the necessary information for constructing a complete contoured map with very little consideration of form, and, in fact, in ordinary surveying, contouring is principally a matter of location of points and geometrical construction, but the military sketcher must treat contouring as a means of graphically expressing what he actually sees more than as the solution of a problem for which he has acquired data by instrumental observation. He may and should check the accuracy of his work by observation from time to time, but much of his work must be an actual sketching by means of contours of the forms he sees. Nor by this is it meant that the completed map of the expert sketcher gives only a rough idea of the actual form by means of contours. It means that he has made himself so proficient in the use of this medium of graphical expression that he is able to produce accurate results with great rapidity.

Having outlined as briefly as possible the general problem of military sketching, the following pages will be devoted to a description of the methods which it is thought will aid in the acquirement of the necessary proficiency in contouring military sketches, since military sketching in this particular, contrary to what is the case with the plain details of the map, is done by methods entirely different from those used in other kinds of surveying. It will be seen that theoretically the subject is simple and its description will take up but little space. It is not intended that any particular method shown is the only one, or even the best, for in the end the best sketcher is the one who gets the best results, and in few subjects does the personal equation enter to so great an extent. Nevertheless, since the methods given have been found good, it is suggested that they be used until the student is perfectly sure he can get better results another way; and again, the caution must be given to go slowly in the beginning. Representing a slope by contours of a certain spacing can be of value only when the spacing is correct. If the slope is read correctly to the nearest degree, it will be sufficiently correct for our purpose, and as most of the slopes met with will be from zero to eight degrees, it will not be hard to learn to look at a slope and at once put its measure on paper in contour distance, particularly if the War Department adopts a standard set of scales, and, even better still, a vertical interval so varying with the scale as to make the same contour distance always represent the same slope.

At first, however, distances and slopes must be measured and plotted to scale. Later the ground measurements may be estimated and the scale used. Finally both may be estimated, but the figures marked on the map. The problem then should be carefully checked by comparison, when possible, with an accurate map or even with sketches over the same ground, and in the latter case the comparison should be made on the ground represented, so that it can be seen which is correct, or in what the error consists. Estimated distances and slopes should be measured and the measurements compared with the values marked on the map. Plotting done by estimation should be checked by the scale so as to find the error. This may be done immediately on finishing the map, or better still, by first plotting by estimation and immediately checking with the scale. The use of the scale should be abandoned only when careful checking of work in which scale distances have been estimated shows that the sketcher works with sufficient accuracy without it. It will be always well to have a copy of the scale attached to the drawing board or the ruler for occasional comparison.

Completed problems not checked as above suggested are of little value, and the sketcher who completes a problem and then throws it aside is not likely to advance much in his work. It adds much to the interest of the work and to the rapidity of advancement if several work together and compare and check work afterward, but the single worker can obtain much valuable assistance by using his completed sketch as a basis of study. In the very beginning, it is well to work on ground of which a fair map is obtainable, and after a small amount is finished, to compare results with the map before going further and see where errors have been made. But in working this way, uncover only so much of the map as has been already sketched. All of the value of such work is neutralized by putting down anything from memory of the map, instead of from study of the actual ground forms.

While proficiency in the construction of contoured maps by exact instrumental methods is a great aid to facility in all parts of military sketching, this alone is not sufficient preparation in that part of the work which has to do with contouring, nor is it an indispensable prerequisite.

In military sketching a very thorough knowledge of the principles governing contours is necessary, as well as an equally thorough knowledge of the appearance of the contours representing the different ground forms. In fact, proficiency in military sketching is of great value to the officer or soldier, even though he may never be called on to make a sketch, as a proper study of map making and map reading are so intimately related that it is hard to acquire skill in one without a corresponding advance in the other.

Probably the best aid to study of the principles of contouring is the sand table. This is no more than a table, preferably about six feet square, with a plentiful supply of moist sand. The sand can be roughly shaped with the hands so as to represent all typical simple forms, and finally the most intricate combinations. Then the contours can be roughly traced on the sand with a pointed stick or pencil.

As an exercise it is well to take a statement of the principles which govern contours, and verify the correctness of each principle by making the actual formation in the sand. A few sample exercises follow as suggestions for such study:

1. Make a single symmetrical mound showing the contours as concentric rings.

2. Make one side of the mound steeper than the other, showing how the horizontal distance between contours diminishes for steep slopes. This can be carried to the point where the contours run together and to where they cross.

3. Scoop out the sand from the top of the mound to the bottom, forming a gradually widening and deepening water course, as water would have eroded the softer part of the hill in the beginning, small at the top and gradually gathering volume and effect. The contours will show the form representing the typical simple water course. A few small streams about perpendicular to and emptying into this, and finally another water course joining it in practically level ground at the foot of the hill will show the typical forms imposed on contours by the natural water system and the forms of water courses and the dividing spurs or watersheds. As most of the minor irregularities of surface are due to erosion, a thorough understanding of these forms is most important.

4. The formation can now be complicated by making another hill with the intervening ground

higher than the bottom of either hill. This will illustrate the col or saddle.

5. All the above examples illustrate closed contours and the surface should now be arranged so that some of the other contours will be cut by the edges of the table.

It will be found that it is much easier to create typical forms on the sand table than it is to find them on the ground. It is easier, too, to comprehend the relation between the form and its graphical representation, because the whole form or combination of forms is of such size as to be seen in its entirety. The exercises should be continued by making as complicated a form as possible, building up a small hill here and digging out a hollow there. Each time the contours should be drawn on the sand and then on paper.

The reverse of this process is, if possible, even more valuable, for in the beginning it is easier to make the contours for any particular formation than it is to interpret some of the more intricate combinations on the maps. Therefore maps should be studied with the sand table, and when any portion of them does not give a clear idea of the ground forms, work out the problem in the sand.

This method of study is so valuable an aid to the understanding of contoured maps, and is so easily provided, that a sand table should be maintained at some convenient place wherever instruction in map making and map reading is being given.

The principles governing contours are not difficult to comprehend, for while there is an infinite variety of irregular ground, most of the variations are those of a few easily recognized typical forms.

Having made himself familiar with these principles, the student should study contours in connection with the ground. One valuable exercise is to place himself at an elevation about midway between the high and low points of a considered area and without moving to trace out with the eye a line, keeping always the same elevation. Some find this exercise much facilitated by sighting over the extended arm, gradually sweeping around. Then, without moving, note the difference in shape of the next higher and the next lower contour. This exercise may be varied by drawing these lines roughly on paper until the whole area is mapped. The first part of the exercise is of particular value, and if the student will make a practice of examining from this point of view the country he passes over in his walks or rides, he will find that it will not only be interesting but in a short time will very greatly increase his knowledge of ground forms and his ability to represent them graphically, and what is even of more general value, the facility with which he reads maps. The ability to read maps and to make them by the methods to be hereafter stated are so intimately related that facility in one is impossible without a corresponding mastery of the other.

For this reason another most important preliminary exercise is to study country in connection with a contoured map whenever it is possible to procure one. This method is, unfortunately, not always available, but should not be neglected when possible.

A thorough knowledge of one other condition is necessary to the acquirement of proficiency in sketching. It is the relation between ground forms and the scale of the map, and the necessary information on this subject will properly be acquired while the student is perfecting himself in other parts of the problem. While no authoritative order has ever been issued which fixes the scales to be used for the different classes of sketches, custom at least has established about what these scales should be. In the absence of a governing order for the whole army, it has already been found necessary to issue orders where troops have been brought together in large bodies, establishing a uniform set of scales for the command.

The beginner, or even the expert who has used a different set of scales, must make himself familiar with just how much of the detail of the ground forms can be shown to the scale ordered. As the student examines almost any piece of uneven ground he is ordered to sketch, he will usually see at first almost an overwhelming number of the typical ground forms he has been studying. But he is not concerned so much with what is apparent on the ground, but with what he can and should represent to the ordered scale. On a map of a scale of three inches = one mile, for instance, a spur 100 feet long on the ground would be just a little more than a twentieth of an inch in length, and if the trouble were taken to bend an otherwise regular contour to show this, no one would notice it, or care anything about it if he did notice it. The beginner urges that the neglected feature would furnish cover for a number of men, but the commander does not have maps made for posting minor divisions under cover. When such features become of importance a larger scale must be used, and the only guide to follow is the effect of any inequality of surface on the map as actually constructed. The sketcher should determine the minimum size of the ground forms he can show to the scale ordered, and regard the ground, as far as anything smaller is concerned, as perfectly smooth and regular. This tremendously simplifies his work. To impress this condition on the student, the instructor should, if possible, pick out for one of his first sketching problems a piece of ground with some well marked forms which can be shown to scale and which is also well supplied with small minor forms, tending to create the impression on the student that it is very difficult to sketch. He will invariably complain about the smallness of his scale, failing to realize in the beginning that the details he cannot map are not wanted.

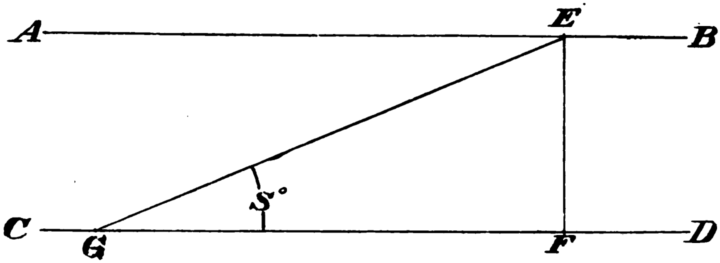
To avoid any possible misunderstanding it may be necessary to state that this applies to irregularities of surface, bends in roads, and streams, and similar matters, and not to details of importance which must be shown, although impossible to show them to scale. Houses, bridges, widths of roads and streams, etc., can not, of course, be shown to proper size on small scale maps, their representation being a well understood convention.

Considerable space has been devoted to the statement of preliminary study and the governing principles of the sketching problem. It will be found that there is little complication in the methods of actual field work. It has been the endeavor to show that cumbersome methods will not be possible, that much more than half the problem of sketching the ground is knowing the ground, and that in the end the methods which will be found best are those by which the individual sketcher can produce satisfactory results with the greatest rapidity.

The basis of the determination of contour points in military sketching is the measurement of the slope. This can be done with sufficient accuracy with some form of clinometer. Many different forms of the instrument are available, all of which indicate the divergence of the line sighted from a horizontal line established by plumb line or by a spirit level. The simplest form of clinometer is a "slope board," a rectangular board to which is attached a plumb line moving over an arc or tangent scale, and marking zero when the top edge, which is the sighting line, is horizontal. In many respects this is the ideal form of slope measurer for military work, and is generally arranged on the board which holds the paper on which the sketch is made. If properly constructed, it will read accurately to the half degree, which is as small a limit of error as it is necessary to impose.

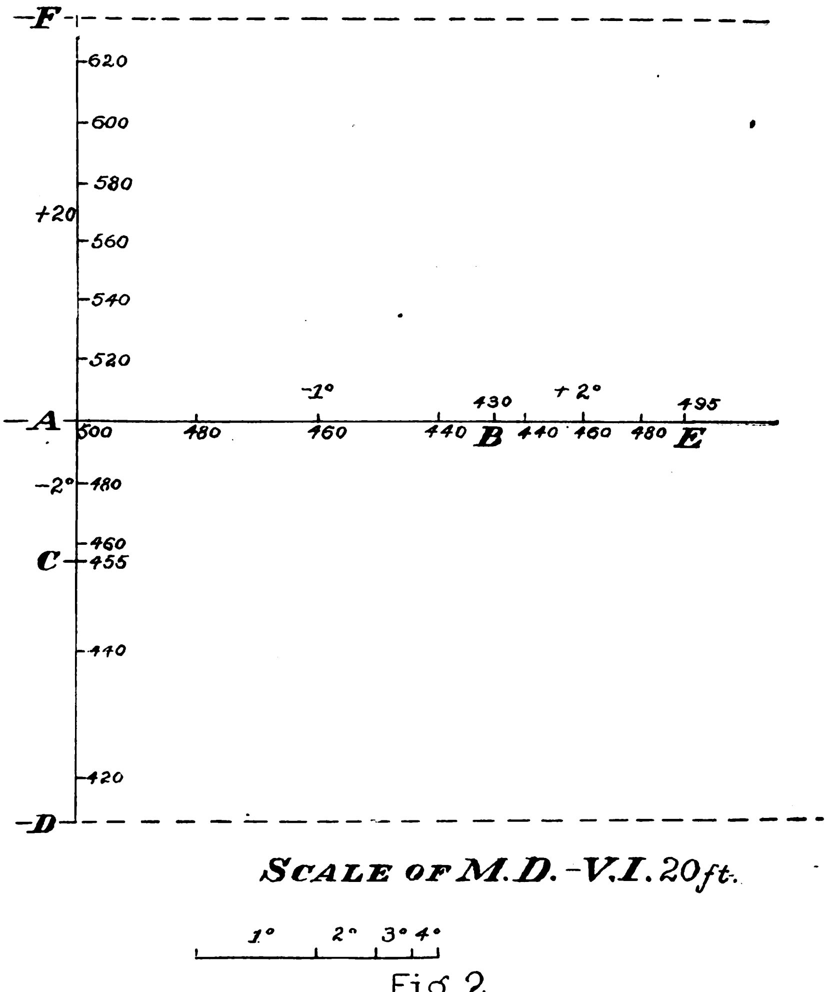
If the slope of the line is known, the only other data needed to plot the points where contours cross the line is the elevation of a point of the line. In beginning a sketch, this is ascertained or assumed, and is thereafter carried forward from that point by the plotted contours. These contours are plotted by a scale of map distances, the term "map distances," which will be represented by the abbreviation M. D., being the distance between mapped contours, for a given slope, vertical interval, and scale, expressed graphically or in inches.

In Fig. 1, AB and CD are the contour planes, cut by a vertical section. GE represents a slope of an angle of S°, and EF is the vertical interval between contour planes. While GE is the actual distance between two adjacent contours on a slope of S° and for a vertical interval of EF, the distance GF is the dis-



A
E
B
S°
C
G
F
D

Fig.1



F
620
600
580
+20
560
540
520
-1°
430
+2°
495
A
500
480
460
440
B
440
460
480
E
-2°
480
460
C
455
440
420
D
SCALE OF M.D.-V.I. 20 ft.
1°
2°
3°
4°

Fig.2

tance between the projection of the contours on a horizontal plane, and is called the "horizontal equivalent" for this vertical interval and slope. As it is the base of a right angled triangle, of which the hypothenuse is the distance measured on the slope and the altitude the vertical interval, we have as an expression of its value—

$$GF = EF \times \text{cotang } S^\circ \quad (1)$$

or using H. E. for horizontal equivalent and V. I. for vertical interval—

$$\text{H. E.} = \text{V. I.} \times \text{cotang } S^\circ \quad (2)$$

and as the cotangent of any angle up to 15°, which is the limit of slope usually found in such country as would be used for military purposes is very nearly—

$$\frac{\text{cotang } 1^\circ}{S^\circ}$$

we have—

$$\text{H. E.} = \frac{\text{V. I.} \times 57.3}{S^\circ} \quad (3)$$

57.3 being the cotangent of 1°.

The H. E., that is, the projection of the actual ground distance between contours, is of little use in military sketching, what *is* used being the length of the H. E. to scale of the map, the map distance between contours or the M. D. Its value will be—

$$\text{M. D.} = \text{H. E.} \times \text{R. F.} \quad (4)$$

R. F. being the representative fraction of the scale used. Substituting the value of H. E. from (3) we have—

$$\text{M. D.} = \frac{\text{V. I.} \times 57.3}{S^\circ} \times \text{R. F.}$$

or remembering that the R. F. is a fraction with unity for the numerator—

$$\text{M. D.} = \frac{\text{V. I.} \times 57.3}{\text{S}^\circ \times \text{D. R. F.}}$$

D. R. F. being the denominator of the representative fraction. A solution of this would give the M. D. in feet if V. I. were expressed in feet as is usual and to avoid the necessity of remembering to reduce it, we may get the M. D. in inches, which is the desirable unit for our system of measurement, by the following transformation :—

$$\text{M. D.} = \frac{\text{V. I.} \times 12 \times 57.3}{\text{S}^\circ \times \text{D. R. F.}}$$

$$\text{M. D.} = \frac{\text{V. I.} \times 687.6}{\text{S}^\circ \times \text{D. R. F.}}$$

or as dropping the fraction and using 688 will not, with the scales used in the sketching, affect the result to a degree capable of measurement, we have finally

$$\text{M. D.} = \frac{\text{V. I.} \times 688}{\text{S}^\circ \times \text{D. R. F.}}$$

in which, to recapitulate, M. D. is the map distance in inches between adjacent contours on the map for a slope of S° and a vertical interval V. I. expressed in feet.

Having ascertained the values for the M. D. for any scale and the vertical interval for each degree and half degree up to about 12°, we may construct a graphical scale of map distances between contours. Such a scale is most convenient for use if made according to design of Major T. H. Rees, C. E., which is shown in Fig. 11. Such a scale provides for a number of M. D.'s for each variation of slope and allows the successive contour points on a plotted line of determined slope to be laid off without the use of dividers.

A study of the equation

$$\text{M. D.} = \frac{\text{V. I.} \times 688}{\text{S}^\circ} \times \text{R. F.}$$

shows the following relations between its constituent quantities to exist:

1. For maps of different scale and the same vertical interval, the M. D. for the same slope varies directly with the scale.

2. For the same M. D. on maps of different scales and the same vertical interval, the slope varies directly as the scale.

3. If on maps of different scale the vertical interval varies inversely as the scale, the same M. D. will represent the same slope.

A system of scales based on this principle is peculiarly advantageous for military sketching, and is almost necessary if any facility is to be acquired in making maps and reading maps without the constant interposition of a scale. If the same distance in inches always represents the same slope, it is very easy to become so familiar with the intervals of the scale that the contour intervals of a map can be at once translated into ground slopes. It is even more important to be able to look at the ground and convert the slopes there seen into contour intervals. Experience has shown that such facility is not hard to acquire, and it is easily demonstrated, although space is not here available for the purpose, that a perfectly logical set of maps for different military purposes can be prescribed in accordance with this principle.

A scale of M. D. for the desired V. I. and map scale having been constructed, all that is necessary for the location of contour points on control lines is the elevation of one end of the line and its slope. If the slope is uniform within the limits of the map, no other measurement than that of slope is necessary. This is of great use in road sketches, which are strips of a definite width with the main road running through the center. When offsets are taken on lines, the slope of which does not change within the distance to which it is desired to extend the map, no distance measurement is necessary. The direction of the line is plotted, the slope measured and the spacing of the contours determined by the scale of M. D. If the slope does change within the limit the distance to the point of change must be measured and the number of complete contour distances determined on the plotted line by scale. If after laying off the full number of complete contour distances, starting from the end of the line, the elevation of which is known, the other end of the line is not reached, the proportion of the remaining distance to a complete M. D. for that slope gives the difference of elevation between the last contour and the end of the line, and thus determines its elevation as a new starting point. If from that point on the slope is uniform no further measurement of distance is required.

Both on offsets and on the main traverse line the elevations of all points after the point of beginning are determined graphically by the scale of M. D. As an illustration of the determination of contour points and elevations as above described, refer to Fig. 2. Start at A, elevation 500 feet, ABE being along the road which is being sketched, the dotted lines parallel to the road representing the limits to which the sketch is to be carried laterally. The slope along the offset AF is uniform for a greater distance than AF and measures +2°. Apply the scale and dot in contour points to the limiting line.

On the offset AD the slope is —2° and is uniform to C. As C is well within the limits of the map the distance AC must be measured. The scale shows that the distance AC will contain two complete M. D.'s for 2° and a remainder of one-fourth of the M. D. The lowest contour point is 460, and as C is one-fourth of the V. I., or five feet lower, it has an elevation of 455. From C the slope is —1° and is uniform to the limits of the map, and no further measurement is required. If from C we laid off the M. D. for 1°, the next contour would be that having an elevation of 435. But we have started in with a system to which this does not belong and the contour desired is the 440, the first of the system below the 460 already located. This is fifteen feet or three-fourths of the V. I. below C. Lay off three-fourths of the M. D. for 1° to locate the 440 contour, and thereafter lay off the full M. D. for 1° to the limits of the map.

This method is theoretically correct, but, as will be shown later on, the practiced sketcher seldom finds it necessary to take any measurements for locating contour points on offset lines. The distances to points where slope changes can usually be measured by intersection, and, when this is not possible, errors made by estimation of distance will make errors in location of contour points which are local. Along the main traverse, however, the distances must be measured anyway, and contour points and elevations will be determined by this method, and as errors of elevation, due to errors in distance, are carried along the traverse, greater care in making such measurements and in plotting the elevations is necessary than on offsets. Fig. 2 still further illustrates the method used along the traverse.

By the application of the same method the difference of elevation between the ends of a line may be determined without reference to the surface of the intervening ground. In Fig. 3 the upper half shows a steeple as observed from A. The slope of the line AB is S°. Applying the M. D. for this slope to the projection of the line AB we find it is contained three and one-half times, and B is three and one-half times the V. I., or seventy feet above A. This method of obtaining elevations is very much used in sketching.

In Fig. 4, AB is along a traverse line, the line AC being the direction of the line along which a section of the ground is shown by A′D′C: From A draw the line AC and measure the slope of the ground to D (A′D′) and also the slope of a line joining A and the point of the ridge C (A′C). From B lines BD and BC locate by intersection the map positions of D and C. Applying the M. D. for the slope of a line joining A′ and C to AC, the projection of this line, it is contained, say seven times, and the elevation of C is 360. Then apply the M. D. for the ground slope from A′ to D′ to AD and it is contained five times. The elevation of D is 400 and we interpolate the 380 contour.

This method of locating points where slope changes by intersections from the traverse line to the water course or watershed lines will be found of great use,

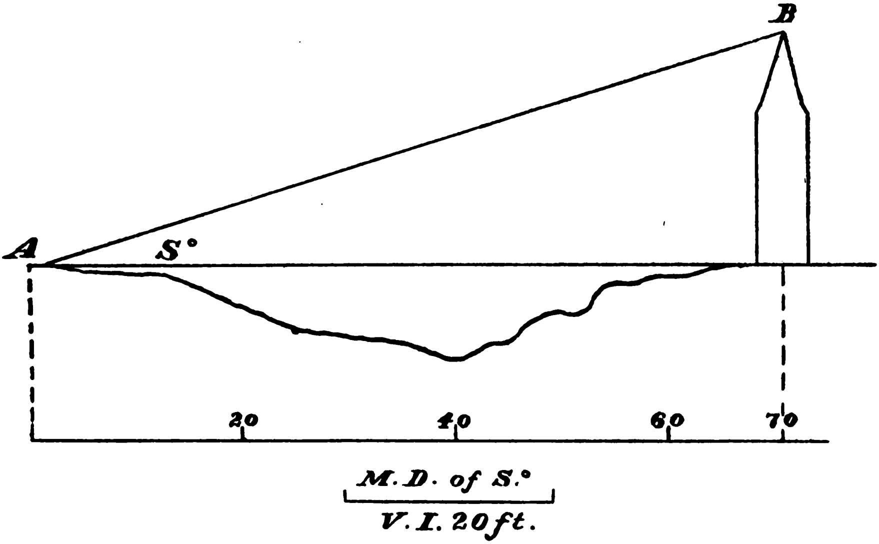

B
A
S°
20
40
60
70
M.D. of S.°
V.I. 20 ft.

Fig. 3.

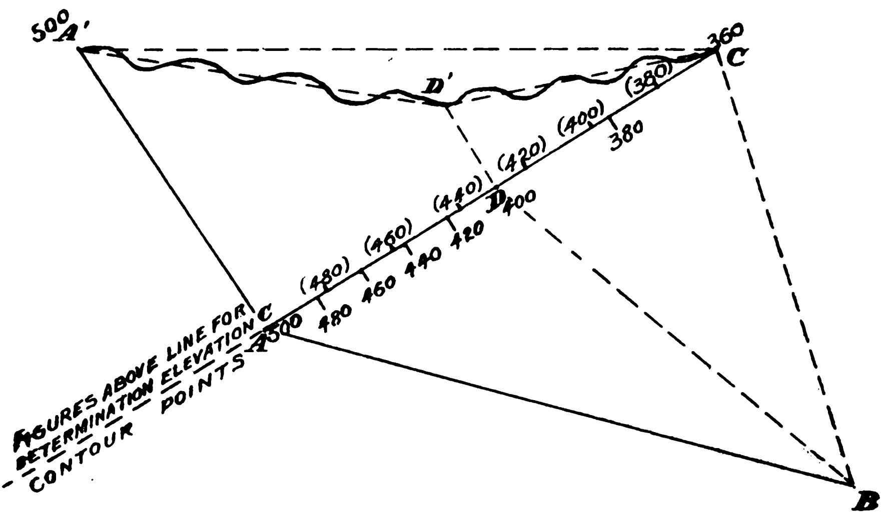

500 A'
360 C
D'
(380)
(400)
380
(420)
(440)
D
400
(460)
420
(480)
440
460
480
C
A 500
B
FIGURES ABOVE LINE FOR
DETERMINATION ELEVATION
CONTOUR POINTS

Fig. 4.

the lines being drawn from a station occupied before reaching the axis or after passing it. If the intersections are to be made after passing the features, care must be taken to draw the line of its general direction when passing it.

Water courses, except where the stream cuts deeply into the ground, are generally of uniform slope, but this is not the case with watersheds, which are found in five general regular classes, besides those not following any rule. The term watershed is here used as meaning a spur of whatever size separating watercourses in which water runs either habitually or at time of rainfall only. They are:

1. Of uniform slope.

2. Steep slope at the top with an abrupt change to gentler slope.

3. Gentle slope at the top with abrupt change to steeper slope.

4. Concave curve without any marked point of change.

5. Convex curve without any marked point of change.

In any of these types the slope can be measured to advantage from a point suitable for viewing it in profile and from which the lines for locating points of change by intersection can be drawn, as the point B in Fig. 4, by holding the top of slope board or sighting line of clinometer parallel to the slope. In slopes of the third and fifth classes this is particularly desirable, as the slope could not be measured along the axial line without going out to a point where the foot of the slope could be seen.

With slopes of the fourth and fifth classes the practiced sketcher measures the slope of a line to the foot and the distance to this point, and after ascertaining the number of contours contained therein spaces them by eye according to observed conditions. This method is illustrated in Figs. 5 and 6.

The beginner should measure slopes and plot contour points according to the above methods. These methods should also be used in position sketching, but in actual road sketching by experienced sketchers under service conditions when it would be impracticable to leave the road, the following method is recommended: The sketcher should learn to estimate with considerable accuracy a distance of 300 yards. He should then measure either along the axis or in profile the angle to a point 300 yards from the road. Having obtained from the scale of M. D. the number of contour points contained in the distance, they should be spaced according to the shape of the ground. This would lead to no considerable error, as the number of contours in the distance would be correct and the spacing would show the most essential feature of the slope, which is whether or not one can see up or down it for the entire distance. When there is a distinct point of change in the slope its distance can be closely estimated and its location shown by an abrupt change of the spacing at that point. If the point of change is within the 300 yard limit and the slope beyond is uniform for some further distance, the spacing beyond the point of change can be continued as far as desired. Where the change is such as to form a military crest and takes place beyond the 300 yard point, the measurement to this point will give the proper spacing to carry to the actual point of change, and the distance to this can be estimated. Beyond this a change to a

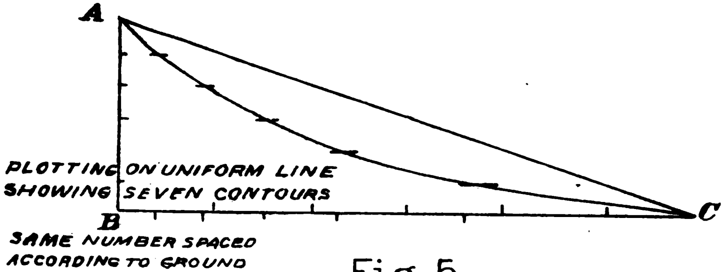


Fig.5

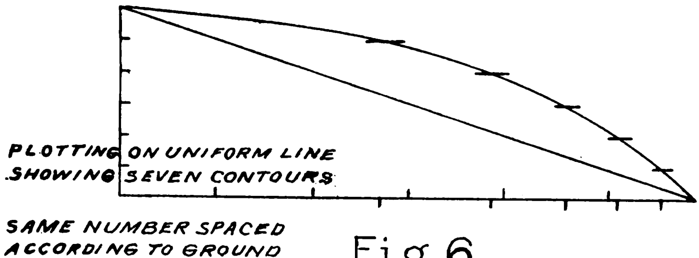


Fig.6

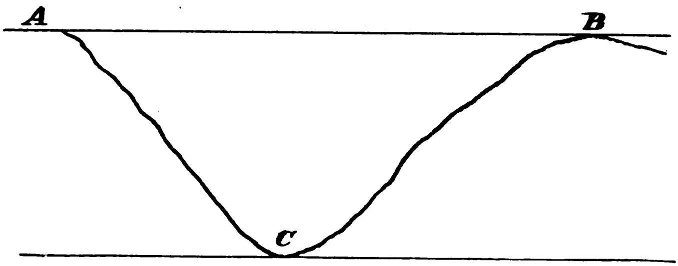


Fig.7

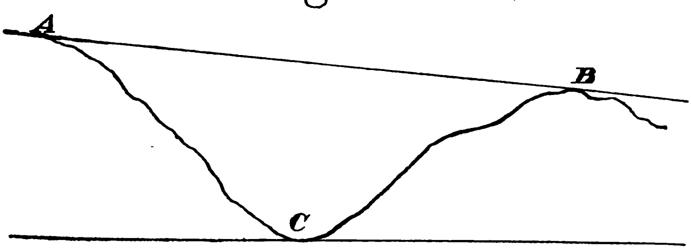


Fig.8

greater spacing will show the crest on the map. Whether this latter spacing is correct is of no importance. Where the change is in the opposite direction, 300 yards will be far enough to carry the measurement, but a crest should be located when it is within range of the road. However, even when it is desired to continue the information beyond the 300 yard limit, the slope measurement should be taken to the 300 yard point, because by always using that point the sketcher will acquire a high degree of exactness in his estimation of that distance.

In speaking of points where slope changes, consideration must be given to the scale used. In road and position sketching the scales used are generally quite small, and only such changes should receive attention as can be shown on the map, that is, as will appreciably affect the shape of the contours. The ground may be very uneven, so that its section would constantly cross and recross a straight line, but still have a uniform average, so that one standing on one of the high points could see for some distance to a point where the average changes very perceptibly. In such a case the average slope should be taken, but what the size of features must be to receive consideration depends on the scale, and must be learned by actual experience.

In the foregoing directions for measuring slopes, it has been assumed that the measurements were along water courses and watersheds. It is not intended to convey the idea that no other slopes will be measured. The same typical forms will occur frequently and be measured similarly while working along hillside roads.

There is one weak point about this otherwise excellent method of contouring. The method is, however, so admirably suited to the purpose of the military sketcher that it must be used for much of the work, and frequently for all of it, and this defect neutralized by a thorough understanding of what it is and how to avoid its effect to as great an extent as possible.

This weakness consists in the fact that the number of contour points on a given line depends on slope and distance. While error in distance and slope can be made fairly uniform, the error in the resulting number of contours or the elevation obtained therefrom does not vary uniformly with the error of measurement, for the M. D. for a steep slope is very much smaller than for a gentle slope, and an error in measurement which may on a gentle slope make scarcely an appreciable error in elevation will on a steep slope make quite a considerable difference. Furthermore, with the usual methods of measurement in sketching, the error in distance is greatest on steep slopes just where it has its maximum effect on elevation, and the errors will not balance even when a downhill slope is opposed by an uphill slope of the same degree, as the error in distance by pacing or timing is differently affected by up and downhill slopes. A careful observation of the pacing of a number of men shows that the pace is shorter both going up and down hill than on a level, but not uniformly so for slopes of the same degree. Distances obtained by timing would manifestly be so different on the up and downhill slopes, even when these slopes were not great, as to very seriously vitiate the work.

When, however, this source of error is guarded against, its effect can frequently be eliminated or at least minimized. This is accomplished on the main traverse, the only place where the error is of sufficient importance to cause trouble, by constantly taking sights ahead to points of the same level, or if such cannot be sighted, then to points to which the angle is as small as possible. In the first case the far elevation is independent of distance, and in the latter the distance with its accumulated error has applied to it as large an M. D. as possible, and the effect of the error in distance is much less than if the elevations were obtained by application of the M.D.'s of the actual ground.

In Fig. 7, the sketcher at A with slope board or clinometer finds a point B of the same level as A, and when B is reached marks its map position with the same elevation as that of A. The slope AC is then measured, and, making such allowance as experience may show to be necessary for a slope of that degree, the elevation of C is determined. The contour points between C and B are then interpolated.

In Fig. 8, the elevation of B is determined by measuring the slope of AB, and when B is reached applying the scale for the slope of AB to the total distance. The contour points between A and C and C and B are then determined as in the preceding case.

In all these slope figures the slopes shown are excessive when compared with actual conditions. They are so drawn because the vertical ordinates are so small compared with horizontal distances that if drawings are made to fit actual conditions the contrasts will not be sufficient to make the proof as apparent as it is when the exaggerated figures are used, the exaggeration not being apparent until the actual angle between the lines is noted. We are so accustomed to using an exaggerated vertical scale that sections made with the same horizontal and vertical scale do not seem to represent natural conditions.

That the condition is a serious one even with actual ground slopes of moderate degree, is apparent when we consider that an error of distance which makes an error of one contour interval on a slope of 1° will make an error of eight contour intervals on a slope of 8°.

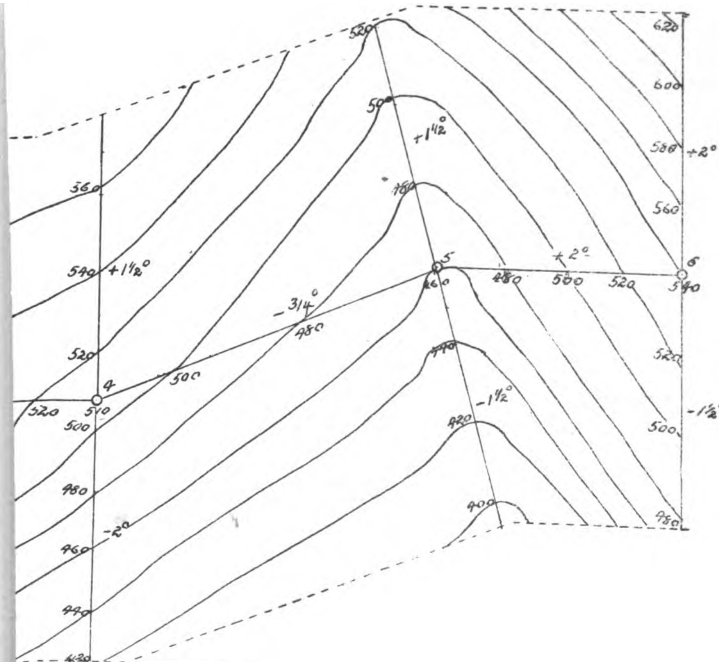
Even when the slopes encountered are not very steep, points of the same level some distance ahead should be constantly sought, as we thus get results independent of any error of distance and can localize the errors over any intervening ground. It will be a great aid to the sketcher if he will find a number of slopes, varying from one to eight degrees, and measure distances on them by accurate methods, then by a set of tests with field methods sufficiently exhaustive to obtain an average, prepare a table showing his error or that of his horse in measuring distances up and down hill on each of the different slopes. If, then, the error in the elevation of the distant point was minimized by the methods already given, the intervening information could be corrected by such a table so as to be quite accurate. For instance, in Fig. 7, the distance AC as measured could be corrected by finding the error per hundred paces or minutes for the slope of AC from the table. Still more important, in Fig. 8 the distance AB would be the sum of the corrected distances AC and CB. If, then, the elevation of AB was obtained by using the large M. D. of the slope of AB, the error of the elevation of B would be the minimum possible with practicable methods. While this has taken considerable explanation, after such a table was once prepared it would take a little longer to determine the elevation of B with the minimum error than to obtain it by applying the M. D. of the steep slopes to successive distances with maximum error of measurement.

It is quite possible that tests of pacing or timing on a set of slopes with a number of men or horses, would give average results of value, but this has not yet been tried.

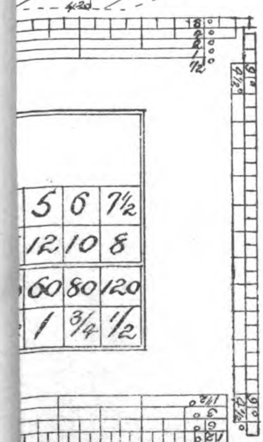
The exceeding appropriateness of using some form of slope measuring instrument in connection with the scale of M. D. for contouring military sketches is based on the fact that the contour points between the station occupied and a distant point may be plotted without going to the distant point, and even in many cases without measuring or estimating the distance to it. In road sketching it is seldom necessary to leave the road, although it is necessary to draw the contours for a considerable distance on each side of it. However, the elevations on the main traverse will be badly out unless the precautions above suggested are observed with great care. These take time, and in thickly wooded country it may be impossible to keep checking ahead, and elevations would be much better measured with the aneroid barometer. Elevations obtained with it are independent of errors of horizontal measurement. Its error, due to causes other than changes of elevation, are under average conditions so slight and gradual as to come well within the limit of error. In position sketching, especially in combined work where greater accuracy is required, the task assigned each sketcher will not be so great but what we will have ample opportunity to check the rate of change of the barometer due to changes in temperature and weather conditions by sighting ahead to points of the same level and eliminating error thus found.

The combination of the pocket aneroid for obtaining the elevations of points occupied, and of some form of slope measuring instrument for measuring vertical angles to points not occupied, seems to be the ideal combination for military sketching. Frequently, however, the barometer will not be obtainable nor will any other instrument for slope measuring except an improvised slope board, so the sketcher should know how to minimize the error of his traverse due to error of distance measurement.

The diagram in Fig. 10 shows the general method employed in making a road sketch. An examination of this figure will show that the contour lines are drawn through points established by use of the scale of M. D., just as in other classes of work they are drawn through points located by interpolation between points of known elevation. In theory this is correct, and this method is the one that should be used by the beginner. In the particular example, points of corresponding elevation are connected by straight lines. This could only be correct when observations were made on all lines which could exert any influence on the control. Starting out with this method, the sketcher as he advances in facility must, to attain the necessary skill for working with sufficient rapidity, learn to do with fewer control lines and to draw his contours between points of the same elevation on control lines according to the shape of the ground. In the final stage of proficiency he should need control lines only on main watersheds



520
620
500
600
+1½°
580
+2°
560
480
560
540
+1½°
+2°
5
6
460
480
500
520
540
-3/4°
480
520
500
4
520
510
440
-1½°
-1½°
500
420
480
500
460
-2°
460
400
480
440
420



8
6
3
1
1½
5 6 7½
12 10 8
60 80 120
1 3/4 1/2

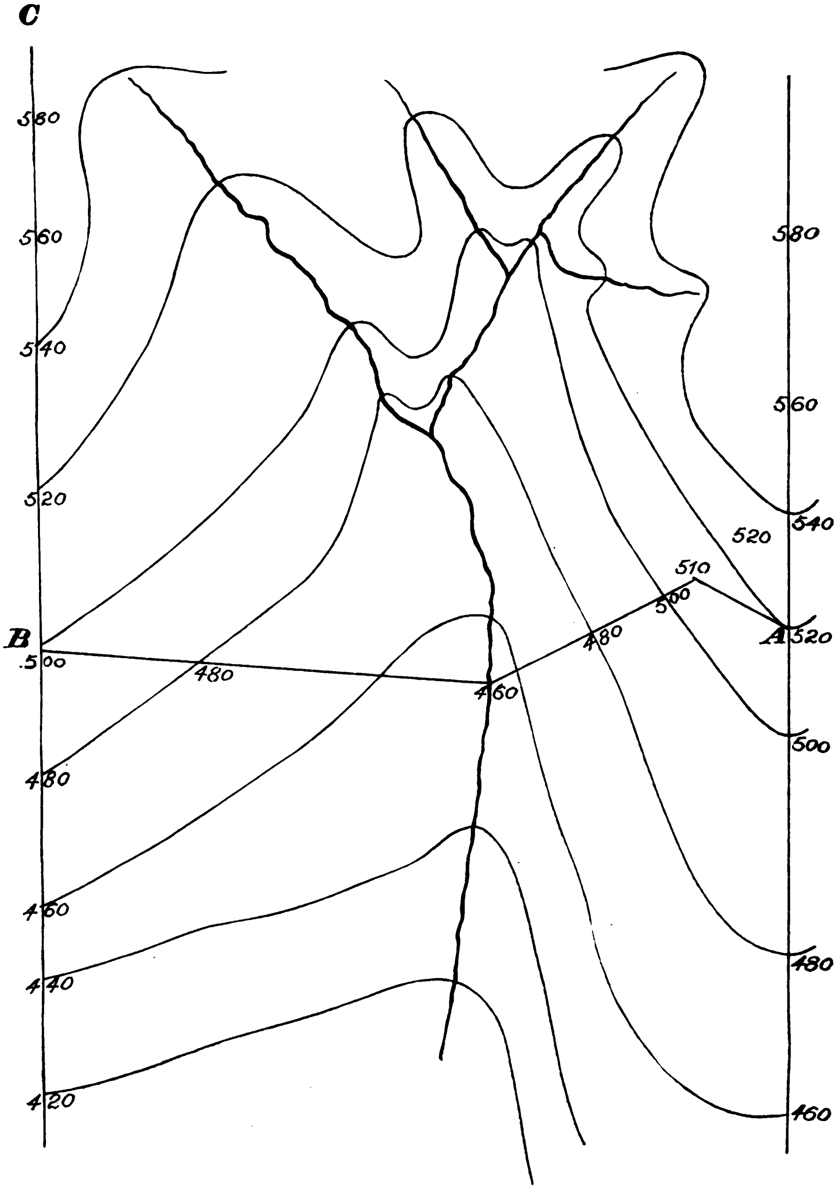

C
580
560
540
520
B
500
480
480
460
440
420
580
560
540
520
510
500
480
A
520
460
500
480
460

Fig.9

widely separated, and from which a view of the intervening ground may be had.

In Fig. 9, the sketcher at A has determined the contour points shown. He has three points on the 520 contour. Orienting the sketch and sighting over his extended arm, he can trace by eye on the ground the course of the 520 contour, checking on the known points. The next higher and lower ones are then drawn through the known points, their variation in distance from the 520 contour being determined by the greater or less slope of the ground at any point compared with the slope between the corresponding contours as seen on the distant line. For instance, having drawn the 520 contour, start the 500 from B. It crosses the water course at a point where the slope is about half as steep as at the starting point, and the interval is therefore doubled. Then it turns the small spur a little steeper than at B, and turns the point of the spur at about the same angle as at B, and so on to the next located point. The sketcher is all this time at A and has the 520 contour for reference. The map distance for the slope BC he has on his sketch and the ground slope he can see on the distant line represented by BC. As the ground slope changes he varies the map distance proportionately. The contours are correctly located at the known points, considering, of course, the limit of error, and when the sketcher attains proficiency in spacing his contours to represent the ground slopes, they show the shape of the intervening ground and even its actual slopes to a surprising degree of accuracy. In fact it is much better to spend what time is available in increasing the accuracy of a few locations rather than in increasing the number of locations. The sketcher must learn so to select his locations that they will have the greatest value in the control of the work. A few well selected points may be of much more value than many poorly chosen ones.

Facility in doing the work depends mainly on practice and good judgment. It is much like stenography, in that speed is essential. The best worker, after mastering the general theory, adopts methods which suit him and which might not be the best for others of equal skill.

In making a road sketch it is usual to carry the ordinary detail to a definite width on each side of the road, generally 300 yards. In addition to this, important points, such as villages, artillery positions within range, etc., are shown on the map at their approximate distance, obtained by intersection when possible, otherwise by estimation. Towns and villages to which roads branching out from the road being sketched lead, but which are out of reasonable limits, are indicated by marking the road leading to them, *e. g.*, "To Kickapoo, 8 miles."

The limits should also be extended in contouring, when breaking off the contours at the limiting distance would fail to give a graphical idea of the country adjoining the road. In Fig. 12, the dotted lines show the ordinary limits of the sketch. If it be covered beyond these lines it will be seen that the contours show nothing except the degrees of slope, and it is necessary to read the figures to tell when changes in the direction of the slope occur. When the entire sheet is uncovered a complete graphical representation of the ground between the lines is shown independent of the figures on the contours. Watershed and water course contours should always

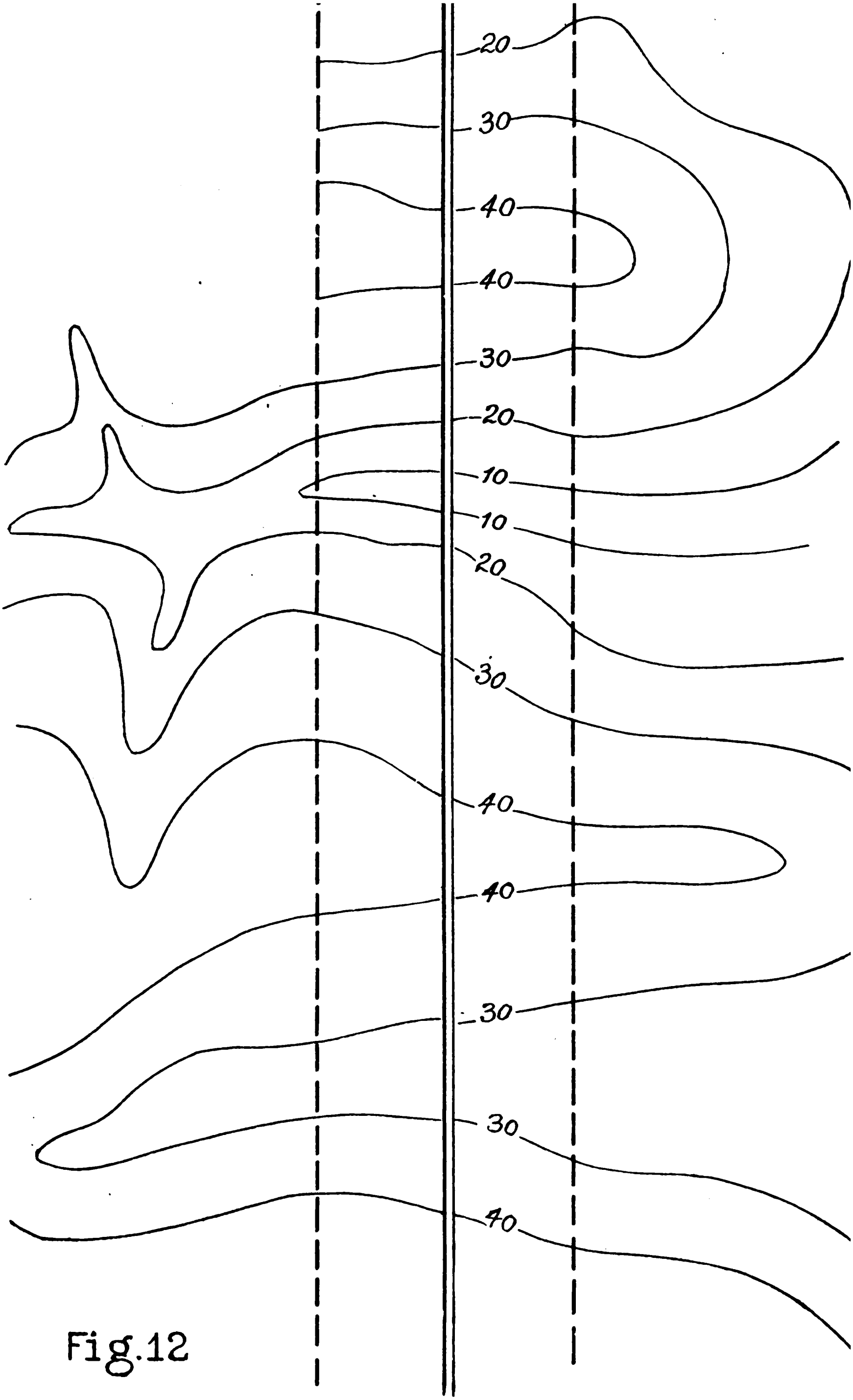


Fig.12

be extended as indicated, although on an ordinary road sketch so much of them as is beyond the limiting lines may be sketched in by estimation. If the sketch is one of a number being made simultaneously on roads practically parallel with a view to combination, the sketch should always be carried to the limit of reasonably accurate work, somewhat more care being taken with distant work than when it is extended merely to complete the graphical representation.

The problem of position sketching, while similar in its essential elements, has many points of difference. Generally the sketch made by any one man does not cover the whole area to be mapped, but must be combined with sketches of adjoining sections made by others. The different methods of harmonizing such portions are considered in the second part of this pamphlet. The problem differs mainly from road sketching in the selection of the control lines, so that the same average of accuracy is maintained throughout the limits of the sketch. If the work is to be combined it is essential that however large the limit of error, variation from exactness shall be due to gradually accumulated error and not to mistakes or to careless treatment of certain parts of the work.

When the conditions of the work do not impose certain control lines used in common by sketchers of adjoining portions or when the whole area is mapped by one man, rapidity is largely dependent on the proper selection of the control lines. As far as possible, considering other conditions, these should run perpendicular to the water course and watersheds, as this will enable slopes to be measured in profile and distances to be measured by intersection. It will also give good views of the country from high points on the watersheds. A control line along either of these features makes it necessary for the sketcher to traverse it from end to end and then to cross over to the next similar feature and pursue the same course of action in a contrary direction.

The scale of position sketches is generally larger than that used for road sketching, ordinarily twice as large, and consequently smaller features will exert an influence on the shape of the contours and must receive consideration. For special purposes the scale may be still larger, but it should be kept down as much as possible, as much greater care is necessary with large scales and the time needed to obtain satisfactory results is much greater.

Outpost sketching is done on about the same scale as position sketching, and differs from it only that it must be done from a line which it is unsafe to cross. This involves the location of points by intersection or by estimated distance on lines of measured direction. To the practiced sketcher who is accustomed to contouring with the minimum number of located points and who understands how to show what he sees by contours of proper spacing and direction, the problem will present few difficulties.

Even when a considerable number of points on the contour have been located, there will never be enough to accurately determine its form. Generally the locations will be but few, and will be sufficient only to check the sketcher at a few points while he is drawing in the contour as he sees it on the ground. For this reason it is necessary for the student to study typical forms, both on the ground and on accurately contoured maps. There is a particular tendency on the part of the unskilled topographer to

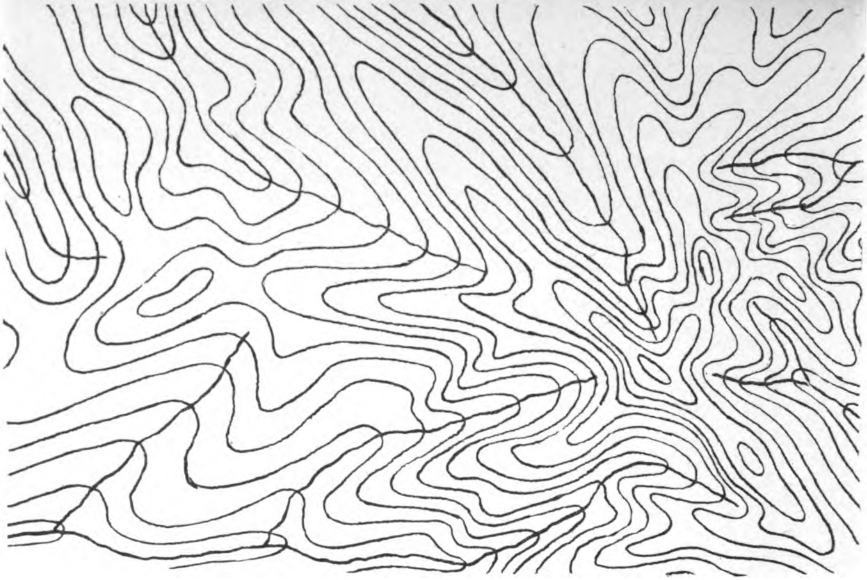


Fig.13

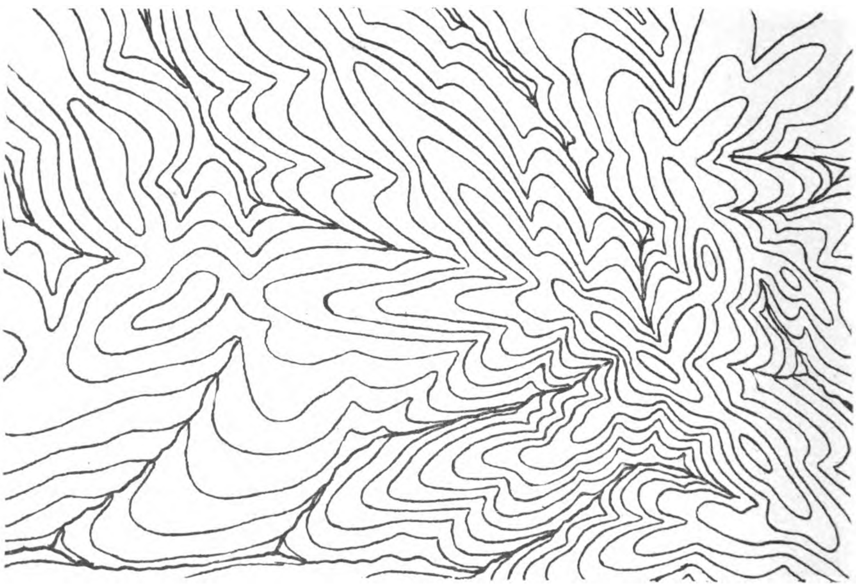


Fig.14

draw water courses and watersheds alike, making each with rather flat elliptical curves and making them of about equal width. It is generally the case, particularly where the erosion is principally due to rain fall, that the water course is much narrower than the adjoining spur and is rather pointed, being formed by the intersection of two curves with the convex sides toward the stream, while, were it the same as the spur turned upside down, the concave side would be toward the stream. Figs. 13 and 14 were drawn by Mr. Glenn S. Smith, C. E., a topographer of long experience in the U. S. Geological Survey, and illustrates the point very well. Fig. 13 shows the contour forms as they would be drawn by an inexperienced sketcher, and Fig. 14 shows them as they would be correctly drawn for the same area. It cannot be said that the space between two spurs will never have the rounded form, especially when the erosion is due partly to wind, but the forms as shown in Fig. 14 are those which will be most often encountered.

In conclusion, it seems necessary to add one caution. If in attempting to use the methods suggested herein, the student makes a sketch showing the shape of the ground in the crudest way with contour distance, having little reference to real slopes, he should not think he has made a success of his work. The writer is aware that, to one accustomed to contouring by exact methods, the statements contained herein will, in many cases, appear ridiculous, and he would hesitate to make them if abundant application of the methods for several years by a number of officers of the Infantry and Cavalry School had not proved that by their use good contoured maps can be made and that the student can learn to make them with surprisingly little practice. It has not been intended to convey the idea that any sort of sketch is good enough for military purposes, but that the difficulty of making contoured maps is very greatly overestimated, and that by the use of a few simple principles the student can learn to draw what he sees in contours. Until the result he secures is a contoured map on which the representation of all the features of the ground which are of military importance will be found on comparison with the ground to be substantially correct in themselves and in their relation to other features, the sketch is not up to the standard of what any educated man of average ability, with even a very limited amount of experience, can accomplish by the methods herein set forth.

PART II.

COMBINED SKETCHING.

GENERAL REMARKS.

An army taking the field at the outbreak of war will be supplied by the Military Information Division with maps suitable for strategical purposes. Such maps will be on a scale of about one inch to the mile, with contour intervals of about fifty feet. It is not possible to do more than this in the way of preparing maps in advance, except of possibly a few of the more important strategical areas.

As a rule, therefore, an army must itself supply the means for elaborating these maps to the scale and contour interval suitable for use for general tactical purposes, such as development for action, preparation of positions for defense, the orderly conduct of the march of large bodies of troops, the rapid pursuit of an enemy, or the attack of a position.

It is well to note the distinction in regard to the necessity for maps that exists between large and small bodies of troops. So long as the movements of troops, either on the march or in battle, fall under the immediate supervision of the commander in conformity with whose plans the movements are made, there is no great necessity for anything beyond the strategical maps above mentioned. Thus, in the march of a detached battalion or regiment, or even brigade, changes in the orders for movements may be made at any time without disastrous confusion, because no other interest is involved. The orders for such a body of troops emanate from a commander who is of necessity familiar with the topographical conditions by reason of his presence on the ground.

Thus it is seen that the necessity for elaborated maps does not appear until the unit reaches the size of a division. For this and greater units, all operations are governed by orders emanating from a commander not actually on the ground. They are therefore map problems, and the machinery for furnishing maps in sufficient detail and of sufficient accuracy for proper control of operations becomes essential. It is desirable, but not absolutely necessary, for smaller units.

The work of furnishing proper maps is the function of the topographical corps of any unit in the field. With small units, the extent of ground to be covered will not be so great as to be beyond the powers of a single sketcher.

To meet the requirements of a division or any larger body of troops, road and position sketching must be carried on over extended fronts, involving the work of many sketchers. The results must be combined and the maps issued with the minimum possible delay. This requires thorough individual instruction of topographers, flawless methods of control, and perfect organization. From the nature of the results required and the time available for the work, it is evident that only reconnaissance methods can be used.

It is to be noted that when a size of unit is reached where combined sketching becomes necessary for proper handling, there is also found in its front a line of observation thrown out to a considerable distance in the form of a cavalry screen.

This clearly defines both the time and space limits within which the topographical work of an army must be done.

In the preparation of road maps, the topographers have access to the space between the cavalry screen and the head of the main body, the space which will form the succeeding day's march for the various columns. The topographers must work within this area, the results of their work must be combined, the resulting maps reproduced in sufficient number for the needs of the main body, and they must reach the main body in time for the march orders for the succeeding day to be based upon them. Otherwise the work of the topographers will be of little use.

In position sketching, the time available is that between contact of the line of observation and the collision of the main battle lines, which may be assumed as but little greater than the marching time over the distance separating them, or one day.

For an offensive battle, which is the rule in forward movements, the work will be carried on at the limit of the distance reached by the line of observation, which allows practically one full day for the work. Defensive battles will generally occur in retrograde movements, on ground to which the surveyors following the army have had access.

The ground for defensive battles will therefore have been accurately mapped if the topographical work in rear of the army has been carried on as it can and should be done.

The general rule deduced from the foregoing considerations is that whatever topographical sketching is undertaken at daylight in the morning must result in the advance copies of the finished map not later than midnight, with sufficient additional copies to meet the needs of the main body delivered one hour before the time for the execution of the orders based on the advance copies.

The previous discussion has had in view the conditions of service in time of war, and is not to be confused with the question of maps for purposes of instruction. Map problems involving small units are but preparation for controlling larger units in the same way.

The following methods of combined sketching covering a large extent of territory were worked out, and have been tested and improved in the practical work of the course in topographical sketching at the Staff College.

The condition already pointed out, that of being able to complete in one day any work commenced in the morning, has been held steadily in view.

COMBINED ROAD SKETCHING.

All sketchers to be mounted on horses carefully rated at walk and trot.

Scale of sketches 3 inches=1 mile. Vertical interval 20 feet.	Unless otherwise ordered by competent authority.

All lettering should be so placed as to be right side up when the map is being followed in the same direction as the sketch is made.

Equipment of Sketcher:

Sketching case,
Aneroid barometer or clinometer,
Scales,
Stop watch,
Lead pencils (grade HB).

Combined road sketching is necessary in connection with the march of bodies of troops requiring the use of two or more parallel roads. Such conditions require a more accurate knowledge of the character of the road than can be had from small scale maps prepared in advance. Roads shown as in good order on such maps may have become impassable at a later date. Orders for the march of one column might under such circumstances assign it to an impassable road. A subsequent change in the line of its march might not be possible without serious interference with the march of adjacent columns. Combined road sketching may be advantageous in obviating these difficulties. The work may be carried on under many different conditions.

As to topographical conditions,—

1. Where fairly accurate small scale road maps are available.
2. When no road maps are to be had.
3. In a thickly populated country where roads are numerous.
4. In a sparsely settled territory where roads are few and poor.

Conditions 1 and 3 will usually be combined, as will 2 and 4. Bearing in mind that combined road sketching is necessary in connection with larger units, conditions 1 and 3 will usually be associated with the character of the country suitable for the operations of such units, and will therefore be the normal condition.

As to the military situation, combined road sketching may be required,—

1. In friendly territory.
2. In hostile territory.
3. In the close vicinity of the enemy.
4. At a distance from the enemy.
5. In advance, usually against an enemy of inferior strength.
6. In retrograde movement, usually before an enemy of superior strength.

Conditions 1 or 2 may be combined with either 3 or 4, and any of these combinations may occur with either 5 or 6.

CONTROL.

The most important combination of the above conditions from the sketching standpoint is where the army is advancing in a hostile country in close proximity to an enemy little inferior in strength, fairly accurate small scale maps being in the hands of the chief topographical officer. The strength of the unit may be assumed as a corps, since in case of a wider front it will be practically necessary for each corps to handle the sketching on its own front independently. Any system which will meet the demands of this situation can by modification in the direction of simplicity be made to meet the demands of any other.

The topographical situation is shown in Figure 1. The front of the cavalry screen at the halt on the night of May 1, is on the general line XY. It will

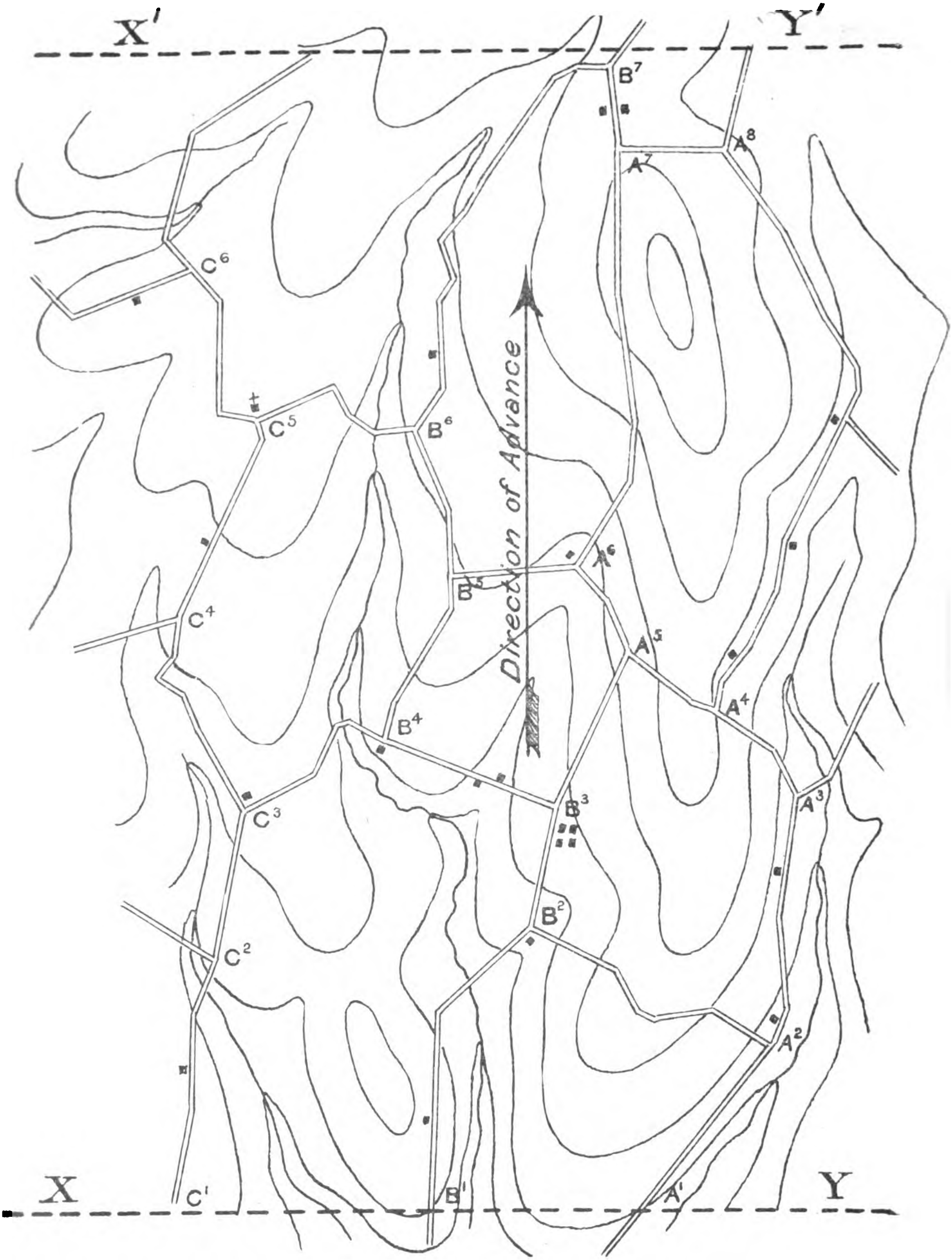

X'
Y'
B7
A8
A7
C6
C5
B6
Direction of Advance
A6
B5
C4
A5
A4
B4
B3
A3
C3
B2
C2
A2
X
C1
B1
A1
Y

Fig. 1.

probably cover the territory between this line and X′Y′ on May 2, over which on May 3 the main body will march.

The problem in sketching is, therefore, on May 2, to obtain all necessary information, compile it in a map, to reproduce this map, to deliver five copies of it at some point on the line XY before 12 midnight, May 2–3, and to deliver twenty-five additional copies* at the same point at or before 4 A. M. May 3.

There are three principal roads included in the front, with numerous crossroads. The system must provide for covering all roads included between XY and X′Y′, all crossroads being identified at points of junction with main roads.

Organization of Parties.—To provide for covering all roads and to enable the resulting sketches to be combined, the following organization has been found satisfactory.

Parties A, B and C, one each for the principal roads leading to the front.

Party A.	
One director One principal sketcher Six assistant sketchers	8
Party B.	
One director One principal sketcher Three assistant sketchers	5
Party C.	
One director One principal sketcher Three assistant sketchers	5
Total	18

* Five copies for Corps Commander. (first five sent.)
Four copies each Division Commander.
One copy each Brigade Commander.
Four copies each Army Commander.

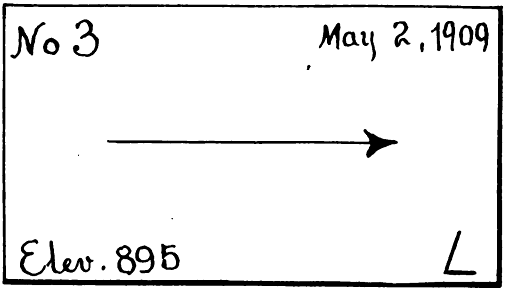
DUTIES OF THE DIRECTORS.

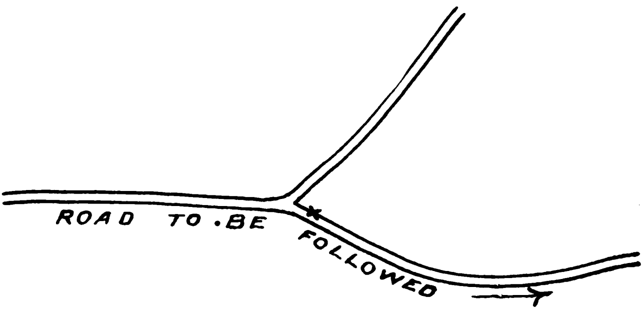
The duty of ascertaining the proper road to follow, of finding out what is to be done in case the guide map is at fault, and of keeping touch with adjacent parties, will occupy so much time that these duties must be separated from that of making the road sketch. If the road sketching is to keep pace with a rapid advance, it must be able to maintain a rate of fifteen to eighteen miles a day steadily, with a maximum limit for a single day of about twenty-five miles. The actual work of sketching fifteen to eighteen miles of road per day is a sufficient day's work for one sketcher, without hampering him with other duties. Therefore, a director is necessary. His duties are to mark the road for his party so that they may follow him without hesitation throughout the day. To do this, he should mark every crossroad with a suitable mark which will indicate to his party which road to take, and in such manner that adjacent parties will be able to tell when they have encountered his main road, and serve to identify this point on the sketches of his own and adjacent parties.

This has been done in practice by the use of cards of different colors. These cards must be posted so as to indicate the proper road to the sketchers following.

A suitable size of card is about 3 x 5 inches, and they should be marked as shown in Fig. 2.

The cards must indicate by their position the road for the principal sketcher to follow, and for this purpose should be posted beyond the forks of the road, in the included angle between the roads, with





X INDICATES POINT WHERE CARD IS TO BE POSTED

THE CARD IS PROPERLY MARKED TO BE POSTED AT THIS POINT.

Fig. 2

the arrow pointing along the road to be followed, as indicated in Fig. 2.

The color of the card indicates the party to which it belongs. They are numbered serially for each day's work and posted in order. A card is posted at every branch road unless evidently leading only to a house. If any doubt exists, a card should be posted and an assistant sketcher will determine whether it is a farm road or a crossroad.

The elevation is determined by an aneroid barometer, one being carried by each director. A crayon of the same color as the cards should be carried by each director, with which he should mark elevations on bridges, at hill crests, and at other points along the route for the use of the principal sketcher.

In the lower right hand corner of the card should be marked R, L, or C, according as the right, left or center road, facing in the opposite direction to the arrow, is to be followed to retrace the route of the director.

Letter designations for the parties may be used, with cards all the same color. In such case, the letter designation of the party should be conspicuous on the card. Crayons may be used, trusting to find at each crossroad some suitable surface on which to mark the proper designation, but mistakes in numbers are likely to occur with this method.

If cards are used, each director should prepare his cards for use for the day by numbering them serially, dating, and placing the shaft of the arrow on them. The arrow head and elevation can not be placed on the card until they are ready to be posted.

The cards furnish a convenient means of communication between the principal sketcher and his assistants, as all members of the party are continually on the lookout for cards.

DUTIES OF THE PRINCIPAL SKETCHERS.

The duties of the principal sketcher are to sketch the main road to which his party is assigned, and to control the work of the assistant sketchers of his party.

The first part of his duty requires nothing but the ability to sketch at a rate of three miles per hour with careful attention to accuracy in distance and in direction. The second part of his work must be carried out in accordance with a system which will prevent duplication of sketches. The system adopted, and which has worked satisfactorily in practice, is to assign an excess of strength to party A, and to require that party to sketch all side roads to the right of its main road to a distance of a half mile, and all side roads to the left until cards of the next adjacent party are encountered; to require party B to sketch all side roads to the left of its main road until cards of party C are found; and to require party C to sketch all side roads to the left of its main road to a distance of a half mile.

It may be desirable to indicate to a sketcher that he is to rejoin his party by a different road from that which he is sent to sketch, but it is usually safer to require him to return by the same road he has sketched, and follow the main road until he overtakes the principal sketcher.

The method of handling assistant sketchers found to work best in practice, is to assign numbers to them, and to direct that they sketch the side roads in regular order. Thus for party A, No. 1 takes card No. 1 and if the road leads to the right of the main road, sketches it for a distance of a half mile; if it leads to the left, he sketches it until he reaches the main road of party B. In either case, he places his initials on the card at the time he begins his sketch. When he has finished, he returns to the main road, follows it, examining all cards at crossroads, and, if he finds one with no initial on it, sketches it according to the above rule. The remainder of the assistant sketchers proceed in like manner in their turn. The assistant sketchers of other parties proceed in like manner, except that only roads leading to the left are sketched.

The principal sketcher may either execute his sketch *ab initio*, or he may merely correct and amplify an outline sketch furnished him by the topographical officer. If the topographical officer has found his small scale map to be fairly accurate and reliable, he may cause it to be enlarged to the proper scale, and call upon his principal sketcher merely to fill in this outline. If the small scale map is inaccurate and unreliable, he will furnish a copy in outline for use of the principal sketcher, but will require the principal sketcher to execute a new sketch of the main road.

The principal sketcher must initial every card that he passes and put its identification number on his sketch at the proper point. The initials are for the information of the topographical officer and the members of the party, showing whether the principal sketcher has or has not passed the point. The identification number is for use in combining the sketches.

The contours should be extended as far to the side as may conveniently be done within the speed limit required. If necessary, they should be left out at unimportant points to allow time for a wider extension at what are important military positions. Especially is this the case under the conditions that have been assumed.

Collision with the enemy is likely to occur at any time. Aggressive action on his part may make it desirable to form up for action in any favorable position. Under such circumstances, these favorable positions would be pretty clearly outlined on the combined road map.

The principal sketcher will place his main reliance for elevations on the data left by the director.

It is to be remembered that in road sketching a missing contour or a contour that ends nowhere is comparatively unimportant, hence too great attention to the question of consecutive numbering of contours is unnecessary.

DUTIES OF THE ASSISTANT SKETCHERS.

The assistant sketchers have nothing to do except carry out the instructions of the principal sketcher. Having reached a crossroad which his general instructions require him to sketch, the assistant sketcher places his initials on the identification card, places the designation of the identification card at the beginning of his sketch, and sketches such distance on the side road as may be required. If the assistant sketcher starts at a crossroad, he should indicate on the card which direction, right or left, he has taken. If he connects with the main road of another party, he places the designation of the marking card at the end of his sketch, and rejoins his party in such manner as his principal sketcher may have directed.

Each side road sketch will be identified by its terminal numbers, as A^6 B^8 (Fig. 1) showing at once the points on the principal sketches which it connects.

It has been assumed that the topographers have free access to the area XY, X′Y′. This will be the case in operations at a distance from the enemy, in which case the distances covered will require such free access.

In the near vicinity of the enemy, there will be the liability to encounter parties of the enemy, and movement other than in company with patrols of our own cavalry screen will be impossible. In this case the advance will necessarily be much slower, and the patrols will cover all crossroads. Opportunity will thus be presented to sketch the crossroads if an understanding is had between the commander of the cavalry screen and the chief topographical officer. Upon each main road, a considerable body of cavalry will move—the supporting squadrons of the contact troops. The director will accompany that contact troop which will enable him to perform his required task.

The principal sketcher will move with the supporting squadrons, and the assistants with the patrols sent out from it.

The commander of the cavalry screen should order coöperation with the topographers, even to sending escorts with sketchers whenever required.

If the population is hostile, it may be necessary to detail a special escort for the topographers, to be subject to the call of the principal sketcher when required for protection. Stringent measures must be taken to prevent interference by hostile population.

When the work of sketching is carried out under circumstances which prevent movement of sketchers except in connection with patrols, the parties should be strengthened by the addition of a number of assistant sketchers to provide for delayed return of those sent out. Inasmuch as all patrols sent out from the supporting squadrons will eventually rejoin them, the assistants will also rejoin their principals, but such return may be delayed and require other sketchers to perform their work until they return.

MODIFICATION OF CONTROL DUE TO DIFFERING CONDITIONS.

If no road maps are available, the directors must be governed in their movements by the cavalry screen, upon which will fall the duty of ascertaining the road by means of guides, voluntary in friendly country, and impressed in hostile. If the inhabitants are friendly, it will do away with the necessity for escorts for the topographers, and the information derived from them will be of material assistance to the entire topographical force.

In the close vicinity of the enemy, the need for protection for the sketchers has been pointed out. At a distance from the enemy, all movements will be freer, and only in case of very hostile population will protection for the topographers be necessary.

In the close vicinity of the enemy, there will always be the possibility of a collision, in which case provision must be made for bringing the road sketching to an abrupt conclusion, and immediately starting the work of position sketching for possible contingencies. At a distance from the enemy, information concerning the roads is of prime importance. As the vicinity of the enemy is reached, this gives way in importance to the topography between the roads. The slower progress in the near vicinity of the enemy enables this condition to be fulfilled.

In retrograde movements, the operations occur on ground which should have already been mapped, unless a change of line of communications has been forced. In this case the topographical work would be handled as in an advance, the topographers having greater freedom of movement on account of having the main body between them and the enemy.

Permanent Parties.—In the prosecution of the topographical work of an army, whatever the method adopted for control, it is requisite that the parties shall day after day perform the same tasks, in order that successive days' work shall be a mere matter of routine. The directors should be officers of energy and resource, and need not necessarily be expert sketchers, though it may at times be desirable for them to do sketching. The directors having once been found capable of the work required of them, should remain continually on this duty.

The principal sketchers should, from the nature of their duties, be the most expert sketchers of the topographical force. The work required of them is the most difficult of all the tasks, but is easier on the horses than is the work of the assistant sketchers. There should be two principal sketchers selected for each party, and they should alternate daily as principal and assistant sketchers. The work of the assistant sketchers should, when possible, be assigned in conformity with the ability of the sketchers and the condition of the horses.

With such permanent organization, the difficulties of control are minimized, the instructions for a day's work consisting in specifying the road to be covered by each party. The day's sketching follows as a matter of routine.

COMBINATION AND REPRODUCTION OF SKETCHES.

For purposes of rapid combination of sketches, it has been found advantageous to do all work on a special kind of tracing paper (See Fig. 3 for sample).

FIG. 3.

Any paper of the same general character will answer the requirements. The qualities required are toughness, a surface that will take pencil work readily and stand erasing, resistance to water, and a reasonable degree of transparency. (See note on celluloid, page 105.)

In position sketching, the prints are made directly from the pencil sketches. In road sketching, while the prints are not made directly from the sketches, the transparency of the sketches is of great advantage in adjusting the sketches in position for tracing. For convenience in tracing, the streams should be overrun in red, and a piece of white paper should be placed under the sketches to make them show up more plainly.

The combination of the different sketches in road sketching must be done by tracing. The discrepancies in distance are too great, and the separate sketches too numerous, to allow any other method to be used. It will greatly hamper and delay the work of combination if there is shown too great divergence in distances on principal sketches. Hence the necessity for accuracy on the part of the principal sketchers.

The process of combination is as follows:

At the beginning of a day's work, a rendezvous is appointed at which all sketches are to be turned in at the close of the work. At this point the wagon or other transportation bearing the necessary tents, drawing tables and materials, is ordered to report at as early an hour as possible. All preparations are made in advance for tracing the sketches if conditions allow.

As soon as the wagon has arrived and the first batch of sketches are handed in, the work of tracing begins. If only one batch of sketches is in, the side road sketches are immediately traced in their proper places on the principal sketch. All tracing will be done in lead pencil, since a good pencil tracing will make a good blue print, and alterations may be made readily by erasure.

If all the principal sketches are turned in at about the same time, which should be the case, the two principal sketches which most nearly agree in scale are selected as the standard, and the remaining principal sketch is made in tracing to conform in distances.

The work of tracing these sketches should be done by competent draughtsmen practiced in the peculiar class of work. These draughtsmen would ordinarily be civilian employees on the payroll of the chief topographical officer.

When the sketches are handed in, the principal sketchers should be required to remain in the immediate vicinity of the draughting tent or room until the work of combination is completed, as should all of the sketchers if it is possible to assemble them.

As a matter of rations and supply, it will be necessary for the topographers to camp together at night, and the wagons with their baggage and rations should accompany the map wagon.

The presence of the sketchers during the work of combination is necessary to explain doubts and questions that may arise in the course of the work. They should be kept out of the draughting tent except when called to answer questions. Every sketch should bear the name of the sketcher who made it, in order that the proper sketcher may be called on in case of question.

The draughtsmen will then, under the supervision of the chief topographical officer, proceed as rapidly as possible to make the pencil tracing of the work of the day, adjusting differences in the distances and elevations in the manner indicated by the explanations of the topographers who made the sketches.

With a little practice two draughtsmen can work at once on the tracing with little interference. With two draughtsmen working on the tracing, the sketches of three parallel roads covering the maximum day's march should be combined in about two hours. If the principal sketchers fill in outline sketches furnished them, they will fit without compensation when turned in. This will expedite the work of combination.

With fresh, rapid, blue print paper, blue prints may be made without unduly long exposure until about one-half hour before sunset during the portion of the year when active operations are carried on. If the sketches can be completed by about two o'clock in the afternoon, it will be possible to make the necessary copies of the road map by blue printing by sunlight.

Assuming that the work of sketching begins shortly after daylight, as it must necessarily, there will be available about nine hours for the work. Sketching at the rate of three miles per hour will result in twenty-seven miles of principal roads covered by 2 P. M.

If the work starts about daylight and continues without any unnecessary delay, the ordinary day's march can easily be covered by the topographers, the sketches combined, and the blueprinting accomplished by sunlight. This allows plenty of time for sending the maps back to headquarters in ample time for use for the succeeding day's march. Should the completion of the sketching be delayed and the combination not finished in time to blueprint by sunlight, or should the sun be obscured by clouds, provision must be made for making the necessary prints by other means.

This can be accomplished, and has been accomplished in practice, by the use of magnesium light. Magnesium ribbon one-eighth inch wide can be obtained as a commercial article, and by burning this ribbon in a proper lamp, a light of sufficient brilliancy for blueprinting is obtained. A form of lamp suitable for this use is shown in Fig. 4. Should an automobile be available whose motor could be used for driving a dynamo to furnish an arc light, the blueprinting could more certainly and conveniently be accomplished.

Issue of Maps.—If it becomes apparent that the required number of maps can be completed by 9 P. M., the entire issue may be sent back to the main body at one time, under escort if in hostile country. If the completion will be delayed beyond this time, the first five copies should be sent back as soon as completed, and the remainder at a later time.

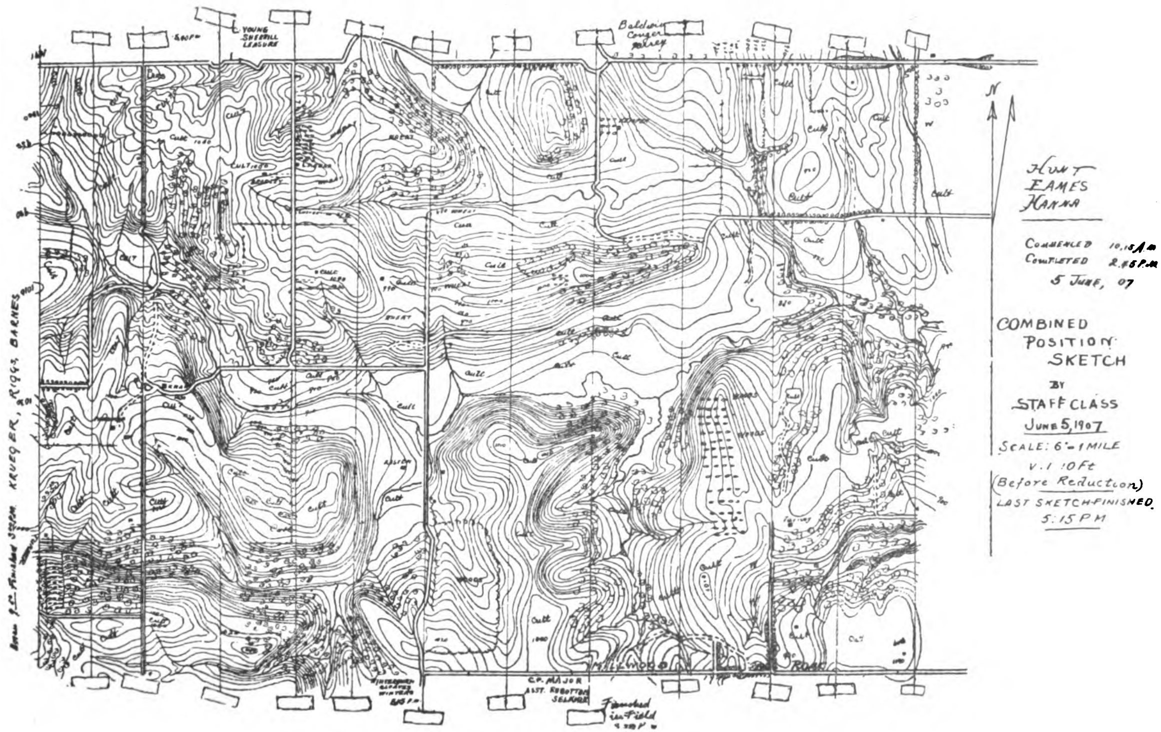
COMBINED POSITION SKETCHING.

Scale, 6″ = 1 mile.
Vertical interval, 10 feet.

All lettering to be so placed as to be readable when map is held so as to look toward its north.

Equipment of individual sketchers:

- Drawing board,
- Box compass.
- Tracing paper, sheets 11″ x 14″.



REDUCED COPY OF COMBINED POSITION SKETCH MADE BY METHODS HEREIN DESCRIBED.

Thumb tacks.
Clinometer.
Lead pencils (grade HB).

The chief of party carries a reserve supply of pencils and thumb tacks, and in addition a tin tube containing a reserve supply of tracing paper. An aneroid barometer will also be of great use to the chief of party.

For whatever purpose position sketching is undertaken, the object to be aimed at is to produce in one day a contoured map of sufficient size for the deployment for action of the unit to which the topographers are attached. To accomplish this end, the topographers of an army corps must be able to cover a front of approximately one mile per 5000 men, or about nine miles. For fronts greater than a corps, the front of each corps would be handled independently, the proper general relation being maintained by the instructions of the chief topographical officer of the army. For fronts smaller than a corps, the method of position sketching will be the same as for a corps, now to be described.

The first problem is to so select the location of the position sketch that an area of nine miles flank to flank and two to two and one-half miles front to rear will give the maximum topographical information to the commander of the corps.

The selection of the location of the position sketch is therefore the same problem as the selection of the position itself, and the topographical officer must be competent to do the latter. If this duty be performed by another officer, the time required for transmitting the information to the topographical officer necessary to enable him to control the sketching is just so much time wasted. This consideration fixes one of the most important duties of the chief engineer officer of the corps upon the officer who performs the duties of chief topographical officer. For the best organization, these two offices should be combined.

As a preliminary to any position sketch, a reconnaissance must be made to determine the position. The method of making this reconnaissance need not here be discussed. However, or by whom it is made, it will result in the determination of a line nine miles long which must be included within the position sketch. This line will normally be the one to be occupied by our own troops, and it is desirable to map what will be the foreground of this position. Thus in Fig. 5 the line AB has been determined as the line to be occupied, the front of the position being in the direction shown by the arrow. Experience has shown that a depth of two to two and one-half miles is as much as can be mapped satisfactorily from one control line. It is also the maximum for one day's work.

The problem in sketching is therefore that of mapping the area AaB, B'a'A' in such manner as to form a complete contoured map, everywhere showing the ground with sufficient accuracy for military purposes. It is to be noted that the map will be satisfactory for military purposes even if the relative elevations of points A and B are in error by 50 feet, or if the absolute distance from A to B is out by 5 per cent., provided the errors in elevation and distance are distributed along the line AB so that there is nowhere any great error thrown into the map in such a restricted space as to make that portion of the map unlike the ground.

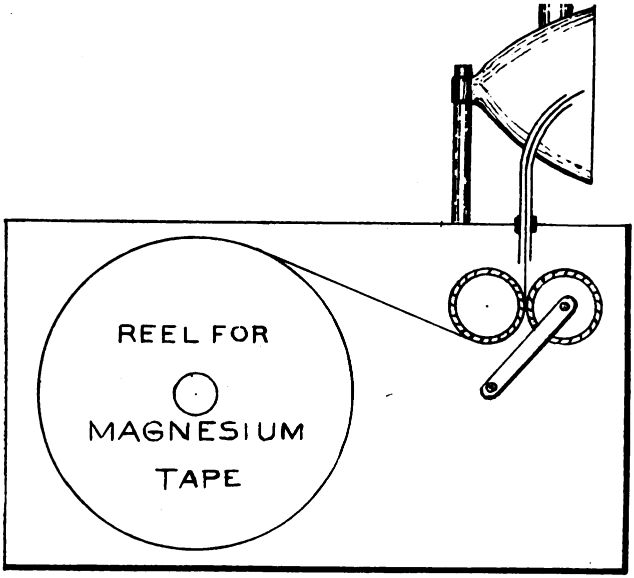


Fig. 4

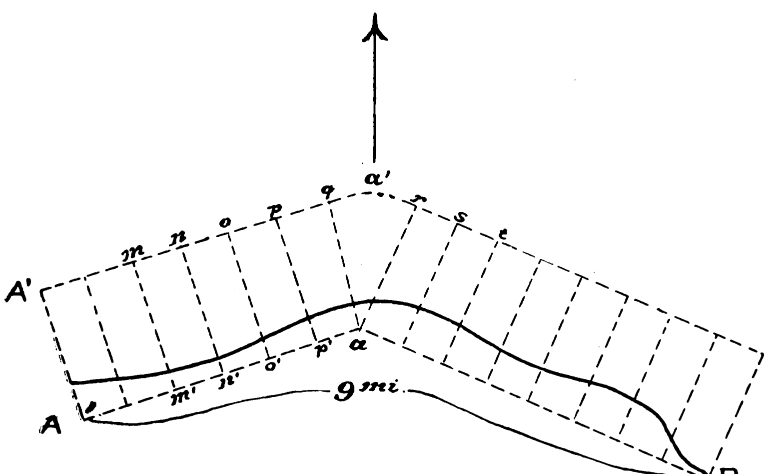


Fig. 5

To map the area according to this idea, it is necessary to establish control both horizontally and in elevation, and to divide the area into tasks such that each party may complete its task in six to eight hours, to assign these tasks to parties, and to provide for the adjustment of errors in such manner that the sketches of adjoining areas will match along the edges, both horizontally and vertically. Unless the latter condition is fulfilled, it will be impossible to combine the sketches in any length of time consistent with the idea of getting the map out the same day.

Vertical Control.—The first requisite in establishing control for the purposes of combination is the determination of the levels along the line AaB (Fig. 5) so that all work along the line may start at the same time with elevations referred to the same datum plane. It is necessary that these levels be known before work is commenced. The determination of the levels at proper points along the line must therefore be made at the same time as the assignment of parties to areas.

It has been found possible to do this only by the use of the aneroid barometer. With the ordinary pocket surveying aneroid (Fig. 6) elevations may be read by estimation within five feet.

Since these elevations must be read along the line as the parties are deployed, some time will elapse between the readings at the extremities of the line. There may, therefore, be an error in the relative elevations of the points A and B as determined by the barometer, due to change in atmospheric conditions, in the time required to pass along the line.

The maximum change in barometric readings due to changing atmospheric conditions is ordinarily about twenty feet on the elevation scale per hour. In settled weather, the change will be usually not more than ten feet per hour, rising on the elevation scale from 9 A. M. until 1 P. M., and falling from 4 P. M. until 7 P. M. Since the work of assignment of tasks may proceed at the rate of about six miles per hour, or even greater, it is seen that the relative error in elevations will be distributed along the line, and will not be greater under ordinary conditions than five feet per mile. This is a greater degree of accuracy than can be attained except by the use of instruments of precision, and is entirely satisfactory for military purposes.

If time and conditions permit the use of a station barometer for determining the change in pressure due to change of atmospheric conditions, these variations can be eliminated and the relative elevations along the line will become known within five feet.

To use a station barometer, it is merely read at a fixed point at half hour intervals during the time when the field barometer is in use. From its readings, a table may be prepared showing corrections to be applied at half hour intervals, from which the corrections, at times when the field barometer is read, may be determined. The barometer then furnishes a satisfactory means of determining elevations along the line for vertical control.

Areas.—It has been found that the proper size of area for assignment to each party is about one square mile, this being the maximum that can be covered with sufficient care in the time that can be allowed. This area consists of a rectangle one-half mile along the base line by two miles front to rear, as indicated in Fig. 5.

The control line will be generally a broken line. To assign the tasks so that the work may progress without confusion, a general knowledge of the line is essential. Thus, starting at A (Fig. 5) the position of some other point on the line, as *a*, must be known. No matter what the sinuosity of the line from A to *a*, all areas between these points are given bounding lines perpendicular to the straight line joining A and *a*. When the point *a* is reached, a point in advance on the line, as B, is selected, and the bounding lines of areas from *a* to B are perpendicular to the line *a*B. This gives one or more wedge-shaped areas in the vicinity of *a*, whose bounding lines will be divergent. It is more convenient in practice if the area at *a* does not come to a point, but has some intercept on the base line. The rule is that if the divergence in the bounding line is 10°, the intercept must be reduced to one-fourth mile, and for a triangular area the divergence must not exceed 20°.

Thus, if the angular change in direction of the control line at *a* is 20°, there may be used a single triangular area with bounding lines diverging 20°, or preferably two areas with intercepts of one-fourth mile on the control line and with bounding lines diverging 10°.

Neither of these forms of area contains quite one square mile, but it is inadvisable to make the areas wider at the outer end than given by this rule on account of the difficulty of assembling the members of the party at the outer limit of the area and of filling in the space unmapped if the sketchers are widely separated.

Parties.—To each area is assigned a party of three —one chief of party and two sketchers.

The method of sketching to be used in each area is as follows (Fig. 7):

In establishing control and assigning areas, two stakes, k and l, are placed in position by the chief topographical officer, and their elevations as determined by aneroid barometer are marked on them. These two stakes, with a magnetic azimuth perpendicular to the control line, determine the limits of the area C to be sketched.

Sketcher No. 1 of party C, in company with sketcher No. 2 of party B, is charged with the duty of sketching along the line kk′ (Fig. 7), and extending the sketch 300 yards on either side, as shown by the dotted lines. It is preferable in this part of the work for the best sketcher of the two to make the sketch, the other acting as assistant.

When the point k′ is reached, shown by a distance of twelve inches as measured on the sketch, the sketch is cut apart on the line kk′, which is merely the cutting line of the sketch. It is not necessary that the sketchers follow the line kk′, but they should so direct the traverse as to secure in the most convenient manner, reliable data for 300 yards each side of the line kk′. After the sketch is cut apart, each of the sketchers takes the part of the sketch pertaining to the area assigned to his party, and from the point k′ sketches along the outer boundary of his area.

Similarly, sketcher No. 2 of party C, in company with No. 1 of party D, sketches along the line ll′, separating at the point l′ and sketching on the outer boundaries of their own areas.

Meanwhile the chief sketcher of party C has run a careful traverse from l to k, and has then proceeded toward the outer extremity of his area, looking for

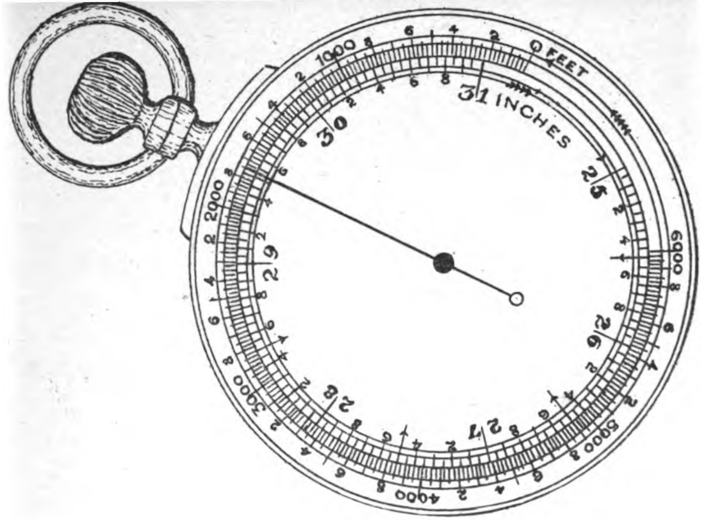


Fig. 6

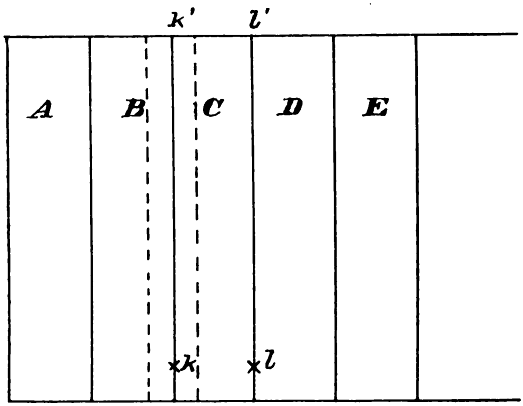


Fig 7

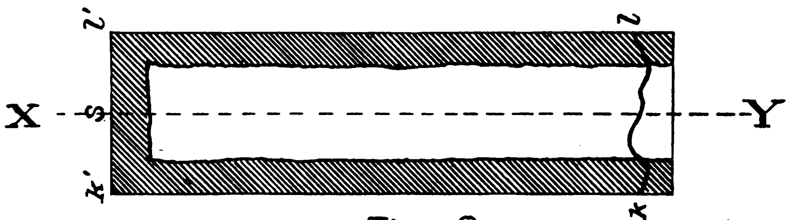


Fig. 8

his two sketchers. He should be provided with a whistle to attract their attention at a distance.

Having ascertained their whereabouts, he keeps touch with them in order that there may be no delay in getting them together on the outer boundary of the area.

It is not advisable for the chief sketcher to fill in the topography along the traverse, or to sketch outward in the center. All connecting up can be done more easily and satisfactorily while coming back.

When the party assembles at the point s, the chief sketcher will have a plotted traverse, showing the distance between the parallel lines kk′ and ll′, and the sketchers of his party will have each a sketch of a strip of topography about 300 yards wide along each edge of the area, which, when placed alongside the sketches of areas B and D, will accurately match as to topography, and will require no adjustment in either elevation or distance.

The known portions of the area are represented by the shaded portion in Fig. 8. The separate sketches are now placed one over the other, the distance apart being known from the traverse kl, and the azimuths of kk′ and ll′ (usually parallel) enable the sketches to be placed in their correct relative position. With the sketches in position, a knife cut is made clear through both sketches and the blank part of each removed. The edges will fit along the line xy, and the pieces are secured in position by thumb tacks. Two rubber bands will hold the edges down while finishing the sketch.

It only remains to proceed back toward the control line, along the center of the area, connecting up the contours and topographical features and adjusting differences. The strip will ordinarily be so narrow that little, if any, instrumental work will be required to fill in the interior.

In no case must any change be made along the boundary, as it is already made to combine without alteration.

The sketch having been completed according to this method, it will fit accurately along its edges with adjoining sketches on both sides, and all are ready for combination without any alteration whatever. Before turning in the sketch of his area at the appointed rendezvous, the chief sketcher secures the two parts of his sketch in position with *passe partout* pasters, as described in the process of *combination.*

It will be seen that discrepancies in distance and elevation may arise at the outer portion of each area. These must be harmonized by the chief sketcher.

Discrepancies that must be adjusted will arise in any topographical work. This can be done with far better results by the topographer on the ground than by a draughtsman in the office. This is one of the chief advantages of the method of combined sketching here described.

Horizontal Control.—It has been stated that the areas assigned intercept ½ mile on the base line. This distance is determined approximately in the assignment of areas by timing a horse at a rapid gait. Stakes are placed at these intervals along the base line, and the line so staked out is the control line for the sketch. Traversing the portion of the control line lying within an area is the first duty of the chief sketcher of the party assigned to the area. Thus in the course of the work of sketching, a traverse is run along the entire control line, and the control thereby established is as effective as if the entire line had been traversed by a single sketcher. Vertical control is established by elevations determined by the aneroid barometer, as before described.

The control line will usually conform to the position to be occupied. It may, however, be more convenient in some cases to establish control along a line in the middle of the area to be mapped. No change in method is caused by this. The portion of each area lying on each side of the control line is handled exactly as described for the entire area, the area extending a mile on each side of the control line. This method will give better results where it is practicable to apply it, since the errors to be adjusted are those arising in traversing one mile instead of two. If this method is adopted, an hour must be fixed at which work on the last half of the area will be started, and all sketchers must be on the line ready to start at the appointed hour.

The Execution of a Combined Position Sketch.—The successful execution of a position sketch by the methods herein described will largely depend upon the speed with which the parties are deployed along the line and assigned to areas. This can best be attained by the following method:

Assuming that the position sketch is to be executed for a corps, the extent of the line will be about nine miles. Assuming that the chief topographical officer has knowledge of the line which is to form the basis of the map—the line AaB, Fig. 5—the entire topographical force of the corps, which must number at least fifty-four sketchers, proceeds to one extremity of the line, as A. The force has previously been divided into eighteen parties, the chiefs of party designated, and the best of the two sketchers in each party designated as No. 1, and the other as No. 2.

Arriving at the point A, the most distant visible point of the control line, as *a*, is pointed out to all the chiefs of party. Sketcher No. 1 of party A determines the magnetic bearing to this point, from which the magnetic bearing of lines perpendicular to it is determined. The chief of party A is meanwhile directed to determine a point along the line Aa ½ mile distant, at a gait not slower than a trot. All topographers follow the chief of party A. Having given to sketcher No. 1 of party A the magnetic bearing of the boundary line, and having given him the elevation by aneroid barometer, the topographical officer rides rapidly to overtake the rest of the party.

When the chief of party A has determined the point ½ mile distant from A, he halts with his No. 2 sketcher and No. 1 of party B, and marks the point by a stake or selects some natural object in the near vicinity, as a tree or fence post.

As soon as the topographical officer arrives, the chief of party B starts at once to determine the next half mile point along the line.

The topographical officer halts, calls out to the chief of party A, "Magnetic bearing of boundary, ——°; elevation, —— feet," and again rides forward to overtake the party.

The chiefs of the parties in regular turn, accompanied by their No. 2 sketcher and No. 1 of the next party beyond, determine the half mile distances along the base line, halt at the proper points, and receive their instructions from the topographical officer as he passes along the line. This method is continued until the point *a* is reached, when the magnetic bearing of a new point, as B, in the line is determined, and from it the new bearings for the boundary lines and the angular change at *a*. The topographical officer determines the method of "turning the corner," decides the number of wedge-shaped areas necessary, assigns the bearings to enable the proper angular change to be made, adjusts the width along the base line to correspond, and then proceeds along the line to B in the manner before described.

The assignment of tasks at a point where the line changes direction may occasion a small delay, but if the decision is made promptly, this delay need not be more than ten or fifteen minutes.

The topographical officer should read the elevation at the point *a* as soon as he arrives, and if any delay occurs, the barometer should be set at this same elevation when he leaves.

By following the method above outlined, it will be seen that the topographical officer may establish control almost as fast as he can ride along the line if everything is done methodically and every one thoroughly understands what his duty is and does it without hesitation.

For service in the field, the parties would be permanent, and the systematic prosecution of work offers no difficulty. For instruction purposes, it is necessary to alternate in the duties, and reorganize the parties daily, so as to cause topographers to gain experience in each class of work.

In instruction work, it has been found possible always to complete the work in a day by this method if desired. If the work commences shortly after daylight, the first blue prints should be completed by 4 P. M. It is simply a question of six topographers per mile along the line to be mapped. With permanent parties, the actual work of sketching should occupy five to six hours. Control is possible over nine miles front in one and one-half hours. The last sketch should be turned in within eight and one-half hours from the time the first sketcher starts work.

Certain points in the above method should be noted. First, each half mile along the base line must be covered by the chief of the party which is responsible for this area, because the chief of party must see *both* the points which mark the edge of his area. Thus, if the chief of party A had been left at A, he might never find the marker at the other side of his area.

Second, it may seem that the chief of party has so little to do that his services might be dispensed with. A little consideration will serve to show that the portion of the base line within the area must be traversed while the edges of the boundary are sketched, otherwise when the outer limit of the area is reached the actual distance apart of the bounding lines would not be known and the two sketches could not be placed in their proper relative position. If one of the sketchers is required to make this traverse, the other sketcher along the boundary must wait for him to complete the traverse.

It may seem unnecessary to have two sketchers go along each boundary, as the chief of party might seek the sketcher of the next adjacent party and secure from him the sketch of the part of his area and then meet the sketcher of his own party. Under this method, the sketcher of the next adjacent party is helpless until he can find the chief at the outer end of the area. This plan, however, is the most promising of all for increasing the area that can be covered by a given number of sketchers.

It must be borne in mind that no military work is ever planned solely with a view to economy of labor. What is required is the absolute certainty of accomplishing a given result in a given time, and the presence of the extra sketcher not only materially expedites the work of sketching the area, but experience has shown that he is necessary to insure the completion of the work satisfactorily and on time. There is no chance for failure in the method of position sketching described except by the failure of the three members of each party to get together at the outer limit of the area. To reduce this chance of failure to a minimum, the chief of party has been given but two duties to perform: to traverse the part of the base line within his area, and then to gain and keep touch with his sketchers. In practice this has never failed of accomplishment but once, and that in one of the earliest trials.

In open country, the areas may be widened slightly, but the difficulty of keeping touch with his party is greatly increased for the chief, and the chance of failure is equally increased.

Combination.—This method of covering each individual area here described has been adopted in order to expedite the combination of the sketches into a map. It is practically useless to do any sketching unless a map is to result. If one day be the limit of time for the production of a map, it may be stated that any method which depends upon the combination of a large number of individual sketches by a draughtsman adjusting ("fudging") and tracing them is doomed to failure. The combination and tracing of eighteen separate sketches is more than a day's work in itself.

For this reason it has been decided to execute the sketches originally on tracing paper in clear, black, pencil lines. The final sketch of each area must be turned in with a margin of at least an inch on each end for pasting together. Such sketches will blue print well by either natural or artificial light. The fit of the sketches along the edges has been secured by the method of sketching adopted. All "fudging" is done in the interior of the rectangular areas by sketchers on the ground.

When these sketches are turned in they fit their neighbors on both sides, having been cut from them originally. Therefore, it is only necessary to place their edges together in their proper relative positions, and secure them at each end by a small paster of *passe partout* binding tape, and there results by this simple process a tracing of the entire area. The time required for this work is not over thirty minutes for a corps front.

This saving of time in combination is the foundation of the entire system. Under ordinary circumstances the original sketches, as made in the field, are used directly as a part of the final tracing from which the blue prints are made, and not a line is traced or redrawn. If the sketches have been carefully handled in the field, they will be ready to turn in as soon as completed. If the work has been interfered with by rain or the sketches have otherwise become soiled or unsightly, it may be necessary to retrace the separate areas, but each draughtsman has a small area to trace and can finish it in about half an hour. The class of paper described is such in resisting power to water as to permit of prosecution of work in the rain if effort is made to protect the paper. It will, however, be necessary to trace it afterward.

Fortunately another substance is available which is so admirably adapted to this purpose that its use would be practically demanded under service conditions where rain would so seriously interfere with the work on tracing paper, and might seriously delay its completion even when the paper is carefully selected. This substance is celluloid, with one side roughened like ground glass. It can be obtained in large sheets only $\frac{5}{1000}$ of an inch thick. It is so pliable that it may even be rolled on a sketching case without taking a permanent set. It takes the pencil perfectly, and the lines are not blurred or erased by the rubbing incidental to drawing, even when they are covered with water. They may, however, be erased perfectly with a soft rubber whether wet or dry. The printing quality of the celluloid is very much higher than that of tracing paper, and a drawing placed under and in contact with it seems little more obscured than by the ordinary transparent celluloid. It may be obtained from the Celluloid Company, 30 Washington Place, New York, in sheets 50x20 inches for fifty cents each. This price is so low and the substance so admirably adapted to the work that it would seem to be folly to risk using tracing paper in actual warfare, even in fair weather, when a sudden storm would seriously impede the completion of the work. Then, even if the weather were fair throughout the day, the blue prints could probably be made in half the time that would be necessary for tracing paper; and as this work would usually have to be done under adverse light conditions, this is a matter of importance. The prints would be of finer quality, as on the even rough surface the pencil makes a firmer, blacker and more regular line.

Under the most unfavorable conditions, blueprinting can begin in about an hour from the time of the arrival of the last sketch at the rendezvous.

Reproduction.—As in combined road sketching, such tasks have been assigned as will permit the completion of the work in time to permit blueprinting a sufficient number of copies by sunlight. In case of failure, due to weather or other unfavorable conditions, blueprinting may be done by magnesium light, or velox paper may be used in a field or ordinary photographic dark room, printing by weak artificial light or ordinary daylight.

Blueprinting.—Blueprinting is the ideal process for reproduction of maps in the field. All that is necessary to produce a blueprint, is to expose the paper under a tracing for a proper time to a light of sufficient actinic power, and then wash it in water. The length of time necessary to expose it is dependent upon the light and upon the formula used for sensitizing the paper. The most rapid commercial paper requires an exposure of about thirty seconds to sunlight. The proper exposure can be determined by the appearance after exposure for the first print, and may be regulated by time after the proper exposure has thus been determined. Blueprint paper may be handled in ordinary daylight without damage unless too long exposed. This fact and the simplicity of printing with it make it far the best paper for field map reproduction. The chemicals for the sensitizing solution are not subject to rapid deterioration when not mixed, and sensitizing may easily be done in the field.

Other sensitizing solutions may be used which will enable printing to be done by weaker light, but on account of extreme sensitiveness they deteriorate rapidly and can not be conveniently handled. Further, they uniformly require a chemical solution for developing and fixing the print, and are thus difficult to handle in the field.

RAPID ROAD SKETCHING.

An army may find itself in a situation, as in the pursuit of a rapidly retreating enemy, where it is desirable to keep the commander of the pursuing force informed as to the roads in his front.

Such sketching must be done in the most rapid manner possible and the sketches sent back at frequent intervals. Thus executed, they may be invaluable in preventing delay to the pursuing columns. A similar condition would arise if a small column were separated from the main body and forced to regain touch by a rapid detour.

To meet such a contingency, the speed aimed at and actually secured in practice at the Staff College is five to six miles per hour.

This speed can be attained only by sketchers of more than ordinary ability and practice.

The methods to be adopted will be somewhat dependent upon the ability of the sketcher, but some of the most important short cuts are as follows:

Elevations will be largely by estimation, few readings being possible at the speed stated. Thus, arriving at the top of the hill, a point at a distance in advance is selected which is at approximately the same elevation. If it appears so to the sketcher it will also appear so to the one using the sketch. The vertical distance to the bottom of the intervening depression is estimated, using the height of a telegraph pole, or a tree or some other object as a guide in the estimation. Arriving at the forward point sighted on, the contours are filled in by eye so as to show the estimated difference of elevation. Mental note is made of the time at which features such as houses, streams, etc., are passed, and these are located on the sketch corresponding to their time intervals.

The sketching case is only roughly oriented except for long sights, and may be oriented by placing the last portion of the road sketched roughly parallel to the portion of the road represented.

By practice, stretches of from one-half mile to a mile of road may be covered and the topographical details remembered sufficiently to form a surprisingly good sketch of the road. Until sufficient practice of the memory is had, notes may be made to assist the memory, as:

3-h
5½-br
7-8-W-1

meaning that at three minutes from the origin on the time scale a house was passed; at five and one-half minutes, a bridge; at seven minutes one edge and at eight minutes the other edge of a wood on the left hand side of the road.

Thus the road may be covered in stretches of about a mile at a rate of eight miles per hour, and a halt for a period of two and one-half minutes made each mile. Naturally the sketches resulting will not meet the standard of the drawing academy, and topographical signs will give way to symbols, but the sketches will be serviceable, which is what is required. The roughest sketch which has the desired information on it, if available at the time it is needed, is more valuable for military purposes than the most accurate topographical map executed by the most skillful draughtsmen would be the next day.

Sketches have been executed by these methods by Staff College student officers which are surprising both in accuracy and in the amount of detail shown.

PLACE SKETCHING.

What has, for the lack of a more suitable term, been called "place" sketching, is a substitute for military landscape sketching. It rests upon the hypothesis that a sketcher has reached a point from which the enemy's position, or a portion of it, can be seen, but where any movement upon the part of the sketcher would draw the fire of the enemy. Instead, however, of executing a perspective sketch of the enemy's position, the sketcher makes a contoured map of the portion visible.

Distances are by estimation, directions by compass or by sighting with an oriented board. Visible portions of the area are sketched in full lines, invisible portions are filled in by dotted lines as they must be approximately from the adjacent visible topography. This method has the advantage over military landscape sketching in that no special skill in drawing is required to make an intelligible sketch.

It has the further advantage that estimated distances are shown according to scale, and that an intelligible idea is given by the sketch of the sketcher's estimate, not only of distances to objects in the foreground, but also of the distance *between* objects in the foreground, which no perspective sketch does.

The results secured by this method have shown that a fairly satisfactory map may be thus secured.

Combined Place Sketching.—While no results can be secured by this method comparable with those secured by combined position sketching when access to the ground to be mapped can be had, it is still possible to make a map by the methods of place sketching which will be far superior to no map at all, and it may possess great military value.

The particular situation in which this method of mapping would be resorted to is when the army is about to deploy before a position to be attacked. Movement of sketchers over the foreground of an enemy's position is of course impossible. They may move up to concealed positions as close as possible to the enemy's position and there execute place sketches.

The organization of parties is the same as for combined position sketching. The method to be followed is illustrated by reference to Fig. 5. AaB is the general line occupied by the enemy; m, n, o, p, q, r, etc., are positions as near the line as can be reached under cover.

Two sketchers are left at each of these points, and the azimuths of the dotted lines, generally perpendicular to the front of the enemy, are given them. The two sketchers at m make a place sketch, showing the topography for 300 yards each side of the line mm′. The two sketchers at n make a similar sketch for the line nn′. The chief of the party responsible for the area mm′n′n runs the traverse under cover from m to n.

The sketches made at m and n are cut apart along the lines mm′ and nn′ respectively, and the portions pertaining to the different areas are handed to the chiefs of party. For each area, the chief of party orients the sketches and spaces them by the traverse that he has run, and seeks a point under cover from which he can complete the sketch of his area. Thus, for the area mm′nn′, the chief of party would find some suitable point between m and n, and there complete the sketch by joining up the topographical features shown on the two portions of the sketches made at m and n.

To establish vertical control, a sufficient number of aneroid barometers must be provided for each two sketchers at the points m, n, etc., to have one. They may be read simultaneously at a specified hour for the elevations of the points, or read by each party as soon as it reaches its initial point.

The combination of the sketches is effected by the same means as described for combined position sketching.

GENERAL RULES FOR USING ANEROID BAROMETERS.

The best type of aneroid barometer for use in reconnaissance is one with a dial about two and three-quarter inches in diameter, graduated to 3000 feet on the scale, with a least reading of ten feet.

In using the aneroid barometer:

1. Keep it at as nearly a constant temperature as possible. This is best done by keeping it in an inner pocket, where it will be nearly the temperature of the body. Remove it from the pocket only for the purpose of reading and return it as soon as possible.

2. Always hold the barometer with its dial horizontal when reading it, and tap it gently two or three times with the finger before reading.

3. In clear, settled weather, it will be found that the pressure variation, due to change of temperature, follows a regular law. Beginning at about 9 A. M., the elevation scale will show a rise of about ten feet per hour for about four hours. It will then remain stationary until about 4 P. M., and will then fall regularly until about 7 P. M., when the same reading as at 9 A. M. will be reached. A knowledge of this change will enable proper corrections to be made.

4. In unsettled weather, before or after a storm, note, if possible, the movement of the needle for an hour before starting work, to ascertain its direction and rate of change, and thus be enabled to make proper corrections.