FM 21-26

DEPARTMENT OF THE ARMY TECHNICAL MANUAL

MAP READING

DEPARTMENT OF THE ARMY

MARCH 1956

PREFACE

The ability of large groups of military personnel to learn how to use maps for military purposes has been found by research to be dependent upon the concepts presented and the manner in which they are taught. Soldiers with varied educational backgrounds can be taught by an average troop unit instructor, and they will retain what they are taught if the instruction emphasizes only those concepts required to meet the actual needs of the individual soldier.

In basic training two very important things the young soldier must learn how to use are: his weapon and his map. Just as he is taught the proper use of his weapon without mention of ballistics, so he can be taught to use his map without reference to cartography. The needs of the individual soldier are to find out on a map where he is, where he wants to go, and a route to get there. These three needs are the basis of the first part of this manual. The actual instruction will use visual training aids which cover a much wider scope, using at first only those needed to develop these fundamental concepts. When the soldier has confidence in his ability to use a map in selecting the safest, quickest, and easiest course to an objective, then and then only, should he be given instruction in the more advanced phases. The individual, regardless of his rank or state of training, who feels a need for review of basic principles will find it in part one. The remainder of the manual covers map reading and related subjects for leaders and technicians who must fully utilize map reading in their duties. It is applicable to all ranks and all branches.

FIELD MANUAL }
No. 21–26 }

DEPARTMENT OF THE NAVY
WASHINGTON 25, D. C., *28 March 1956*

MAP READING

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PART ONE

INTRODUCTION TO USE OF MAPS

CHAPTER 1

GENERAL

1. Purpose

This manual has a dual purpose—

a. To guide the instructor of basic classes in map reading by presenting, in part one, those simple concepts he must teach, and to provide those soldiers who desire to review the subject with a simple statement of the basic principles.

b. To provide a reference text which is a more advanced presentation of map using and reading.

2. Scope

The first part of this manual expresses, in simple language, those basic map reading principles which the soldier must fully understand before he can be expected to use a military map for the purposes for which it was made. Assuming that these fundamentals are understood, the subsequent parts of this manual present complete instruction in map reading and map using, including related subjects such as sketching and land navigation.

3. What is a Map?

A mapmaker will tell you that a map is a scale drawing of a part of the earth. A map user will tell you that maps are pictures of areas of the ground showing its shape, the location and types of roads, railroads, buildings, landmarks, woods, swamps, rivers, lakes, and so on. You will be told by both that maps have always been used to guide travelers. You can see for yourself that a map pictures a section of the earth's surface and the things men have built upon it. Instead of showing the land from the ground level (fig. 1), as you ordinarily see things, the map gives a view from directly overhead (fig. 2). When you look at a map remember that a map is a picture drawn to scale; it is not a photograph. As a picture, it uses symbols for objects instead of photographs. Figure 3 shows a map of the same area covered by figures 1 and 2.

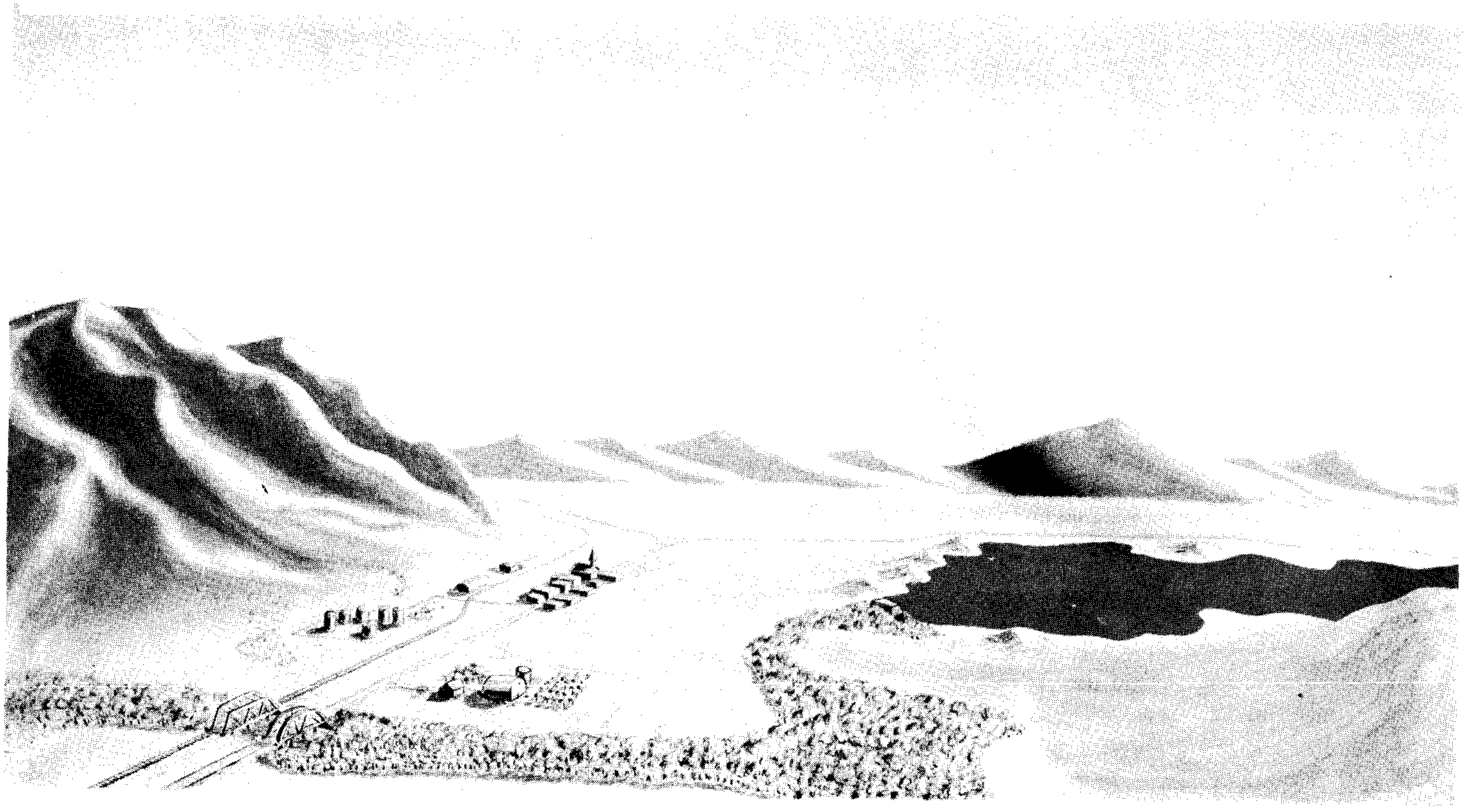


FIGURE 1. *View from ground level.*

FIGURE 2. *View from directly overhead.*

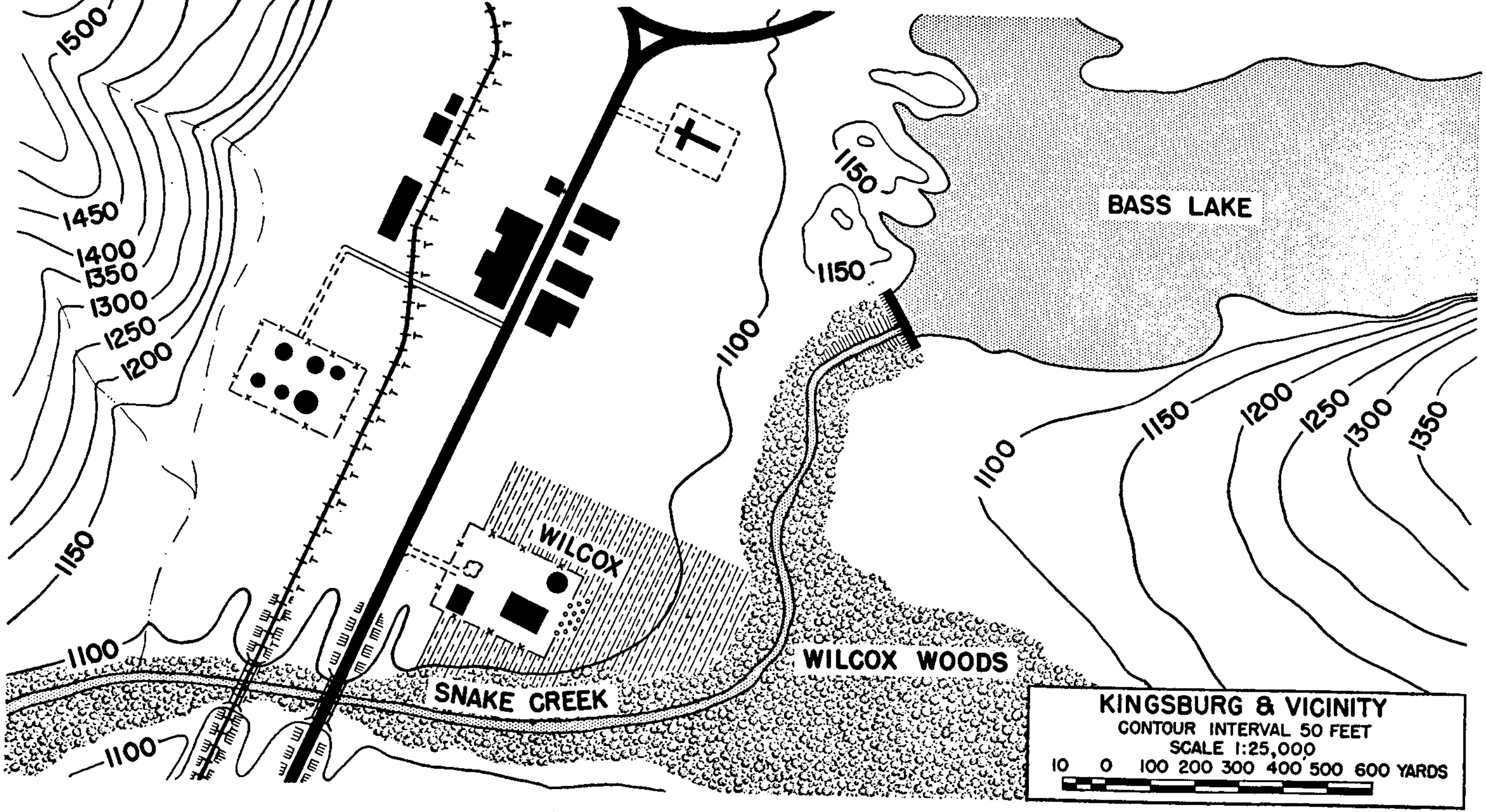


FIGURE 3. *A map of same area.*

4. Why Learn to Read a Map?

In civilian life it is possible for a stranger to find his way around a large city or town by merely asking for directions. Any policeman or friendly native of the town can supply enough information so that the stranger can locate the street or building he wants. He may have to overcome a few wrong directions thrown in with the right ones, but he is sure of finding his way. Many times a soldier finds himself in a strange country, without friendly people ready and able to help him find his way. As a soldier, you will have to ask directions, like any other stranger, but you will ask your map for the information. Your map has all the answers if you are able to read it; and if you can read it, it is one of your best friends. The soldier must carry a mental picture that takes in everything of the area about him. The military map helps provide the picture. When you are on a patrol, you and your patrol members are on your own. At times, you may be entirely alone and your map will be your most trusted friend and guide. Reports from men in combat say that every soldier must know how to read and use a map if he wants to stay alive. Many times both the unit commander and the individual soldier in the field must know the location of certain dangers to himself and the rest of the unit *before* he gets to them, not after. A native of a place can tell you lots of things to help you, but you have to be able to speak his language. In the same manner, you must also learn to read and understand the language of a map. It is a simple and clear language. You will use it very often in the Army; many times when you are in a tight spot. If you learn to use it correctly, it will not let you down.

5. How Maps Can Help You

a. You are familiar with roadmaps distributed by oil companies. No doubt you have used such maps many times in traveling by automobile. When you had to go from one place to another for the first time, you got a roadmap and found out which roads to follow. Most roads are well marked with signs which tell you the number of the highway and the distance from one place to another, so all you needed to know from your map was which numbered highway to follow, and how far it was to the place you were going; then you could figure out about how long it would take you. After you started along the right highway going in the right direction you didn't have to look at the map again until you came to a place where there was a crossroad that wasn't marked or a big town with many streets. Even then you needed the map only to guide you to the right road again. In England during World War II, when the British considered German invasion imminent, they removed all road signs and city markers to hinder the advance inland of any possible invaders. You can expect the same treatment if you enter enemy territory under similar circumstances.

b. Military maps are also guides. The main difference between a roadmap distributed by an oil company and a military map is the amount of information shown. The roadmap shows the motorist what he wants to know, which is usually only how to get from one place to another over the shortest route and the best roads. The military map shows the soldier not only how to get from one place to another safely, quickly, and easily; but also what the surrounding country looks like, how high the hills are, and many other things which are discussed in this manual. Since you are a soldier, you will often have to move from one place to another in strange lands—usually where there are no roads or streets—and you will have to be able to choose a way to go that will get you there safely, quickly, and easily. Instead of following roads, this route will probably be crosscountry. There will be no road signs to follow. You will have to do what Daniel Boone did. You will have to follow the land, reading, instead of road signs, the same signs that helped Daniel Boone, such as the shapes of the hills, the direction the creeks flow, and the location of woods and rocks. However, you have one thing that many explorers did not have, a map which, if you know how to read it, will help you use these signs to find your way. The military map is your guide.

6. Every Soldier Needs Maps

The need for learning the use of the map is not limited to just one type of soldier. Here is a list of just a few of them—

a. Infantryman. Where is his march or attack objective and the best route to it?

b. Artilleryman. What is the position of his target and the distance and direction to it?

c. Engineer. Where is the location of his work projects and where are the troops he is supporting?

d. Signalman. Where to locate communications and what routes to use for communicating between units?

e. Military Policeman. Where to locate and set up traffic regulation and convoy control points and where to set up protective security for vital installations?

f. Ordnance Personnel. Where to locate ammo distribution points near friendly combat units. Where to locate maintenance and supply installations most advantageously; and routes to use in locating, recovering, and evacuating battle damage equipment.

g. Quatermaster. Where to locate supply installations to support combat units and to locate isolated burials for grave registration.

CHAPTER 2

BASIC MAP READING

Section I. WHAT IS ON A MAP?

7. Maps are Drawings

As we have mentioned before, maps are picture drawings. They are drawings of the ground and the important things on the ground. They provide a picture of the ground as seen from the air. You can see the same picture by flying over the land. When you take a quick look at the ground from an airplane above it, you will usually see too much of some things and not enough of what you want to see. A map is formed by drawing on paper those objects which may be of interest to the person using it and leaving off those features on the ground which may be unimportant or useless. Putting every single feature on a map that exists on the ground will clutter up the map so much that it would be too difficult to read. Therefore, in the case of a military map, the objects included will be those that interest an army in the field. This means that objects of interest to the infantry, artillery, combat and service engineers, transportation units, signal corps, medical corps, ordnance, armored, and quartermaster are all there. The drawing of a map does not include all of the features existing on the ground, but shows only that portion of the total picture which will be of interest to all soldiers. Now you can understand the big difference between a map and a photograph of the ground. The photograph shows too many of the features and objects on the ground to be read quickly and easily. Another difference between a map and a photo is that the map tells you what each object and feature is by signs and symbols instead of showing the exact true form of it. Many times the real shape of something is difficult to recognize even on a large aerial photograph. Of course, these signs and symbols resemble the actual features or objects they represent as closely as possible without looking like something else. The names written out on a map tell you the names of features such as towns and cities, rivers and lakes, or outstanding mountain peaks, so there can be no mistake.

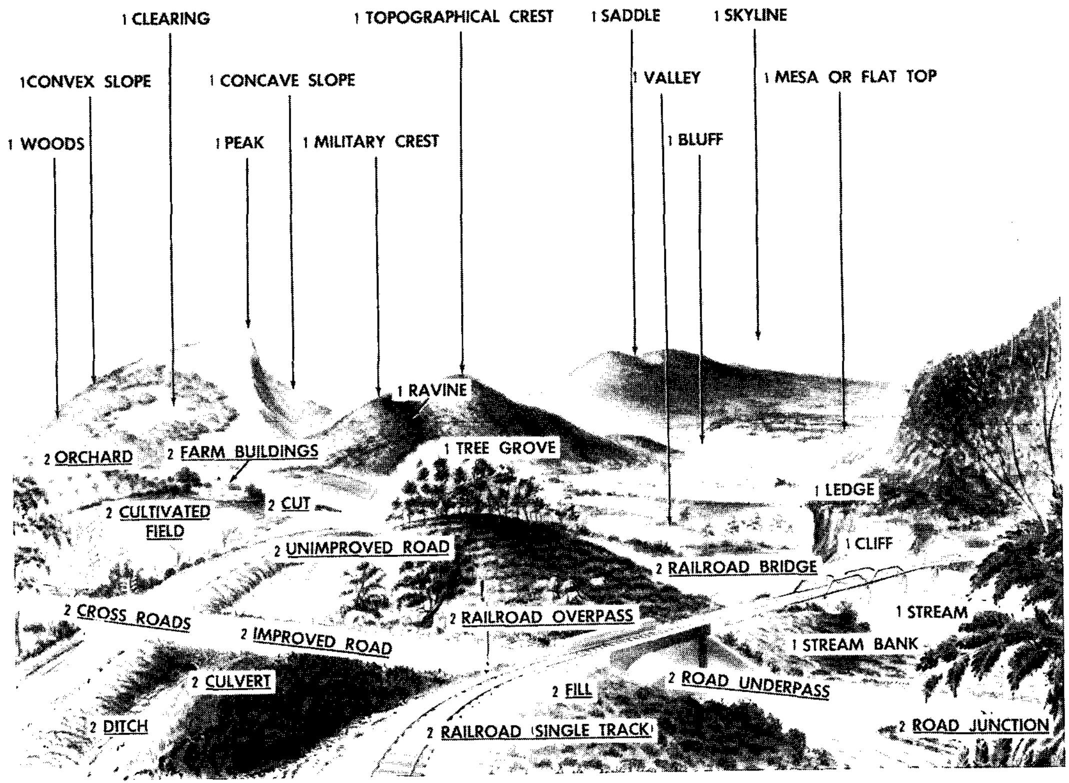
8. The Land Itself

a. The Shape of the Land. In order to read the story of the shape and form of the ground that the map shows on its flat paper surface, we must be sure that we understand something of the various shapes and forms of the earth around us. The general shape of the earth's surface is a continual series of ups and downs. We know that the earth goes up as much as 29,000 feet above sea level at the summit of the Mt. Everest, down as much as 1,292 feet below sea level at the surface of the Dead Sea in Palestine. With a difference of over 30,000 feet there is a lot of room for ups and downs. These ups and downs take many forms and have many names. However, in normal field duty you will have to concern yourself with only the most common of these shapes and forms. To the mapmaker these land shapes and forms of the earth are called *topography*. Most of the earth's surface has been shaped by action of the weather wearing away portions of its face. This is done by freezing, thawing, strong winds, and the fall of water flowing down from high to low ground. The results of this action are shown in an unevenness of the height of the ground and many varied shapes. The variation in heights is called *relief* and the shapes such as hills, ridges, valleys, are given the general name of *ground forms*.

b. The Highs and Lows of the Earth. The highs and lows of the earth are of great importance to an army in the field since they affect every move combat troops make and help determine the placing of weapons, observation posts, defensive positions, command posts, supply areas, and so forth.

c. Relief and Ground Forms. Since ground relief has an important role in military operations, it is the duty of the individual soldier to become familiar with the nature of the ground on which he is to fight or work. You cannot always actually study an area yourself. Your map gives you the next best thing to an actual study, it shows the picture of the relief and ground forms that exist within the area shown on the map. From a study of a military map you can pick out the ground forms that will be either aids or obstacles to your mission.

d. Ground Forms and Ground Features. Nearly every person has become familiar with the common ground forms that exist everywhere. We can readily picture in our minds what they look like when we mention such things as *hills, valleys,* or *ridges.* Likewise we can quickly call to mind what these ground features look like when we hear mention of streams, lakes, ponds, marshes, fields, woods, trails, roads, road intersections, road forks, and built-up areas. These and a few other terms, identified in figure 4, are used many times when referring to both ground and map and describing what exist around you.



1 Natural ground features. 2 Manmade features.

FIGURE 4. *Land features.*

9. Objects on the Land

After considering the relief of the land and the forms that the ground takes, we can see next, by looking around us, many objects on the ground that are not a part of the natural features of the ground. These objects are manmade. Because they show the degree of development of the land by man, these objects are important. All objects and features on the ground not naturally formed are, obviously manmade. Manmade objects which are common to most maps are—

a. Roads and railroads.

b. Bridges.

c. Cities, towns, and villages.

d. Buildings.

e. Telephone, telegraph and electric power lines.

Figure 4 shows some of these and other manmade objects.

10. The Big Picture

One of the main objectives in the reading and use of maps is to form in the mind a picture of the ground from the information shown on the flat surface of the map. Both the natural ground forms and the manmade objects are taken together and put on the map to form the *big picture* of the land around us. When seen together we see that the relief of the land determines the location of many of the objects existing on it. Now let us see how this big picture is drawn onto a relatively small and flat piece of paper so that all the objects and ground forms are shown clearly and understandably.

11. The Language of the Map

a. Symbols. An object or feature of the ground is usually shown on a map by a symbol resembling it simply and clearly. The symbol may vary in size according to the size of the map but it will still be the same shape. In order to read a map we must become familiar with these symbols and learn what they represent. The symbols shown in figure 5 represent some of the more common features, manmade and natural, in map language form. Put each of these signs in its proper place on a map, (1) figure 5, and you can see that they can all still be recognized because they are similar in shape to the actual objects. Each symbol is made up so that no other symbol looks exactly like it.

b. Standard Symbols. There are a great number of objects and land features which must be shown but there is not room on the map sheet to show their true outlines. So the mapmaker uses a set of standard symbols to show them. These standard symbols, although not exactly true to shape are as close as possible to the form of the actual object. They are usually made to appear as though seen from the air above. According to the language of the mapmaker these standardized symbols are called *map symbols.* As with all symbols used on maps they are used not only to show the objects but also to point out landmarks for points of reference. A complete list of the map symbols used in U. S. military maps is shown in FM 21–31.

c. The Army on the Map. In addition to the symbols for the permanent features of the ground that are shown on the map, the Army has a standard system for showing the position and movement of its troops on the map. This system is also used to show the position and movement of the enemy. These military symbols are used to represent the different types of units and their equipment as they may be located in a map area. Some of the more common symbols used to represent troops and equipment are shown in (2), figure 5. In FM 21–30 you will find a full list of the military symbols used. Remember that these symbols are usually added on the map only when required and are not originally printed on the map. The symbols for the different kinds of army units are simple and some part of each symbol is related to the unit it represents. You can see this by comparing them with the pictures accompanying each symbol in (2), figure 5.

12. Colors Help You Read

a. There may be times when you will see a map upon which everything has been printed in black. This will be an exceptional case because whenever possible, the maps used by the U. S. Army are printed in more than one color to help you read and understand the story of the ground printed on it. The colors usually used and what each represents on a map are—

(1) *Blue*—all water features, such as lakes, streams, swamps, rivers.

(2) *Green*—all vegetation features such as forests, orchards, high grass, jungles.

(3) *Brown*—all land forms such as contours, cuts and fills.

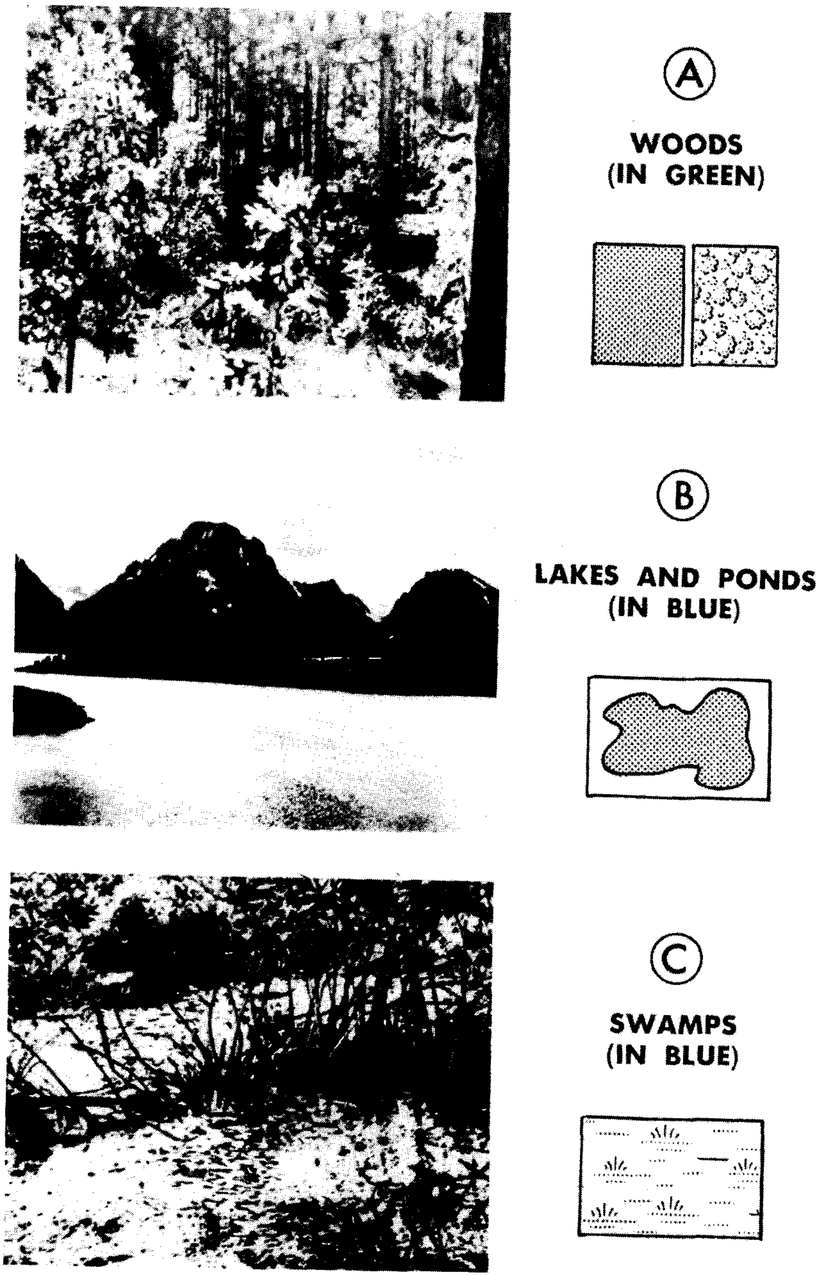
(4) *Gray*—sometimes used in place of brown.

(5) *Red*—main roads and, occasionally, restricted or danger areas.

(6) *Black*—all manmade features such as buildings, bridges, railroads, and ordinary roads which are not shown in red.

(7) *Yellow*—sometimes used to show cities.

b. When the army moves onto the mapped area special symbols are shown in color also. Friendly troop positions and installations are always shown by symbols marked in *blue* and enemy troop positions and installations are always marked in *red.* Two other colors it will pay to remember when reading military symbols



1 Natural ground features and manmade objects.

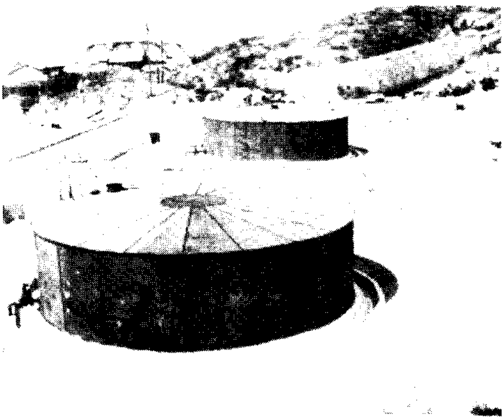
FIGURE 5. *Map symbols.*

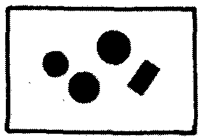
(D)

BUILDINGS

(E)

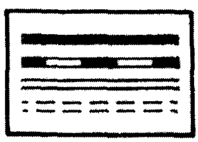
TANKS





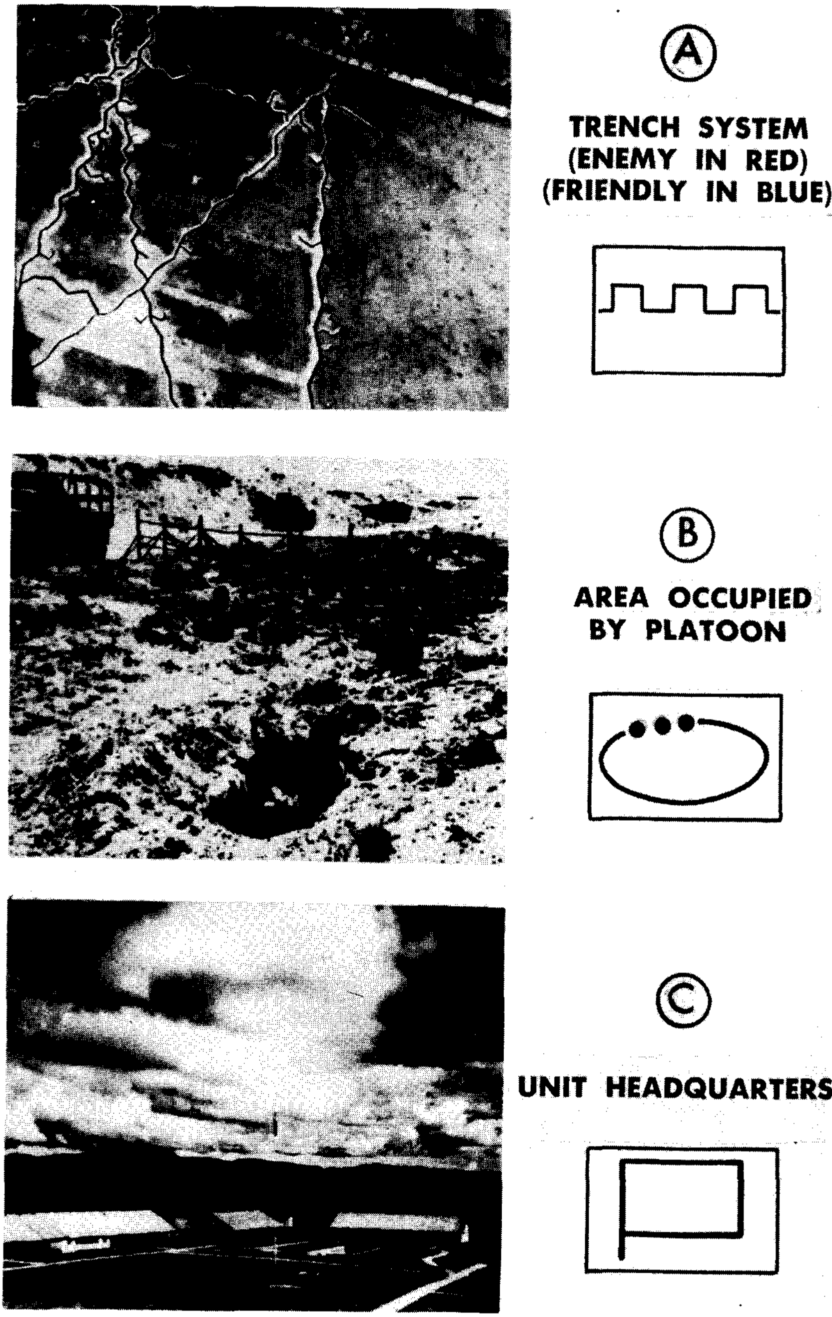
(F)

ROADS



1 Natural ground features and manmade objects—Continued.

FIGURE 5. *Map symbols—Continued.*

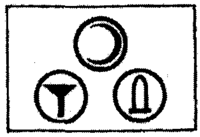


2 Military symbols.

FIGURE 5. *Map symbols—Continued.*

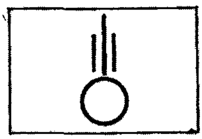
(D)

DUMP



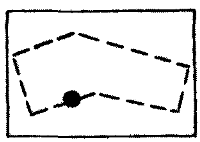
(E)

HOWITZER, LIGHT (105 MM)



(F)

MINEFIELD (ANTI-TANK) (GREEN)



2 Military symbols—Continued.

FIGURE 5. *Map symbols—Continued.*

are green and yellow. These colors help show up places of special importance when used with military symbols. Green is used for obstacles including minefields friendly or enemy. Yellow is used for all deadly contaminated areas. When the colors blue and red are not available to show friendly and enemy troops, symbols drawn with a single black line will be used to show friendly troops and symbols drawn with a double black line will be used to show enemy troops. (See FM 21–30 Military Symbols.)

Section II. HOW HIGH ARE THOSE HILLS AND OBJECTS?

13. Hills and Valleys on the Map

We have seen in paragraph 11 that the objects and features of the ground are shown on the map by symbols. How about the height and shape of the ground itself? How high are those hills and how deep are those valleys? So far we have talked about showing objects as being flat on the map. This makes the objects look as though they are also on a ground area that is flat as a football field so that all the objects can be seen one from another. But we know that because of hills and valleys that exist nearly everywhere, it would often be impossible to see all objects in a given area from only one spot. A soldier in the field needs to be able to tell from a map how much of an area he may be able to see—and, when traveling from one place to another, how much he will have to climb. In order for a map to be useful to a soldier, whose every move depends on the ground relief around him, there must be some way of showing him the form and height of the land to guide him in picking the right position or the safest path. The military map uses a method which shows not only the highs and lows of different places on the ground but also shows the form of the ground by means of lines that connect all points at the same elevation. These lines are only imaginary, they are not marked on the ground. These lines are called *contour lines.*

14. Contour Lines

There is a well-known saying that water seeks its own level. The surface of any body of still water is even and level at all points along the surface. Where it meets the land the shoreline is a level line. If a heavy rainfall added a great amount of water to a lake filling it up so that the waterline or shoreline was higher by 10 feet this new shoreline would be 10 feet above the old shoreline at all points along that line. Since we can picture ordinary shorelines on a map then we can picture imaginary shorelines up the sides of the hills at regular changes in height from the original line. To get a clearer picture of this, figure 6 shows a typical hill form placed in a tank of water. When we add enough water to raise the shoreline 1 foot it looks as in figure 7.

When more water is added the shoreline is raised as in figure 8. Looking at this hill form from above (fig. 9) we see the different shoreline marks.

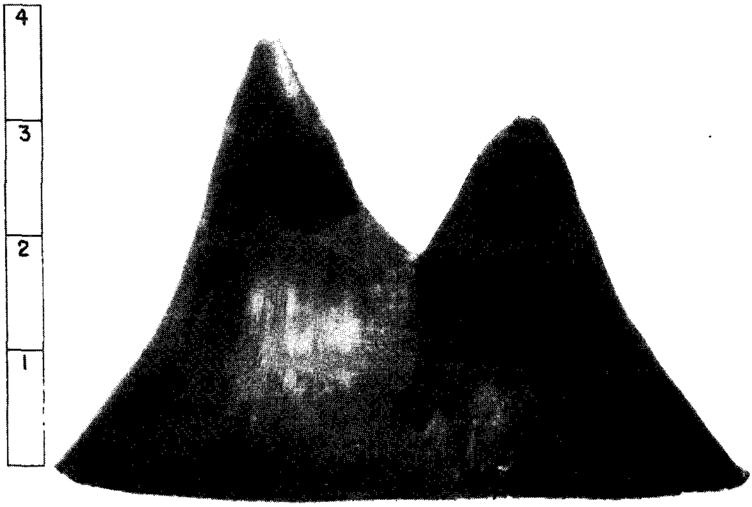


FIGURE 6. *Hill model in tank.*

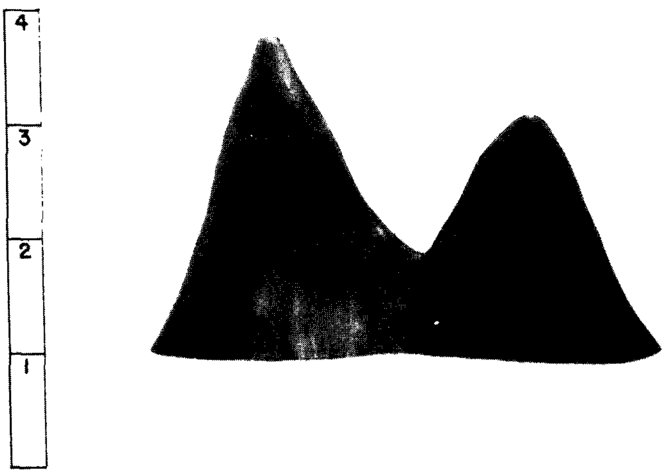


FIGURE 7. *Water added at 1 foot.*

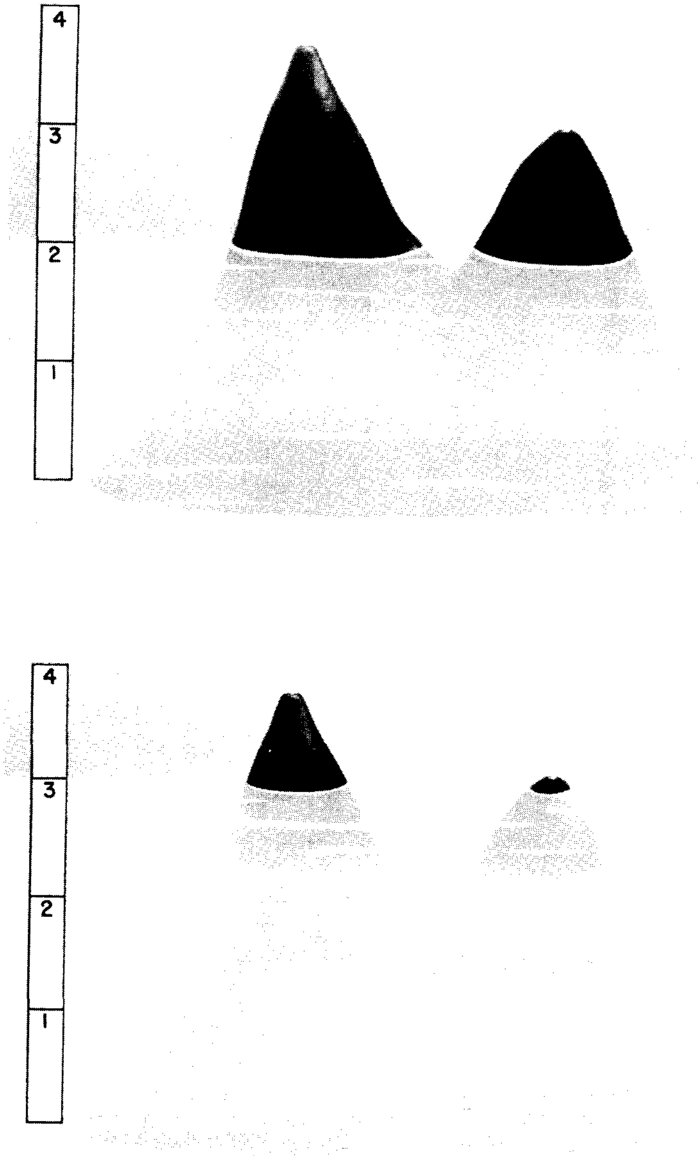


FIGURE 8. *Water added at 2 and 3 feet.*

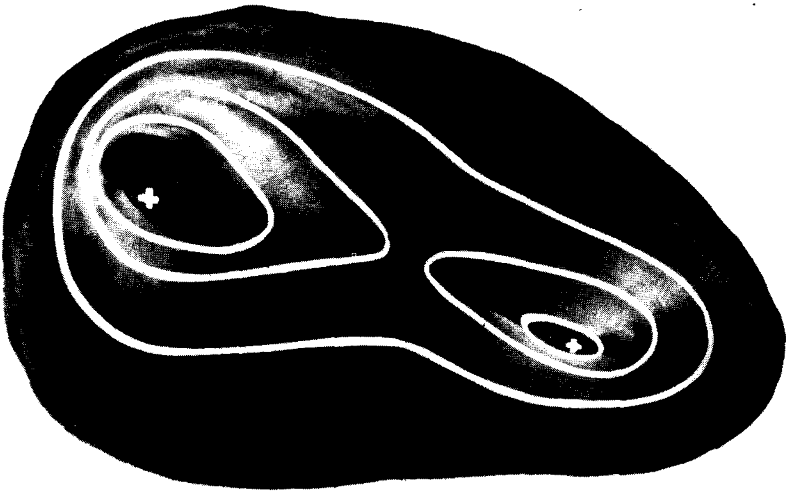
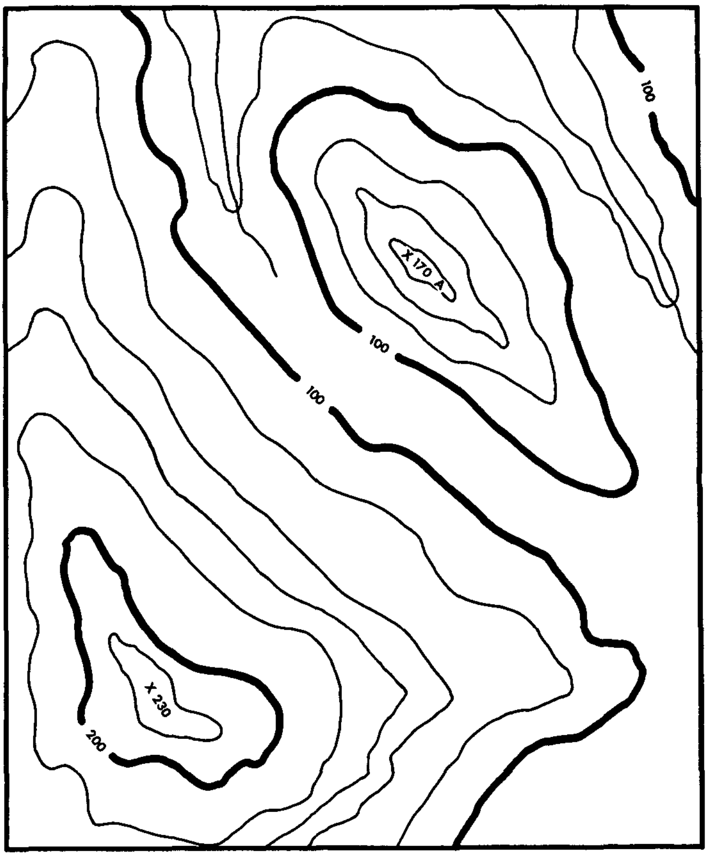


FIGURE 9. *Vertical view of waterlines around model.*

These shorelines show the shape of the hill at each elevation. Thus we can see not only how the shape of the hill changes at each additional elevation (fig. 9), but by counting the number of shorelines, we can tell how high the hill is. Each shoreline or water level line indicates points of ground at the same elevation. As the water rises, each new shoreline shows a successive line of equal higher elevation. If the water level rises at even amounts such as 10 feet, then the marks of the shorelines at each 10 feet, when shown together, will give a clear picture of the height of each hill and also show the shape of each hill as seen from overhead. If you will look on any military map showing a relatively small piece of ground, you will see those imaginary shorelines drawn on the map in the color used for representing ground forms—brown. Because these are not true shorelines but only imaginary ones they are given the special name *contour lines.* A contour (line) is an imaginary line on the surface of the earth, all points of which are at the same elevation. Remember that a contour line on a map represents a contour line of the earth. The vertical distance between successive contour lines on a map is the same. This difference in height between contour lines on a map is called the *contour interval.* If you look in the margin of a map usually at the bottom (fig. 116, app. IV), you will find a note giving the vertical interval between contours on that map. Remember that even though neighboring contour lines may be close together or far apart, the distance from one contour line to the next represents a change of height of the ground at that spot equal to the contour interval, or a rise or fall of a certain number of feet (meters) as indicated in the marginal information.

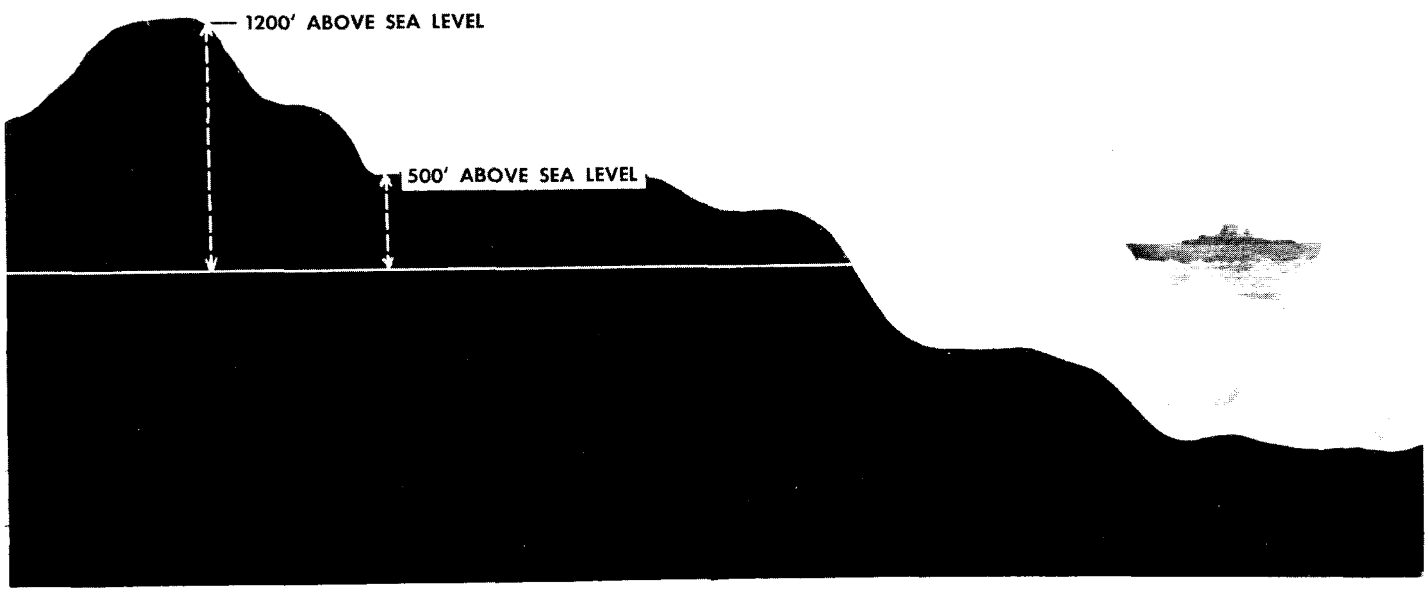
15. Height Above What?

When we find a *contour line* with a given number value for the height of the ground at that contour line, do we know from where the height is measured? Take, for example, the elevation figure given for the contour line at the base of hill A in (1), figure 10. Instead of reading 0 feet as you might think, it reads 100 feet. Looking at other hill bases on the map, it can be seen that the height values are not given from the base of each hill. There is some other place from which elevations or heights are measured. On all maps, height of the ground at any point is figured from sea level. That is, we compare the height of all land at any place to the average shoreline of the sea ((2) fig. 10). This is reasonable because most of the earth is covered by the sea and we know that



1 Map cut showing hill A.

FIGURE 10. *Height measurements.*



2 Elevations above sea level.

FIGURE 10. *Height measurements—Continued.*

water seeks a level surface when at rest. Sea level is zero for all height measurements and even though a hill is far from the sea, we can still read its height above the zero level of the sea. Surveyors have carried this zero reading inland from the sea to compare the differences in height across the entire continent. If our contour lines were started at zero at the base of each hill or mountain it would be difficult to tell how much higher one mountain was than another and there would be places in valleys below the base of a hill with a *minus* height. But, starting with zero at sea level makes all contour lines on dry land *plus* values. We have *minus* contour lines in the Salton Sea area in California, in the Dead Sea area in Asia Minor, in parts of Holland, and offshore in the oceans. The minus contours offshore are called *depth curves.*

16. Other Ways of Reading Height

As an additional aid in studying the ground relief on the map you will find at several points across the map sheet little black or brown x's, triangles and squares with numbers printed alongside. These are the values for the height of the ground at that exact spot. These are called *spot elevations* and they can be used to check the height reading of the nearest contour lines and to pinpoint actual tops of hills. Many spot elevations are used to name hills in combat. Hill 230 means the hill in that area is 230 feet (or meters) above sea level. Besides spot elevations you will find by looking on a map (fig. 116, app. IV), that the elevation of every fifth contour is written out and inserted in the line at several places. To make them easier to follow, these fifth contour lines are drawn heavier and appear darker than the others.

17. The Shape of Ground Forms are Also Shown by Contour Lines

Normal contour lines always enclose areas of higher elevation. They form all sorts of patterns; for example, in figure 11, all the lines are circular, each circle getting smaller toward the center. We can tell right away that the model is evenly round, like a cone. If the object is not round, an object other than a cone, these lines can tell also where it bulges and where it pinches in. For example, suppose we stretch one side of the model so that it looks like figure 12. If we draw in the separate imaginary shorelines again, and look from overhead, the lines look like figure 13. We can tell on which side it bulges out. This shows that we can tell not only the size and height of hills but also their shape. Contour lines help you determine the actual shape of the ground that they picture. By comparing the contour lines on a map with the portion of ground that the map covers, you can see readily how the contour lines show the shape of the ground.

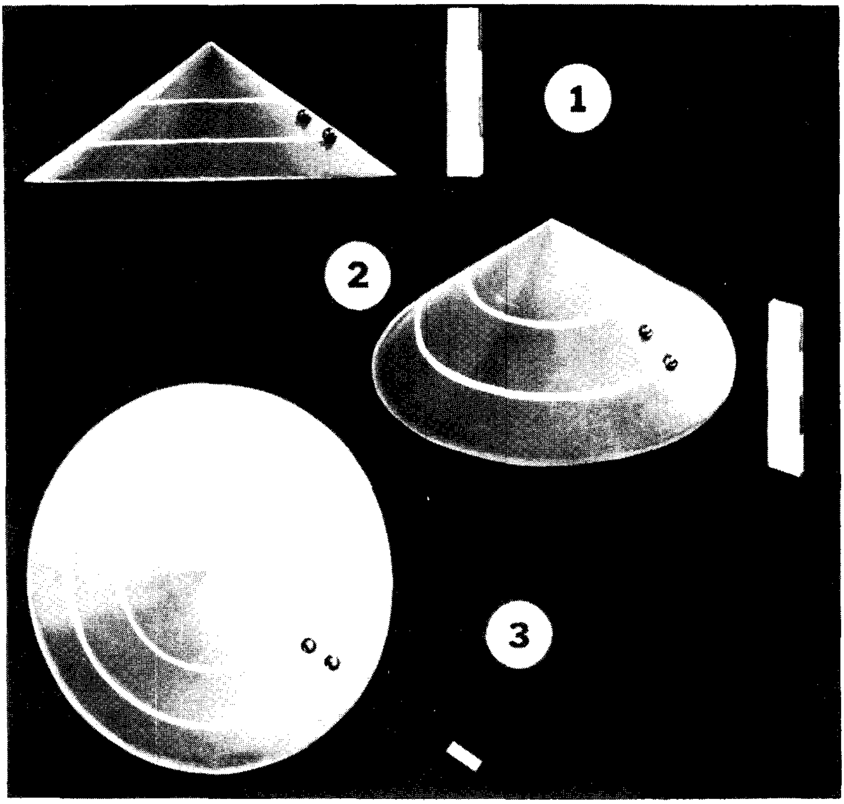


FIGURE 11. *Contours of a cone.*

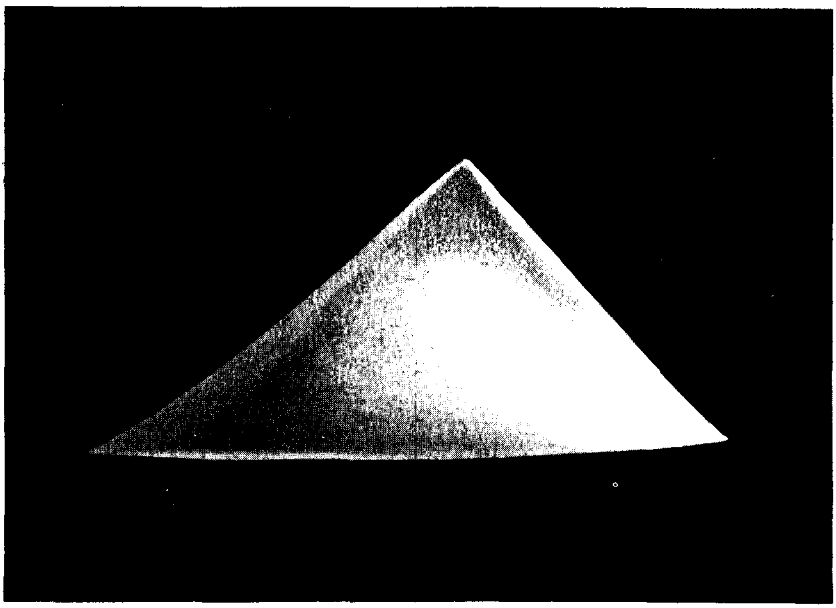


FIGURE 12. *Typical hill model.*

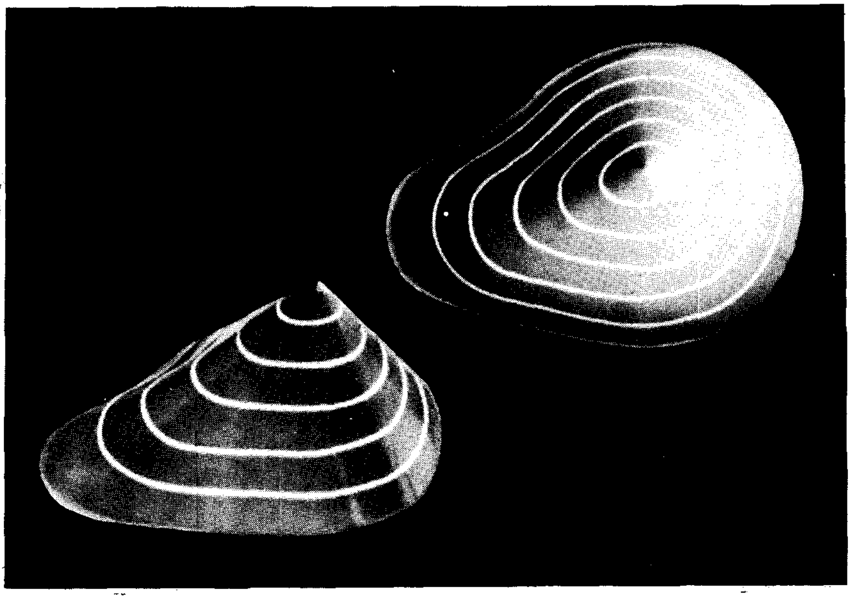


FIGURE 13. *Contours on model in figure 12.*

18. Slope of the Ground

The slope of the ground may be described as the slant or incline of the earth's surface at any point. There is some amount of slope wherever you may be located on dry ground. When you are with combat troops in the field the slope of the ground is important since it affects your selection of route of travel and location of your offensive and defensive positions. You have seen that the amount of spacing between contours on the map indicates the slope of the ground. When a hill is steep, the contour lines appear close together (fig. 14). Remember this also indicates on the map that there is a sharp rise in the ground at the location where the contour lines are close together. When you find a hill that has a gentle slope, the contour lines on the map will be spaced fairly far apart (fig. 15). If there are two hills fairly close together with a dip or saddle in between them, the contour lines showing this will tell us just what shape the two hills are and how deep or how shallow the saddle is between them. Even when streams are not shown on a map, contour lines will indicate the location of lines of drainage or probably water runoff by becoming regularly spaced and forming a series of V's which point uphill. In the event of heavy rainfall or during the wet season, water will very likely flow down hill along a line connecting the points of the V's shown on the map. You can assume then that whenever you see such a series of V's you might choose to follow them as a path in dry weather but not in wet weather. Contours can also tell us several things about actual streams. They tell us the way the stream is flowing, and by checking the amount of space between the contour lines along the stream we can tell just how steep the stream bed is (fig. 16).

19. Contour Lines Help Tell the Story of the Ground

Contour lines identify the high ground and the low ground and the changes of shape of the ground in between. The following is a list of the things that contour lines show on a map:

a. All points on any one contour line have the same elevation above sea level.

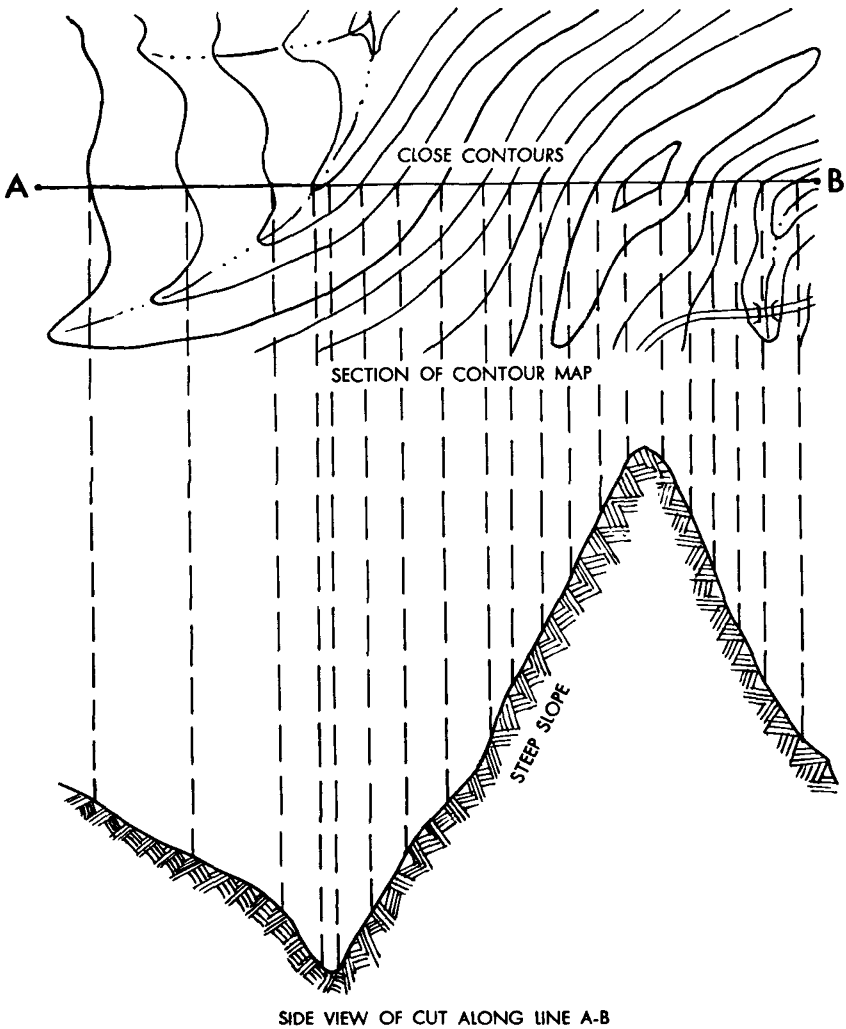


FIGURE 14. *Steep hill, side view and contour spacing.*

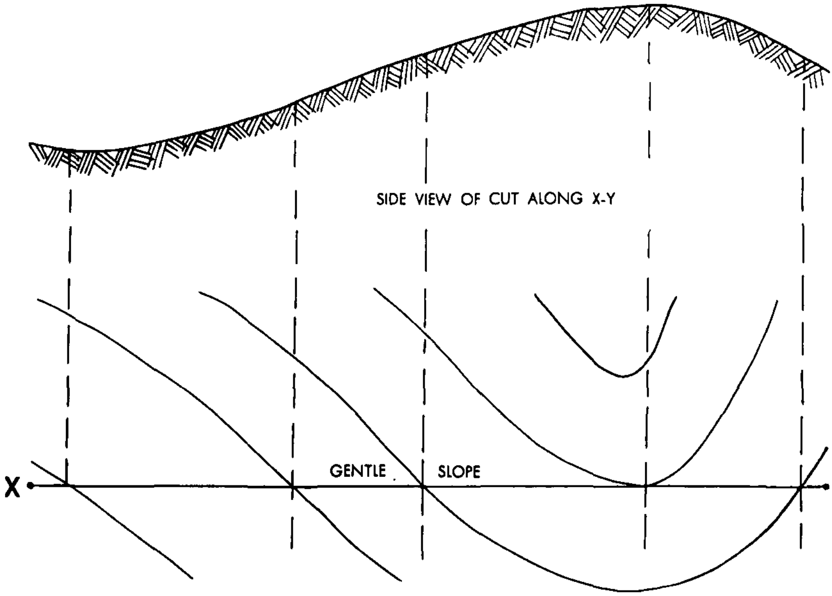


FIGURE 15. *Gradual hill slope, side view and contour spacing.*

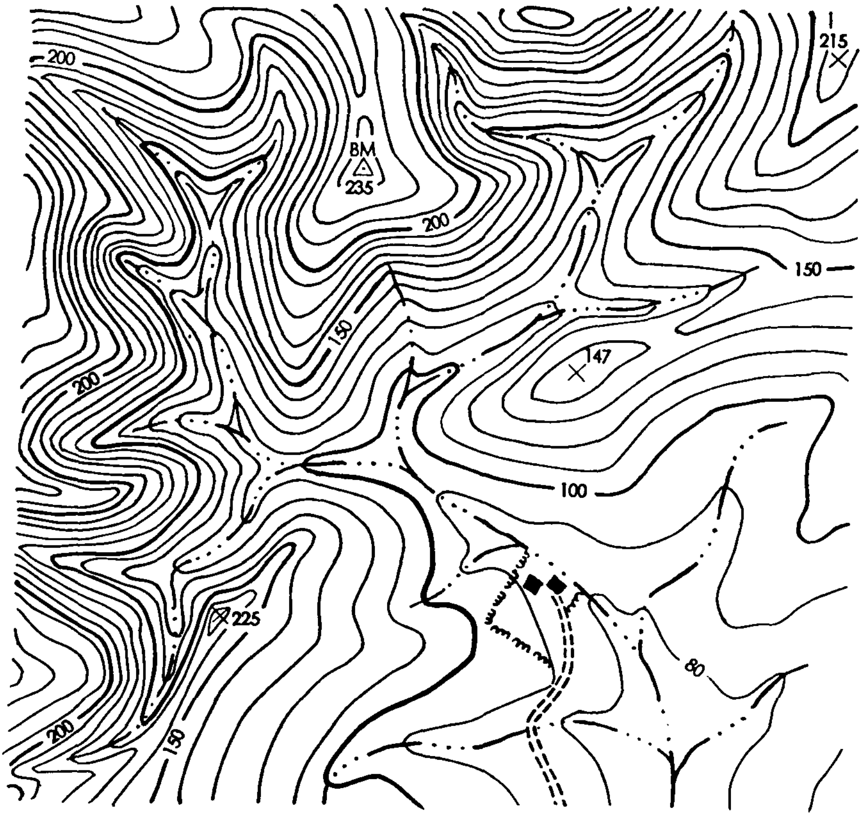


FIGURE 16. *View of stream bed and contours.*

b. Every contour closes on itself and encloses an area, either within or beyond the border of the map. In the latter case the contour line will run off the edge of the map.

c. A contour which closes within the border of the map encloses either a hill or a low area. In a low area there will be found usually a pond or a lake or marsh. Where there is no water in a low area it will indicate a depression in the ground and the addition of thick marks on the downhill side of the contour line represents a *depression contour.*

d. Contours never split. *Regular* contour lines normally do not cross each other.

e. Contours will appear close together when showing a steep hill. Contours will appear well spread apart when showing gentle sloping ground.

f. Contours are spaced equally apart when the slope of the ground is uniform.

g. When smooth rolling hills are shown, the contours are farther apart at the top and bottom than near the middle.

h. In crossing a valley, the contours run *up* the valley on one side, turn at the stream, and run back *down* on the other side.

i. As a rule, contours are closer together near the sources of streams, as a stream bed is usually steeper near its source.

j. The larger the stream the flatter the slope; hence, contours on main streams are usually farther apart than on tributaries.

k. Contours are always at right angles to the lines of steepest slope. They cross the streamlines and ridge lines at right angles.

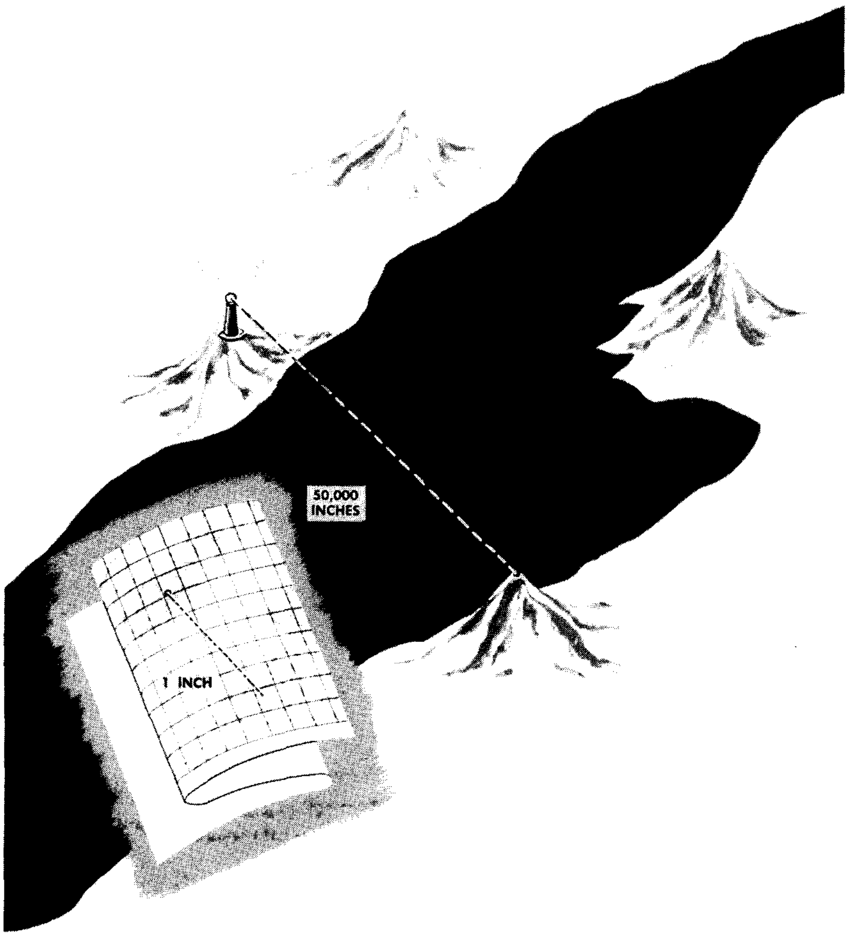
l. In crossing a ridge, the contours run along one side, turn around the ridge line, and run back on the other side of the ridge.

m. Contour lines when in V shape point upstream; when in U shape point down ridge.

Section III. HOW BIG ARE THEY?

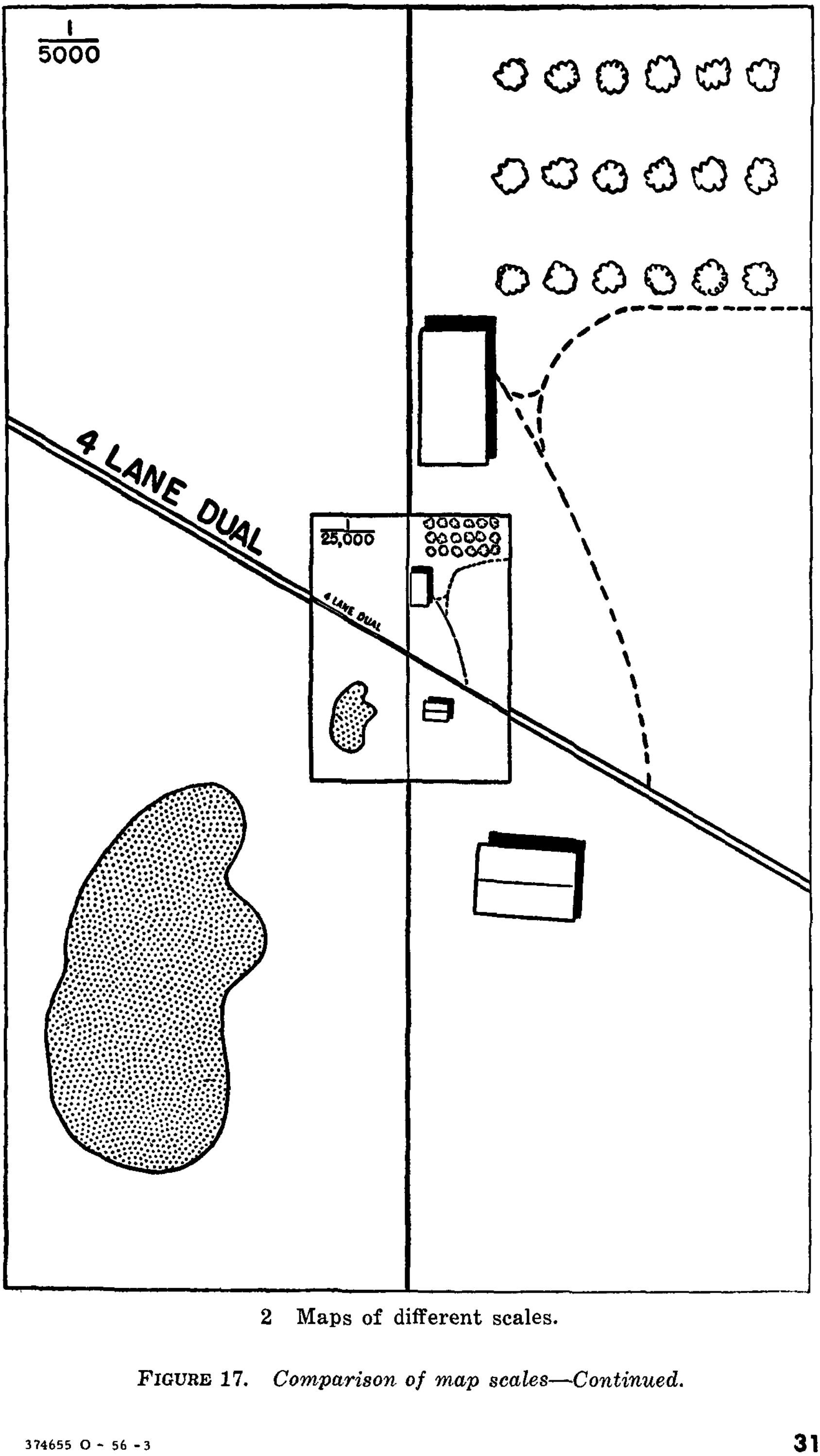
20. Ratio of, Map to Ground, Distances

A map is a picture in which one inch in any direction on the map represents many inches on the ground. The most common military maps that you will work with in the field are drawn so that all ground distances are 25,000 times or 50,000 times larger than the distances on the map. If we compare the map to the ground then, the map picture is 1/25,000 or 1/50,000 the size of ground it represents. This expression of the comparison of map size to ground size is the scale of the map, ((1), fig. 17), which is written in this manner: 1:25,000 and 1:50,000 or whatever the scale is. You will see later on that military maps can be at several scales ranging from 1:12,500, which usually covers only a single town, to 1:25,000,000 which includes the whole world on one sheet. When comparing scales of maps, we call one map smaller or larger in scale than another. When the scale is 1:25,000 the map is a large-scale map while the map of 1:25,000,000 scale is a small-scale map. An easy way to remember whether a map is a large- or small-scale is to think of the scale as a fraction; 1/25th is larger than 1/50th and 1/25,000th is larger than 1/50,000th. The larger the denominator of the scale fraction the *smaller* the scale of the map. The relationship between maps of different scales is shown in (2), figure 17.



1 Map and ground.

FIGURE 17. *Comparison of map scales.*



2 Maps of different scales.

FIGURE 17. *Comparison of map scales—Continued.*

21. The Size of Objects Seen on a Map

The picture that an ideal map would show would be the *exact* illustration of *every* feature of the ground area represented on the map in *true* shape and proportion. However, such a picture is just about impossible when you consider that the features and objects on the ground are being reduced to 1/25,000 or 1/50,000 of their original size. On a map at a scale of 1:50,000, a square mile on the ground must be condensed into a small square a little over an inch and a quarter on a side (1.27 inch by 1.27 inch). If every feature on the ground were plotted on the map true to the scale of the map, the result would be too difficult to read. Many objects would have to be drawn with such fine lines that they would not be recognizable even under a magnifying glass. Some objects are too small to show at the map scale. An important building such as a hospital whose length is 500 feet would be only ⅛ of an inch long on a map of a scale of 1:50,000. In order to emphasize such important buildings the size of the building may be enlarged on the map. The symbols representing the different objects and ground features must be drawn to a size which, although not at the actual scale of the map, is readable and clearly understood. Even though the symbol takes up more room than it should if shown at the same scale of the map itself, the center of the symbol and direction in which it is faced is intended to correspond to the true center and facing of the actual object on the ground. Remember that a symbol will vary in size with the scale of a map that it is shown on. As the ratio comes closer to 1:1, the map symbol assumes a shape and proportion more nearly the actual shape and size of the object represented.

22. Sometimes Things Shown are No Longer There

You will notice about you that nearly every day there are changes being made to the earth's surface. Buildings are being torn down. New ones are being put up. Roads are being abandoned or changed. New highways are being built. Woods are being cleared. New forests are being planted. A mapmaker can only show those things on a map that were on the ground when he made the map. Because of this a map may show things that are no longer on the ground that it pictures. For the same reason a map will not show new things that have been added since the map was drawn and printed. Before you use your map make sure you check the date that it was prepared so that you can get an idea of how much to rely on the part of the map picture showing the objects and other changeable features. A note in the margin of every U. S. military map will show what year the map was made, drawn up, and printed.

23. The Map is as Accurate as Possible

The map is as accurate as the information from which it was made. If a map was drawn up from accurate field surveys by engineers, then the map they have produced can be considered very accurate. Each map will tell you in its margin how it was made and indicate how accurate it should be. When using a map, check to see whether objects and ground features not shown are important enough to you to worry about. If they are, you need a larger scale map, or the missing items should be reported to your leader for passing on to the mapmakers who will correct the maps as soon as possible to include the important features left out.

Section IV. WHERE ARE YOU?

24. Finding Out Where You Are

One of the most important things to be learned from the map is finding your location on the map. When you have to go from one place to another for the first time, you must know, first, where you are both on the ground and on the map. To find out where you are, you will have to be able to turn your map until the roads or rivers or hills or woods around you look as if they are in the same places on your map as they are on the ground. The best way to do this is to go up to the top of the nearest hill and look at the country around, and then at the map. Almost as soon as you turn the map, shapes on the map made by the lines for roads or streams will begin to fit shapes on the ground. When the shapes or patterns of these map lines look very much the same as the shapes or patterns of the land lines in every direction, then you have your map turned to the right direction. When you put the map down on the ground to find out where you are, you turned the map until it matched the way the land looked from the hilltop. This is called *orienting* the map. It is a short way of saying that the map is turned so that the north side of it is toward the north, the east side to the east, and so on. With your map oriented, the direction of things on the ground will be the same as on the map (fig. 18). By looking at the ground around you and at the map, you can easily determine the exact point on the map where you are on the ground. Remember always that when using a map in the field you must first orient the map before using it to locate either yourself or any other place on the map.

25. Finding Yourself on the Map

a. One of the man reasons for lining up a map with the ground and orienting it is to help you find out, in the easiest way, where you are on the map. Therefore to make it easy for yourself you must orient the map to use it to locate yourself. When orienting

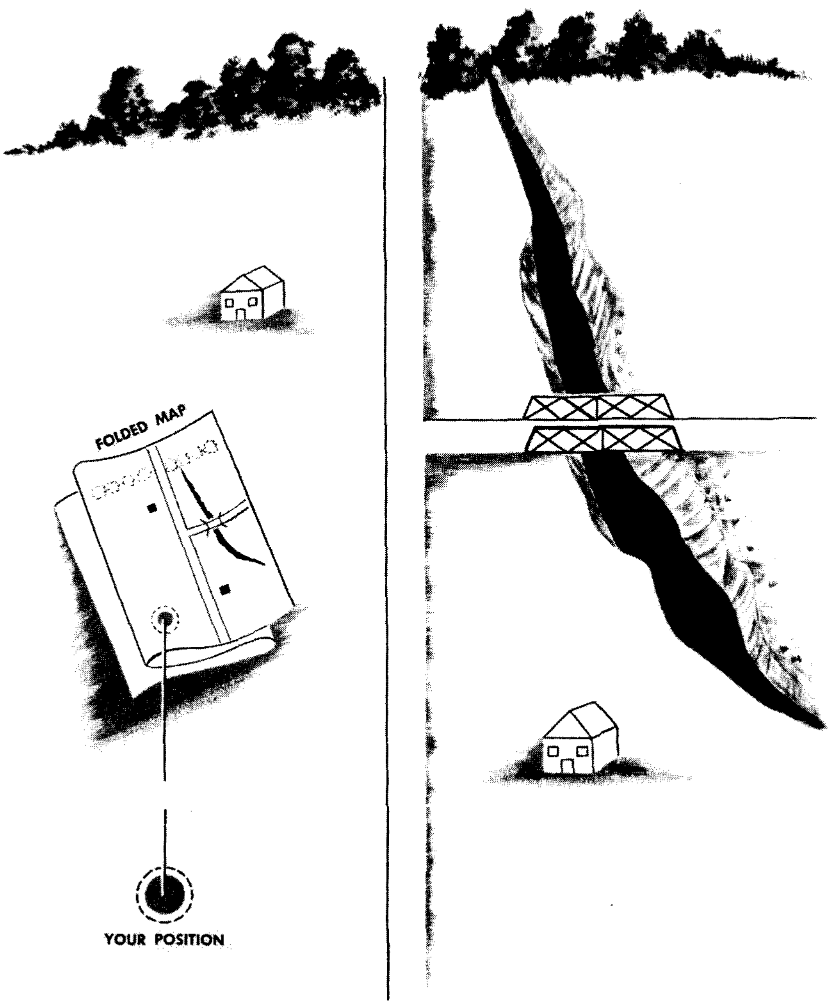


FIGURE 18. *Orientation by inspection (view of map and ground).*

it and comparing it to objects on the ground, lay your map on a smooth, level surface so that you can sight over it to distant objects. If there are enough outstanding ground features and manmade objects nearby which you can identify on the map then you should be able to compare their positions on the map with where you are standing. By *inspecting* the map and the ground as described in paragraph 24 to line up your map you can also find yourself on the map.

b. Your location on the map is a point where all lines between you and objects on the ground meet. Using this as a guide we can use another method to help us find ourselves on the map. With the map oriented, find two clearly visible objects on the ground somewhere in front of you which you can also pick out on the map. It is best to find two points that are a good distance apart and easy to sight on. With a ruler or folded piece of heavy paper to use as a sight rule, sight along the top of the rule to one of the points and draw in the line of direction from the symbol representing that object on the map. See figure 19. Do the same for the second point and you will find that the lines intersect at a point on the map between your position and the two symbols on the map. The point of intersection is your location on the map. This method of finding your position on the map is called resection.

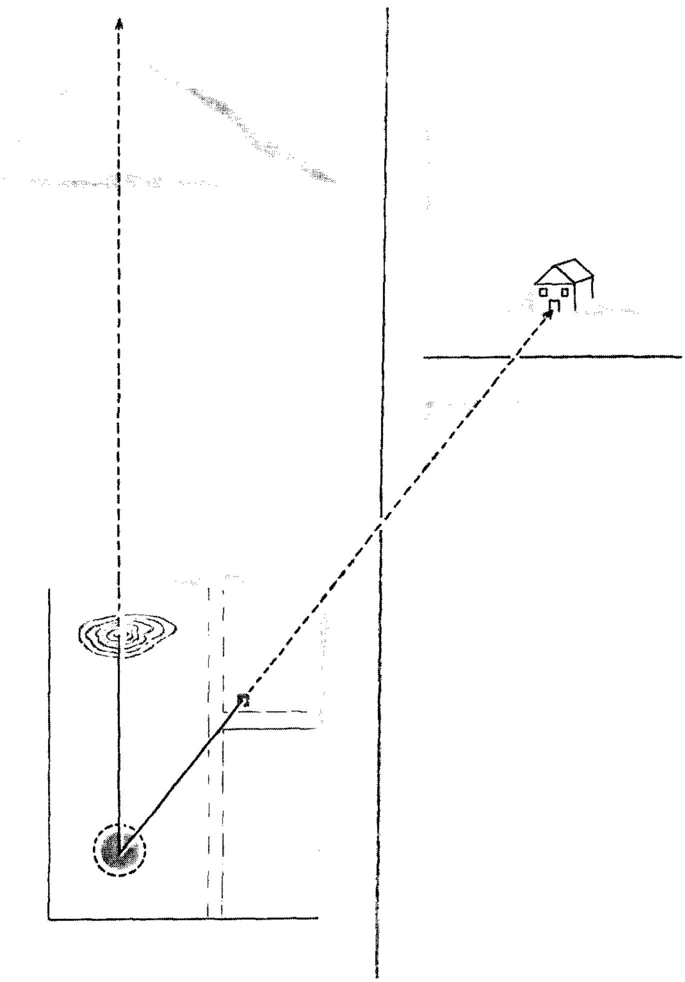


FIGURE 19. *Finding yourself on the map.*

Section V. WHERE ARE YOU GOING?

26. Where is It?

To locate a new point or position from where you are you must know two things, which way it is and how far. You ask the question—"Where is it?" when you are trying to find out where you are going. Perhaps you can't see the place because trees or hills are in the way. Here is where your map comes in. The map will show you what is hidden behind those trees or hills. By using your map and by looking around you, you can find out where you are going.

27. Which Way?

Whether we take a main highway or go cross country to a new location we still must know which way to go in order to make sure we are ever to get there. Even with the game of baseball, if you don't know which way to go from home plate you will never get to first base. Here are some common expressions for giving or following directions that you hear nearly every day—left, right, straight ahead, back, up, down, northerly, easterly, and so forth. These expressions can also be applied to normal use in field operations. However, they are not always accurate enough to use when reading a map. More exact expressions than just simple ones as "straight across" or "bear left" are needed to know which way you are to go when making cross-country marches. A system which is known throughout the world for expressing direction (in ancient times it was used to describe from which way the winds were blowing) is the use of the familiar terms North, East, West, and South, and combinations of each of these four to give us separate direction lines from any point without using fractional points. Their relative positions around a point are shown in figure 20. (Even more accurate directions are expressed by a method shown later in chapter 3, section II.) You can use the map itself to help you find out at least the principal directions. When you have your map oriented you know which way the four principal directions, North, East, West, and South are because the edge of the map that contains the large printed name of the map area is the north edge and the ground lying past this edge of the map is to the North. The right edge of the map then faces East, the left edge faces West, and the bottom edge where the graphic scale is located faces South. Other natural means of showing us direction are by the sun in the daytime and stars at night. In the daytime the sun is a *rough* guide to finding the direction. It rises in the East, sets in the West, and at noon it is approximately South of you when you are any place above the equator. At night, you can still find north by looking at the stars and picking out the special star named for its direction finding use—the North Star (see fig. 21). Use the North Star as a guide at night by roughly lining up (orienting) the north top side of your map with the North Star. The use of the North Star is good only at places on the earth above (north of) the equator. For places below (south of) the equator the main star to find direction by is identified by the Southern Cross (fig. 22). The direction you find with the Southern Cross is south in this case.

28. How Far?

a. Of the many questions that a map can answer for us one of the most important is—How far is it from one place to another? If we can identify two places on the map, we can measure the ground distance between them directly on the map since the map is a true-to-scale picture of the land. For example: If the map were

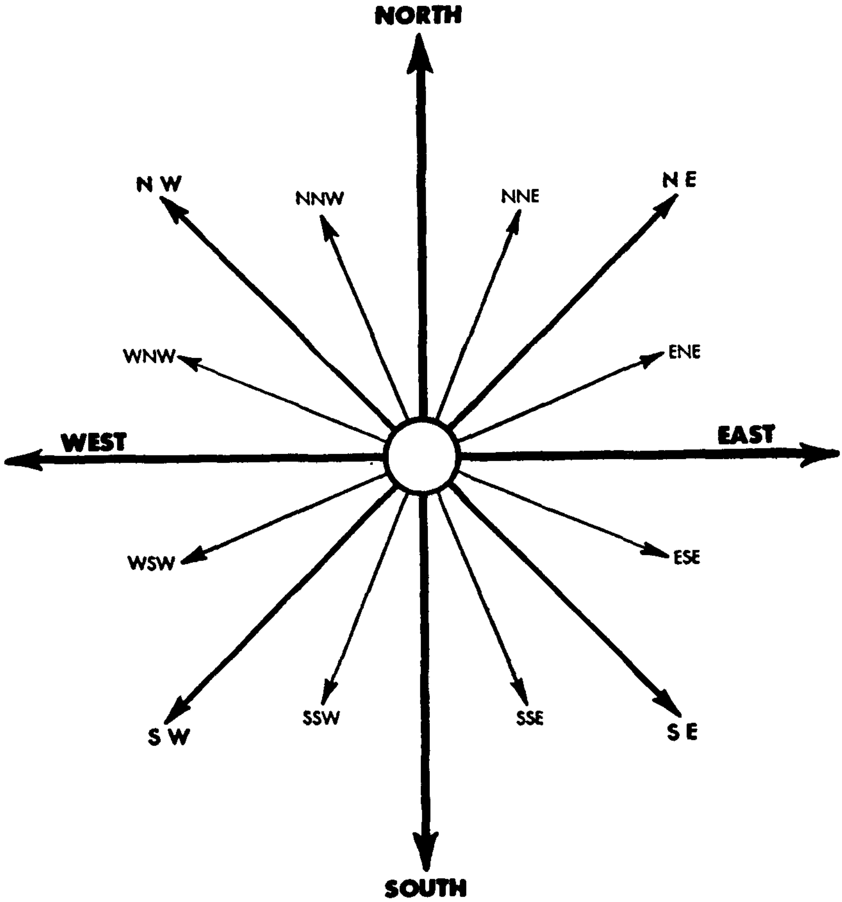


FIGURE 20. *Points of direction.*

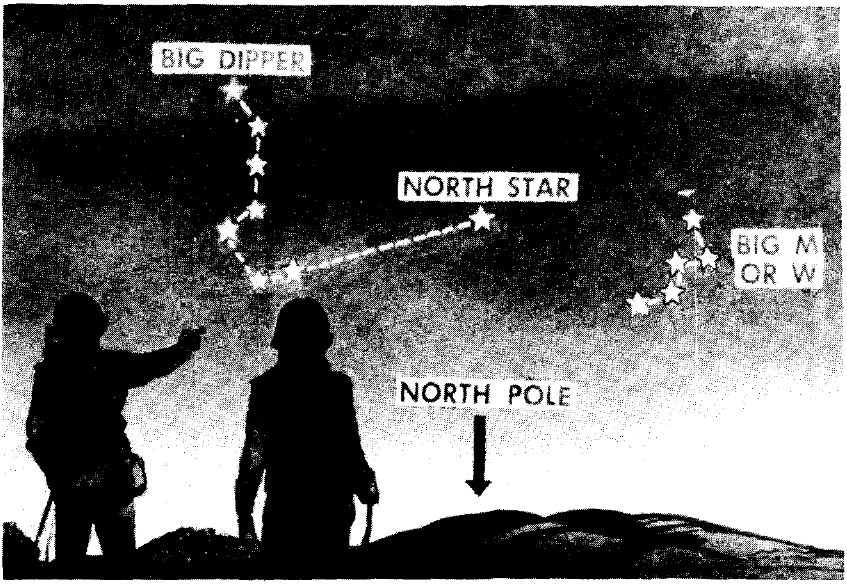


FIGURE 21. *Finding direction by the North Star.*

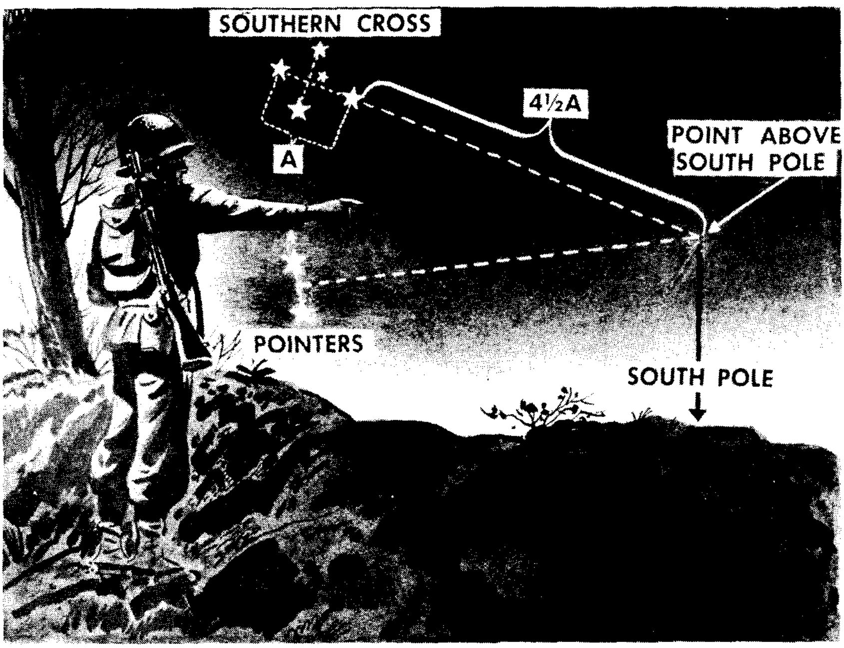


FIGURE 22. *Finding direction in the southern hemisphere by the Southern Cross.*

1/10 the actual size of the ground or drawn at a scale of 1:10, then no matter which way one inch were measured on a map, all measurements on the ground corresponding to all those made on the map will be 10 inches each. In order to find the actual distance between two points on the ground measure first the distance between the same points on the map. Then multiply the map measurement by the denominator of the scale ratio and the answer will be the true ground distance between those two points. The ratio, for the scale of the map, is shown on the map at the bottom center of the margin. Practice this on the map in Appendix IV. Find out how long the longest north-south airfield runway is at National Airport in the northeast corner of the map. First place an ordinary ruler along the runway symbol; it reads a little over 3 inches. Now the figure at the bottom center of the margin says that this map is 1:25,000 the size of the actual ground it represents. Since this means that 1 inch on the map equals 25,000 inches on the ground, we must substitute 25,000 for each inch measure on the map. In this case we multiply 25,000 times 3 and the answer is an actual ground distance of about 75,000 inches for the runway. Divide this figure by 12 to find the distance in feet, or divide it by 36 to find the distance in yards.

b. A simpler method has been provided on the map for finding the distance between points. It is a special map ruler which helps measure the ground distance in yards or meters directly on the map. This ruler is called the *graphic scale* and is usually found at the bottom of the map. To use this graphic scale to measure distance we do the following:

(1) Place a straight strip of paper on your map along a line joining the points you wish to measure in figure 23 which in this case is an airfield.

(2) Then place marks on the paper opposite the two points as seen in figure 23.

(3) Pick up the strip of paper and lay it along the graphic scale on the map which shows what the length of the field really is (lower fig. 23).

There is another thing to notice about this scale. It has two parts. From the zero mark to the right it reads in large numbers 500 yards apart. From the zero mark to the left it breaks down this distance into smaller distances of 100 yards apart so we can measure more accurately. For example, in figure 23, the marks on our paper are farther apart than the distance between the zero and the 500 yard marks on the graphic scale. If we place the right-hand mark at the 500 yard point on the graphic scale, the left-hand mark overlaps into the smaller divisions or 100 yard graduations. We see that it is about at the second mark to the left of the zero or at the 200 yard mark. By adding 200 yards to the first 500 yards we can judge that the runway is about 700 yards long. A further example of using the graphic scale is shown in figure 24. For purposes of allowing different units of measure to be used on a map, there are found more than one scale on the map. For example, one of the scales may be measured in miles, another in yards, or another in meters. In any case there is a note on the scale which tells you what the unit of measure is, and you can use any of the scales shown on the map.

c. We have so far determined how to measure straight line distance between points. But how about those distances along irregular or curved lines such as the road distance from one town to another as in figure 25? To measure the distance, divide the curved lines of each section of road into small straight sections. Then lay the edge of a strip of paper on the tick marks, one after the other, adding each section to what has already been marked. This results in a straight line distance along the edge of the paper strip with total length of each curved road section on it. We can measure the ground distance with this on the graphic scale in the same way as we did for the straight distance between *a* and *b*, figure 24. At times, you may wish to compare the distance on the ground with the map to check how far you have come from a previous position. If you have a measuring tape, you can measure distance reasonably accurately on the ground. Using a tape, however, is time consuming and takes too much effort for your purposes. The best measuring devices for you to use are your legs, if traveling on foot, or use the mileage gage on the speedometer of your vehicle, if riding. To use your legs for measuring (ground distance) you must first determine the length of your average step. A stride is the distance between the heel of one foot and the point at which the same heel meets the ground again while walking. It is equal to two steps; the length of a step is approximately 30 inches or 2½ feet for the average soldier. To find out your individual length of step measure a 100-foot distance on ground of average slope for the area you are in and see how many steps it takes to cover the 100-foot distance. Divide the 100 feet by the number of steps it took to cover the distance and you will get a figure for the average length of step you take when walking across the ground. The mileage gage on your vehicle's speedometer has a counter on the right hand side that reads off tenths of miles when you drive down the road. This will enable you to measure road distance to the nearest tenth of a mile. Remember that when you move up and down hills you are actually covering more distance than shown by measuring straight across a map. This is because you are going up and down over vertical distances in addition to the flat level distance that you measure with a ruler on the map. This additional distance is usually small and is not important enough for you to worry about when you move for short distances within the area shown by a single large-scale map.

Section VI. USING THE MAP

29. Using Your Map to Get There

a. When you know where you are and where you are going, the next thing to find out from your map is the best way to get there.

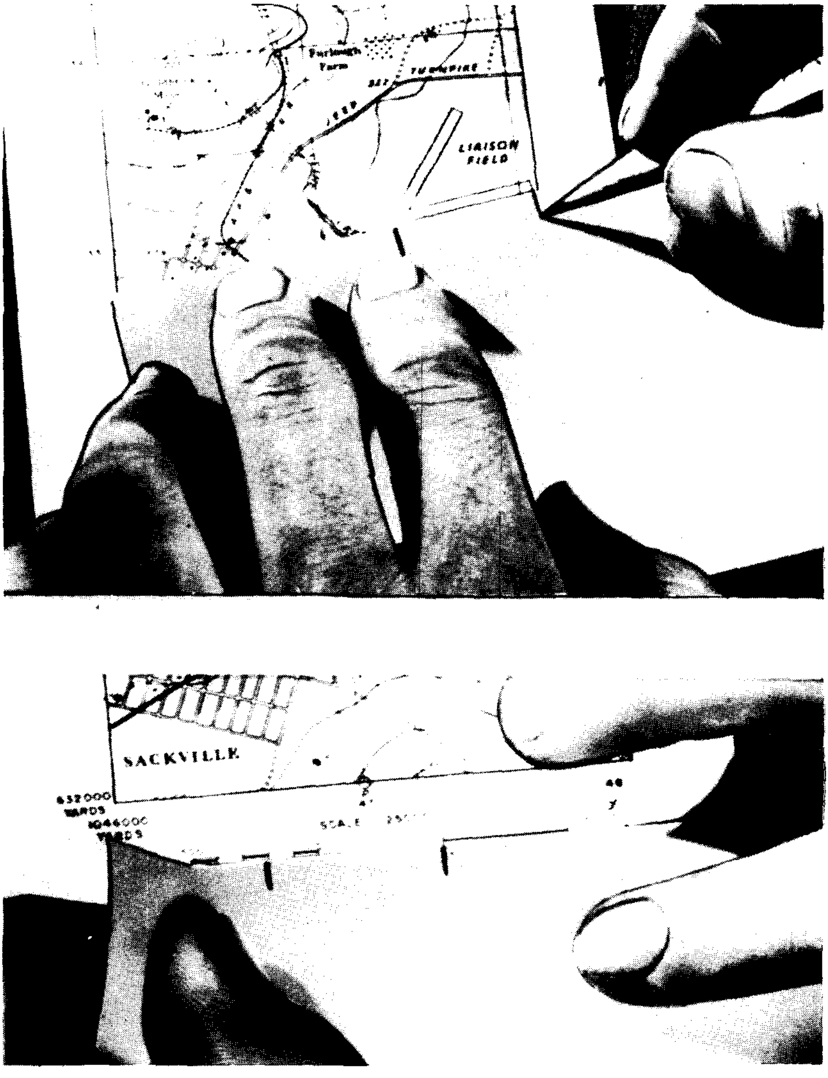
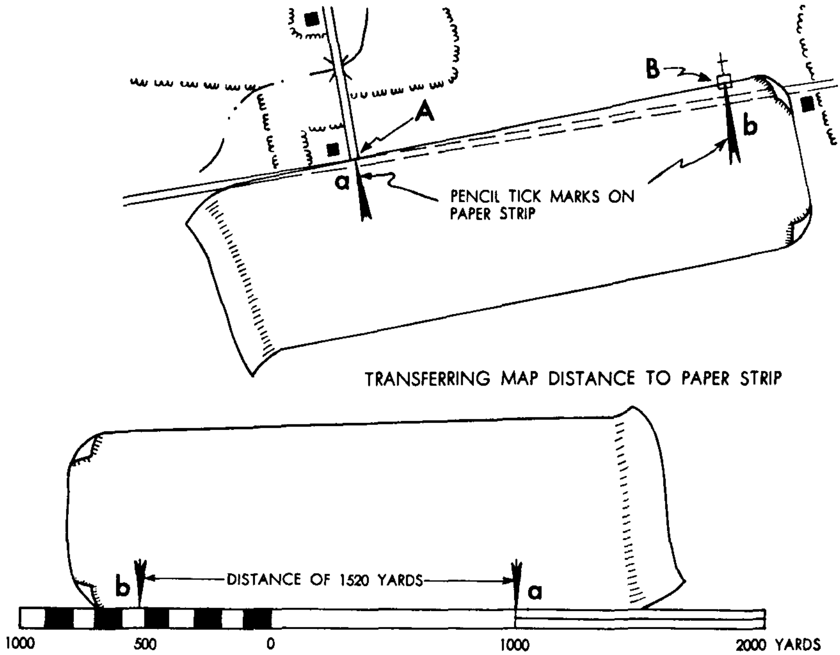
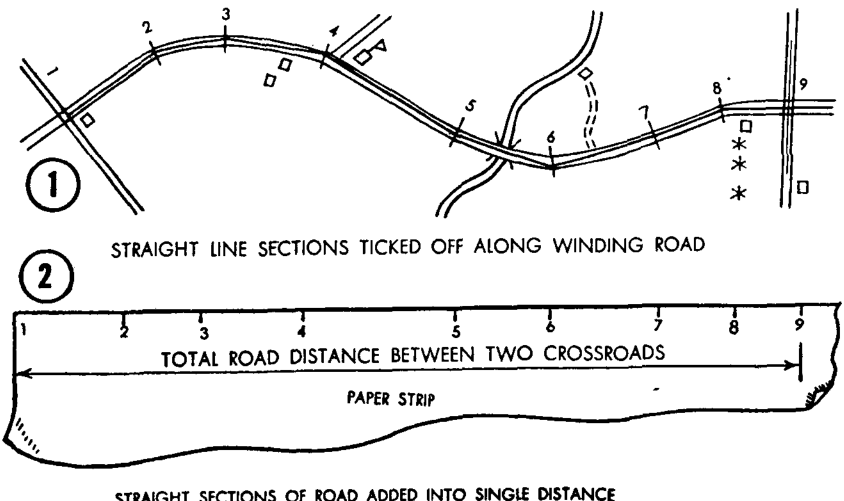


FIGURE 23. *Measuring ground distance from a map by use of paper strip.*



MEASURING MAP DISTANCE ON SCALE

FIGURE 24. *Example of use of graphic scale.*



STRAIGHT SECTIONS OF ROAD ADDED INTO SINGLE DISTANCE
FOR MEASURING ON GRAPHIC SCALE

FIGURE 25. *Measuring ground distance along curved road.*

It is always important to get there alive and in one piece. So, you will choose a way that gives you cover, where enemy bullets can't hit you, and *concealment*, where the enemy can't see you. Usually this safe way will be farther around than a straight line between where you are and where you are going, and sometimes by going a little farther around, you will still be able to go faster and easier. So, you choose the way that will be safe, quick, and easy. The things in your way that will slow you up, like swamps, dense woods, or steep hills; and the things you will have to go around, like lakes, high mountains, or bends in rivers, are all shown by the way your map is drawn. When you know how to read the map, you can use it to get to where you are going safely, quickly, and easily.

b. Suppose you are moving from point A (fig. 26) to a new position, point B. By orienting your map you can learn first which general direction you have to go. Measuring across the map on a line from A to B, you can read the approximate distance you are to travel. Looking closely at the map you see that you can travel part of the way by roads or trails (lines A–X) but for the rest of the way you will have to follow the map features cross-country (line X–B).

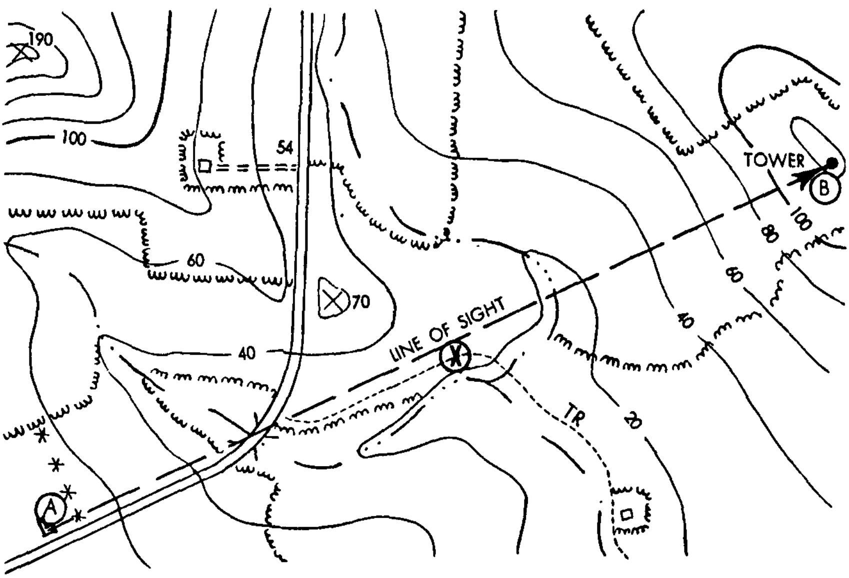


FIGURE 26. *Moving to a new position.*

c. How do you follow a line cross-country to get to where you are going? Let us follow through an imaginary example to see at least one way of doing it—

(1) You are at point A somewhere west of Hollin Hall (fig.

27), and your unit leader tells you to report to a certain bridge at point B. He draws a line on the map from your position to the bridge. Your job now is to get to the bridge. That means you must walk somewhere along the line drawn to get there. Because the enemy force is watching the area, there are no safe roads going in that direction, so you will have to follow that line cross-country. How do you do this?

(2) First, as always when getting ready to read the map in the field, orient your map. Here you can orient it by turning it to match the detail on the ground. Again the map must be on a level place so that sightings can be made over it after it has been oriented.

(3) Now, sight along the line drawn by your unit leader toward your destination to look for the first big outstanding landmark on the line of sight. If this landmark is the bridge you were told to report to, then all you have to do next is to follow the line of direction straight to it. If you go down hill out of sight of the bridge when you are walking toward it, check the features of the ground to the right and left of you with the map to make sure that you will keep going in the direction toward it.

(4) If, while at point A, you cannot see the bridge directly from your position, sight along the line with a sight rule to the first outstanding landmark that is clear enough to follow while walking toward it, for example, the water tank on hill 108. Pick up the map and move to the landmark sighted. Orient your map again and sight down along the line on the map toward your destination, the bridge. If you cannot see the bridge yet nor any other good landmark on the line of sight, look a little to the right or left. Suppose there is a corner of woods just to the right of the line of sight. Then you will move forward keeping a course so that the corner of the woods will stay just to your right. As you move forward toward your destination you will repeat the process of checking your position on the map, orienting the map at each stop and sighting on such major features along the line as trees, fences, power lines, forks and bends of streams, large buildings, towers and steeples, unusually shaped hills until you can actually see the bridge. Sometimes on long marches to a new position look back to where you have been to make sure you are on the line.

(5) If the bridge, point B, happens to be in enemy hands, and your unit leader has designated you to help capture it,

you must be continually on the watch for any places along your route of approach that may be under the watchful eye of the enemy. You may sight and follow your course to outstanding landmarks but do not occupy them. As the landmarks are outstanding to you they are also outstanding to an enemy force in the vicinity and are kept under observation. Stay away a little to the right or left of a landmark that you want to use for sighting. Use it as a point of reference but take into account that you are a little to the right or left of it when you are looking toward your next point.

(6) When moving to an objective under fire such as the bridge at point B, you must plan your route of approach first at some concealed location where you can study the map in safety. There you pick out a safe route and some points of reference along the route from the map memorizing them so that when you do start out toward your objective you can check them off in your mind as you pass them. This is much better than risking your life by stopping to find where you are and where you are going in the midst of enemy fire.

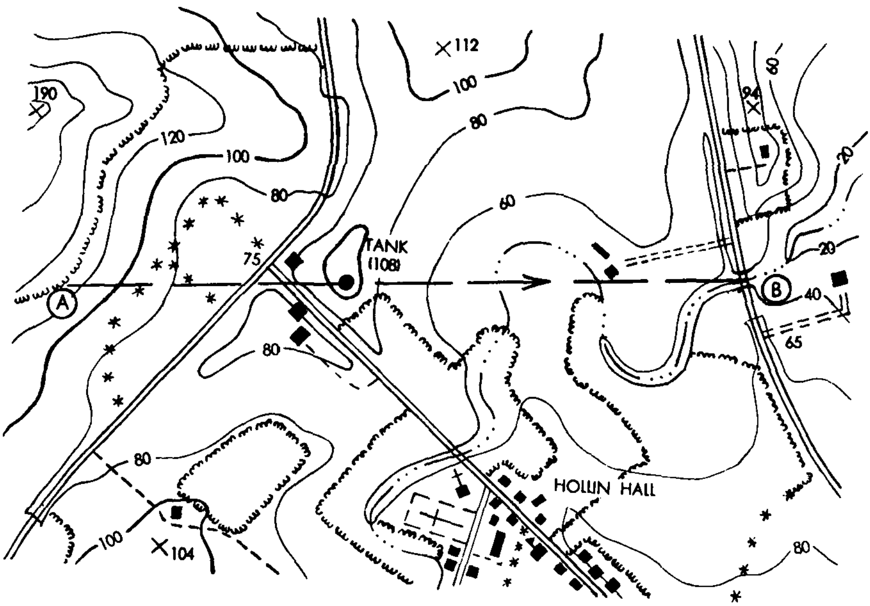


FIGURE 27. *Following the map cross-country.*

30. What to do if You Get Lost

We know that a person walking across open country can get lost very easily without a map. It is also very easy to get lost when you drive along a road, even in the United States where there are all kinds of signs and directions set up for the use of the motorist. It is even easier to lose your way in a strange country, especially in wartime. The map is an important instrument to use to keep you on the right road. While traveling you must keep your map oriented if you are to follow the right roads. This is done easiest by inspection. You must chek your location often. Watch your mileage gage on your speedometer at all of the important points, keeping a record on your map so that you can check your distance from your starting point. Reading off the distance along the road on the map will also help you check your position on the road as you progress. If you get confused as you travel towards a new location and think you are lost, keep calm, take a rest, think it over. Find north; retrace your route in your mind and try to recall the ground features and objects you have passed. Then try to locate one of them on the map. Determine your position by checking yourself against the ground features you have identified and the principal direction—north. Now you can continue on your mission. Keep checking your movement on the map and the ground.

31. Bringing Back the Information

When you are sent out on a reconnaissance or scouting mission you will find information concerning the land around you which must be brought or sent back to your commander. To keep this information clear and understandable you must set it down in writing by a simple and quick method. This can be done by using your map and a sketch. Chapter 6 tells how to make sketches. If you have time you may want to make an overlay. An overlay is simply a piece of tracing paper used on the map and to which is added your own information to give a clear picture story of what you wish to tell your unit leader (fig. 28). An overlay is also used to send back information obtained by reconnaissance. Instructions for making overlays are given in chapter 16.

32. Take Care of Your Map

In the field your map may be as important as your weapon. Take good care of it as you do your own assigned equipment. Fold your map small enough to slip under your jacket or in your shirt to protect it from bad weather. Figure 29 shows how to fold it so that it faces outward. Folded this way, you can read parts of it without unfolding the whole map. When you mark your map mark it lightly; it may have to last you a long while. Many marks on it

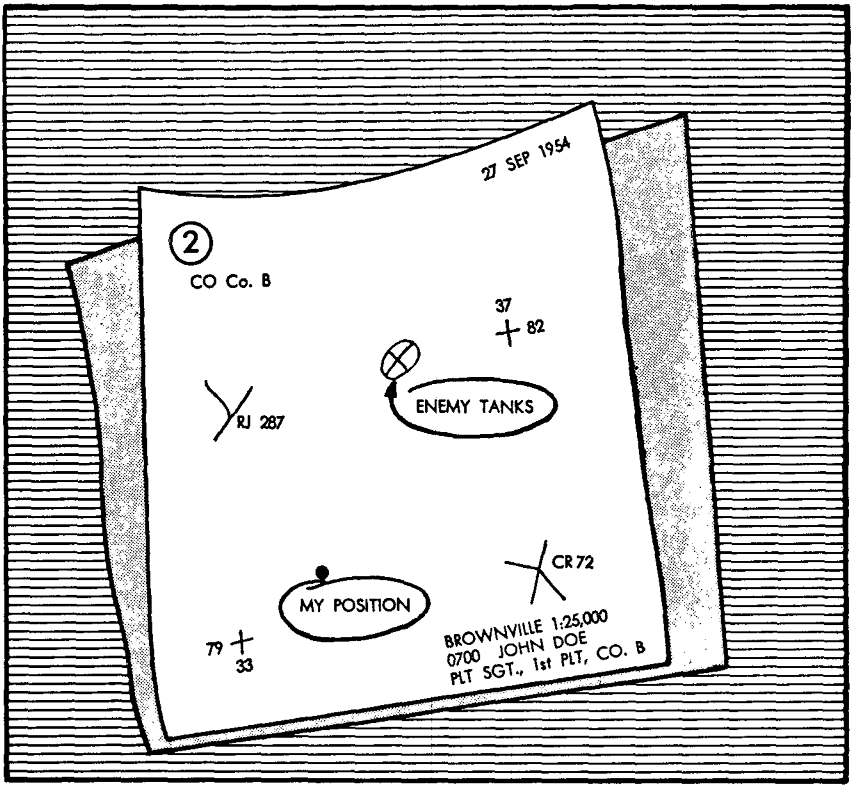


FIGURE 28. *A typical map overlay.*

will confuse you. Erasures of heavy lines will smear it and make it difficult to read. Try to avoid getting it dirty with mud or grease that is hard to clean off. Keep your map out of enemy hands. Especially when you have been marking your movements and making other notes on the map, it becomes an important document to an enemy trying to learn about your unit's location, size, and movements. If in danger of capture, burn it. If you can't burn it, tear it into small bits and scatter them widely. If you can't do either, fold it as small as possible and bury it.

Section VII. SUMMARY

33. Practice Reading Your Map

Practice recognizing the use of the different colors on the map, the common map symbols, and the ground forms that the contour lines show. The shape of the ground and the ground forms are also shown by comparing the streamlines and the ridge lines identified from reading the contours. Taking time to practice reading and understanding these parts of the map picture now will help in

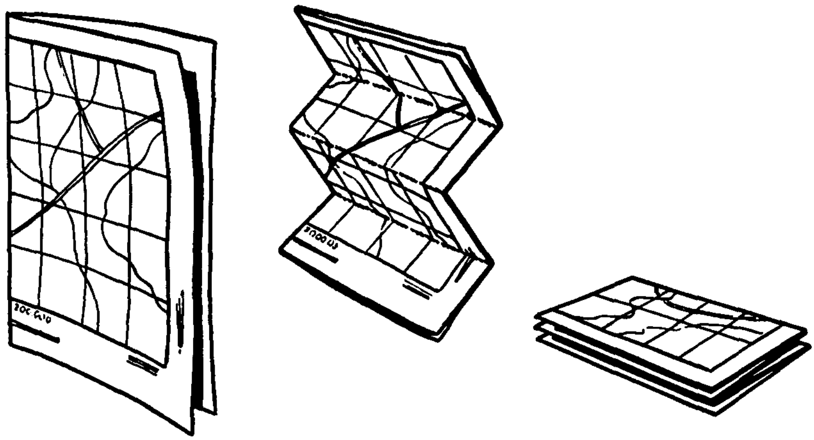


FIGURE 29. *How to fold a map.*

acquiring the ability to read a map at a glance when you are in the field and have little or no time to figure out what the map is trying to tell you. Pay attention to information in the margins outside the map picture. You will find such things as the graphic scale, the ready ground-distance ruler built into the map. There are diagrams provided that show you which direction north is, which is the next map sheet, and what some of the special map symbols mean.

34. Which Way + How Far = Where it Is

Remember the principle of using direction and distance to locate places both on the ground and on the map. Direction and distance each must have a reference from which to start locating a new point. For the military map, north is your main reference for direction and your position located on the map is the point of reference from which to measure how far.

35. Review What You Have Learned

a. A map is a graphical representation of a portion of the earth's surface drawn to scale. The military map is not just a picture of the earth's surface, but a guide drawn up by the most accurate means available to assist both individual soldiers and army commanders in planning field operations and in actually following them through. The map is used both in defense of your position and in attack on the positions held by the enemy. You as a soldier are expected to learn the principles discussed in the previous sections so that you may at least locate yourself on the map and know how to read and follow it. If you can understand most of all that we have discussed so far, you have a sound enough background to continue with the remainder of this manual.

b. Use the following as a checklist for describing and using the map:

(1) You read them like you do a picture.

(2) Know what they show as you know your own weapon.

(3) Maps give you an "airman's-eye" (bird's-eye) view of the land about you.

(4) They are costly to make but make up for the cost when you need them.

(5) Military maps show the ups and downs of the land—contour lines.

(6) Maps show hills, streams, protective cover, safe routes, shortcuts, easy ways to get to places.

(7) The map is used for reconnaissance and patrolling; for planning movements and selecting positions.

(8) The map is an aid to survival. It helps get you back to friendly lines.

(9) Learning maps is not only smart, but also a form of insurance against soldiering mishaps.

(10) Learn to read and understand maps because the information taken from a map is only as accurate as the skill of the map reader.

PART TWO

POINT LOCATION

CHAPTER 3

MAP MEASUREMENTS

Section I. MEASURING DISTANCES

36. Importance of Map Scale

It is essential to the user of a map that he know how to measure on the map the distances he wishes to use in operations on the ground. Several different methods for measurement exist, but all are dependent on the scale of the map for their solution.

37. Map Scale Described

If it is known that the features on the ground are 1,000 times larger than they are on the map, it is a simple matter to measure distances on the map. Multiply these map distances by 1,000, and thereby determine the actual ground distance. A map scale represents the relation of map distance to ground distance. In the example above, the scale shows that one unit on the map equals 1,000 units on the ground. However, it is more convenient to write it 1:1,000. This is the method commonly used when the scale is printed on the face of a map.

$$\frac{\text{map distance}}{\text{ground distance}} = \frac{1}{1{,}000} = 1{:}1{,}000 = \text{map scale}$$

It is important to note that map scale always refers to map and ground distances in the same unit of measure. The inch is the most convenient unit for map measurement when measured disstances are in inches. It is most commonly employed with measured distances being in inches also. The centimeter is the most convenient unit when converting to units in the metric system.

38. Use of the Graphic Scale

To aid in actual measurement of map distance, use is made of the graphic scale which is usually printed in the lower margin of each map, and which is actually a paper ruler for use in measuring ground distances directly on the map. Since it measures the ground distances directly, conversion is *not* necessary. The graphic scale is usually a combination of three rulers: one measuring in miles, another in meters, and the third in yards. Part one of this manual describes the method of determining map distance with the graphic scale. Generally, graphic scales on standard maps are subdivided into graduations of 1/5 of the unit of the scale. However, in order to read distances smaller than 1/5, a portion of the smallest division (to the left of the zero) may be approximated into fractions thereof to the nearest tenth of the unit being used (fig. 24).

39. Use of the Engineer Scale

The engineer scale is a handy tool for measuring ground distances from a map. Its six separate scales permit such measurements on any military maps, on some by direct reading and on others by a simple arithmetical multiplication or division of a direct reading. For example, maps with scales such as 1,000, 10,000, and 100,000 permit direct reading on the "10" scale. Maps having a scale of 1:5,000 and 1:50,000 could be scaled with the "50" scale. A 1:30,000 map scale would call for the "30" scale, 1:60,000 for the "60" scale, and so forth. When the map scale is such that it cannot be read directly on one of the six scales of the engineer scale, it becomes necessary to subdivide or otherwise change the numberings of a division to make it fit. An example might be the measurement of a ground distance on a 25,000 scale map, which could be solved by using the "50" scale and dividing by two. The distance read on a "40" scale multiplied by two would give the true measurement on a 1:80,000 scale map; a "50" value divided by 4 would be true on a 1:125,000 map. However, the most common method of using the engineer scale on maps, and the easiest to remember, is to use the "10" scale for all measurements and to multiply by the map scale to get the true ground distance. Since the "10" scale is an inch scale, the measured values, after multiplying by the map scale, will always be in inches. This means that the inches must be converted into miles, yards, meters, or whatever unit is desired for ground operations under consideration. A good understanding of the scale ratio of the map makes simple the use of the engineer scale for measuring true ground distances on a map of the area, regardless of the scale of the map. Conversion factors for yards and meters are found in appendix V.

40. Unknown Scale

If the ratio and the graphic scale are both missing from a given map, they may be computed as follows:

a. Computing Map Scale. On the ground measure the distance between two features which can be identified on the map, such as a bridge and a road junction. Then measure the map distance. Enter these two figures as a fraction—

$$\frac{\text{map distance (in inches or centimeters)}}{\text{ground distance (in inches or centimeters)}}$$

The scale can be quickly computed. Unless the map is of foreign make, the scale is likely to be in round figures and in one of the conventional scales (table I).

TABLE I. *Conventional Map Scales and Representative Contour Intervals*

Scale ratio	Interval in feet	Interval in meters
1:6,250	5	1.524
1:12,500	10	3.048
1:25,000	20	6.096
1:50,000	50	15.240
1:100,000	100	30.480
1:250,000	250	76.200
1:500,000	500	152.400
1:1,000,000	1,000	304.800
1:5,000,000	5,000	1,524.000

b. Drawing a Graphic Scale. If for convenience it is desirable to prepare a graphic scale for a given map, the scale should be rendered as shown in figure 30. In this example, the map scale has been determined as 1:25,000, and a 3,000-yard graphic scale is to be constructed.

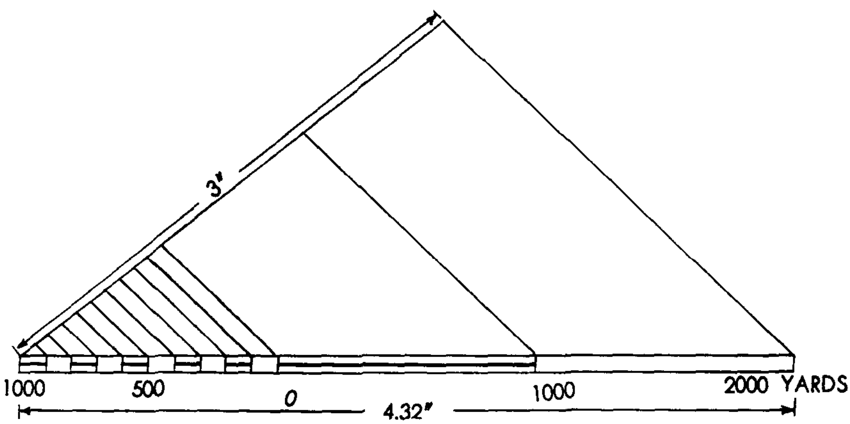


FIGURE 30. *Graphic scale construction, yards.*

(1) Calculate the map distance which is equal to 3,000 yards on the ground.

$$\text{map distance} = \frac{\text{ground distance}}{25{,}000} = \frac{3{,}000 \text{ yards}}{25{,}000 \text{ yards}} = 0.12 \text{ yards}$$

0.12 yards × 36 = 4.32 inches (map distance equal to 3,000 yards).

(2) A base line of 4.32 inches is then laid off and divided into 3 equal spaces representing 1,000 yards each, as shown in figure 30. In this example, the new scale is divided in three parts by placing a simple ruler at approximately 45 degrees to the new scale desired, with the zero end of the ruler and the —1,000 end of the new scale intersecting. A line is drawn from the 3-inch mark to the +2,000-yard end of the new scale, and parallel lines are drawn from the 2-inch and 1-inch marks to the new scale. This automatically divides the new scale into three equal parts, of 1,000 yards each. Lesser subdivisions are made in the same relative manner. The graphic scale thus produced can be used to make all measurements on its accompanying map. The diagonal line is drawn any convenient distance, and the required number of equal intervals are marked off along the line. Three inches is used here only because it is convenient.

(3) It might be more convenient to measure distance in a unit other than the yard, and a graphic scale in that unit would be required. The construction steps would follow those just outlined, regardless of unit of measure, but for comparison purposes a graphic scale in meters is shown in figure 31 for the same 1:25,000 scale map for which the scale in figure 30 was produced. Note that the scale of meters is longer than the scale of yards, because the meter is some 3 inches longer than the yard. Also, from the formula in (1) above, 3,000 meters on the ground equals 0.12 meters on the map which converts to 4.68 inches for the length of the metric graphic scale, compared to the 4.32-inch length of the scale in yards.

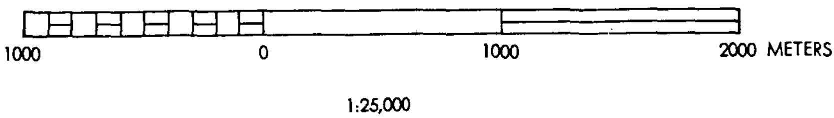


FIGURE 31. *Graphic scale construction, meters.*

41. Horizontal Scale

It must be remembered that distances measured on a map are horizontal. Consequently, true ground distances are seldom measured on a map. In order to obtain true ground distance, the increase caused by the differences in elevation along a given line must be added. The distance traveled on the ground is actually the slope distance. If there is more than one slope along the line, the sum of slope distances is equal to the total length of the line on the ground. The calculation of slope distances is discussed in paragraph 72*c*.

42. Scale Confusion

When one map is said to be of larger or smaller scale than another, the meaning of the statement may not be immediately apparent, even to experienced map readers. Paragraph 20 in part one of this manual explains the comparison. It is well to note that a map scale is like a fraction wherein ½ is larger than ¼. Likewise, 1/5,000 (or 1:5,000, as it is preferably written) is a map of larger features and scale than 1/25,000 (1:25,000). Figure 17 gives an example in which the highway appears larger in the 1:5,000 scale map than in the 1:25,000 scale map, although they cover an identical ground area.

43. Time-Distance Computations

Most military operations in the field require the use of a time-distance calculation; that is, the time required to traverse a certain distance on the ground is an important factor in the operation as a whole. This requirement can be quite readily determined during the planning of the operation if a map of the area is available.

a. Conversion of Distance to Movement Time. The ground distance is scaled from the map and divided by the rate of movement to give the total time necessary to make the movement. For example, the average speed of a motor convoy is 5 miles per hour, and the distance between two supply points in a forward area is 30 miles as scaled from a map. Therefore 30 divided by 5 equals 6 hours required to move a convoy from one point to the other.

b. Conversion of Movement Time to Distance. It is often necessary to determine the distance a column can march, or a convoy can travel in a given time. The distance is the product of the time in hours and the hourly rate of movement, or $D = T \times R$. For example, a motorized unit averaging 25 mph can cover 4×25 or 100 miles in 4 hours. This distance is measured along the road to locate the head of the column at the end of 4 hours. Thus, the position of the head of the column at the end of any given time can be determined. By substituting values of distance and time in the formula $D = T \times R$, and solving for R, the rate of march is determined.

c. Time-Distance Scales. It may be desirable to construct a scale graduated into time intervals instead of distance intervals. This type of scale is useful in determining the position of a moving column at the end of any given time. For example, if an infantry column is marching 2½ mph, a time-distance scale in hours and minutes on a map whose scale is 1:62,500 is made as follows:

(1) In 1 hour the column marches 2½ miles, or 2½ × 63,360 inches, or 158,400 inches.

(2) To obtain the length of the scale to represent this distance on the map, substitute in the formula:

$$\frac{1}{62{,}500} = \frac{MD}{158{,}400}$$

$$MD = \frac{158{,}400}{62{,}500} = 2.53 \text{ inches}$$

Section II. DIRECTION ON MAP AND GROUND

44. General

When making use of the map as a guide during military activities, not only should the user be able to locate features and measure distances on it, but the direction between features must be determined and written in a uniform manner. The purpose of this section is to define the terms employed in the expression of directions on a map, and to discuss direction in all its phases as applied to military map reading.

45. Direction Defined

Direction has been defined as an imaginary straight line on the map or ground. Every straight line represents a direction, be it imaginary or real, be it on a map or on the ground. Each direction is measured from a common base line or line of zero direction. For a long time, north has been regarded by the military as the line of zero direction. Directions are expressed as angles, measured clockwise from north throughout the full range of the directional circle. these angles are called azimuths. The clockwise angles, or direction angles, may be measured in more than one kind of unit just as distance may be measured in inches, yards, or any one of many other units of distance measurement. The mil and the degree are the commonly used units of angular measure for determining direction.

46. Units of Angular Measure

a. Degrees. The common group of terms used to express an angle are degrees (°), minutes (′), and seconds (″). A circle is divided into 360 equal angles when, like the spokes of a wheel, lines drawn from the center of the circle divide the circumference into 360 equal arcs. Each of the equal angles thus formed represent one degree of angular measure. In a similar manner, every degree is divided into 60 equal minutes, and every minute is subdivided further in 60 equal seconds. This plan establishes over one million seconds in every direction circle, and through their use it is possible to measure direction angles as accurately as is ever necessary. Such a direction angle or azimuth is written thus—

$$267^\circ\ 30'\ 27''$$

Except for special purposes, these are the units of angular measure in military use.

b. Mils. The mil is the unit of angular measure used for fire control purpose. For military purpose, it is 1/6400th part of the circumference of a circle. For practical usage, a mil is the angle subtended by 1 yard across at a distance of 1,000 yards from the center of the circle. It may also be expressed as an angle the tangent of which is approximately .001. The mil relation is expressed by $m\!\!\!/ = W/R$, where $m\!\!\!/$ is the angular measurement in mils between two points, W is the lateral distance in yards be-

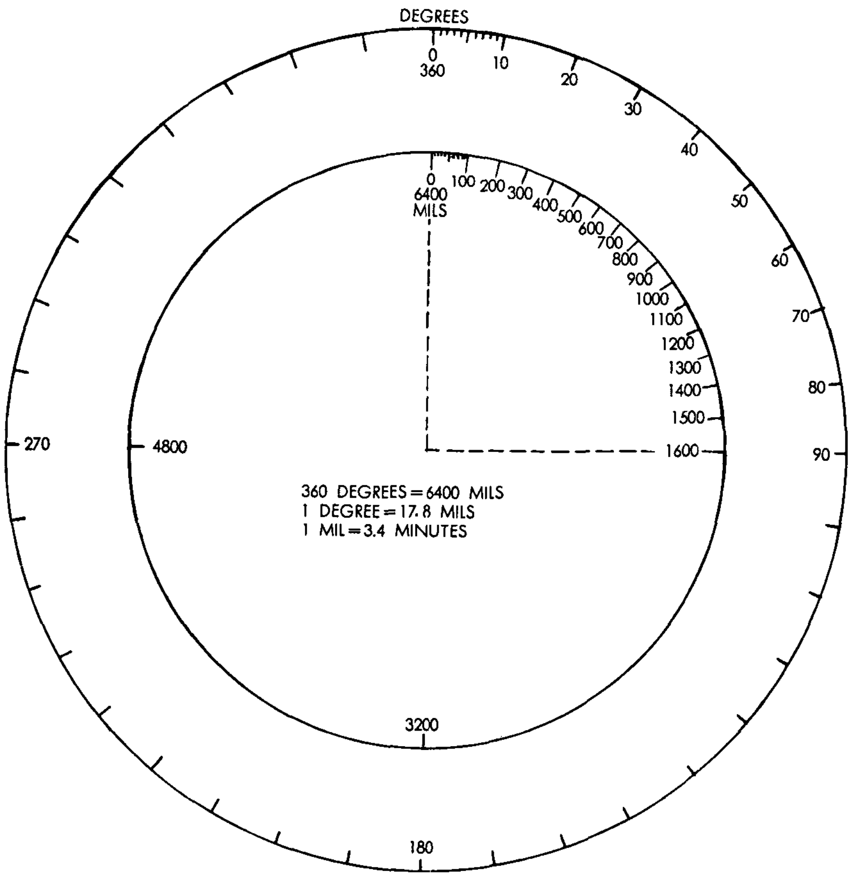


FIGURE 32. *Scale relation of mils to degrees.*

tween the points, and R is the mean distance to the points in thousands of yards. The mil relation is approximately true for angles less than 400 mils. Figure 32 shows the direct relationship between mils and degrees. Appendix V contains a table giving conversion factors from degrees to mils. The use of the mil is convenient for military purposes because a change of one mil in the direction of the tube of a weapon changes the center of impact of a round 1 yard at a range of 1,000 yards, 2 yards at 2,000 yards, and so forth.

c. Grads. In the centesimal system, the unit of angular measure is the grad. Four hundred grads comprise a full circle. It is a convenient unit since, as is characteristic of all metric units, it is subdivided by the decimal system. Its use is generally limited to maps of foreign make, however.

d. Conversion Tables. A table for the conversion of units of angular measure, one to another, is contained in appendix V.

47. Base Direction Defined

North has been established as the base direction from which to measure angles in a clockwise direction. Actually, three separate north directions have been designated as bases for direction measurement. These are true north, magnetic north, and grid north.

a. True North. True north is the direction to the North Pole. On the map, true north is represented by the meridians, or lines of longitude. This base is commonly used in precise map-making, but it is rarely used by troops in the field.

b. Magnetic North. Magnetic north is established by the compass and is, therefore, commonly used in military field operations. Figure 33 is helpful in explaining how magnetic north differs from true north. The figure shows that the true North Pole and the magnetic North Pole are two separate points on the earth's surface.

c. Grid North. Grid north is the direction represented by the north-south grid lines on a map. This type of base direction is normally used when a map is involved, especially in military operations.

48. Variance of Base Directions

Except for true north, base directions, as defined above, are not constant for all sections of the earth's surface nor are they constant on the maps representing portions of that surface. This paragraph discusses these variations and introduces a means of distinguishing them. How to deal with them for map reading purposes is also explained.

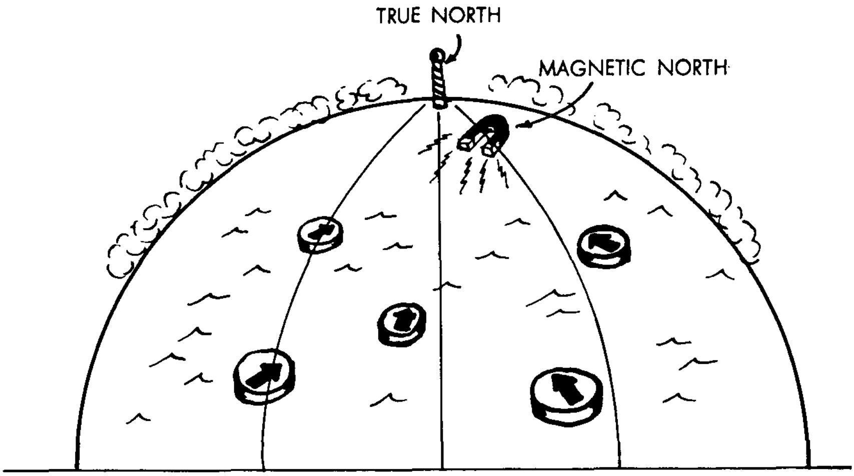


FIGURE 33. *Magnetic declination.*

a. Magnetic Variation from True North. Magnetic attractions in the earth's core cause the compass needle to be pulled away from true north. Variances in the amount of pull are a direct result of variances in the magnetic attraction in different localities. Furthermore, the attraction in one locality is not constant over a period of time; there is a gradual change. The changes in magnetic north and the local variations are illustrated by the values in table II, which were taken from official records of the Geophysics Division of the United States Coast and Geodetic Survey. It should be noted that on the west coast, the compass needle points east of true north, while in Maine it is west of true north. Yet both change from year to year in the amount of variation, making more difficult the use of the compass in conjunction with precise direction reading.

b. Grid North. Grid direction also varies in different localities. Since this property is constructed into a grid when superimposed on a map, this variance has no connection with map reading from the standpoint of grid coordinates. The variation of grid directions are illustrated in figure 34 which shows a grid superimposed on a projection of the world with meridians as true north lines.

c. Declination. The angular difference of magnetic north and grid north from true north are known respectively as magnetic declination and grid declination. Since the military map user works principally in terms of the grid, he must know the relationship of magnetic north and true north to grid north in the area in which he is located. These values are therefore printed on the face of maps, usually in the marginal information. On large-scale maps, the information is diagrammatically expressed and a note containing directions for use of the diagram is found beneath it.

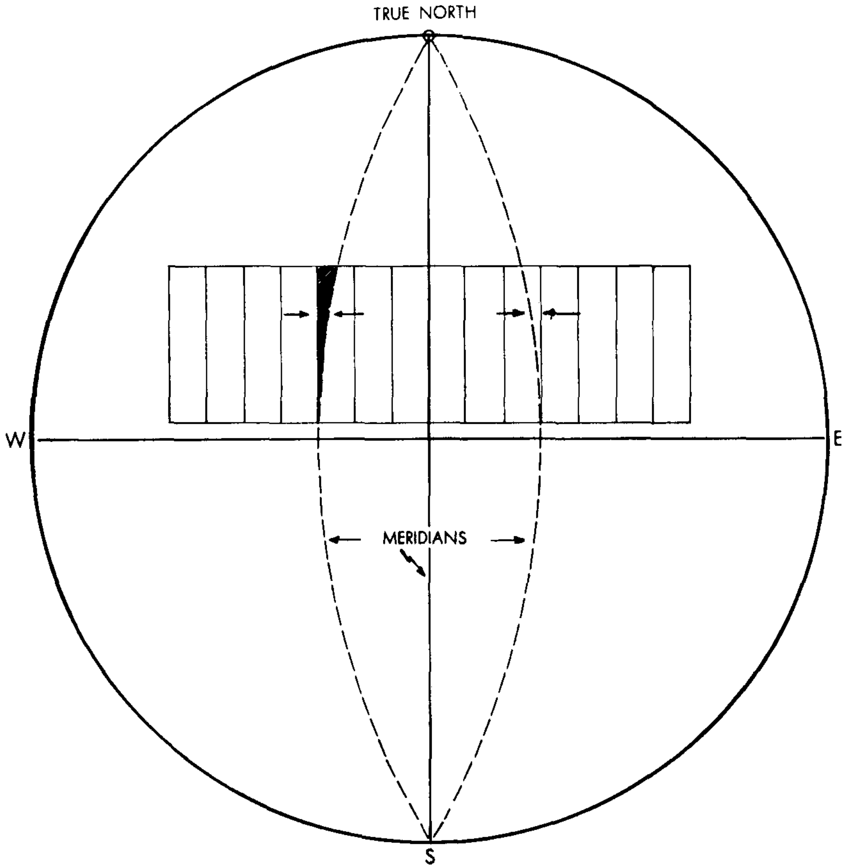
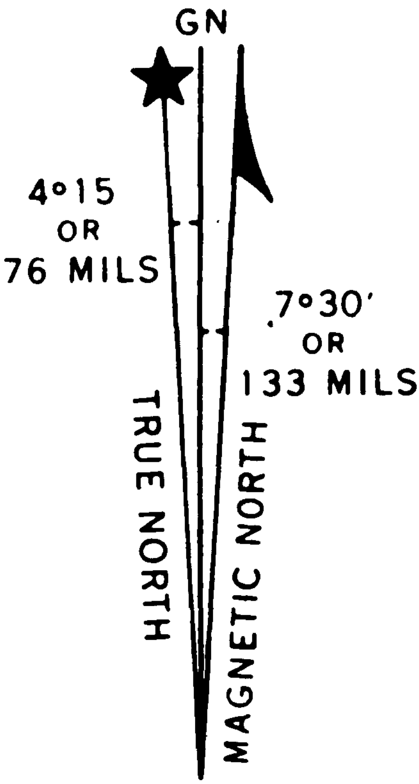


FIGURE 34. *Grid declination.*

This is known as the declination diagram. The sample declination diagram in figure 35 illustrates and labels the three base norths in proper relative position for the map from which it was copied. It gives the value of the difference between magnetic north and grid north prevailing as of 1945.

d. Annual Change. Although the relationship of true north to grid north remains constant, the relationship between magnetic north and grid north is not constant, since the magnetic declination gradually changes by an amount predicted from past records. Each map has a note under the declination diagram which gives the magnetic declination for a certain year and the amount of annual change. This change should be considered in relation to the specific year and the date it is being used. This date may be as much as 4 years prior to the production of the map. The magnetic declination is usually taken as of a particular 5-year period. Thus, a map printed in 1954 may give declination data as of 1950.



APPROXIMATE MEAN DECLINATION 1945
FOR CENTER OF SHEET
ANNUAL MAGNETIC CHANGE 6′ WESTERLY

Use diagram only to obtain numerical values. To determine magnetic north line, connect the pivot point "P" on the south edge of the map with the value of the angle between GRID NORTH and MAGNETIC NORTH, as plotted on the degree scale at the north edge of the map.

FIGURE 35. *Declination diagram.*

The change is labeled easterly or westerly, indicating whether it should be added or subtracted, depending upon which side of true north it originated. Magnetic declination varies from about 25°

easterly on the west coast (table II) to about 22° westerly in the State of Maine. The annual change is as much as 4 minutes for some sections of the United States. From this, it is obvious that the compass needle points inward from each coast and that, as the central region of the United States is approached from the coasts, the declination becomes less and less.

e. Agonic and Isogonic Lines. Somewhere in the middle of the continent there is a point or series of points at which the needle points due north (to the North Pole) and the declination is zero. These points form a line that meanders in a general north-south direction across the country. It is called the agonic line. Other lines have been determined which run generally parallel to the agonic line and on either side of it. These are lines which have equal declination at all points along the same line. They are called isogonic lines. Charts covering the entire world, with these lines plotted on them, are available for determining the declination of areas covered by specific maps. It is from these that the mapmaker obtains information necessary to construct declination diagrams. Figure 36 is a chart of the United States showing the approximate location in 1950 of the agonic line and the isogonic lines, spaced at intervals of 5° declination.

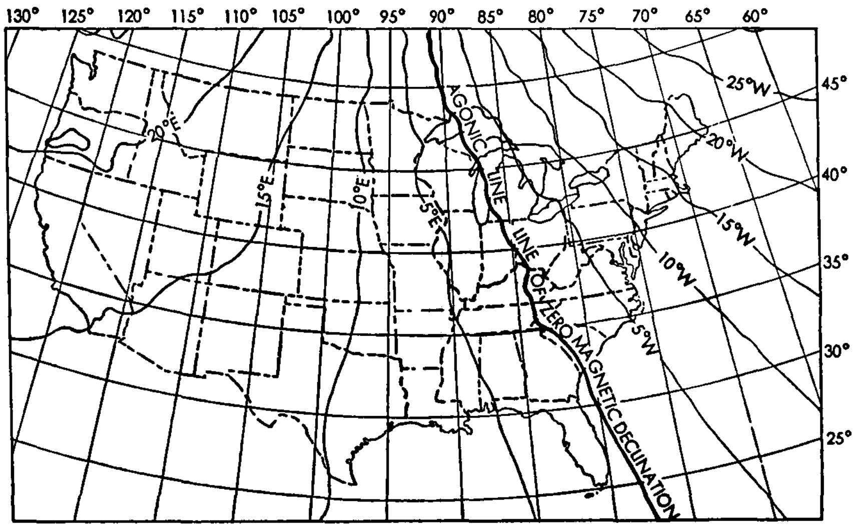


FIGURE 36. *Isogonic chart of the United States for 1950.*

49. Finding North

It has been determined that the north direction is the base line for measuring angles. Three different base norths are shown on a map. None are of any value if the map cannot be fitted to the

TABLE II. *Magnetic Variations*

	Magnetic declination for 1946	Magnetic declination for 1953	Seven year magnetic variation
Portland, Maine	17° 06′ W	17° 01′ W	05′ E
Boston	15° 18′ W	15° 15′ W	3′ E
Brooklyn	11° 17′ W	11° 13′ W	4′ E
Trenton	10° 19′ W	10° 23′ W	4′ W
Washington, D. C.	7° 00′ W	6° 54′ W	6′ E
Cleveland	4° 52′ W	4° 43′ W	9′ E
Fort Wayne	0° 48′ W	0° 40′ W	8′ E
Knoxville	0° 36′ W	0° 27′ W	9′ E
Indianapolis	0° 39′ E	0° 47′ E	8′ W
Cincinnati	0° 44′ E	0° 52′ E	8′ E
Atlanta	1° 38′ E	1° 46′ E	8′ E
Key West	2° 52′ E	2° 56′ E	4′ E
Chicago	2° 28′ E	2° 34′ E	6′ E
New Orleans	6° 19′ E	6° 24′ E	5′ E
Houston	9° 01′ E	9° 01′ E	0
Denver	14° 00′ E	13° 48′ E	12′ W
Cheyenne	14° 29′ E	14° 14′ E	15′ W
Los Angeles	15° 37′ E	15° 22′ E	15′ W
Portland, Oreg.	22° 37′ E	22° 17′ E	20′ W
Olympia, Wash.	22° 58′ E	22° 37′ E	21′ W

Note. Data from official USC & GS records, Geophysics Division.

ground because the map is the guide for ground action. Therefore, north on the ground must be known for orientation and subsequent use of the map. Methods of determining north in the field are outlined below.

a. Compass North. The compass is the most common means of finding north, that is, magnetic north. The use of the compass is explained in paragraph 50. Once magnetic north is known, the map can be oriented and true north or grid north can be established on the ground.

b. North by Use of a Timepiece. An ordinary watch can be used to determine the approximate true north. In the North Temperate Zone *only*, the hour hand is pointed toward the sun. A north-south line can be found midway between the hour hand and 12 o'clock. This applies to standard time; on daylight saving time, the north-south line is found midway between the hour hand and 1 o'clock. If there is any doubt as to which end of the line is north, remember that the sun is in the eastern part of the sky before noon and in the western part in the afternoon. The watch may also be used to determine direction in the South Temperate Zone. However, it is used a bit differently. Twelve o'clock is pointed toward the sun, and halfway between 12 o'clock and the hour hand will be a north-south line. If on daylight saving time, the north-south line lies midway between the hour hand and 1 o'clock. The temperate zones extend from latitude 23½° to 66½° in both hemispheres. Figure 37 illustrates the use of a timepiece in determining direction in either temperate zone.

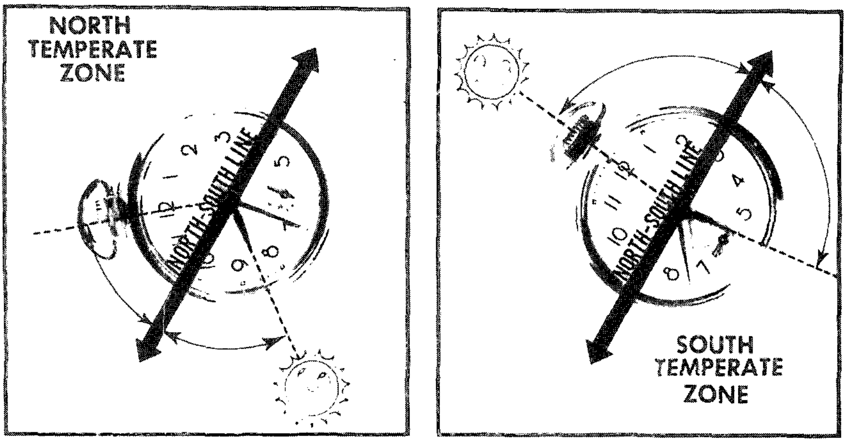


FIGURE 37. *Determining north by watch method.*

c. Shadows Indicate North. A shadow from a pointed object can be used to establish true north, as illustrated in figure 38. A plumb bob, or other heavy object on a string is dropped from the point of the elevated object to the ground (X). Using the ground point as a pivot, at 1100 hours standard time, an arc is scribed on the ground from the point of the shadow (a). Two hours later, the shadow point will cross the arc at (b). The bisector of the arc (a) (b) from (X) is true north in the northern hemisphere, and true south in the southern hemisphere.

d. North Determined by the Stars. The North Star is almost directly above the North Pole, and the true north direction on the ground is vertically beneath it. On a clear night it can be identified as the bright star found about halfway between two star patterns, the Big Dipper and the Big M (or W) (fig. 21). South of the equator, the South Pole Star (fig. 22) indicates a true south direction. However, it is not nearly as bright as the North Star and quite often is not visible at all. It is identified by the Southern Cross star-cluster which follows it at a distance approximately 4½ times the length of the long axis of the Southern Cross itself. Thus, north can be determined by the stars when the night sky is clear.

50. Using an Azimuth

a. Azimuth Defined. In military use, a direction angle is always measured from north in a clockwise direction. For convenience, this angle is known as an azimuth. It can be a true

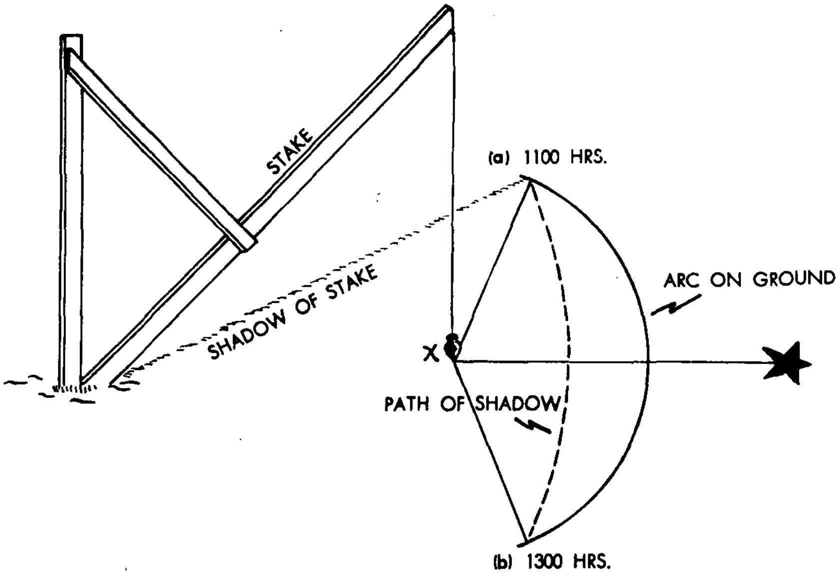


FIGURE 38. *Determination of north by shadows.*

azimuth, a magnetic azimuth, or a grid azimuth, depending upon which of the three base lines it is measured from. The values given in the declination diagram (fig. 35) are used to convert it from one type to another. In any case, it can never be greater than 360° (or 6,400 mils). Figure 39 is a graphic example of the three types of azimuths for the same geographic position, in this case, a schoolhouse corner.

b. Measuring a Map Azimuth. Usually the problem is to measure an azimuth on the map and then be guided to a given destination on the ground by applying that angle to the compass. The protractor is commonly used to measure azimuth angles (fig. 40). It should be noted that grid lines are used as a base in this example, which means that it is grid azimuths which are being measured. The azimuth of line A—B is being read. Line A—B is extended through a north-south grid line to point A1, and the pivot point of the protractor is placed at the intersection (point A1). The clockwise angle from grid north is shown to be 130°. The grid azimuth, therefore, equals 130°. As a second example, the line C—D pivots on C through more than half of the circle. It reads 226°, and therefore, the grid azimuth equals 226°. Either azimuth can now be converted to magnetic azimuth by the addition of 4°, which is taken from the declination diagram in the figure. They can be converted to true azimuth by the subtraction of 3°. It should be noted that the addition of 4° and the subtraction of 3° in these cases is because magnetic north is west of grid

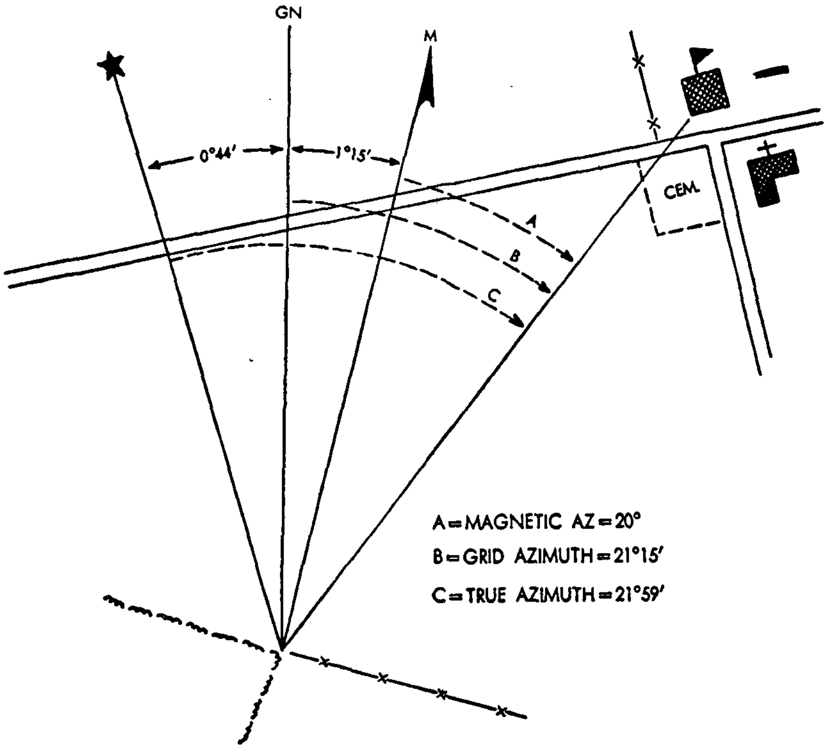


FIGURE 39. *Azimuth types compared.*

north, and true north is east of grid north. It is important that these three types of azimuth not be confused; a mistake during combat could be disastrous. It may be helpful to distinguish between them by picturing the protractor oriented along the arms of the declination diagram extended. This method should quickly reveal whether a declination angle is to be added or subtracted, when converting from one azimuth to another.

c. Sketch to Show Azimuth Relationship. The actual drawing of a rough sketch, as in figure 41, is helpful to guarantee complete understanding of azimuth relationship. The azimuth of line A—B in figure 40 is shown in its three separate capacities; first, as a grid azimuth, and then as a true azimuth and magnetic azimuth. The sketch (fig. 41) is drawn as follows:

Step 1. Draw free hand two lines at right angles to each other and label them as the grid directions (grid N, S, E, and W). Label the intersection A, since our azimuth is from A towards point B.

Step 2. The grid azimuth of A—B has been measured as 130°. Lay it off clockwise from north—don't use a protractor,

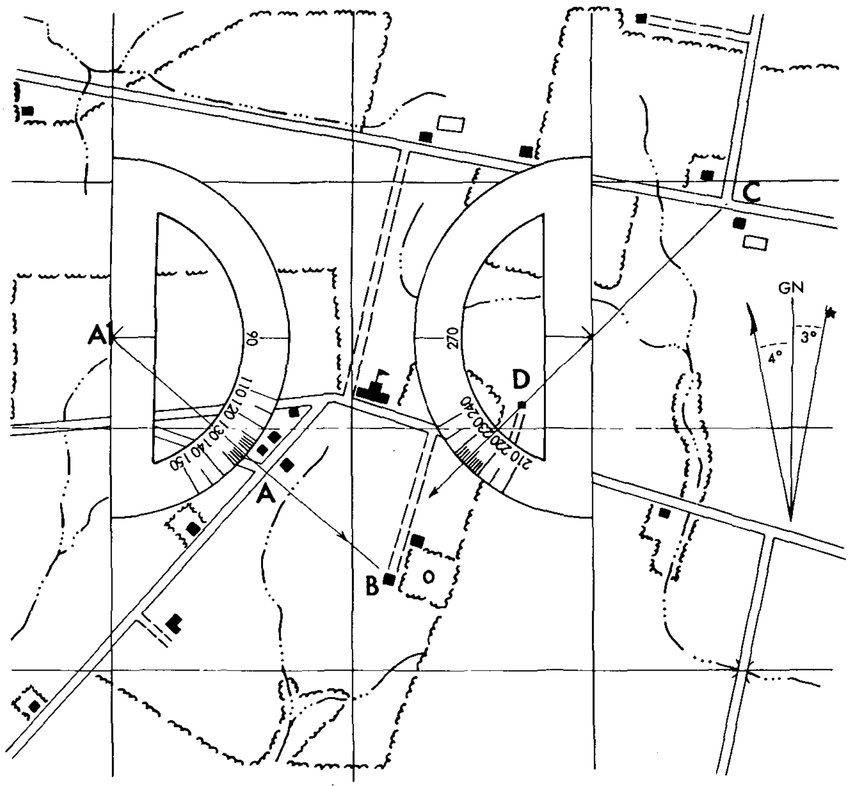


FIGURE 40. *Measuring an azimuth on a map.*

just guess at it, knowing that each of the four angles in the diagram is 90° of azimuth.

Step 3. Now add the declination diagram on the right side of figure 40 to the top of your sketch (fig. 41), and you see that the magnetic azimuth of A—B is a larger angle (+ 4°) than the grid azimuth, and that the true azimuth is smaller (— 3°).

d. Plotting a Map Azimuth. It will often be necessary to read an azimuth on the ground and then use it to plot a feature on a map. For example, an enemy strong point is spotted in a wooded corner near a road junction. Its azimuth, as measured by the compass, will show which road junction it is. Accurate artillery fire can then be directed against the target. Plotting the direction is the opposite process from reading a map azimuth. First, the compass reading is converted to the grid azimuth by the subtraction of 4°. A straight north-south line is drawn parallel to north-south grid lines through the point on the map of present location. The protractor is placed along it with the pivot point at present location, and the angle point is plotted at 48° as shown in figure 42. The

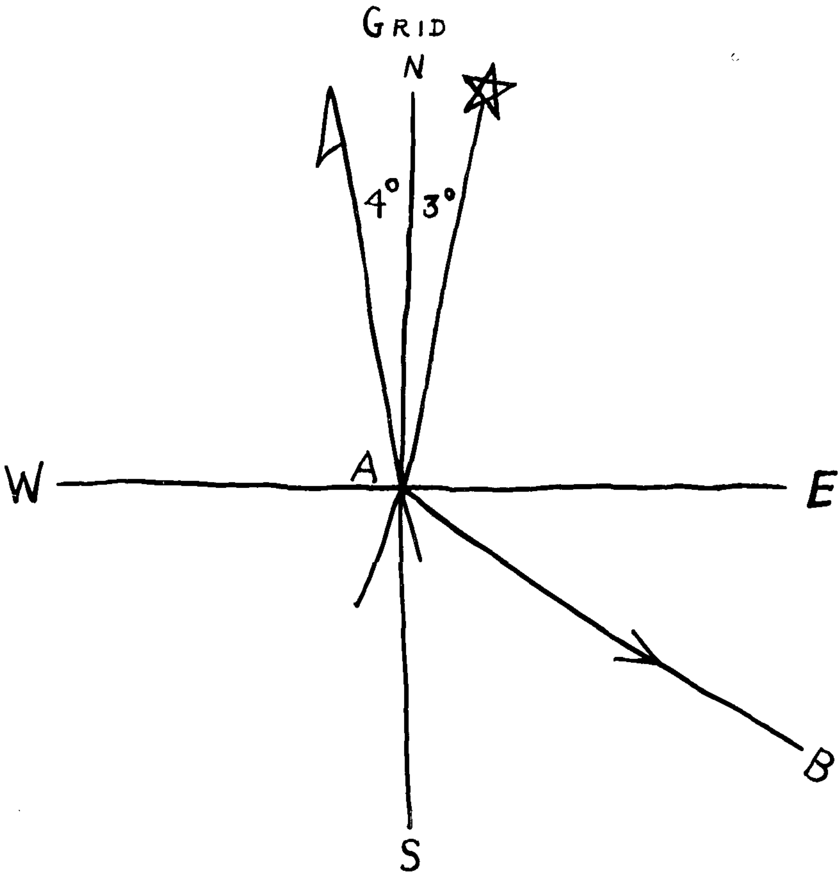


FIGURE 41. *Freehand sketch showing azimuth relationship.*

protractor is removed and a straight line is drawn through the friendly position and the angle point. When this line is extended, it intersects the road junction near the enemy position. Should the friendly position be reversed with that of the enemy, the azimuth would be 48° plus 180°, or 228°. In order to plot this direction on the map, the protractor is placed on the west side of a new north-south grid line through the enemy position, and the new angle point is plotted. A line extended through it and the position of the enemy would intersect the wooded corner (friendly position). This latter demonstrates the method of plotting any azimuth larger than 180°.

e. Using Protractor Printed on a Map. It is not necessary to convert compass readings to true azimuth or to grid azimuths in order to be able to plot or read map azimuths. The magnetic azimuth can be read or plotted directly by using a handy protractor printed on large-scale military maps, such as the map in

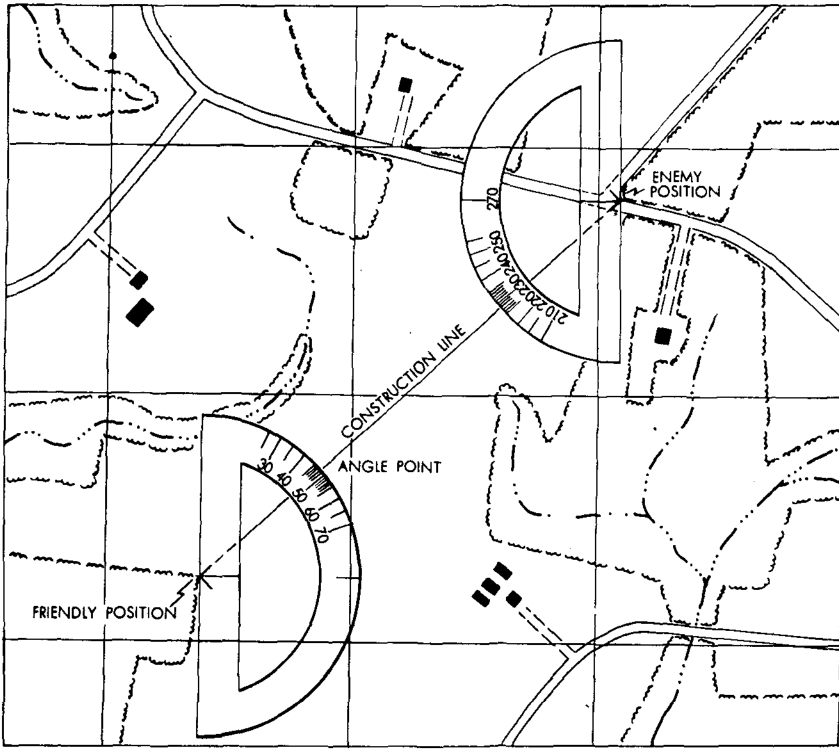


FIGURE 42. *Plotting an azimuth on a map.*

appendix IV. On the lower edge of the map is found a letter P which is at a north-south grid intersection with the lower neat line. Immediately above the P is a small black circle; the center of this circle is the pivot point of a protractor designed as part of the map. The protractor scale is printed on the north border of the map directly above the intersection of the north-south grid line with the neat line. It has enough divisions to include the maximum values of declination and magnetic change indicated in the declination diagram of the map. The pivot point P is connected with a straight line drawn through the value of the magnetic declination on the printed protractor scale at the top, giving a base line for the use of the protractor (separate) while dealing in magnetic azimuths.

f. Orienting the Map with the Compass. To orient a map in the field with a compass, the protractor printed on the map makes it possible to know the correct pointing of magnetic north. Draw a line on the map from the pivot point to the protractor scale at the top of the map, as described above, being sure to select the point on the scale equal to the magnetic declination from grid north as shown by the declination diagram printed on the map. In figure 40 this would be the 4° mark to the left of the grid north line. The magnetic north line drawn on the map need be only long enough to be seen on each end of the compass after it has been opened and laid on the map. Rotate the map until the needle, at rest, and the line are in alinement, and the map is then correctly oriented.

51. Using a Bearing

Bearings, like azimuths, are means of expressing direction. Both are angles measured from the three base lines, true north, magnetic north, or grid north, except that bearings may be measured from the three south directions as well. More specifically, bearings are measured both east and west from north and south. Figure 43 illustrates the direction circle, divided into four equal quadrants of 90° each. A direction is labeled as being in any one of the four quadrants. Bearings are always written as the angle from either north or south, and are rendered as shown in the figure where a

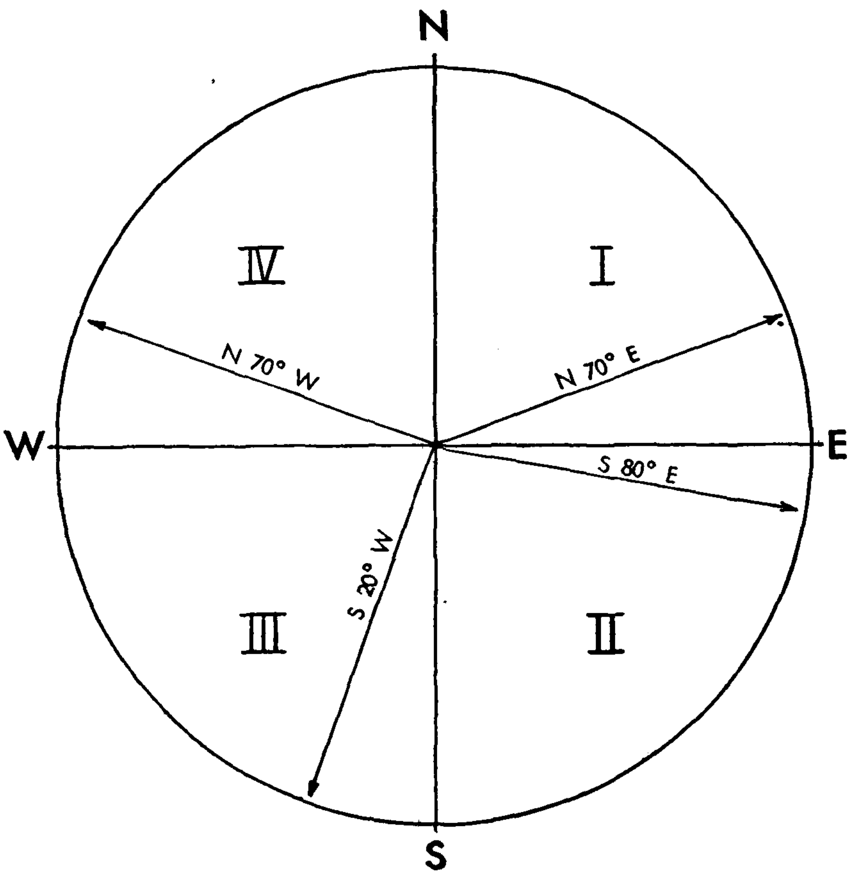


FIGURE 43. *Compass bearing.*

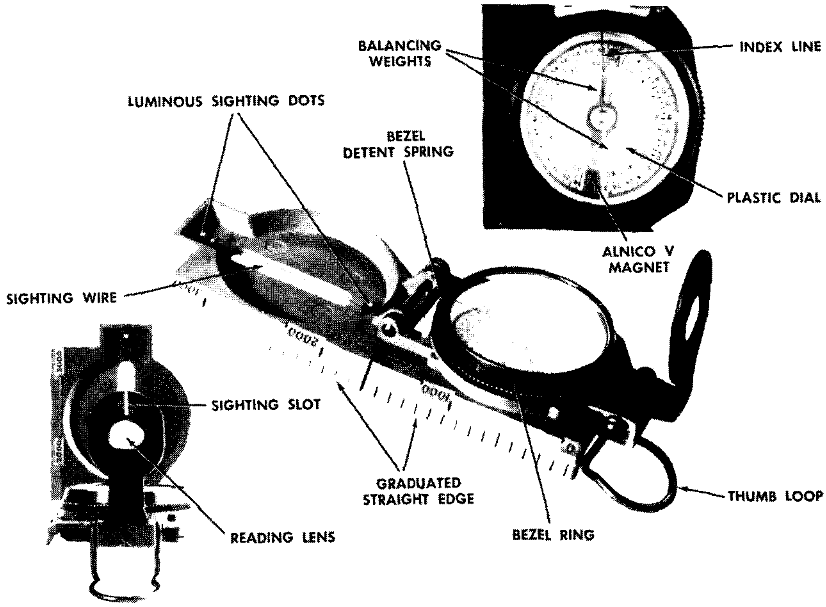
bearing in each quadrant is given. Further, a direction coincident with one of the four cardinal directions is expressed as true north, magnetic east, or grid south. Bearings were in common use before the use of azimuth was adopted, and are still in common use in cadastral surveying. Therefore, a good understanding of the bearing and its relation to the azimuth is valuable to military personnel, although the azimuth is the standard military direction angle.

52. The Compass and its Use

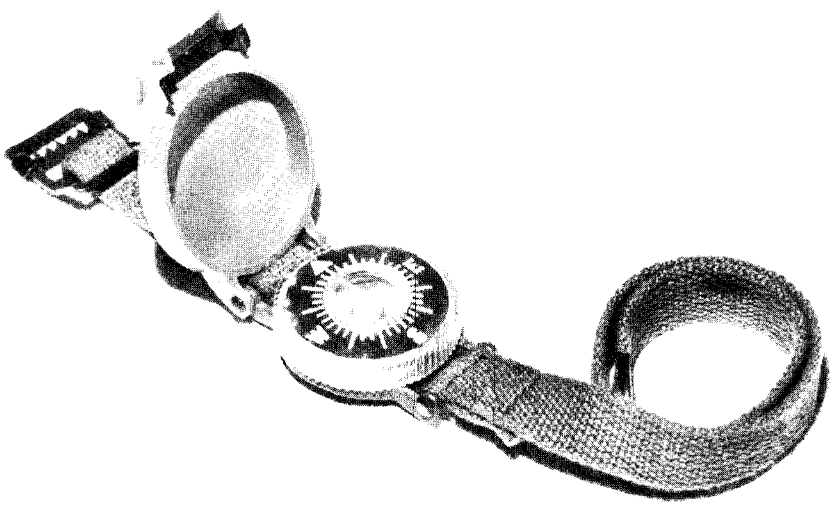
The magnetic compass is the most commonly used and simplest instrument for measuring angles in the field. Its more important features are a floating dial indicator and a sighting device. Three varieties of magnetic compass are standard for military use today, the lensatic compass, the wrist compass, and the artillery (M2) compass.

a. Lensatic Compass. For a photograph of a lensatic compass showing its nomenclature, see (1), figure 44. Its name is derived from the magnifying lens which is mounted in the eyepiece. The case is aluminum and the dial capsule is incased in a silicone rubber cap that automatically seals itself when it is assembled into the compass case. The compass case is about 2 inches long and less than 1 inch thick when closed. This compass has a $4\frac{3}{4}$-inch straightedge in the form of a graduated scale permanently attached with the straight edge parallel to the line of sight. Half of this scale is cast with the case and half with the cover, and connected with a hinge. Open, it is seen to be graduated in 100-meter units at a 1:25,000 scale. The dial of the compass is marked in 5-degree and 20-mil graduations. Magnetic azimuths can be sighted through the lens and sighting wire, and read accurately to within 2 degrees. Closing the compass automatically lifts the magnet and dial assembly off the pivot, thus protecting the parts from wear when the compass is not in use. Cardinal points and markings on the bezel crystal are luminous for reading in darkness. The north-seeking end of the magnetic needle is also luminous. A luminous area in the damping shell further aids in reading in the dark. The lensatic compass is suitable for military units for reconnoitering, determining direction, orienting maps, fire control, and other uses where magnetic azimuths are required.

b. Use of the Lensatic Compass. Sighting with the lensatic compass is illustrated in figure 45. It should be noted that the compass is held level and firm. The slit in the eyepiece, the hairline front sight in the cover, and the target are alined. When holding this position steady, the azimuth can be read directly by glancing down at the dial through the eyepiece. The numbers on the transparent dial are in black and the dial is graduated in mils as well as



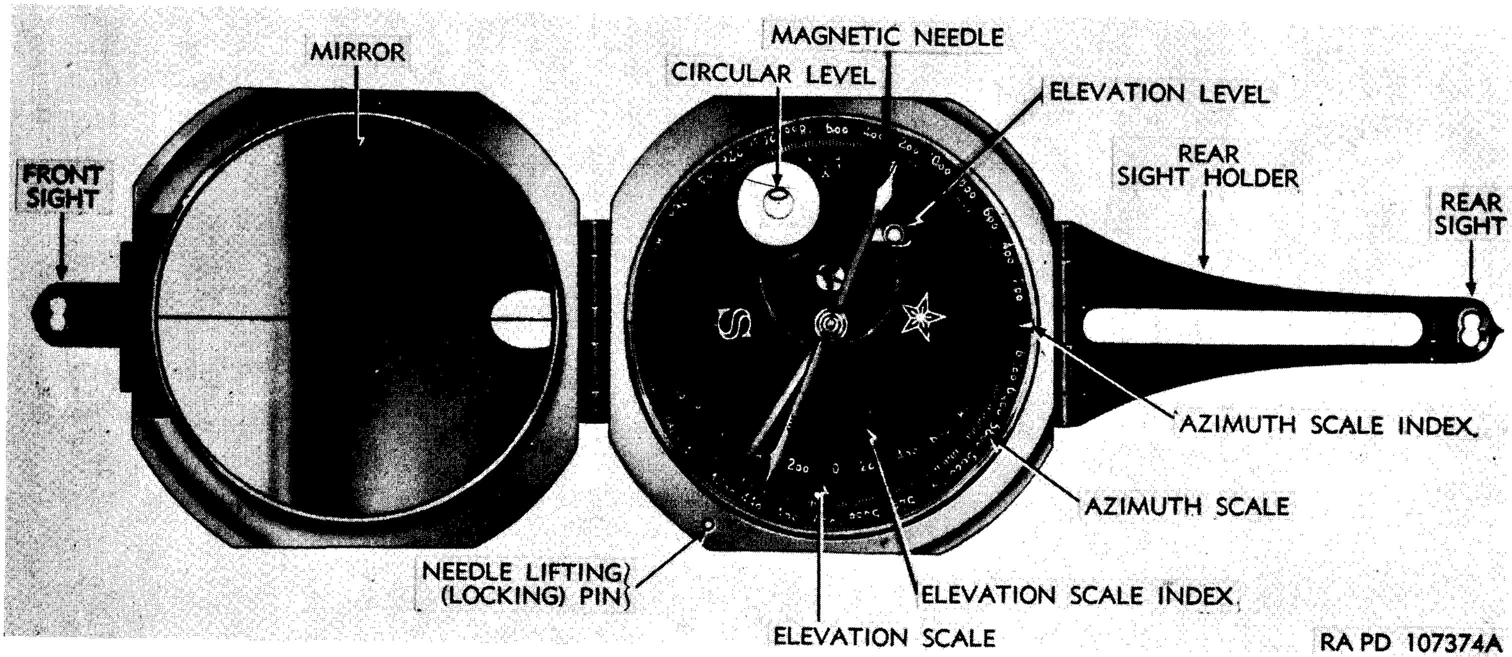
1 Lensatic compass.



2 Wrist compass.

FIGURE 44. *Army compasses.*

in degrees. For night use, special features of the compass are the luminous markings and the 3-degree bezel serrations and clicking device. Turning the bezel produces clicks each of which represents 3 degrees. The bezel stop and spring hold the bezel ring



3 Artillery compass (M2).

FIGURE 44. *Army compasses—Continued.*

in any desired position. The short luminous 45° line on the bezel glass is used primarily to facilitate and speed up the setting of the long luminous indicator to any predetermined magnetic azimuth in the dark. The following are examples of its use:

(1) To set off magnetic azimuths of 45°, 135°, 225°, and 315°, set the short line directly to the 90°, 180°, and 270° luminous dots and the index line respectively. Thus either of these four settings can be made quickly and accurately without counting a single 3-degree click, whereas, without the 45° luminous indicator, these settings could be made only by counting fifteen 3-degree clicks from the cardinal point on either side of the azimuth setting desired.

(2) When used as described above, the short line also provides four additional reference points from which any other settings can be made by counting no more than seven 3-degree clicks. To set off values of 42°, 132°, 222°, and 312°, set the short line to the 90°, 180°, 270° luminous dots and the index line respectively, as before, and then turn the bezel glass one 3-degree click in the counterclockwise direction. Without the short line, the bezel glass would have to be turned a minimum of fourteen 3-degree clicks in a clockwise direction beginning at the index line, 90°, 180°, and 270° respectively.

c. Wrist Compass ((2), fig. 44). The wrist compass is useful for providing bearings for hasty patrol and reconnaissance. It weighs less than 3 ounces and is provided with a long strap for wearing on the wrist over heavy clothing such as that worn in the Arctic. The dial is illuminated and has 10-degree graduations, permitting day and night reading to 5 degrees. The bezel clicking device measures 2½ degrees per click. The cover is molded of polyethylene and serves as a blackout shield for the luminous dial.

d. Artillery (M2) Compass. Figure 44 (3) is a photograph of an artillery (M2) compass showing its nomenclature. This compass is used to measure horizontal angles, angles in azimuth with respect to magnetic or grid north, and limited vertical angles. It has a circular level and a tubular level vial for use in obtaining azimuth and angle of site readings, respectively, and has a leaf sight in conjunction with a mirror in the cover for sighting and reading the angles. In addition, this compass has an azimuth scale adjuster for direct reading of grid or true azimuths, as well as magnetic azimuths.

e. Use of the M2 Compass.

(1) *Measuring Azimuth Angles.* Hold the compass in both hands at eye level with arms braced against the body and

FIGURE 45. *Compass position for sighting.*

with the rear sight near the eyes. Place the cover at an angle of approximately 45 degrees to the face of the compass so that the scale reflection can be readily viewed in the mirror. Level the instrument by viewing the circular level in the mirror, sight on the desired object through the window, and read the azimuth indicated on the reflected azimuth scale by the south seeking (black) end of the compass needle.

(2) *Measuring Angle of Site.* Hold the opened compass in a vertical plane with the rear sight toward the body and the angle of site level lever to the right. Open the cover to an angle of approximately 45 degrees to the face of the compass with the rear sight perpendicular to the holder. Look through the rear sight and raise or lower the instrument until the center line of the window bisects the opening in the rear sight and the object sighted; then level the tubular level reflected in the mirror, by means of the lever. Read the angle of site opposite the index. Care must be taken to maintain the compass in a vertical plane to obtain accurate readings.

(3) *Measuring Gun Elevations.* Open the compass so that the cover and rear sight holder are parallel with the com-

pass face. Place the left side of the opened compass on the leveling plates of the breech ring of the piece or on a level portion of the piece which is parallel to the bore; center the bubble of the elevation level; read the angle of elevation.

f. Compass Precautions. Certain precautions and special considerations regarding the care and use of a magnetic compass should be followed. All of these considerations are important because they assure within reason that a compass will work when and where it is needed.

(1) The compass should be handled with care. While government specifications call for very sturdy design, the compass dial is set at a delicate balance which a shock may derange.

(2) The compass must be closed and returned to its special container when not in use. In this way it is not only protected from possible damage, but is readily available for use when needed.

(3) When the compass is to be used in darkness, an initial azimuth should be set, if possible, while light is still available. With this initial azimuth as a base, any other azimuth can be established through use of the clicking feature of the bezel in conjunction with the two luminous dots on the dial.

(4) Compass readings should never be taken near visible masses of iron or electrical circuits. The following are the minimum safe distances:

	Yards
High-tension power lines	60
Field gun	20
Truck or tank	20
Telegraph wires	10
Barbed wire	10
Machine gun	3
Helmet or rifle	1

Nonmagnetic metals and alloys do not affect compass readings.

(5) Use of the compass must be practiced at regular intervals to assure competent technique in an emergency. Its value to the soldier is comparable to that of his rifle and consequently the use of the compass should be given equal attention.

Section III. ELEVATION AND RELIEF

53. Importance of Elevation

It is possible to read the height of map features, as well as their length and width. This third dimension (elevation, or relief) property of a map may be as important to the military man using it as are the other two dimensions of measurement. This section explains and illustrates in detail exactly how relief (elevation) is expressed on a map and put into use.

54. Relief Described

Most of the earth's crust is irregular, rather than flat. It varies from the great plains to the great mountain ranges, and very seldom is it regular or level between such features. This general characteristic of variability in the earth's surface has been termed "relief." It includes that portion of the globe which is not covered by the oceans.

55. Elevation Described

Elevation is the term employed in speaking or writing about the relief of a given area or feature on the ground. Elevation is used when the third dimension is referred to specifically, whereas relief encompasses all height relationships. Elevation, being specific, has a definite value which is expressed in units of measure that have a meaning and use.

56. Basis of Elevation—Mean Sea Level

The relief shown on a map, or the elevation of each point, is measured from a single plane with zero as its elevation. This zero or base plane has been established as the average level of the ocean which is known as *mean sea level.* Quite often, it is spoken of as the *datum plane,* or the *mean sea-level datum plane.* Figure 46 illustrates the derivation of mean sea level (MSL) as being the horizontal plane halfway between high and low tides. Although high and low tides vary from time to time, this variance has been averaged to establish the mean which is now in common use as the zero plane for elevation. Every object on the face of the earth has an elevation, or exact distance above or below this datum plane, and this includes every object shown on every map. Mean sea level is the basis for measuring elevation.

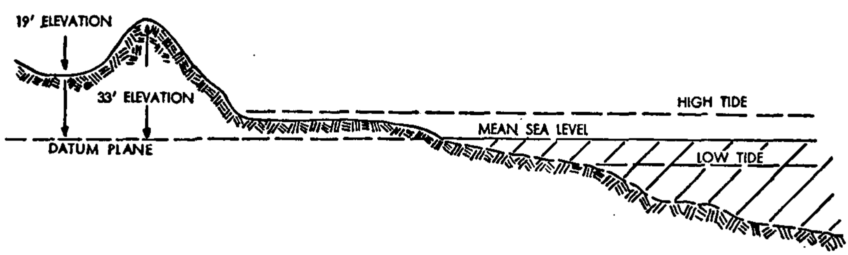


FIGURE 46. *Mean sea-level datum plane (MSL).*

57. The Contour

The customary means of expressing relief on a map is by use of the *contour*. A contour is defined as an imaginary line on the ground connecting points of equal elevation. On the map, the contour is real and represents the imaginary line on the ground. Because it exists only on a map, the word contour always means map contour or the map representation of ground relief. Figure 47 is a section of a map with contours expressing relief. It is called a topographic map.

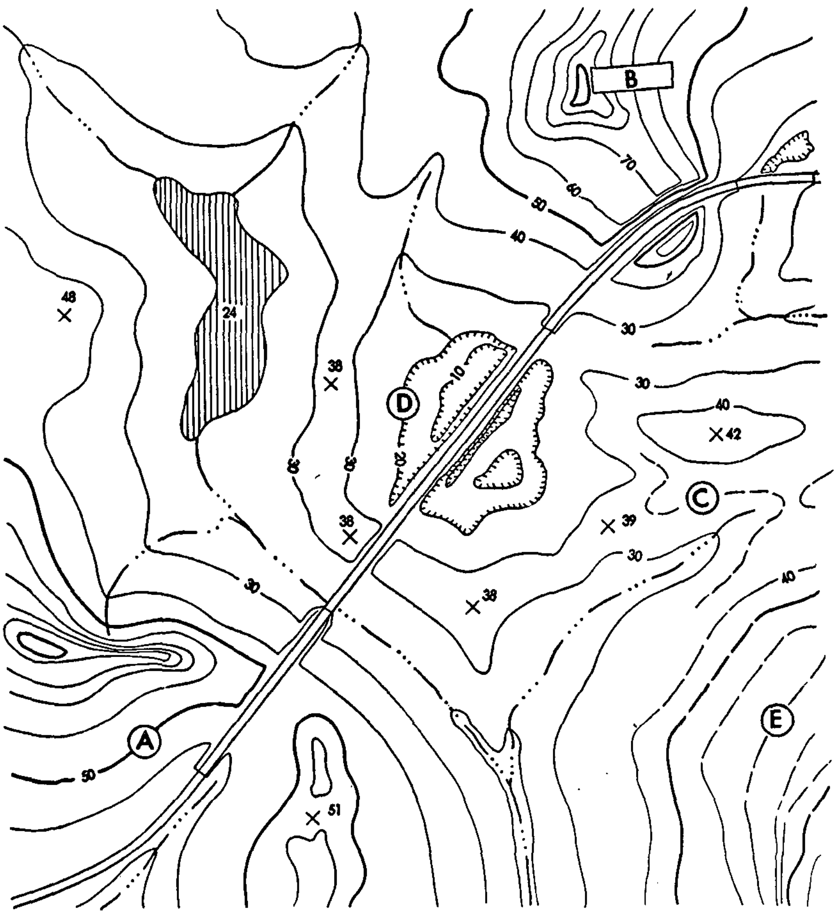


FIGURE 47. *Contours express relief.*

a. Contour Interval. Because mean sea level is the base plane for measuring elevation, the contour representing mean sea level is the zero contour. The elevation of the contour which is next in height above the mean sea level is printed on all maps, usually beneath the graphic scale in the lower margin. It states that the contour interval is a certain number of feet or meters. This means that for the scale of the map, a uniform interval has been selected that does not result in contours being too crowded or too far apart. The contour interval is so established that the user of the map is able to obtain maximum relief information at maximum accuracy to satisfy any given job. That is why maps of different scales are constructed for the same areas when time permits. The detail of the information required by the job at hand determines the map scale to be used. Therefore, the contour interval is established before the map is made. In general, the larger the map scale, the smaller the interval, as illustrated by table I which lists the popular scales of military maps and the contour interval normally established for each.

b. Types of Contours. There are five distinct types of contours. All represent lines of equal elevation, but each has a separate symbol for identification on the map.

(1) *Index Contours.* Index contours are usually every 5th contour, beginning from the zero line. For example, the index contours for a 10-foot interval would be 50 feet, 100 feet, and so forth ((A) fig. 47). They are distinguishable as the heavier lines with respect to the other contours. Their purpose is to make the map easier to read when determining the elevations of features, since the contours can be counted by fives rather than one at a time. Where contours are rather close together, the index contours are usually the only ones labeled with their representative elevations. A 25-foot interval map has the even, hundred-foot contours as indexes, which is an exception to the "every 5th" rule.

(2) *Intermediate Contours.* Intermediate contours are, as the name implies, the four lighter contour lines drawn between indexes, as shown in (A), figure 47. Normally, they are labeled only at the edges of the map and in other places where their value is not obvious.

(3) *Supplemental Contours.* Supplemental contours represent half-intervals and are dashed lines. They are used to produce a more complete picture of the relief in relatively flat areas, where the usual contours are too far apart to properly portray the slope ((C) fig. 47). Their need is more prevalent when the major portion of the area covered by a given map is rugged terrain, in order to clarify the rate of slope of the flatter areas. The larger area dictates the interval, but it leaves the spacing between the contours too great in the more level areas, and the supplemental contour is added. In the case of coastal

sheets, often only the first half-interval contour is mapped, to help portray a better picture of the shoreline area where troop landings may take place. Supplemental contours are not shown as continuous; they are shown in portions or segments and extend as long as necessary to properly portray the slopes. Supplemental contours are always labeled with their representative elevations.

(4) *Depression Contours.* Depression contours outline an area which is lower in elevation than all the surrounding terrain. For example, the inside of a volcano is mapped using this type of contour. The symbol is a line the same weight and type as either the index contour, the intermediate contour, or the supplemental contour, depending on the elevation and type; in addition, tick marks have been added on the downhill side ((D), fig. 47). It may take several contours to depict a very deep depression, one contour inside another. Depression contours are labeled with their appropriate elevations.

(5) *Approximate Contours.* Approximate contours are an approximation of the relief picture, and are used in mapping only as a last resort. The symbol is a broken line the same weight and type as the contour it replaces ((E), fig. 47). In addition, tick marks have been added on the downhill side of the line ((D) fig. 47). Their purpose is to give a reasonable idea of the relative elevation existing in small areas when it is not possible to draw exact contours at the time the map is made. It may be an area that is not accessible to surveyors on the ground, or it may be an area of shadow on an aerial photograph which is being used to compile the map, or it may be an area whose relief is compiled from unreliable map sources.

c. Determining Point Elevation from Contours. The elevation of any point falling on a contour line is the elevation of the contour. The elevation of any intermediate point falling between any two contours may readily be interpolated by measuring the distance from the point to the contour above it, and giving a value to the point equal to its relative position within the contour interval. Roughly, a point halfway between two contours has an elevation equal to the elevation of the lower contour plus one half the contour interval. For example, the elevation of a fence corner (fig. 48) falling halfway between the 120-foot and the 140-foot contours is 130 feet.

58. Form Lines

The form line is another means of portraying relief on a map. It is not a contour line because it does not necessarily connect

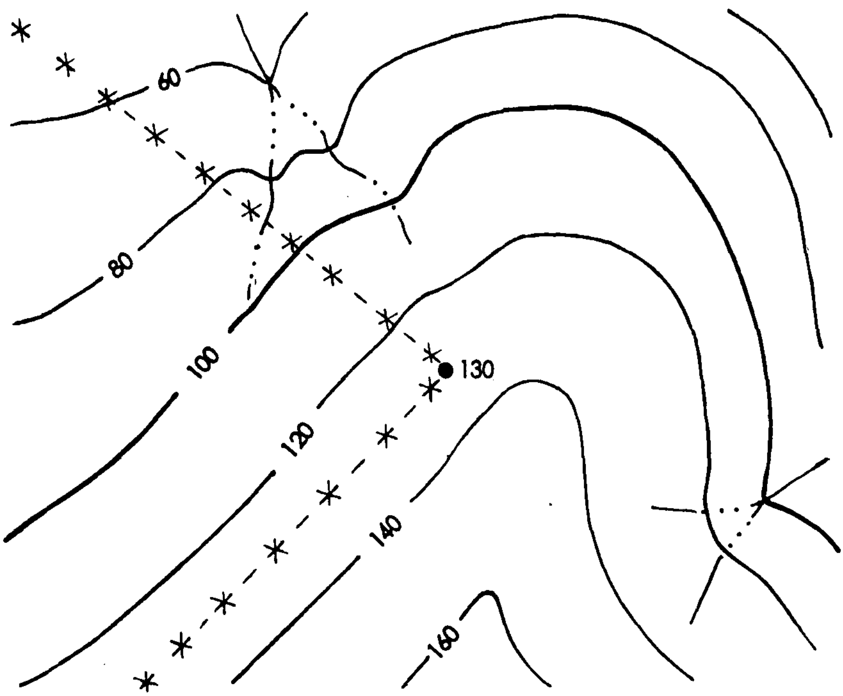


FIGURE 48. *Finding elevation of point by contour interpolation.*

points of equal elevation, and it is not measured from any base plane. It is a very poor representation of relief and is employed only when data to produce a better job are not obtainable. It is normally used for producing hasty maps or field sketches when it is preferable to add relative elevation, or to picture the terrain shapes in general. Form lines have no standard elevation, although an attempt is made to draw them parallel to sea level, and to space them according to the purpose of the map or sketch being prepared. Form lines are shown as dashed lines and are never labeled with representative elevations.

59. Hachures

Like the form line, the hachure method of portrayal represents relative relief formations and terrain shapes, in general. It also is employed when elevation data for contour drawing are lacking. It is the means usually chosen for use on printed maps when this condition exists (fig. 49). In the United States, it is limited to very small-scale maps, but in foreign maps, European maps in particular, the hachure is used on many maps to show the relief picture. This is particularly true in cases where slopes are steep, but not high, as might be found along deep-cut streams. Figure 50 shows a section of a French map with hachures used to strengthen the relief picture produced along streams.

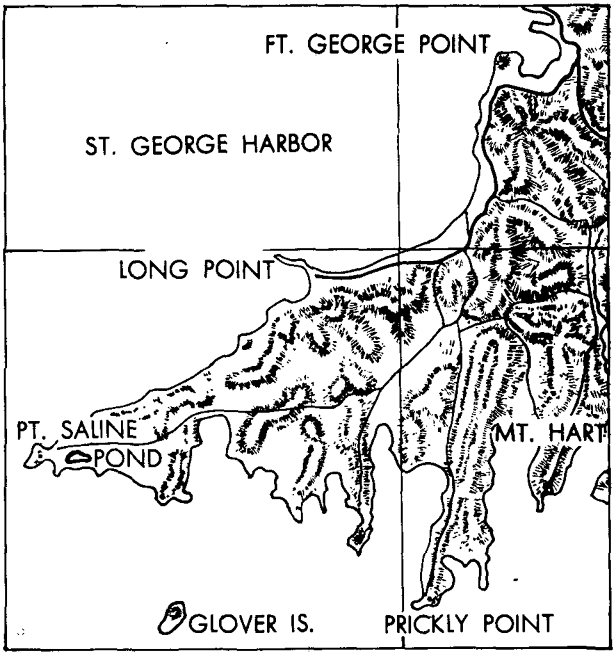


FIGURE 49. *Hachure map.*

60. Shaded Relief

Another means of intensifying the picture of relief is by shading. The map gives the effect of an air photo, with the sun coming from the northwest, with shading on the opposite sides of elevated features which would normally be in shadow. This method was used long before the Wright Brothers flew. There are examples at West Point of such maps dating back to the 1890's which were drawn by cadets. More success has been realized when it has been used in conjunction with contoured maps to add to the map's third dimension.

61. Layer-Tint

This method is similar to shaded relief since it is almost always used to accentuate the relief depicted on a contour map. It is popular for use on maps of 1:1,000,000 scale and smaller, especially in foreign maps. The map is divided into bands of elevation bounded by contours, and a color assigned to each. Usually the lower elevation bands are a lighter color and the higher ones darker, with the bands in between them becoming progressively darker as the elevation is increased. A key to the colors is always printed in the margin of the map. For many years, the layer-tint method has been considered a definite asset to small-scale maps for long-range planning. This method may be used to accentuate

FIGURE 50. *Hachures (European).*

the impression of relief in large scale maps, for study of the terrain in tactical operations.

62. Spot Elevations

In the spot elevation method, relief is shown by selecting specific points on the map area, determining the exact elevations of these points by ground methods, and printing them directly on the face of the map. On large-scale maps, the points of elevation are symbolized by small crosses; on smaller-scale maps, a dot indicates the point of elevation. Naturally, the relief is not as immediately apparent to the user as it is on a contoured map. However, if enough spot elevations (spots) are located, the user has little difficulty in picturing the relief. This is especially true in the case of large-scale construction maps where spots at abrupt changes in elevation are required. Mapping generally employs the spot elevation in conjunction with contours. There are many places in the area of a map where the true relief picture can not be shown exactly, and here a spot elevation can be very useful or even critical to a military operation. Prominent crossroads, saddles, pinnacle rocks in a landing area and the highest points of rounded hilltops are examples of such places.

63. Depth Curves

It is also possible to show the relief of the bottom of a body of water. Contours for this purpose are called depth curves rather than depression contours. Naturally the values of depth curves increase with the depth. Depth curves are used in mapping tidal waters, and are shown in terms of feet or fathoms (fig. 51). A fathom is 6 feet. Depth soudings and bottom characteristics are shown in conjunction with depth curves. Such information is also added to coastal maps for joint military usage or amphibious operations. It is important to know that depth curves in tidal waters use the mean low-water level as their datum or zero line. This is a half-tide lower than the mean sea-level datum used for contours. Therefore, tidal data must be known for proper use of maps having both systems.

64. Relief Models

Another means of showing relief is the actual physical construction of that relief on a map. However, when this is done it is no longer a map but rather a relief model. This map substitute is very popular at large scales when an exacting operation is being planned. Relief models are described in detail in chapter 16.

65. General

In paragraph 56, it is stated that mean sea level is the datum or base for measuring relief (fig. 46). Although datums in other

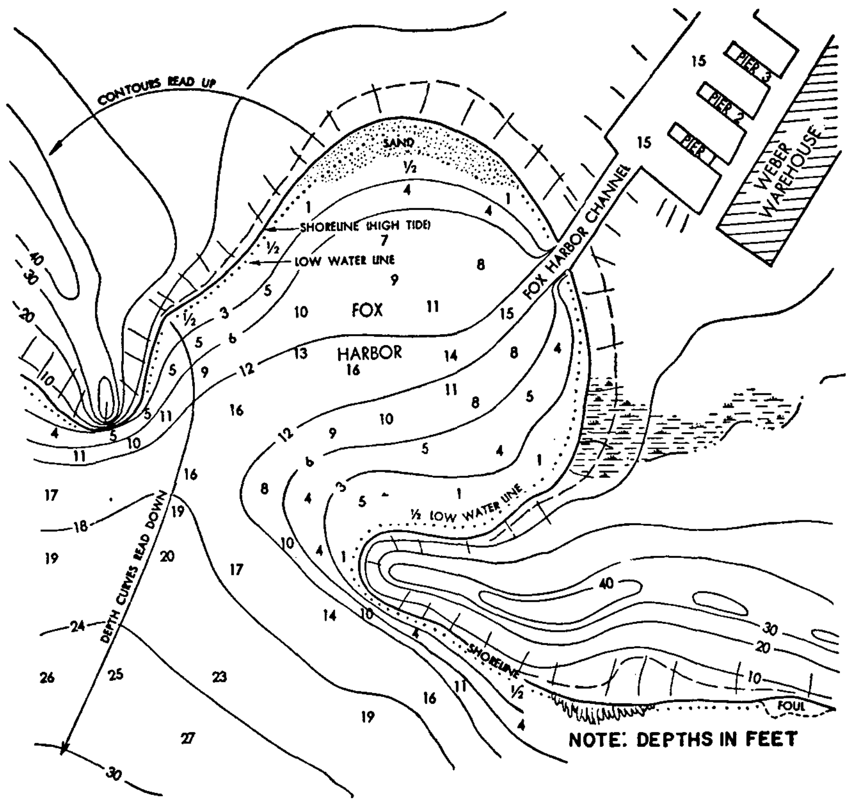


FIGURE 51. *Contours and depth curves.*

countries may vary somewhat from that used in this country, they are similar enough to be accepted as the same datum. Any difference is due primarily to the great variations of tide characteristics and the difficulty in establishing an average level. The establishment of a definite base for measuring relief is universal.

66. Foreign Level Datums

The method by which level datum is produced in a foreign country is important only as general knowledge. Every foreign map showing relief in any manner must have a base plane of measurement, which provides a true relief picture for the map user.

67. U. S. Level Datum

In the United States the base plane is ascertained and its form is established and preserved for the continual use of map makers and field engineers. Mean sea level is, as the name implies, an average level between high and low tides. The average is taken over a period of many years, and is obtained by actual measurement of the high and low water levels. Tide gages, which automatically register the highs and lows, are established at strategic points along both coastlines and up navigable streams and bays as far as tidewaters reach. Mean tide levels are computed and transferred from the tide gages to permanent marks by precise leveling. From these marks a network is established connecting all the tide gages and extending inland. These marks are known as *benchmarks,* and are bronze disks set in prominent cornerstones or special concrete posts at ground level. Each one is stamped with its identification, elevation, and the date it was established. Today, a network of benchmarks extends across the United States, as well as north and south into nearly every remote county. This network of benchmarks is the basis of all contours and contouring operations in the United States. This information, printed in special publications, is available as a guide to the location of benchmarks.

68. Relief Forms

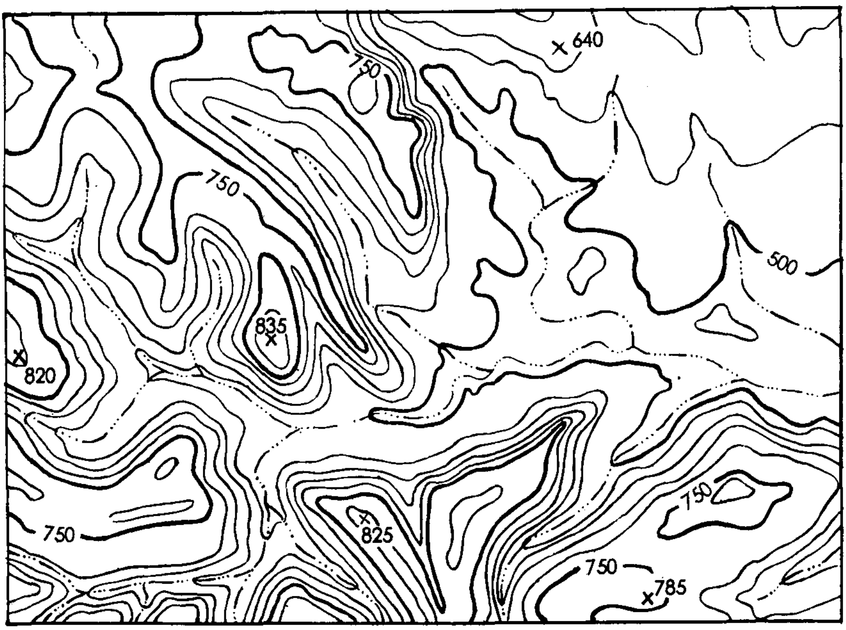
The contour and all other methods of picturing relief and elevation on a map were described in paragraphs 57 through 64 above. The many general land forms in nature which they represent are discussed in the following paragraphs. Since the use of contours is the best way to depict these forms, contours are assumed as a basis for the discussion.

69. Hills and Ridges

A hill is usually understood to be an elevated point which is higher than the surrounding area, and a ridge can be described as a series or chain of hills. Quite often, both are thought of as being pointed or "razor-like" in shape. Although this is possible, it is seldom the case because erosion wears them down over a period of thousands of years. They are usually rounded at the top, or occasionally even flat. This picture of the entire elevated area from the bottom to the top is shown on the map by the contours. The contour interval should be kept in mind, as well as the fact that a contour line connects points of equal elevation. The way a hill and ridge appear on a map is shown in figure 52. Assume that a hill which has an elevation of 835 feet is to be mapped at a contour interval of 50 feet. The top contour is the 800-foot contour, since it is the first whole number less than 835 which is evenly divisible by 50. Each 50-foot contour meanders around the hill to a point of closure. Therefore, a hill will appear as a series of widening irregular circles. As the lower elevations blend with those of the surrounding area, the contours disperse and no longer form complete circles. A range may contain several hill patterns within a larger series of closed circles. Stand on the point of 835 feet elevation and picture the 800-foot contour in a circular form, like a fence closing off the hilltop, but with every point of its circumference being exactly 35 feet lower than the top where you stand. Drop your eyes down 50 feet to the 750-foot contour and see it stretched out all around the hill outside of the 800. This same picture is on the map, the spot elevation marking the highest point, and contours circling and closing on themselves below in ever-increasing diameter as the hill is descended. For the ridge, there are several high points with one or two circular contours around each, but, while still relatively high in elevation, the circular contours around the individual hills or high spots will join ends and form elongated closed contours surrounding the whole ridge. When the bottom of the hill or ridge is reached, the spread of the contour patterns during the descent has pushed out the bottom contour to where it may appear to lose its connection with the elevated area as it leads out and aids in picturing the stream valleys and other lowland shapes. Look on the map for spot elevations with small contours surrounding them. Thus a hill and ridge are identified.

70. Drainage Basins

Another basic feature to be recognized on a map is the system of natural drainage which is characteristic of nearly all the earth's crust. It is a pattern made over a period of time by water seeking the lowest level (sea level). Small streams collect run-off



CONTOUR INTERVAL: 50 FT.

FIGURE 52. *Typical drainage basin.*

from the slopes on each side of a hill, deliver their water into larger streams, the streams empty into creeks, the creeks into rivers, and the rivers into the ocean. Such a drainage system is exemplified by the Mississippi River system. The entire area drained by the river is known as the Mississippi Drainage Basin. Understanding the characteristics and function of a drainage basin makes map reading easier, since the whole area of a map is usually made up of one or more small drainage basins. The water in a stream runs downhill and, therefore, a stream would not follow a contour line. However, the contours form a sharp bend where they cross streams, and these bends always point upstream. Therefore, it is easy to recognize the direction of flow in a stream and to picture the slope rising on both sides of the stream to terminate in hilltops and ridges. Expanding this picture of a single stream into one having several such branches with their separate but similar pictures on the map is one of the basic concepts incorporated into a map by contours. The true test of map reading ability is the capacity to see at a glance the fundamental terrain features of drainage basin fingers, separated by ridges and hills, as shown by contours on a map. Note the basin illustrated in figure 52.

71. Shorelines

The shoreline is recognizable as the line on the map which separates the water area from the land area. Contours confirm this, since they are never drawn through the water, but circle it at a uniform elevation. Even the shoreline of a pond may be a contour if by coincidence the water surface elevation equals the contour elevation. At any rate, the contours show that the area is level and is perhaps a body of water. The shorelines of large bodies of water, including the ocean, have the same physical characteristics, and develop the same types of contours on the map. It is a common occurrence to mistake the shoreline along tidal water for the zero plane of elevation. But this is not true because the tidal shoreline on a map is the mean high-water line, which is the average of the high tides. The mean high-water line (MHWL) has been selected as the shoreline because it usually serves as a basis for political boundaries as established by law. This selection is natural because the MHWL is normally well marked and distinguishable on the ground. The shoreline drawn on a map represents a plane above the elevation datum plane, an amount equal to one-half the tide range.

72. Slopes

The final and perhaps the most important ground feature of map representation which should be thoroughly familiar to the map user is the slope. Any ground surface inclined with the horizontal plane of the map is a slope. Specifically, the slope is important to the military man because almost every move and stand made during military operations is based upon the slope of the ground. The contours on the map permit the military man to visualize the details of these slopes. In general, the contours show the slopes extending from the drainage network upward to the point of highest ground, and down the other side to another stream or drainage network. The pattern is continuous with the contours describing the elevation and characteristics of every segment of every slope.

a. Slope Types. It is helpful in understanding map relief to separate slopes into three general types—uniform, convex, and concave slopes. The division applies to individual slopes, rather than a series.

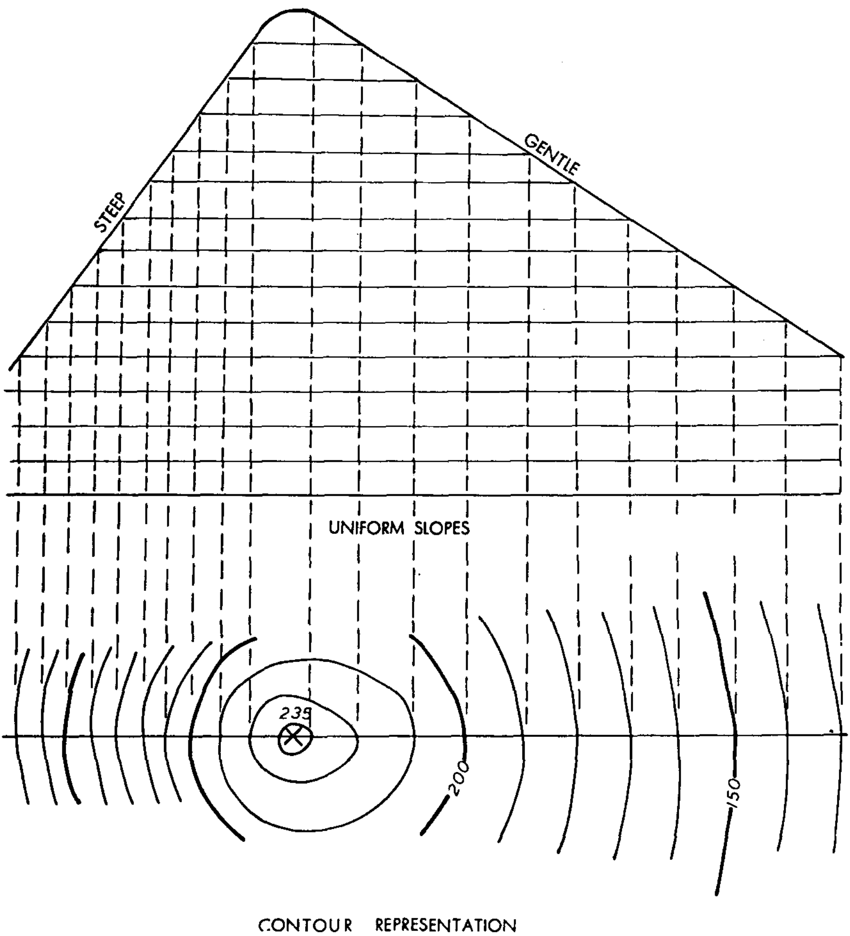


FIGURE 53. *Uniform slope.*

(1) *Uniform Slope.* The uniform slope is best defined as a steady rise or fall in the ground surface. Such a slope can be recognized on a map as equally spaced contours. It ranges from a steep slope to a gentle slope. These extremes are illustrated in figure 53. It should be noted that the spacing of the contours is uniform for each extreme.

(2) *Convex Slope.* The convex slope is one that is rounded rather than uniform in rise or fall. This type of slope is indicated on the map by contours which gradually become closer together as the slope approaches its lower elevation. Figure 54 illustrates the characteristics of a convex slope and its contour pattern. Convex slopes are

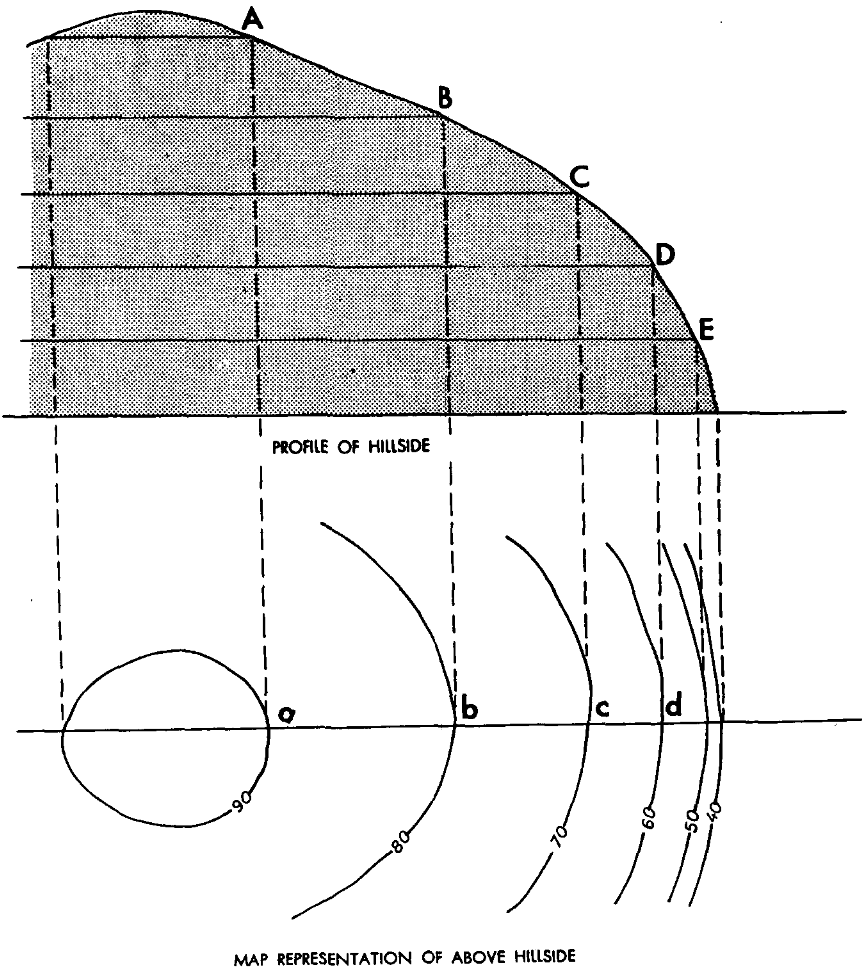


FIGURE 54. *Convex slope.*

formed by excessive erosion of the high and low elevations of the slope, leaving a mound between them. Generally, this indicates a prevalence of soft soils and hard understrata in the area.

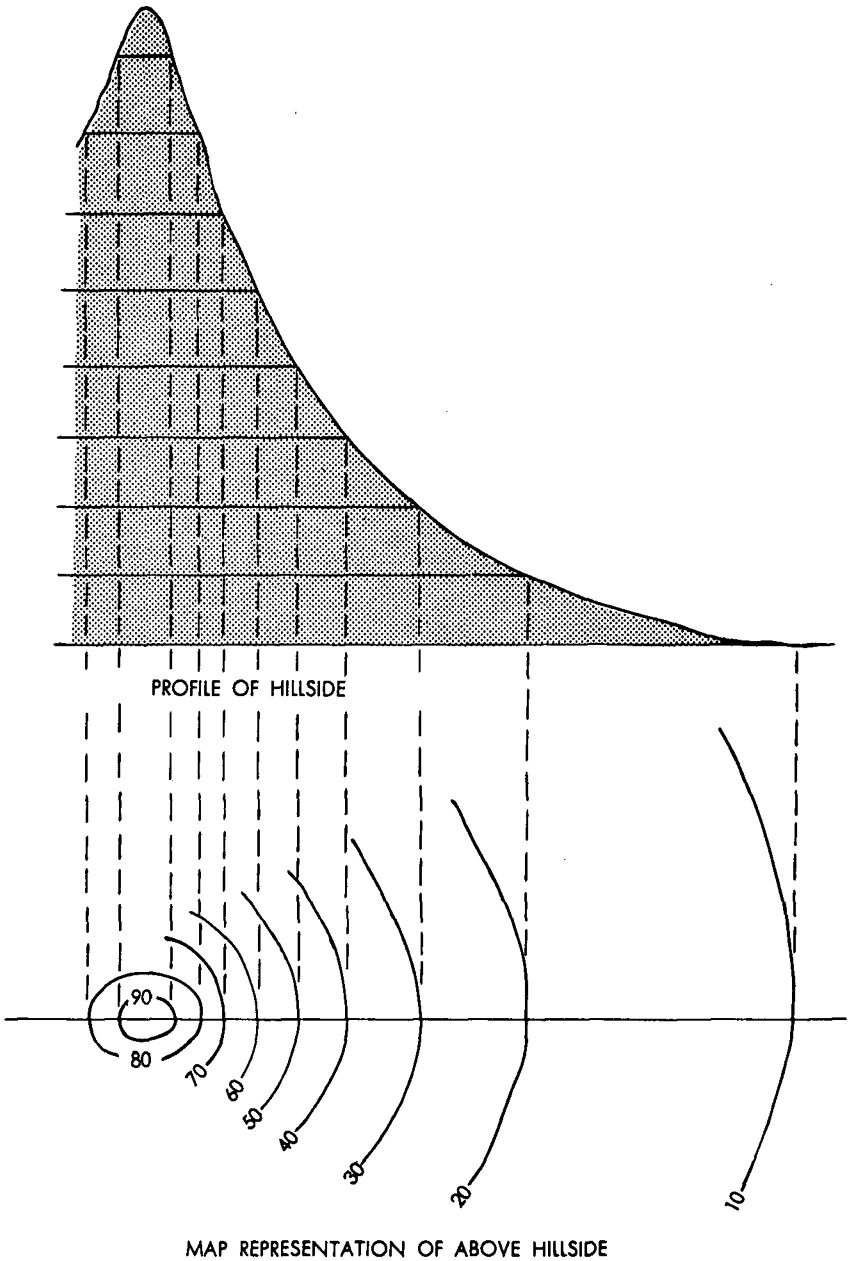


FIGURE 55. *Concave slope.*

(3) *Concave Slopes.* Concave slopes, as opposed to convex slopes, form a dip or depression-like slope rather than a mound. They are prevalent in hard-rock localities where erosion has left sharp peaks with gently sloping deposits of earth between them. An example of a concave slope is a steep mountain side, culminating in an alluvial plain, with the lower portion of the descent absorbing most of the change of slope from steep to gentle. Figure 55 shows the concave slope and the way in which it is represented by contours on the map.

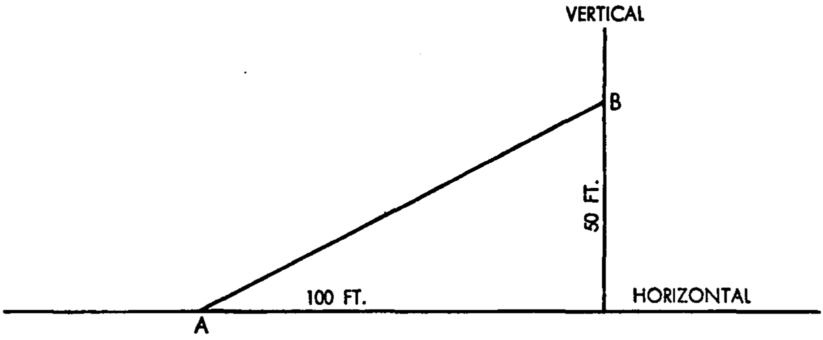
b. Expressing Slope. Since it is necessary to be able to read and write about slope, three separate methods for doing this have been devised and are currently in use.

(1) *Percent.* Starting at a given point, the percentage of slope is measured by the amount of change in elevation over the horizontal distance from the point. For example, a rise of 5 feet for 100 feet of distance is a 5 percent slope. Thus, a line on level ground would be a 0 percent slope and a line on a 45-degree incline would be a 100 percent slope. Slope percentage is commonly spoken of as "1 on 100" or "30 on 100", which, although not a true percentage, means the same thing and is more readily understood by map users. Figure 56 illustrates slope percent and the use of the formula for computing slope on the ground. Computing the percentage of a slope on the map is done by the same formula. The elevation of the bottom and top of the slope is determined from the contours, and the vertical rise is obtained by subtraction. The horizontal distance is scaled directly from the map, between bottom and top, and the figures are entered in the formula. It is important that the unit of measure of the elevation (vertical distance) and the horizontal distance be in the same unit of measure, yards to yards, feet to feet, or meters to meters. Figure 57 is an example of a slope-percent computation from a map. Note that the computed slope is the average slope between A—B. The steepest slope along the line A—B is between 700 and 720 feet elevation.

(2) *Mils.* For special purposes it is sometimes desirable to express slope in mils (1/6400 part of a circle = 1 mil). The following formula is used:

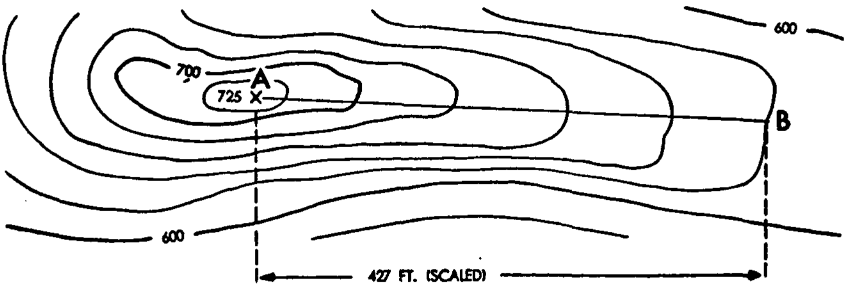
$$\frac{\text{vertical distance}}{\text{horizontal distance}} \times 1{,}000 = \text{slope in mils}$$

The factor of 1,000 is used because a mil is the angle subtended by one yard at a distance of 1,000 yards. The



$$\% \text{ OF SLOPE} = \frac{\text{VERTICAL DISTANCE}}{\text{HORIZONTAL DISTANCE}} \times 100 = \frac{50}{\cancel{100}} \times \cancel{100} = 50\%$$

FIGURE 56. *Percent of slope.*



$$\frac{\text{VERTICAL DISTANCE}}{\text{HORIZONTAL DISTANCE}} = \frac{725\text{-}620}{427} \times 100 = \frac{105}{427} \times 100 = 24.1\%$$

FIGURE 57. *Percent of slope from a map.*

distances are obtained from a map in the same manner as explained in the discussion of slope-percent, that is, both must be in the same unit of measurement. The values are entered in the slope-in-mils formula to obtain the answer in mils of slope.

(3) *Degrees.* Slope can also be expressed in degrees of angle between the slope line and the horizontal. A surveying instrument can be used to determine the angle more quickly, but it can be obtained from the map quite readily. As before, the horizontal and vertical measurements of the slope are determined and the following formula is used to find the answer:

$$\frac{\text{vertical distance}}{\text{horizontal distance}} \times 57.3 = \text{slope in degrees}$$

The 57.3 value varies as the angle grows larger, but a reasonably accurate degrees-of-slope answer can be obtained for slopes under 20 degrees through the use of the formula given above. The value varies because it represents the arc distance instead of the true vertical distance as shown in figure 58.

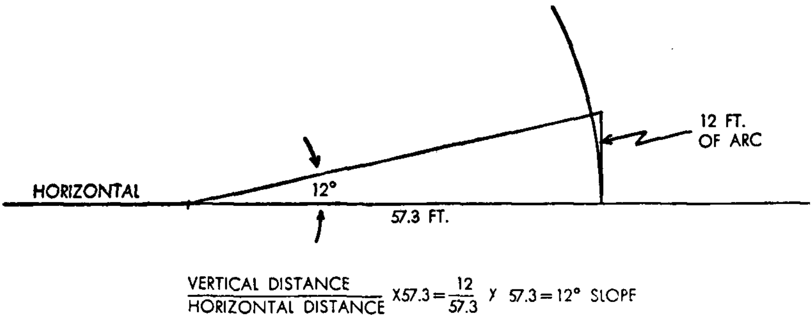


FIGURE 58. *Determination of slope in degrees.*

(4) *Grads.* A slope might be expressed in grads, which is the unit of angular measure in the metric system. Whereas 360 degrees make up a full circle, there are 400 grads in the circle. Slope in grads is derived in similar fashion to slope in degrees, and has approximately the same limitations. The grad unit is more likely to be used in connection with foreign maps in which all other measurements of detail are in metric units.

(5) *Gradient.* The rate of inclination from the horizontal is called gradient. It is expressed either as the ratio of vertical to horizontal or horizontal to vertical distance. Hydraulic gradient is usually expressed as—

$$\frac{\text{vertical}}{\text{horizontal}}$$

For example, a stream with a vertical fall of 1 foot in a horizontal distance of 5,000 feet has a gradient of 1 to 5,000, sometimes written as 1/5,000, or 1:5,000, or 1 in 5,000. The side slopes of earth fills or excavations are usually expressed as—

$$\frac{\text{horizontal}}{\text{vertical}}$$

The face of an earth fill which rises 5 feet in a horizontal distance of 15 feet has its gradient expressed as 3 to 1, 3:1, or 3/1. To avoid misunderstanding when expressing slopes by ratio, it is advisable always to state whether the slope is expressed as vertical over horizontal or horizontal over vertical.

c. Calculation of Slope Distance. The experienced map reader visualizes slope distance through his familiarity with the relief formed by contours in relation to the map scale. For a given instance it is possible to readily determine the slope-distance ratio by observing the difference in elevation, shown by the contours, for a specific distance, and setting the problem up in the form of a fraction, such as 1/10. Then, if the contours are at 10-foot intervals and the distance between contours is 100 feet (as scaled from the map), the ratio of rise or fall is 1/10 or 10 percent. In determining exact slope distances, corrections must be made to account for the length over and above the scaled measurement in a single plane to that caused by the rise and fall of the earth's surface. Thus, for developing an accurate distance, it may be advisable to construct a ground profile whereby the distance may readily be scaled regardless of irregularities. Paragraph 77 describes the construction of a profile.

73. Grades

Grade is another term meaning slope and it is computed and expressed in the same manner as slope. It can be used in reference to any slope, but it is normally reserved for the language of the construction trade. Engineers speak of the surface of a highway or airstrip in percent of grade, both before and after construction. Grade, in its written and spoken meaning, is naturally very critical in railroading. In connection with map reading, the term will be used only when the map is used for construction planning or operations.

74. Reading Relief on a Map

The contours on a map portray the relief of the terrain to its reader. The contours form certain patterns which the trained map reader instantly recognizes as specific terrain features such as hills, slopes, and valleys. The next thing noticed is how high or low the features are, that is, the relative elevation of these features. The lowest point on the map is a given number of feet above or below datum and the highest point has yet another value. A simple subtraction of one figure from the other shows the maximum range of relief for the entire area of the map. Immediately the reader knows whether the battleground requires a considerable amount of climbing and difficulty in the movement of equipment; or it may be apparent that the terrain presents no problem. Field experience teaches the soldier to appraise the significance of terrain features as they are encountered on the ground. The map helps him to know the ground characteristics in advance. Its use in actual ground maneuvers increases the individual's skill in identification of such features.

75. Relief Forms in Combination

Corridors and compartments are examples of the use of natural terrain features for military purposes. They are identified by the relief shown on a map, and generally are useful in the forward movement of troops. Corridors are particularly valuable as a safety factor in the movement of aircraft, while terrain compartments afford certain natural protection to ground troops. It is important for the map reader to be able to recognize these features and to assess their military value. These features, called limiting features, are usually ridges or high ground but may also be woods,

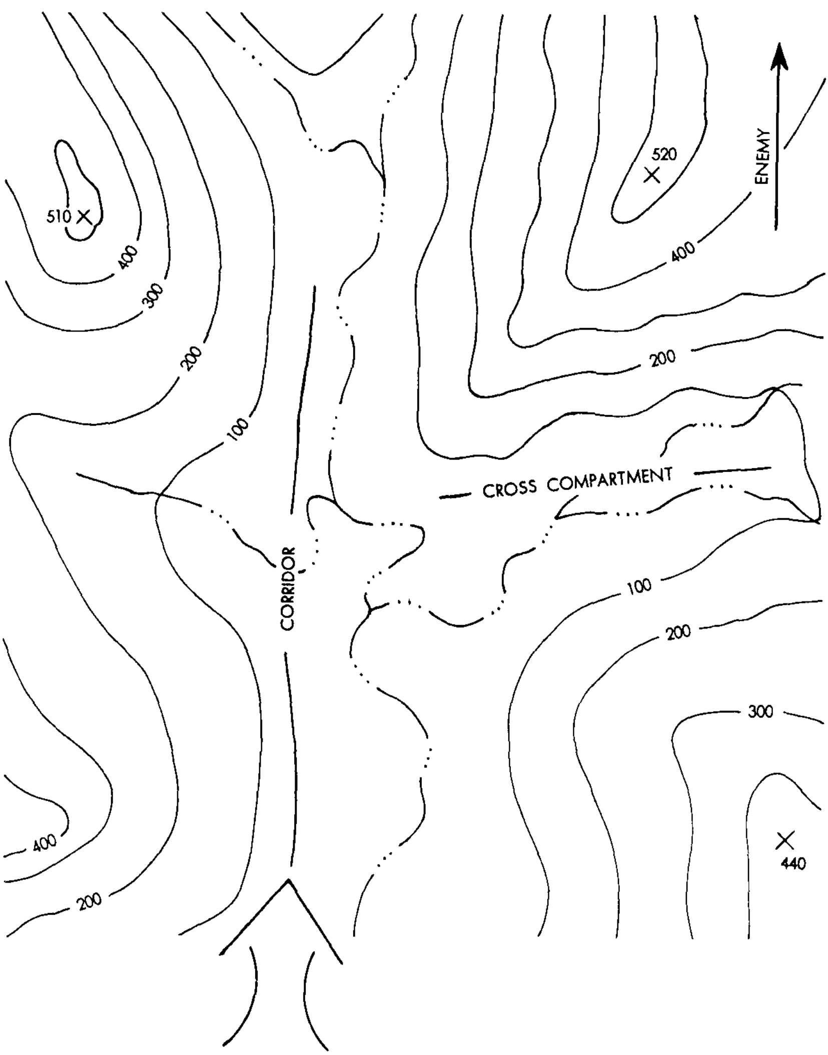


FIGURE 59. *Corridor formed from terrain compartment.*

cities, towns, or wide bodies of water. A terrain compartment includes not only the area enclosed but also the limiting features as well. Taking advantage of natural relief may be of great importance to the success of military operation. Consequently, the relief map reader must be prepared to determine and recommend such areas as may prove helpful in a given operation.

a. Terrain Compartments. A terrain compartment is an area bounded on at least two opposite sides by terrain features which limit ground observation and direct fire into the area. A terrain compartment can take several forms. It may be a street bordered by buildings; a clearing bordered by forests; a plain with a mountain range along one side and a wide body of water on the other; a valley bordered by ridges; or a similar combination of terrain features. Terrain compartments are classified with respect to direction of movement of forces operating therein. They are *corridors* when the longer dimension lies generally in the direction of movement or leads toward an objective (fig. 59); and *cross compartments* when the longer axis of the compartment is perpendicular or oblique to the direction of movement of a force.

(1) *Corridor.* A corridor is a long natural compartment of terrain which runs in the direction of troop movement (fig. 59). It may also be an airlane or other safety zone provided for the movement of friendly aircraft or troops. Figure 59 shows a compartment which may be used as a corridor.

(2) *Cross Compartment.* A cross compartment is a compartment of terrain whose longest dimension runs perpendicular or oblique to the direction of movement, and is, therefore, of value in static positions.

76. Profiles Defined

The slope on maps are best understood after a study of their profiles, because they help the map reader to visualize the vertical changes in the ground surface. The profile is a drawing showing a section through the slope. The profile may depict many slopes connected in a wavy, up-and-down-hill line, or it may be drawn for one specific slope.

77. Profile Construction

Perhaps the best way to understand a profile is to draw one, such as the one shown in figure 60. The upper portion of the figure is a section of a contoured map with the straight line A to B designating the line along which a profile is desired. Assume that a vertical plane has been forced down into the ground along A—B, and that the earth south of the line has fallen away. The heavy and wavy line on the graph at the bottom of the figure is the trace of the ground surface, or the profile. It is drawn on a previously constructed graph of proper vertical scale. The highest and lowest elevations along the line A—B are noted and numbers are assigned to the equally spaced lines of the graph, the highest elevation at the top and the lowest at the bottom. Vertical lines from points on A—B where each contour has been cut, are dropped to the line corresponding in elevation. These points form the profile when connected on the graph. In the figure, note two hills in the profile with a valley separating them. A glance at the map itself shows how much clearer the relief picture of the whole area has become. Drawing an actual profile is not always necessary for the experienced map reader, since he has become familiar with map representations.

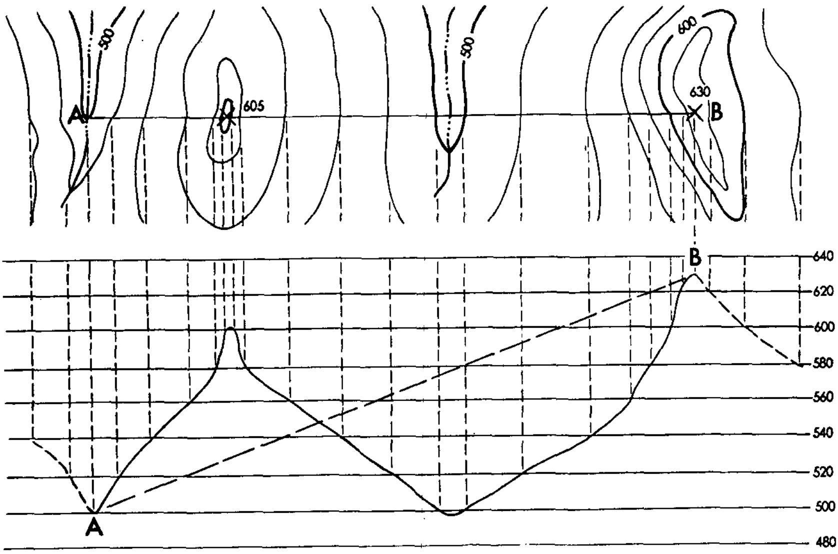


FIGURE 60. *Construction of a profile.*

78. Profile Terms and Expressions

a. Crests (fig. 61).

(1) *Topographic Crest.* A topographic crest is the point of highest elevation on the top of a hill.

(2) *Military Crest.* A military crest is a fixed line or point on the highest part of the forward slope of a hill or ridge from which maximum observation can be made of the slope down to the base of the hill or ridge. The military crest is always below the topographic crest. In those rare cases where the slope is so uniform as to afford maximum observation from the topographic crest, a line or point on the forward slope will be chosen as the military

crest, sufficiently below the topographic crest to avoid silhouetting the observer against the skyline.

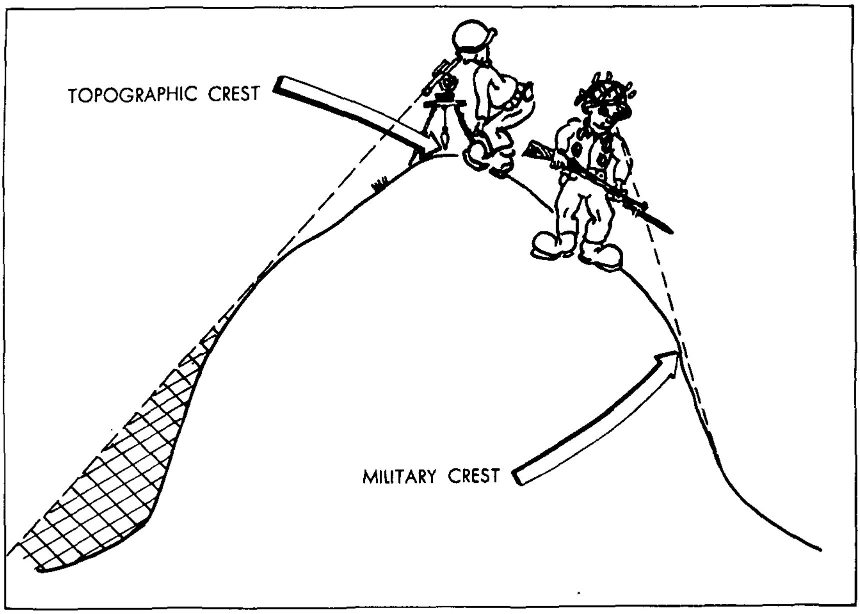


FIGURE 61. *Profile crest.*

b. *Military Terms.*

(1) *Scale.* The vertical scale of a profile is the scale established by the spacing of the lines of the graph from top to bottom. Unlike the horizontal scale, which must be that of the map, the vertical scale is not fixed, except when the profile is to be used in the measurement in slope distances when the vertical scale must be equal to the horizontal scale. It can be varied to suit any given purpose. Usually, it is exaggerated for easier reading.

(2) *Mask.* A mask is a ground feature that stands between two ground points and prevents seeing one point while standing at the other. Also, these two separated points are said to be in *sight defilade* with each other because of the mask.

(3) *Intervisibility.* Intervisibility (fig. 62) is the absence of a mask; two points are visible, one from the other.

(4) *Mask Area.* The mask area contains all the area hidden from view by the mask.

(5) *Sight Defilade.* Sight defilade is the depth of the mask area, the maximum elevation of the mask area, or the elevation at a given point in the mask area.

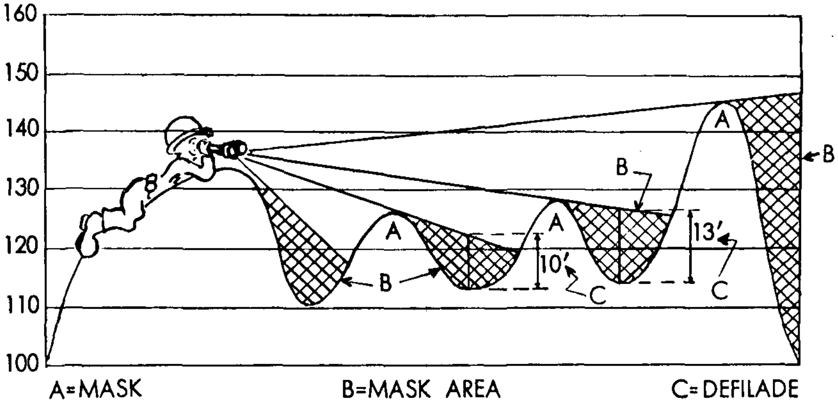


FIGURE 62. *Intervisibility.*

79. Some Practical Uses of Profiles

a. Point to Point. The profile is most commonly used to determine whether two opposing forces are intervisible. It is the simplest profile problem to solve, because it requires but a single profile. The same process as explained above and illustrated in figure 60 is used. A line is drawn on the map connecting the two points of interest, and the profile of this line is constructed. For the purpose of determining intervisibility, it is not necessary to draw the entire profile. The low areas have no bearing in this instance, so only the high points located along the line of sight are plotted. On the profile, the two points are connected by a straight line and if no intermediate elevations extend above this line, one point can be observed from the other. However, if even one hilltop or ridge plots above the line, the view between the two points is blocked.

b. Point to Line. Another application of the profile is in determining visibility along a feature such as a trench or route of travel which crosses front lines. The problem here is a series of point-to-point profiles from the observation point to several points along the road, for example. However, it is necessary to determine only a few profiles if there are any mask areas along the road. The observation point is located on the map and connected with each end of the road by two straight lines. In the angle formed between the sight lines, the highest spots are selected and profile lines are drawn through each one. Each profile is a point-to-point problem in itself, and reveals any existing masks. When found, the hidden portion of the target road must be developed to show the exact limits of the mask area. This means that more profiles must be drawn on either side of the one which first located the mask.

c. Point-to-Area. The problem in this case is that of determining the length and width of hidden areas which might be dead spots in the field of fire or might be areas in which troops could be protected from enemy fire. Several complete profiles showing all low and high points would produce an adequate picture of the area. A typical problem and solution are illustrated in figure 63. Note that three profiles have been constructed for lines OA, OB, and OC drawn on the map section of this figure. Straight lines from O, the point of observation, are drawn tangent to all high points on each profile and have outlined the shaded mask areas. The left and right limits of each shaded area have been transferred back to the respective profile lines on the map. When these

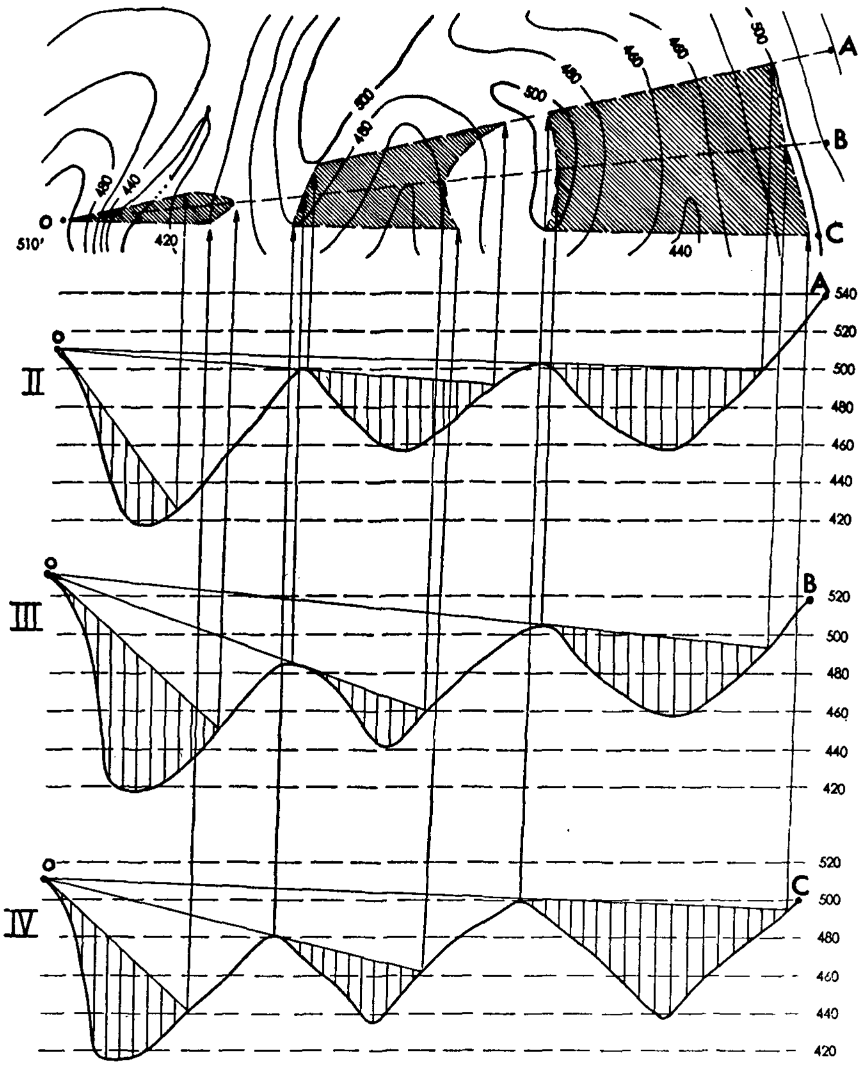


FIGURE 63. *Plotting mask areas.*

have been connected, the mask areas are shown in two dimensions, length and width. They are also shaded for easier reading. Should a greater width of area be involved, more profiles are added on either side and the areas are extended where needed.

d. Line-to-Area. There are times when the observation from several points along a line is in question. For example, when a commander is assigned a section of front to cover from a ridge, he must determine where to place his guns in order to have the best overall field of fire. A point-to-area solution from a number of points along the ridge would indicate the mask areas for each, and overlapping mask areas would reveal dead spots or areas where the guns could not provide effective direct fire.

e. Sight Defilade. There is another problem which is readily solved by the use of the profile. It is one of sight defilade or vertical clearance that might exist in a mask area. Assuming the positions of enemy guns are known, would enemy observers be able to see tanks proceeding along a valley across their front, or would the mask provided by a low ridge in between be sufficiently high to hide a tank, or would the turrets show? A comparison between the height of a tank silhouette and the maximum vertical distance measured from several profiles across the route of march will determine whether clearance for the tank exists.

CHAPTER 4

GRIDS AND GRID REFERENCE SYSTEMS

Section I. GENERAL

80. Purpose and Use of Grids

The grid has been developed as a common-language means of locating points on a map. A grid is a network of two series of straight and parallel lines, constructed perpendicular to each other. One series is in a general east-west direction and the other in a north-south one. The lines of the two series intersect to form squares, all of which are exactly the same dimension on a given map. Each line is given a number and thereby any position on a map compiled on a grid can be identified. There are many different grids, and each one has a different purpose and numbering system, which is explained as each grid is discussed in this chapter.

81. Employment of Grids

a. General. In general, grids are printed on maps of 1:250,000 scale and larger. Maps of smaller scale normally do not have a grid system, since point location is done by geographic positions. Specifically, grids are shown at 10,000-unit intervals on maps of 1:250,000 scale, and at 1,000-unit intervals on maps having scales larger than 1:250,000. The unit may be in yards, feet, or meters, depending on the type of grid. The unit on almost all military maps, however, is the meter. It is possible to have more than one grid system drawn on a single map or map series, in which case, one system is designated the *major* grid. Major grids are always ruled in solid lines across the face of the map. The others may be drawn in a similar manner, but in a different color. However, they are more usually represented by ticks along the neat lines of the map, which can be connected across the map when it is desired to employ a particular grid other than the major.

b. Grid Numbering System. Every grid line on a map can be identified by a specific number which is printed just outside the border of the map, directly opposite the grid line it indicates. The numbers for the vertical grid lines are usually on the south border, and for the horizontal lines, on the right border. Some maps may have them printed on all four sides. Origin lines for each grid system have been established far enough south and west of the area of the grid system area to assure that there will be no confusion of grid line numbers, and to make all grid numbers plus values. They are plus values because the numbers increase in northerly and easterly directions respectively. This means that on every map the grid numbers increase from left to right and from bottom to top. Grid numbers have several digits. As they move farther from their origins, their numbers become larger. Not all of each number is printed on every grid line on the map, only the significant digits of each. On maps larger than 1:250,000 the last three digits (000) are omitted, and on maps of 1:250,000 scale the last four (0000) are not considered significant for printing. Figures 64 and 65 are examples of grid numbering on large- and small-scale maps, which are reduced in size for inclusion on a single page of this manual. They illustrate how grid numbers appear with portions of each number dropped. However, it should be noted that one north and one east grid value is printed in full in the SW corner to indicate the true values of the grid system. Attention should also be given to the fact that one or two digits are larger than the others. This is done to make reading easier. The grid squares at the large scale are in 1,000 units and therefore the two larger numbers increase in units of 1,000 while similarly in the small-scale category the one large number increases in units of 10,000 in relation to the value of each grid square.

c. Overlapping Grids. When a map falls within about 25 miles of an adjacent grid system, that adjacent grid is extended and shown on the maps as an overlapping grid. It is added to be used in fire control and survey operations from the opposite side of the grid junction where only the grid of that system may be printed on the map. Overlapping grids are applied to maps at 1:50,000 scale and larger, and are shown when the major grid on a map falls within 30 degrees or 25 miles of a grid junction. They are usually indicated by tick marks outside the neat lines, and the ticks are labeled in the same manner as the map's major grid lines. It is possible that a secondary grid system would be required on a map, in which event ticks inside the neat line would be used to show it. In all cases a note in the margin of the map would clarify each grid as to symbol and both color and unit of measure. It is further possible for a map to fall astride a junction line between two grid systems. When this happens, the junction line is indicated by accentuated lines printed in the same color as the grid lines. Notes, identifying each grid, are added onto each side of the line. Grid lines are solid lines in their own area, but are continued across into the other portion of the map as overlapping grids. A marginal note aids in the identification of each grid

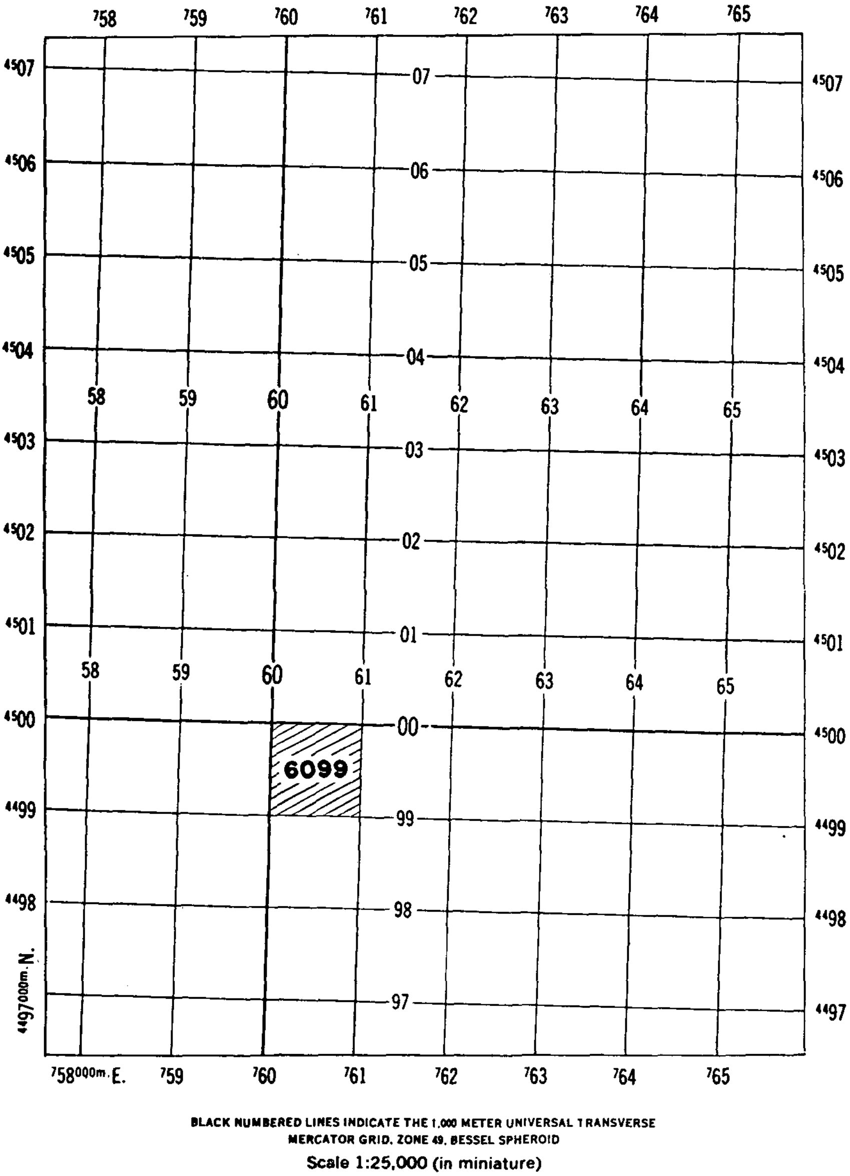
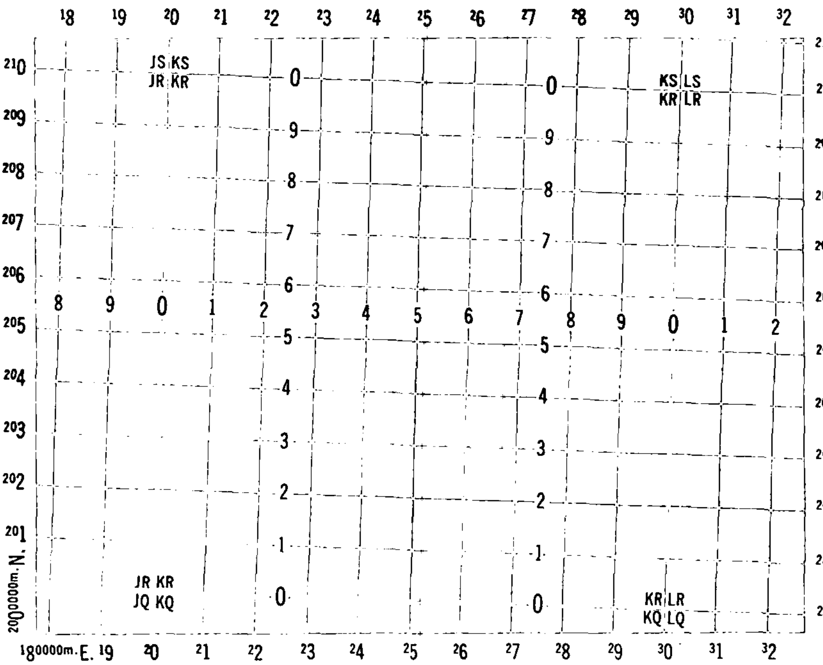


FIGURE 64. *The military grid on a map with scale larger than 1:250,000.*

involved. There exists a third possible type of overlapping grid —grids of different unit values. They are usually symbolized by inside ticks, labeled in the prescribed manner, and appropriately identified by marginal notes.

d. Locating Points by Rectangular Coordinates. The grid system on a map is used as a reference for identifying points on it. The grid position is expressed in terms of numerical coordinates



BLUE NUMBERED LINES INDICATE THE 10,000 METER UNIVERSAL TRANSVERSE MERCATOR GRID. ZONE 20

FIGURE 65. *The military grid on a map with scale of 1:100,000 and smaller.*

(rectangular coordinates), representing its exact position on the two sets of grid lines. The map coordinate must be expressed in an even number of digits. The coordinates of a position consist of two values, the left group of digits (first half) gives the location east of the origin. The right group of digits (second half) gives the location north of the origin. The values are written in the order prescribed by the basic rule for reading all positions: READ-RIGHT-UP. That is, *read* the easting to the *right* across the bottom of the grid, and then read the northing *up* the side. The values are written down in the order read, without punctuation, and are one continuous number. Reading the two values of the coordinates consists of first reading the large numbers only, representing the SW corner of the square in which the point lies, and then following the large numbers by an estimation of the distance in tenths from that corner along the respective sides of the square point. An example of such a number is "916091". The way it is read is illustrated in figure 66. The "91" and "09" represent the SW corner of the square in which the point is located, the "6" means it is 6/10 of the way from "91" to "92", and the "1" states that it is 1/10 of the way from "09 to "10". Coordinates of a point in a particular grid square may be measured using a coordinate scale (GTA 5–12), as shown in figure 77. By use of coordinate scales, grids may be read on large-scale maps to 8 places where necessary. This would pinpoint a ground position to the nearest 10-meter square.

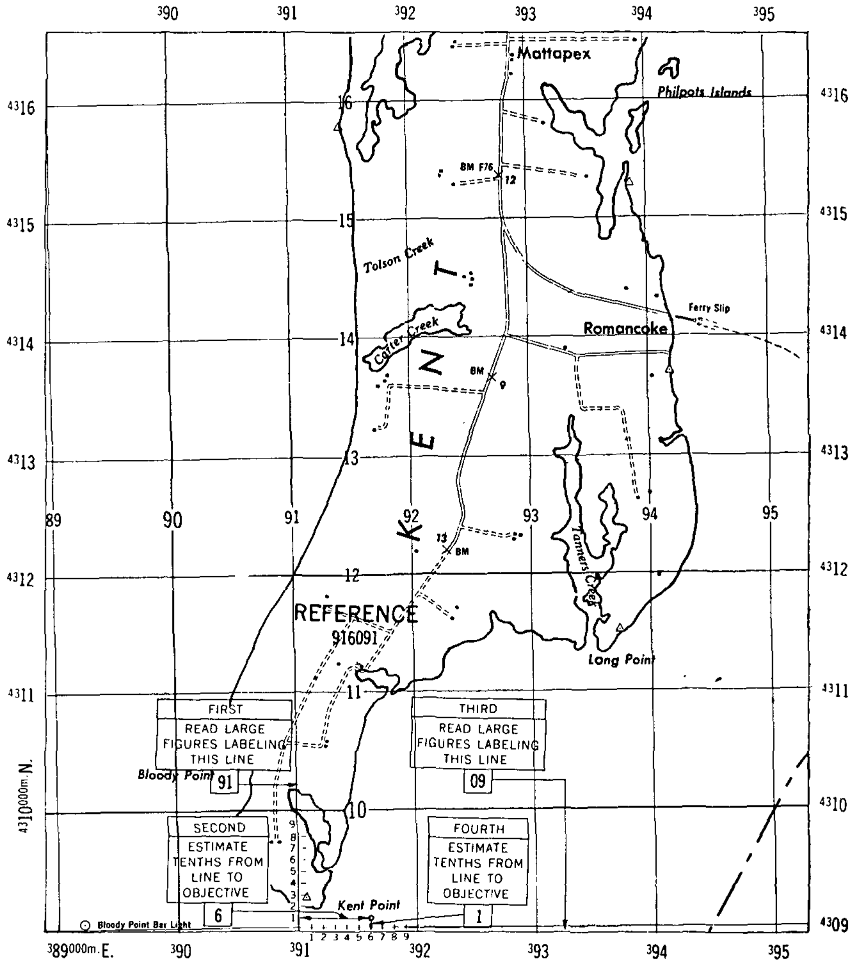


FIGURE 66. *Reading coordinates.*

e. Grids Used on Military Maps. Of the many types of grids in use today, the military has selected two for standardization. The Universal Transverse Mercator (UTM) grid is printed on maps of the area between 80°N and 80°S latitude, and the Universal Polar Stereographic (UPS) grid is used for the remaining areas at the poles of the globe. Both grid systems are explained in subsequent paragraphs.

Section II. UNIVERSAL TRANSVERSE MERCATOR GRID

82. Purpose

The Universal Transverse Mercator grid is standard for use on all United States military maps covering the area between the 80°N and 80°S parallels. The ultimate plan is to convert the necessary grid data to make it world-wide. The UTM grid system

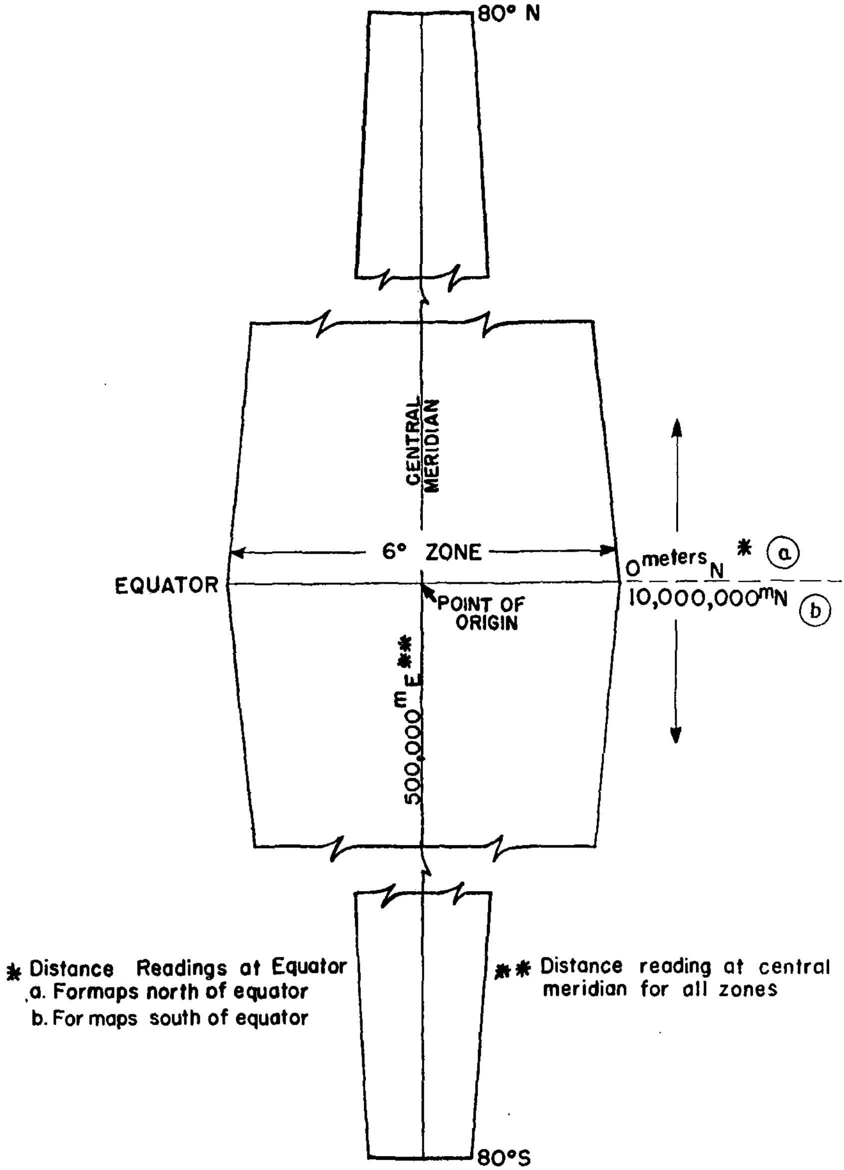


FIGURE 67. *Origin and false coordinates of UTM grid zones.*

is based on the Universal Transverse Mercator projection (app. VI), which was selected because of the important advantages it affords the principal military map users who are the gunners, the surveyors, and the navigators, since all angles measured are very close to true values and all measured lengths are approximately correct.

83. Description

For use of the UTM, the world is divided into 60 zones, each being 6 degrees wide in longitude and 160 degrees deep in latitude, each reaching from 80°N to 80°S latitude. The zones are numbered 1 through 60, in numerical order, beginning at the international date line (180 degrees W) and reading eastward around the globe. Each zone of the UTM grid has its own origin, the intersection of the equator with the central meridian of the zone. In order to avoid negative coordinates, an arbitrary value of 500,000 meters in easting is assigned to the central meridian. While in the northern hemisphere, the value of the equator is zero meters, an arbitrary value of 10,000,000 meters is assigned to the equator for the grid in the southern hemisphere. No coordinate can have negative values with such a system. Figure 67 shows the origin and coordinates of a UTM grid zone.

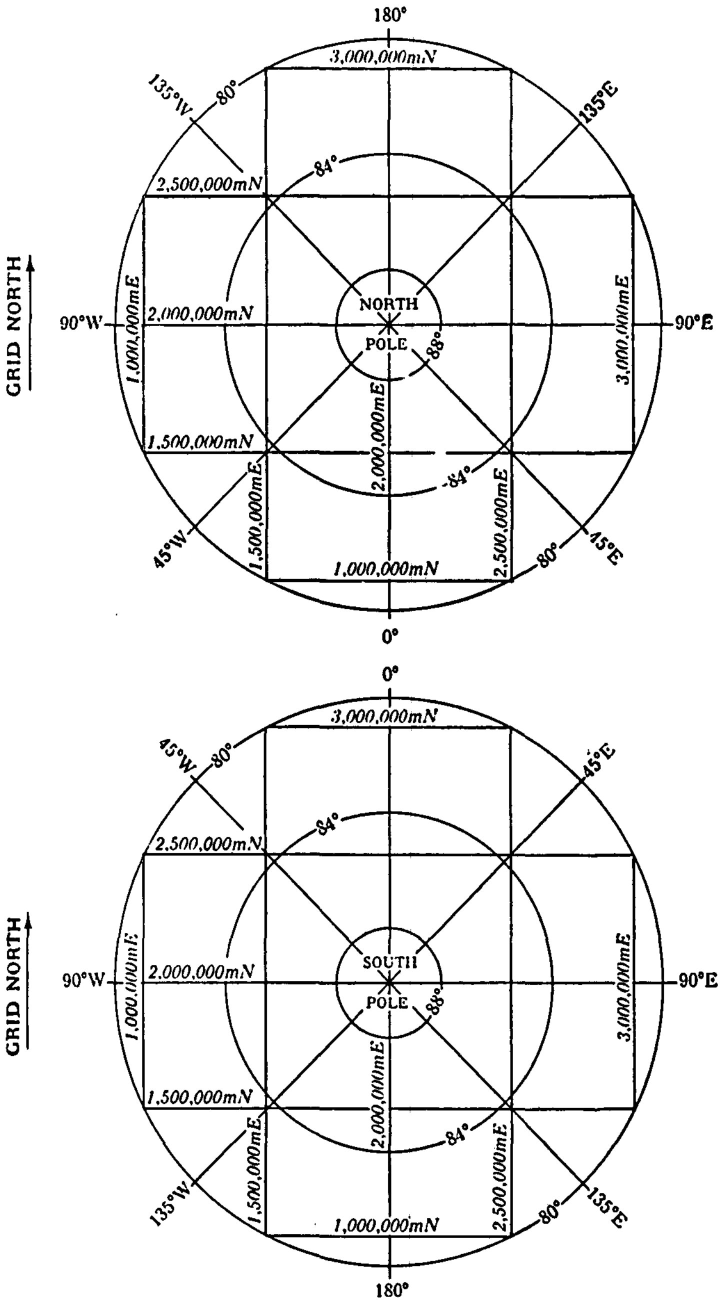
Section III. UNIVERSAL POLAR STEREOGRAPHIC GRID

84. Purpose

The universal polar stereographic grid system (UPS) is used on military maps of the polar regions, north and south of the limits of the UTM grid. The UPS grid is constructed from tables based on the polar stereographic projection (app. VI), which is conformal and possesses the desirable characteristics of all angles being very nearly true and all lengths being of small error, equal in all directions from any one point.

85. Description

In the UPS grid system, the north and south polar regions are subdivided into two zones each, with zones *A* (west) and *B* (east) enclosing the area from 80° south to the South Pole and zones *Y* (west) and *Z* (east) from the North Pole. The two regions are illustrated in figure 68. Note that arbitrary values of 2,000,000-meters both east and west are assigned to the North and South Poles respectively. Distances east are measured parallel to the 90°E and 90°W meridians, while distances north are measured parallel to the 0–180 degree meridian. These meridians serve as the axes of origin for the grid.



North Zone

South Zone

Polar grid systems.

FIGURE 68. *The UPS grid zones.*

86. Purpose

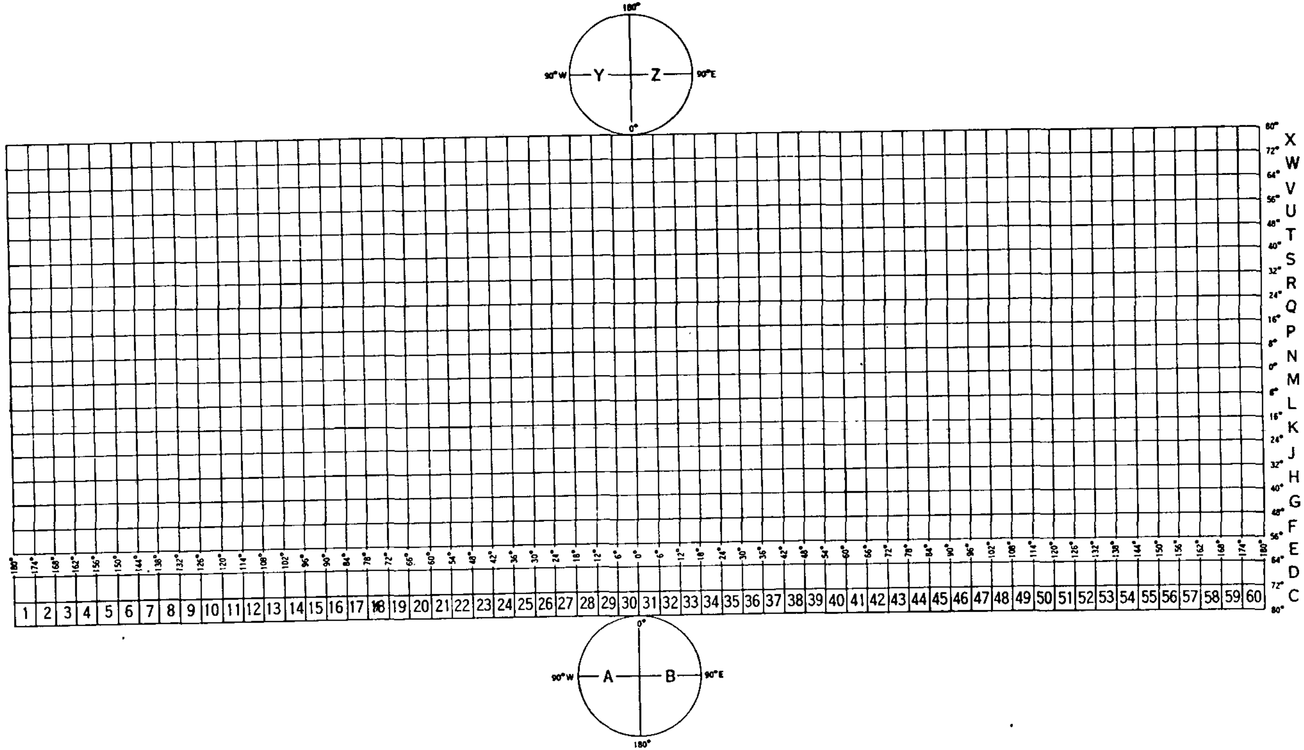
The military grid reference is a special system used by the military for referencing points on maps gridded with the UTM or UPS. The system divides the whole earth's surface into large geographical areas and gives each area a special and separate means of identification called the grid zone designation (GZD).

87. Description and Use

a. Grid Zone Designation. Figure 69 shows how each area is assigned its grid zone designation. First, it should be noted that the diagram is the development of a cylinder, with the top and bottom left attached at the 80° latitude points of the zero degree meridian. The 60 vertical divisions form the 60 zones of the UTM grid, each zone being 6 degrees wide and reaching from 80 degrees south latitude to 80 degrees north latitude. The intervening 160-degree distance is divided into 20 horizontal divisions of 8 degrees each and given a letter designation. From south to north, the areas are lettered from *C* to *X* (in alphabetical order) ; *I* and *O* are omitted as they resemble numbers, *A, B, Y,* and *Z,* are omitted as they are used in the breakdown of the polar stereographic projection. When *read right up,* each area becomes known as a number-figure, for example, *17R.* At the poles, no number is needed; the grid zone designation amount to a single letter, *A, B, Y,* or *Z,* as shown in figure 69.

b. Subdivision of Grid Zone Designations. The next step is a breakdown of each area or grid zone designation (GZD) into smaller areas which may be identified without duplication within distances greater than any one operation would require.

(1) *The UTM Grid Breakdown.* The UTM grid has each GZD subdivided into 100,000-meter squares, each of which is designated by two letters, without repeating. In all cases, each 100,000-meter square is based on the grid of the zone in which it lies. Horizontally, 24 squares span three zones (18 degrees), and they are lettered *A* through *Z* (less *I* and *O*), from west to east, beginning at the international date line (180 degrees W). The alphabet is repeated every three zones (18 degrees), proceeding eastward. Figure 70 shows that the squares on either side of the junction lines between zones are not full-area 100,000-meter squares. This is because the distance east and west of the central meridian of each zone (construction meridian) does not contain an even number of 100,000-meter units, and the last squares must be terminated at the meridian junctions. North-



Grid zone designations of the Military Grid Reference System. The designations identify the polar areas and 6°E.—W. by 8°N.—S. divisions of the globe between 80°N. and 80°S.

FIGURE 69. *Grid zone designations for the world.*

ward, the squares nearly always have a full 100,000-meter dimension, and are also alphabetically lettered. Beginning at the equator and progressing north, *A*, through *V* (less *I* and *O*) carry the system through the first two GZD and into the third. Thereafter, the abbreviated alphabet is repeated in the same order as many times as is necessary to reach the 80-degree parallel. The increment is 2,000,000 meters. South of the equator the vertical lettering of the squares is also from south to

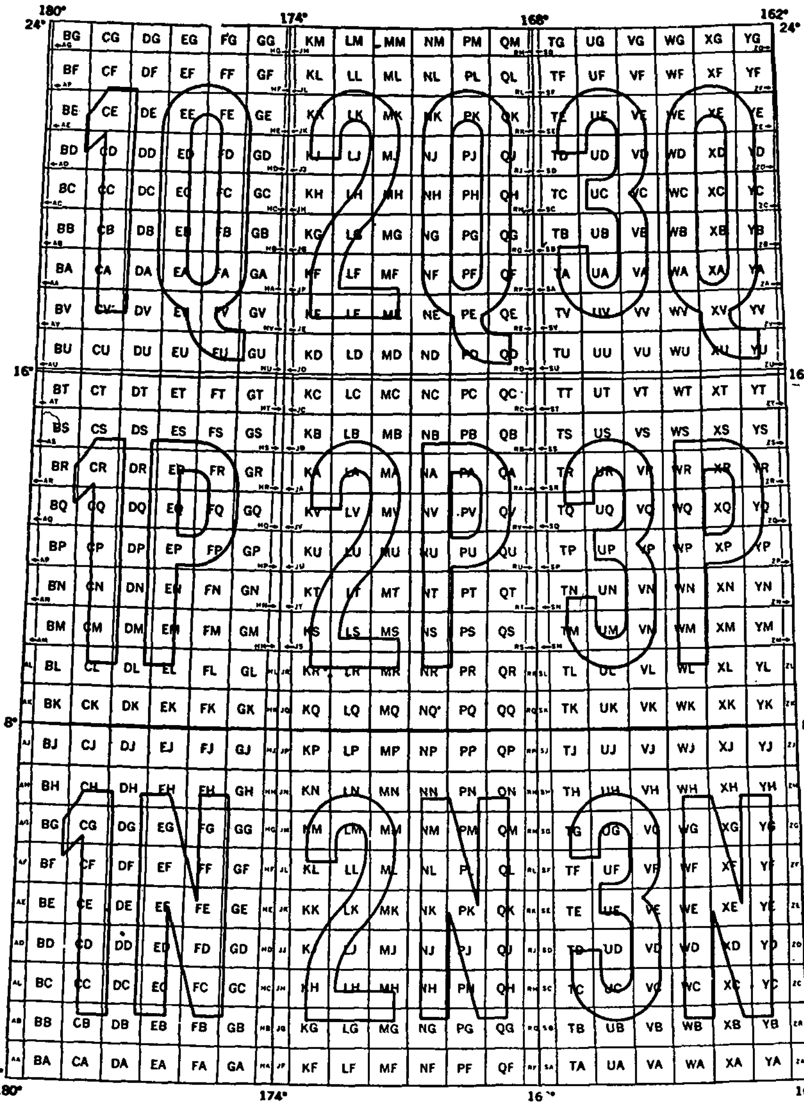


FIGURE 70. *Basic plan of the 100,000-meter square identification with the UTM grid.*

north, using the same shortened alphabet, but in reverse arrangement in order to connect with the designations just north of the equator without conflict. In figure 70 the two letters of designation are entered in each square. It should be noted that they are obtained by the basic rule of *read right up*. The above system of lettering the squares in a north-south direction is true only of the first increment of west-east lettering, which covers zones 1, 2, and 3. Lettering of rows in odd-numbered zones normally begins at the equator, and in even-numbered zones, 5 rows south of the equator; this staggering lengthens the distance between 100,000-meter squares of the same identification, and prevents ambiguity of identification of 100,000-meter squares along grid junctions.

(2) *UPS Grid Breakdown.* The polar areas are similarly divided into 100,000-meter areas and designated by two letters in such a manner that duplications do not exist within any one of the four GZD's. Figure 71 shows how, for the North Polar region, 100,000-meter spacings are laid out along the two axes of origin, the 90-degree and 0 to 180-degree meridians. Vertical and horizontal lines respectively are drawn through these spacings, forming the squares of the subdivided grid. Lettering the divisions along the 90-degree meridian begins with J for the first square on the left edge of zone *Y*, which is shown to be very much shortened, and progresses through *Z* (toward the pole). The letters *I* and *O* are omitted according to the precedent set in lettering the UTM subdivisions. In addition, letters *D*, *E*, *M*, *N*, *V*, and *W* have also been omitted, to avoid confusion with 100,000-meter square designations of the UTM system at the 80-degree parallel where the two systems join. In carrying on the lettering of the 90-degree meridian across zone *Z*, the squares are lettered *A* through *R*, reading from left to right, with the same letter omissions as exist in zone *Y*. Grid north is represented by an arrow on figure 71, and it indicates the direction for lettering the spacings along the 0 to 180-degree meridian. The lettering begins at the 0-degree intersection on the 80-degree parallel and progresses through the alphabet, *A* through *Z* (less *I* and *O*) reaching the 180-degree intersection of the same parallel on the opposite side of the pole. Again, the designation of each square is a matter of *read right up*. The identification of squares at the South Pole is almost the same as for the North Polar Zone. Conversion of figure 71 to fit

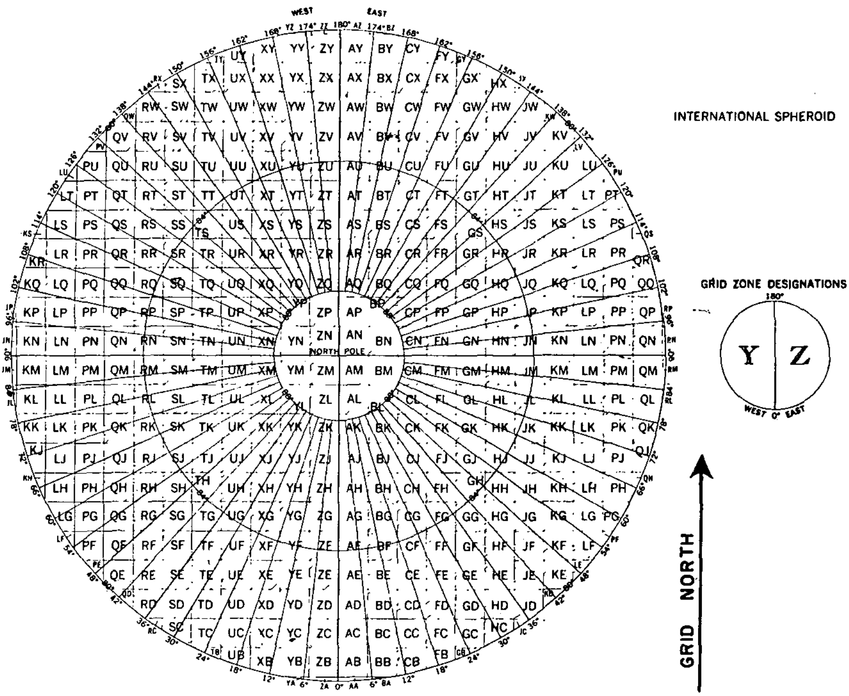


FIGURE 71. *The 100,000-meter square identifications of the UPS North Polar Zone.*

the system for the South Pole would require but two changes: substitution of GZD letters *A* and *B* for *Y* and *Z* respectively, and the interchange of the 0-degree and 180-degree positions on the 80-degree parallel forming the perimeter. Designations of the squares and grid north would remain exactly as they are.

c. Using the Grid Reference in Map Reading. In paragraph 81*d*, the designation of a point on a map by numbered rectangular coordinates was explained in detail. The grid coordinate of a point was described as a combination of numbers which identified that point on the map. Now, by use of the grid reference system, the same point can be located anywhere on the globe. All maps with UTM or UPS as the major grid have a grid reference box in the margin which shows the GZD and 100,000-meter square designation of the particular map. When these two identifications are prefixed to the original numerical reference, the point is given world-wide position. Samples of the reference boxes on the two categories of maps having grids are shown in figures 72 and 73. It should be noted that complete instructions are outlined for point referencing and use. The full reference provided by this system is not always necessary in point designation, as implied by the sample reference in the two reference boxes. The degree of reference required is dependent on the expanse of the theater of operations. In general, if the theater of operations is entirely contained on one map, there is no need for the larger area designation; the numerical reference is sufficient. Similarly, if the theater is larger and covers more than one 100,000-meter squares, the two-letter identification should be added. Furthermore, should the operating area overlap zones, that is, be wider than 18 degrees in any direction, the GZD must be added to distinguish the particular zone. In short, it is a matter of common sense to decide

GRID ZONE DESIGNATION: 18S	TO GIVE A STANDARD REFERENCE ON THIS SHEET TO NEAREST 100 METERS		
100,000 M. SQUARE IDENTIFICATION	SAMPLE POINT: CIRCLE AT KENT POINT		
UT	1. Locate first VERTICAL grid line to LEFT of point and read LARGE figures labeling the line either in the top or bottom margin, or on the line itself: Estimate tenths from grid line to point: 2. Locate first HORIZONTAL grid line BELOW point and read LARGE figures labeling the line either in the left or right margin, or on the line itself: Estimate tenths from grid line to point:	91 6	09 1
IGNORE the SMALLER figures of any grid number; these are for finding the full coordinates. Use ONLY the LARGER figures of the grid number; example: 389000	SAMPLE REFERENCE:	916091	
	If reporting beyond 100,000 meters or if sheet bears an overlapping grid, prefix 100,000 Meter Square Identification, as:	UT916091	
	If reporting beyond 18° in any direction, prefix Grid Zone Designation as:	18SUT916091	

FIGURE 72. *Grid reference box shown in the margin of maps bearing the 1,000-meter UTM or UPS grid.*

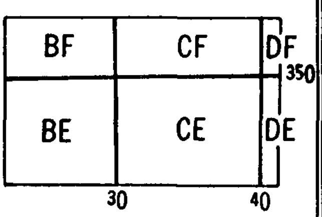
GRID ZONE DESIGNATION: 13R	TO GIVE A STANDARD REFERENCE ON THIS SHEET TO NEAREST 1,000 METERS			
100,000 M. SQUARE IDENTIFICATION	SAMPLE POINT: WINDMILL			
	1. Read letters identifying 100,000 meter square in which the point lies: 2. Locate first VERTICAL grid line to LEFT of point and read LARGE figure labeling the line either in the top or bottom margin, or on the line itself. Estimate tenths from grid line to point: 3. Locate first HORIZONTAL grid line BELOW point and read LARGE figure labeling the line either in the left or right margin, or on the line itself· Estimate tenths from grid line to point:	CF	6 9	3 5
IGNORE the SMALLER figures of any grid number; these are for finding the full coordinates. Use ONLY the LARGER figures of the grid number, example: 3440000	SAMPLE REFERENCE.	CF6935		
	If reporting beyond 18° in any direction, prefix Grid Zone Designation, as.	13RCF6935		

FIGURE 73. *Grid reference box shown in the margin of maps bearing the 10,000-meter UTM or UPS grid.*

how detailed the reference value should be to adequately label it for use.

Section V. MODIFIED BRITISH GRID SYSTEM

88. The British Grids

The British have established grid systems in many specific areas of the world. These systems have been based on different projections, dependent on the period of time when they were originated and/or on the shapes of the areas. Each grid has its own origin and arbitrary values for coordinates, and each grid has its own unit of measure, meter or yard. In short, as a need arose, a grid was established to best suit the need, and as a result, many scattered areas of the globe have grids established and in use. These grid systems were in wide use not only by the British but also by the United States. They cannot all be replaced simultaneously with the UTM or UPS grids, since the replacement of one grid by another requires the substitution of all new maps throughout an area in place of those with the old grid. For this reason, many of the British grids are still in use and, therefore, they are discussed here.

89. The British Grid Reference System

The british have established a reference system for their grid and its use is often necessary, because the British grid may be the only one printed on maps of the area. A grid reference box is printed with the map, to give specific instructions for making a reference. The boxes are modified to contain examples of point reference for each map, and to explain any departures from the standard system. Occasionally, it was necessary for the British to depart from the standard system of lettering in order to meet certain conditions of size and shape of areas, but where such cases exist, the reference boxes explain them.

a. The Standard Lettering System. Like the system used in the United States, the British system subdivides the area into 100,000-unit squares. Twenty-five squares comprise the next larger area, forming a 500,000-unit square in which the 25 squares are identified by the letters of the alphabet, less the letter I. Figure 74 demonstrates the system used to apply the 25 letters to the 25 squares. It should be noted that the lettering begins in the NW corner and progresses from left to right, and southward, row by row. This figure also shows how 25 such large squares are assembled and lettered in a similar manner to form the 2,500,000-unit square. Since there is no need for a more extensive one, this is the largest unit area in the British reference system.

b. Using the System for Referencing. Within the 100,000-unit square, the numerical reference is acquired by the same rule in use

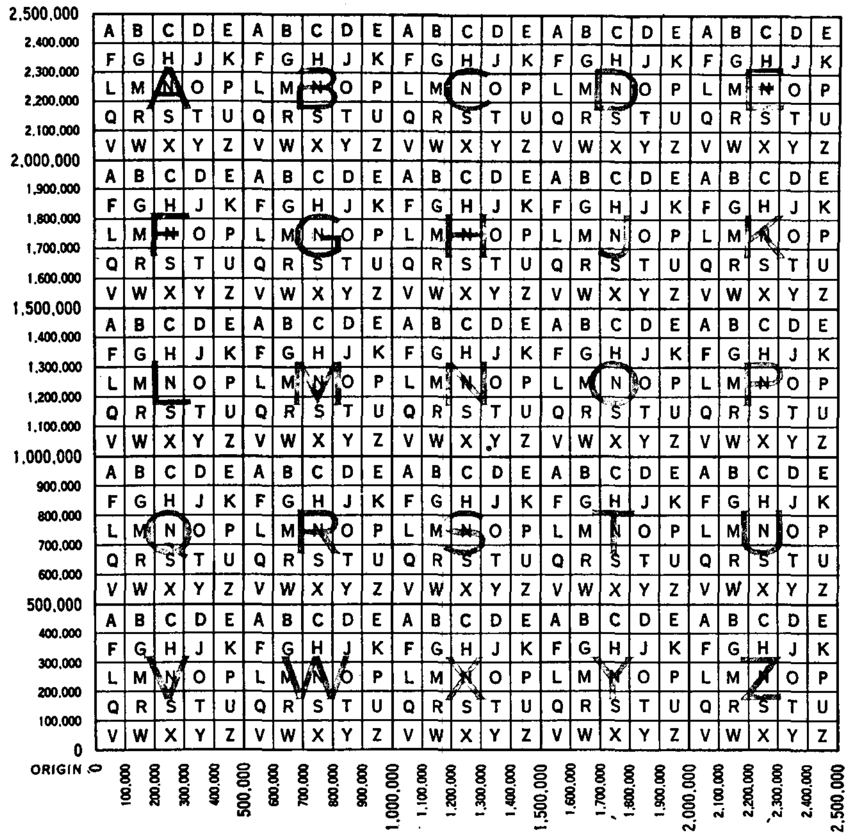


FIGURE 74. *Normal lettering plan for 500,000- and 100,000-unit squares of the British grid systems.*

in the United States: *read right up.* Particular British grids cover areas too small to identify the 100,000-unit squares by letter, and in these cases only the numerical reference is required. In the other cases, which are the more common, the two letters may be used as prefixes to the numerical coordinates of a point in order to identify the 100,000-unit and 500,000-unit squares in which the point lies. The 100,000-unit letter is always written preceding the first digit of the number. When the larger lettered square (500,000-meter) must be identified the order is first the 500,000-meter, next the 100,000-meter letter, followed by the numerical value of the coordinate. The extent of the theater of operations dictates how large an area must be identified by the reference in order to avoid confusion. Note that in the British grid system the numerical value must always contain an even number of digits. If the reporting area is confined within one 100,000-unit square, only the numerical reference is needed. However, when the area extends into two or more 100,000-unit squares, the particular square's identification letter must be prefixed to the number. Further, if the operation reaches across into two or more 500,000-unit areas, such areas must be specified in each reference.

Section VI. POINT-DESIGNATION GRID

90. Purpose

Since aerial photographs are seldom exactly the same scale as the map of the same area it is not feasible to print military grids on them. A special grid is used for designating points on photographs. This grid has relation to neither the actual scale of the photograph nor to the cardinal points of the compass. The point-designation grid is only a convenient method for point or target designations and must not be used to measure distances nor to determine azimuths.

91. Use

It is essential that all personnel designating points or targets on aerial photographs grid their photographs in the same manner. The method of dividing any aerial photograph into grid squares for point designation is as follows:

a. Turn the photograph so that the marginal title and number of the photograph, whether printed in the top or the bottom margin, is in the normal reading position. The edge nearest the reader is then considered to be the bottom edge of the photograph regardless of cardinal direction.

b. Draw lines across the photograph joining opposite fiducial (collimating) marks. If there are no fiducial marks the center of each side of the photograph will be assumed to be the location of the marks.

c. Space grid lines starting with the center lines, a distance equal to 4 cm or 1.576 inches (1,000 meters at a scale of 1:25,000). The coordinate scale can be used for this dimension, but this does not mean that the distances can be scaled from the photograph. Extend the grid past the lower left-hand corner of the photograph so that a horizontal and a vertical grid line fall outside the picture area. In cases where the photograph has been trimmed into the picture area, as shown in figure 75, the lower and left lines can be omitted but the numbering will be as if the lines had been drawn.

d. Number each center line "50" and give numerical values to the remaining horizontal and vertical lines (fig. 75) so that they increase to the right and up.

e. Reference to this grid will follow the rule: READ RIGHT UP. Any grid square will be designated by the coordinates of its lower left corner. Positions within any grid squares can be estimated (fig. 76) or measured using the cut-out scale (GTA 5–12)

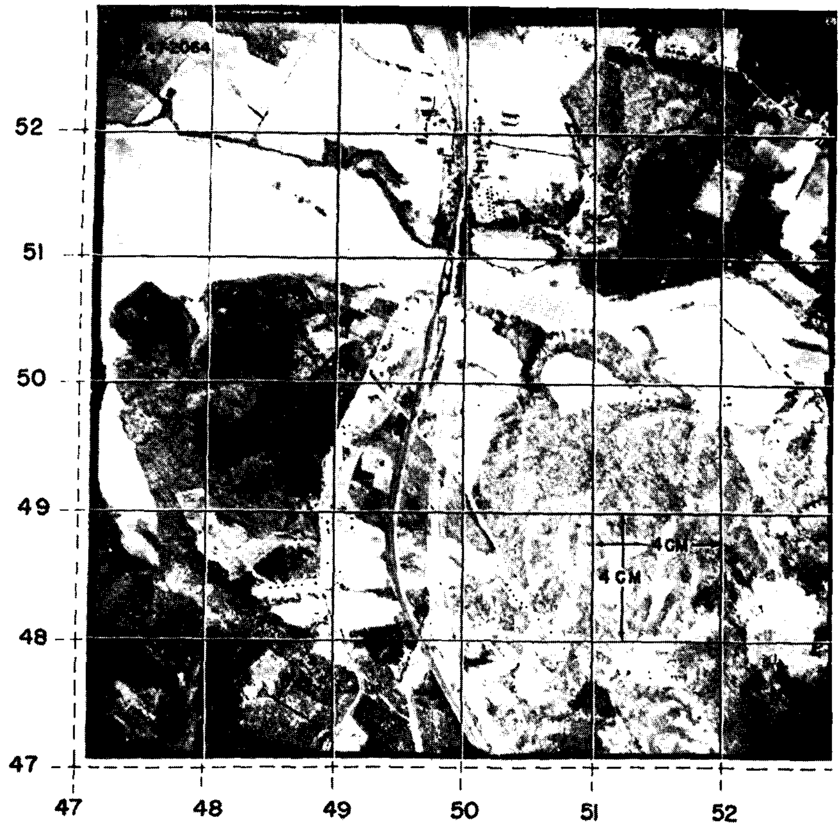


FIGURE 75. *Point-designation grid applied to an aerial photograph.*

as shown in figure 77. Messages involving this system wil state the number of the photograph followed by the location as: "On photo W47–2064 enemy tanks located at position 503515" or written as: "W47–2064: 503515". See figure 76.

f. It must be noted that there is no security value to this type of reference. It can only be used as a convenience. Where security is required the message must be encoded.

92. Fire Control

When the position of gun and target are known, a line drawn joining them on the grid represents the desired distance and grid azimuth. The grid azimuth and distance may be computed readily by using the differences in grid easting and grid northing between the position of the gun and that of the target as the legs of a right triangle. The hypotenuse will be the line "gun-target". The positions of guns, launching sites, and radar are normally located on the grid by field survey from existing ground control. This survey provides the required initial grid azimuth for orientation.

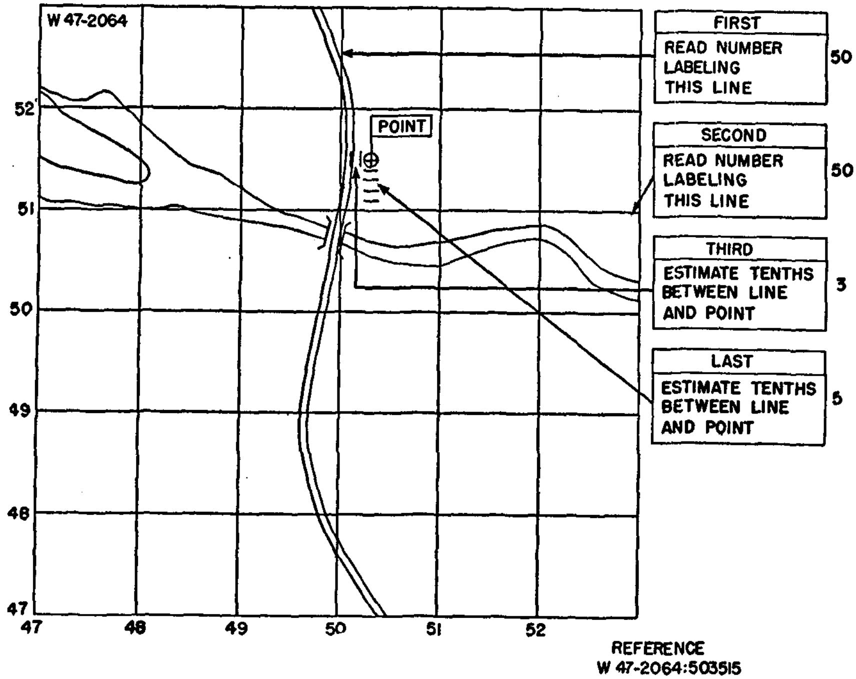


FIGURE 76. *Point-designation grid used to designate point on aerial photograph.*

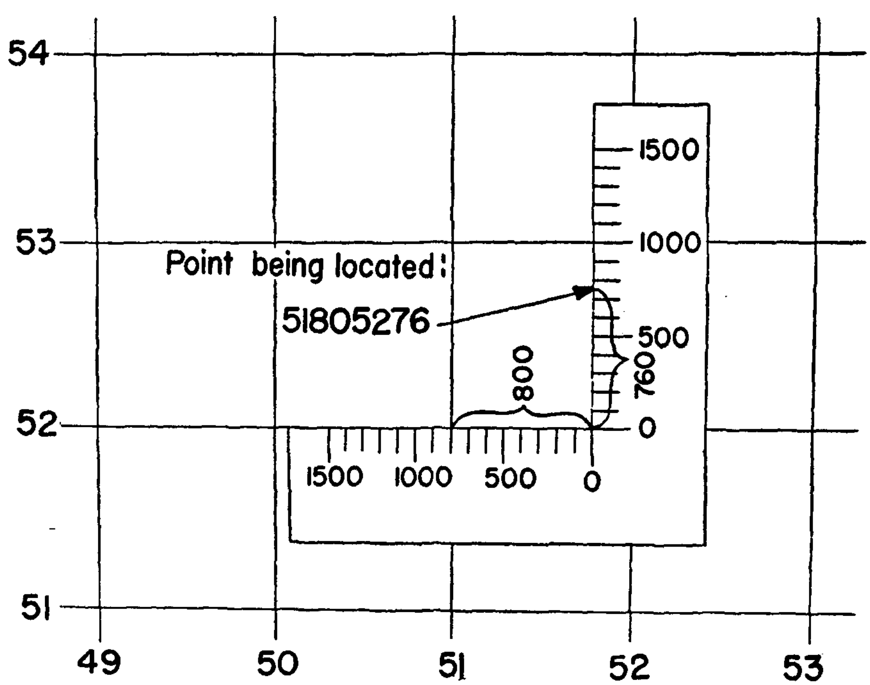


FIGURE 77. *Estimating tenths on coordinate scale.*

93. World Polyconic Grid

The world polyconic grid system has been in use in the many areas of the world where no other specific grid, such as the several British grids, has been adopted. Like the British grids (par. 88), the world polyconic grid is being replaced by the UTM grid for military use, and, therefore, is discussed only briefly here. The world polyconic system is sometimes called the yard-grid system, since the yard is its unit of measure. It divides the world into 5 equal east-west bands of longitude. Each of these bands has 9 equal zones, measuring 9 degrees in longitude with 1 degree overlap between bands and extending to the poles in latitude. Each zone has an established grid which serves as a basis for point reference in much the same manner as the UTM grid system.

94. Target Area Designator System (TAD)

The target area designator system is based on the military grid prescribed for an area of operations and takes its unit of measure from that grid. If it is the UTM system, for example, the meter would be the unit used. The TAD grid is surprinted over the regular military grid on many maps used in specific combat operations. It gives quick easy and accurate reference to a specific small area. It eliminates the necessity to follow marginal references into the face of the sheet, a procedure sometimes difficult to do accurately, especially by the pilots of small aircraft. The TAD system is a means of indicating points within a grid square on a map by subdividing it into 25 equal areas and labeling each as shown in figure 78. The grid thus formed is used for any square on the map and with it any point can be located by the use of a single letter. Designation of the square is accomplished by the Read Right Up method used when reading the grid referencing system on the map. There are two position reference systems for joint use by the U. S. armed services and all elements thereof. They are— (a) The geographic coordinate referencing system in which coordinates are expressed in degrees and minutes of longitude and latitude, and (b) the Military Grid Reference System (MGRS) as developed for use with the UTM and UPS grid system. Therefore, the TAD grid should not be used for joint combat operations and exercises wherein elements of two or more U. S. military services are employed in a coordinated effort against or in defense of ground objectives. In the TAD system a four digit number in the south-west corner is the basis by which any 1,000 unit square on the grid is identified, just as 6099 identifies the shaded square in figure 64. If the military operation covers an area extending 25 miles or more into the next larger division of the grid, it is necessary to identify the 100,000 unit square. Most grid systems employ the 100,000 unit square, but if not, a similar unit must be selected for use. In many cases, the operation is confined to the area of a few adjoining maps, or even a single map, and there is no need to designate the 100,000 unit square. The actual identification is by letters or by the map title if no other method is plausible. For example, assuming the use of the UTM grid, a point might be TAD-referenced (fig. 79) as follows: UT93115S in which the UT denotes the 100,000 unit square, the numbers indicate the particular 1,000 unit square, and the S specifies the section of the smaller area square. The point located is long point. The rules governing the use of TAD specify its inclusion as part of the reference. However, commanders in the field have the prerogative of ordering the omission of its use for certain operations. This grid is printed on the face of the map or chart, in the margin or in one of the grid squares where detail is scarce or lacking altogether.

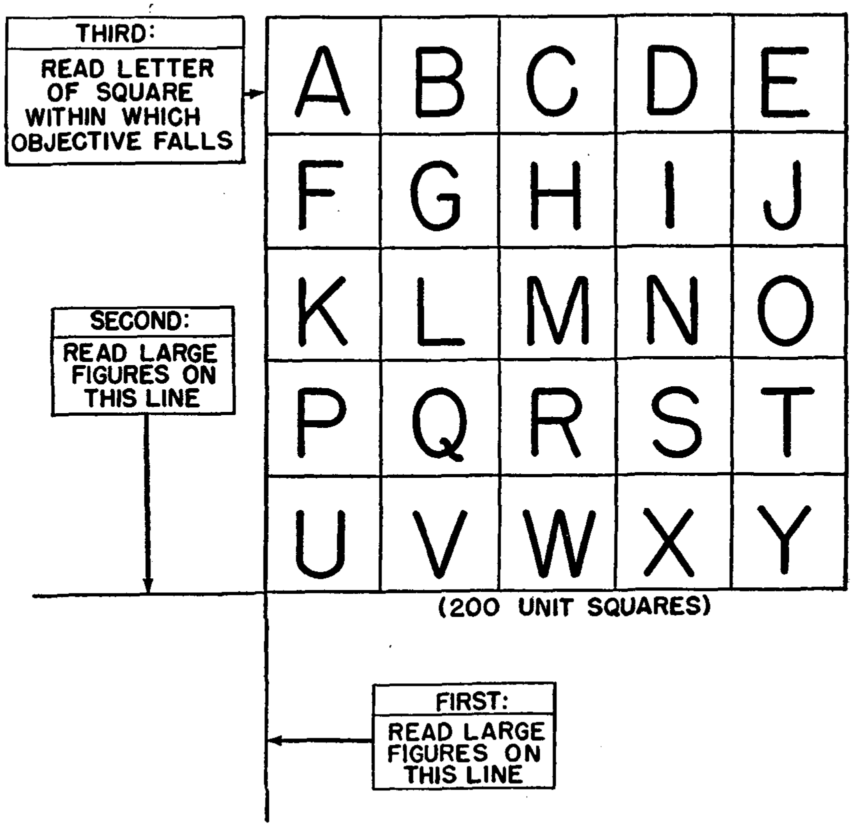


FIGURE 78. *Target area designator grid square.*

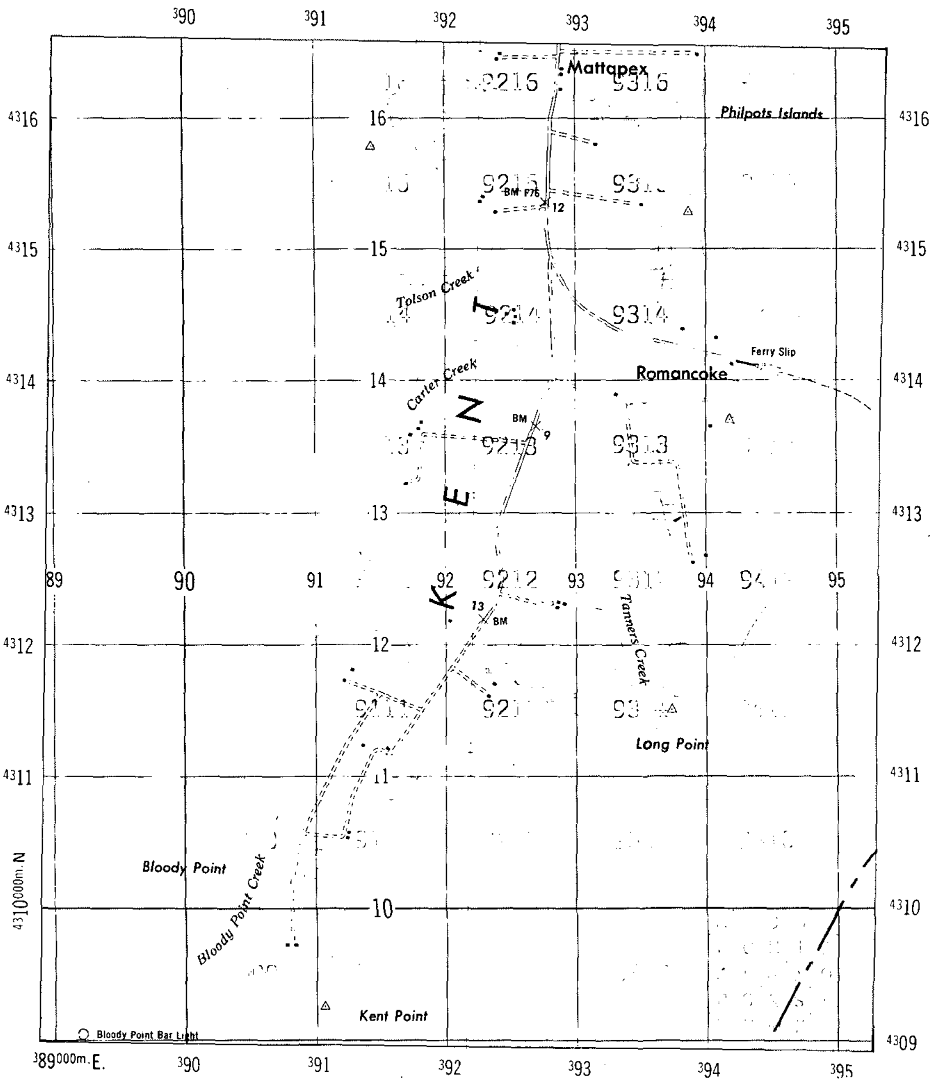


FIGURE 79. *Large-scale map showing the TAD grid.*

Section VIII. MAP CODING SYSTEMS

95. Expedient Point Location Systems

In the past, field commanders have attempted to devise original point location systems or map codes for their own use. Their purpose was to transmit map information in a form which would be unidentifiable to the enemy. In most instances, enemy intelligence has found these codes readily decipherable. However, some of the systems devised were found to have merit for specific situations, and two of them are described here briefly. They are the thrust line and the polar coordinate systems.

96. Thrust Line System

In the thrust line system, a designated line is selected as the coordinate base. The line is usually extended on the map into known enemy territory. It is located on a map by two reference points on the line, or by a point on the line and the azimuth of the line. A designated point on the thrust line is the point from which coordinates are measured. The location of any point is then referenced by distance to the base point and the base line. The system is limited in the area it can cover, and for this reason its use is limited to small units. Its use is also limited to relatively short periods. Its use is authorized only on ungridded maps.

97. Polar Coordinate System

In the polar coordinate system, a code is devised for expressing point location in terms of an azimuth and distance from one important point on the ground to another. It could be used by a sentry to report enemy activity, discovered from a point of ob-

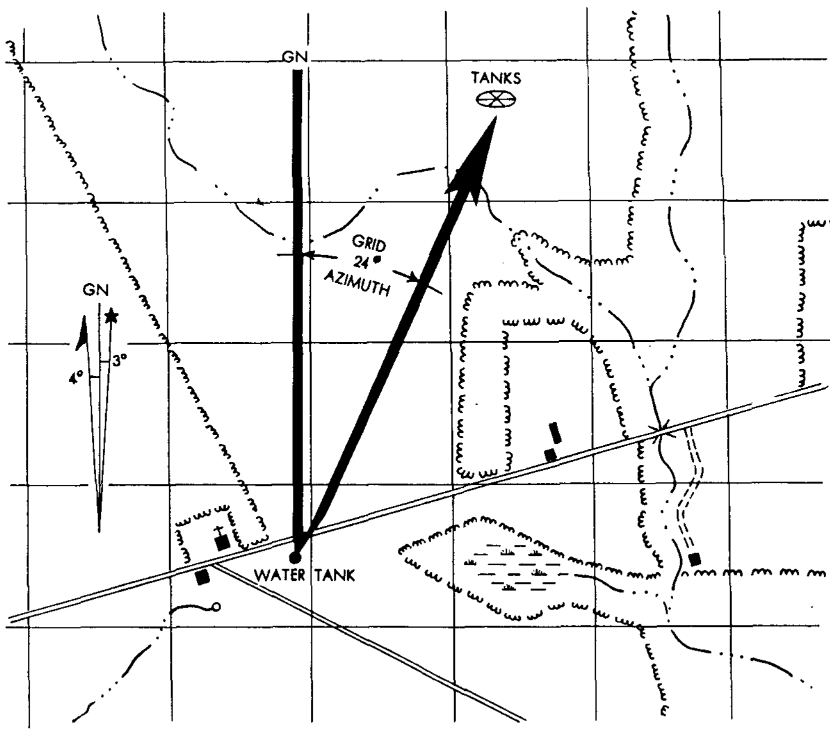


FIGURE 80. *Polar coordinates used to designate position on map.*

servation. To do this the sentry reads an azimuth from his position to that of the enemy position, estimates the distance, and reports the two values to his unit commander. Only the azimuth and distance are necessary since, by prearrangement, his unit commander knows his position. For example, an observer posted on a certain high point discovers enemy tanks approaching from a given direction. By using his compass he determines the direction *to be azimuth 24° and he estimates the tanks to be about two miles* away. Knowing that he is to use polar coordinates to designate position, and to use degrees of azimuth and yards of distance, the sentry sends back the following message: AZIMUTH 24°, DISTANCE 3500, ENEMY TANKS. (Magnetic azimuth 28° minus 4° W declination.) There is no need for the observer to include his position in the message, since this is known by his unit. Upon receipt of his message, the unit commander can establish on his own map the position of the enemy tanks. Figure 80 shows how to designate position by means of polar coordinates. Note that the magnetic azimuth is first converted to grid azimuth before application to the map. The polar coordinate system offers little security and it is suited only to small units in a static position.

CHAPTER 5

LOCATION BY INTERSECTION AND RESECTION

Section I. INTERSECTION

98. General

This chapter deals with the location of unknown points on a map. These are points which can be seen on the ground, but are not marked on the map. The points to be located may be either distant, inaccessible points, or one's own position at the moment. The unknown points fall into two general categories—inaccessible points, and occupied points not readily identified on the map. Distant points are located by a method known as intersection, and one's own position is plotted on the map by resection.

99. Point Location by Intersection

The intersection method of locating a distant point on a map derives its name from the intersection of two direction lines drawn on the map from two separated and known points. Sights on the point of unknown position are taken from these two separated points, and the unknown map position is established by drawing these lines on the map from the known points to a point where they cross. Naturally, the direction of the lines must be accurate to establish a true position. The accuracy of the direction depends on the care taken in sighting from the two separate points. In intersection, there are two approved methods of sighting.

a. Intersection by Compass and Protractor Method. In general, the method of intersection by compass and protractor consists of selecting two known points on the ground, reading an azimuth from each to the unknown point, and using these angles to plot the direction lines on the map. These lines intersect at the unknown point. For a clearer understanding of the method, four steps in its use are listed.

(1) Select a position on the ground from which to read an azimuth to the unknown point. Locate the position on the map, and move to that position on the ground.

(2) Sight the compass on the unkown point and read the azimuth. Convert this magnetic azimuth to grid azimuth, and plot the direction line on the map through the posi-

tion from which the sight was taken. Chapter 3 details the plotting of azimuths with a protractor.

(3) Select a second position, mark it on the map, and move to it. It is important that the distance between the two selected points be neither too long nor too short. The ideal distance is one that is equal to the distance from the unknown point, but this is not usually possible nor feasible, because of conditions limiting the maneuverable area.

(4) Repeat step (2) from the second position. The point of intersection where the two direction lines cross on the map locates the unknown point.

b. Practical Application. A realistic problem, illustrating possible use of this method of intersection, is a determination of the location of an enemy gun position. If the artillery has the grid coordinates of the point, they can destroy it with gunfire. in order

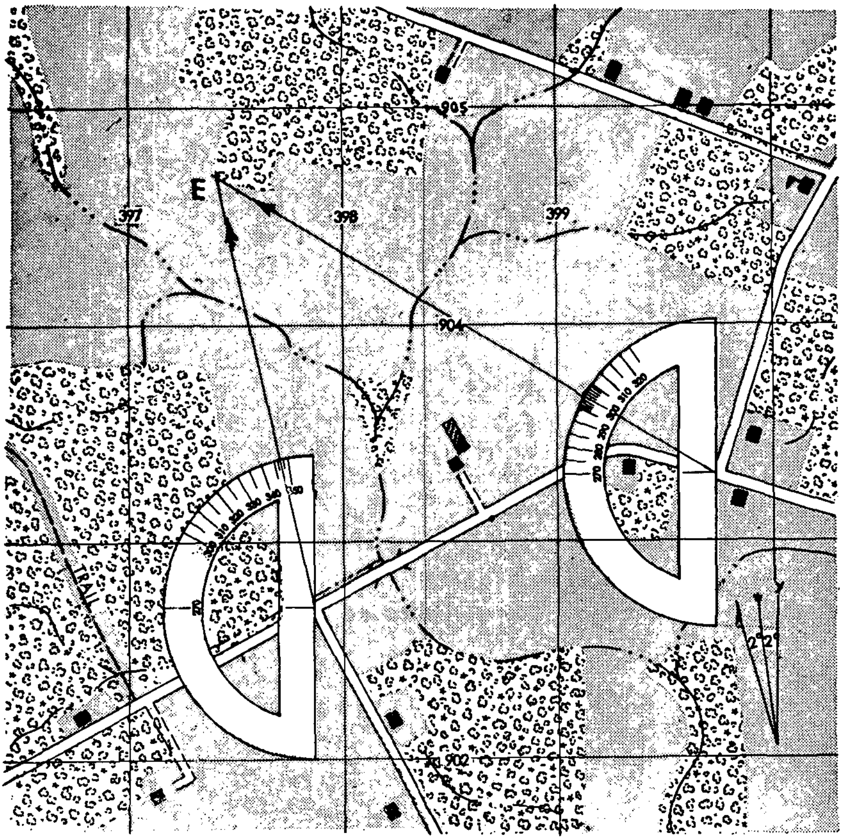


Figure 81. *Map location of a distant point using the compass and protractor method.*

to do this, the location of the gun position would be plotted on the map by intersection, and its grid coordinates read and transmitted to the fire direction center. The location procedure is illustrated by figure 81. The figure shows two road junctions from which azimuths have been read with a compass to the same unknown distant point, the enemy gun position. The two azimuths are being plotted with two protractors, and the enemy position at their intersection is shown located at E. It should be noted that the compass azimuths have been converted to grid azimuths by subtracting 4 degrees, as indicated on the declination diagram on the figure.

c. Intersection by the Graphic Method. Intersection by the graphic method solves the problem by direct sighting on the map, instead of by reading and plotting azimuths. The graphic method of intersection (fig. 82) is accomplished in five steps as listed below.

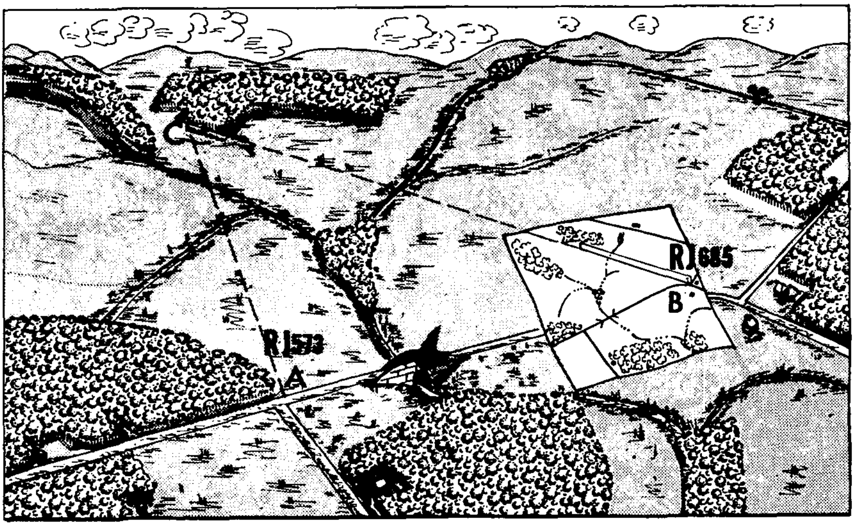


FIGURE 82. *The graphic method of locating a distant point on a map.*

(1) Select two separate points from which the unknown point is visible. In figure 82, these points are road junctions 573 (A) and 685 (B).

(2) Occupy one of the two selected points. Orient the map accurately by sighting along a straightedge laid on the line to a visible known point.

(3) Lay a straightedge on the map and pivot it about the point representing the occupied ground position until it is alined on the enemy position. A pin, placed at the pivot point (RJ–685, figure 82), aids in the sighting procedure.

(4) Draw a line on the map along the straightedge, to lead from the selected point and extend in the direction of the unknown point C (line B–C).

(5) Move to point A and repeat steps 2, 3, and 4. The second line locates the enemy strong point at the point where it crosses the first line on the map.

Section II. RESECTION

100. Point Location by Resection

Point location by resection is the method employed to locate one's own position on a map. The resection method is, in a sense, the reverse of the intersection method, since the direction lines are drawn to the occupied position instead of from two occupied positions. Yet, the two methods are similar in that each can be accomplished in two ways, by the use of the compass, and graphically. In general, two direction lines, from two identifiable objects, are plotted on the map, and their intersection locates the occupied position.

101 Methods of Resection

a. Resection by the Compass and Protractor Method. The compass is used to determine the directions, and the protractor is used to plot these directions on the map. The step-by-step procedure is detailed as follows:

(1) Select two ground features that are about 90 degrees apart, as seen from the position of occupancy. Orient the map as accurately as possible by inspection and mark the two points on it.

(2) Sight on the two features with the compass and read the azimuth to each.

(3) Convert the azimuths to grid azimuths and plot them on the map beyond the two respective features. Then, extend both lines backward towards the occupied position until they intersect, thereby determining this location on the map.

b. A Practical Application of the Compass and Protractor Method. Figure 83 illustrates a practical problem in resection. P represents the occupied position on the ground, which it is desirable to determine. RJ's 113 and 84 on the ground are selected and identified on the map. A compass azimuth of 30 degrees is read to RJ 84, and 327 degrees to RJ 113. Both are converted to grid azimuth by subtracting 4 degrees, as shown in the declination diagram, figure 83, then plotted with the protractor. Then the lines are extended backward to intersect at P, the occupied position.

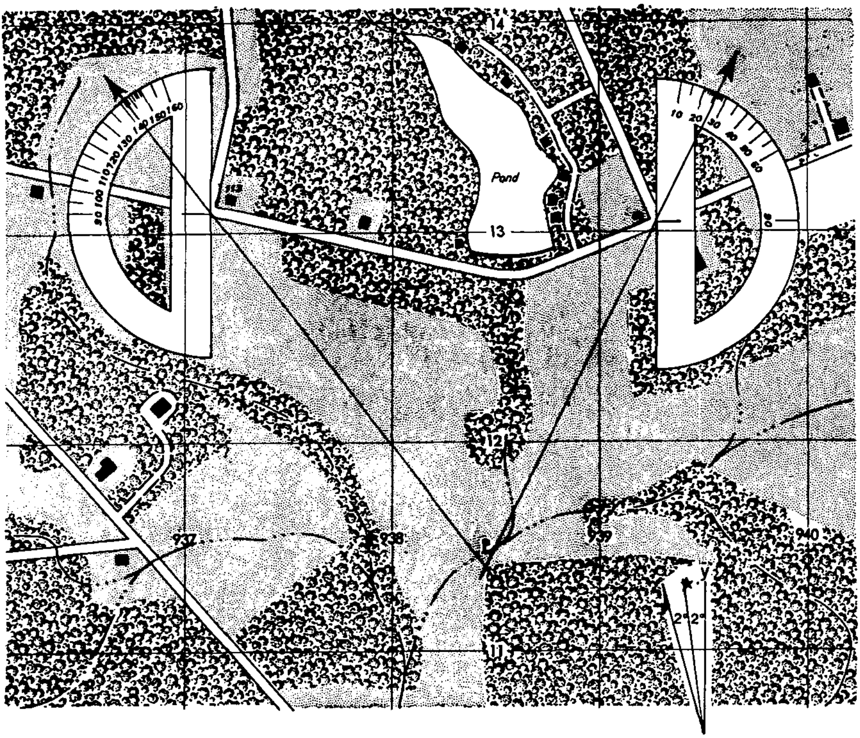


FIGURE 83. *Locating one's own position by resection, using the compass and protractor method.*

c. Resection by the Graphic Method. As in the intersection method, a straightedge is used on the map itself to sight on the distant objects and to guide direction lines to be drawn on the face of the map. The necessary steps in the procedure are as follows:

(1) Orient the map as accurately as possible by inspection by using the compass, and select two distant objects that are known on the map. Figure 84 illustrates this method.

(2) Place a pin in each of the two map symbols representing the two distant objects. With the straightedge pivoted against each pin one at a time, sight along the straightedge and aline one edge of it on the respective ground objects. Draw lines on the map representing the two lines of sight along the straightedge. Their intersection is the occupied location, or the wooded corner in the figure.

d. Three-Point Resection Method. Another graphic method of resection exists which is popularly known as the "three-point" method. It is not used as often as the methods described in *b* and *c* above since it requires additional materials that are not usually

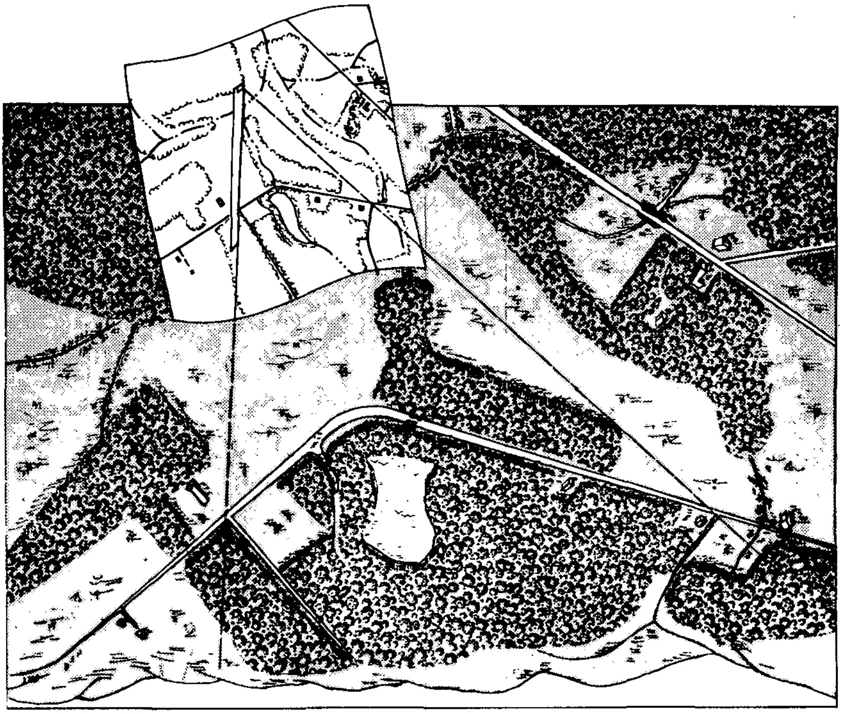


FIGURE 84. *Graphic method of resection.*

available for field use, and since it takes longer to accomplish; but it is considered the more accurate method of point location. Direction lines to three distant objects are drawn on a separate piece of drawing material and then transferred to the map to determine the unknown position, in the following manner (fig. 85) :

(1) Affix a piece of transparent drafting material to a flat and leveled surface. Place a pin in its center to represent the occupied location.

(2) Select three ground features at about 120 degrees to each other and identify them on the map. It is important to keep the angles as near 120 degrees as possible, since the nearer they are to 120 degrees, the more accurate the answer will be.

(3) Using the pin as a pivot for a straightedge, sight on the three ground features one at a time, and draw their direction lines radiating from the pin. Maintain the same orientation throughout the procedure.

(4) Place the transparency over the extended map, and shift it about until the three lines radiate through the three respective map objects sighted upon. In this orientation, the pinhole represents the occupied location on the map,

and can verify the original plotting if both are properly executed. Figure 85 illustrates the procedure for the three-point resection method of locating one's position.

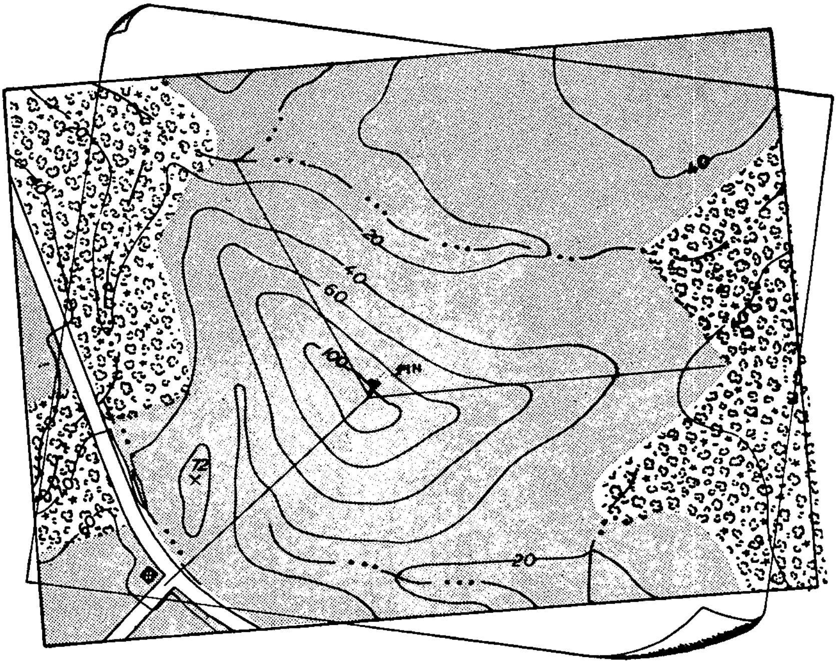


FIGURE 85. *Three-point method of resection.*

CHAPTER 6

USE OF FIELD SKETCHING IN DESCRIPTION OF LOCATION

102. Definition and Purpose

A reconnaissance sketch is defined as a large-scale freehand map of an area or route of travel, showing features pertinent to the mission requiring the sketch. In other words, the sketch is made for the explicit purpose of satisfying some special need, such as a supplement to a reconnaissance report or a patrol report. It is especially useful when available maps are not adequate. The sketch has been found to be the best means of reporting details, because it forms a picture showing their interrelationship, which is often difficult or impossible to express in words. An example is the description of point or position location. The sketch may be considered a supplement to a map. Sections of printed maps can be used as basic sketches to which the military features are added to suit the special need. However, maps are seldom produced at the large scales required of sketches. Photographs or aerial photographs can be substituted for sketches, or used to aid in drawing sketches. However, such photographs are not always available when needed or suitable when available, so should not be relied upon for use. Therefore, it is desirable for military personnel to be familiar with the general facts about approved means and methods of reconnaissance sketching for military use. This chapter presents the subject in detail with occasional reference to other chapters covering related activities.

103. Requirements of a Military Sketch

In order that a military sketch be of maximum value, certain factors must be taken into consideration before and during the preparation of a sketch. These factors are requirements of the sketch in regard to meeting the time element involved, the accuracy required, and the legibility and amount of detail indicated. All requirements are dictated by the situation and modified by practical considerations. Sketches may vary from hasty to complete and detailed. The degree of detail depends upon the time of completion deadline, the accessibility of the area, climatic conditions, the availability of trained personnel and equipment, and the purpose of the sketch.

104. Principal Features Sketched

Certain features are usually of military importance and are shown on a sketch. The degree of detail to which each feature is drawn, or of which notes are made, as well as the number of features included, must be in accordance with the purpose of the sketch. This detail could be any or all of the following items:

a. Trails, Roads, Highways, Railroads. Surfacing, number of lanes or tracks, width of surface, width and depth of ditches, cuts, fills seasonal passability, bordering features, bridges, culverts, junctions, elevations at critical points, grades, length.

b. Bridges, Causeways, Fords, Ferries. Size, clearance, condition, safe loading, normal water depth and velocity, type, elevation.

c. Streams, Bodies of Water, Springs, Glaciers, Swamps, Marshes, Tidelands. Width, depth, velocity, quantity, quality, endurance, bottom, junctions, elevations drainage system, tide influence, bank details, obstructions, surface details, unusual value.

d. Hills, Valleys, Ravines, 'Peaks, Cliffs, Ridges, Mountain Passes. Type and density of cover, outline, elevations, slope, height, depth, length, distinguishing characteristics.

e. Towns, Villages, Camps, Campsites, Power Lines, Communication Lines, Radio and Television Stations and Towers, Beacons, Radio Ranges, Airfields, Airports, Post Offices, Railroad Stations, Schools, Churches, Townhalls, Bus Stations, Federal Centers, Industrial Buildings. Name, size, outline, capacity, serviceability, category, surroundings.

f. Heavy Fortifications, Light Fortifications, Tank Traps, Obstacles, Wire, Mine Fields, Gun Emplacements, Outposts. Size, degree of camouflage, approach terrain, armor.

105. Detail Symbols for Sketched Features

Most of the features usually associated with reconnaissance sketches are those whose details can be drawn in standard map symbols with occasional notes for clarification of abnormal details. Authorized abbreviations for map use are found in appendix IV. Topographic symbols are covered in FM 21–31; military symbols, in FM 21–30. However, there is considerable detail or information regarding roads and bridges that is not covered by standard map symbols. Notes would be too extensive to use, and because this information is always imperative to the military, a special set of descriptive symbols have been agreed upon and are fully described in FM 5–36. Their use in sketching is briefly described below.

a. General. Symbols for the general characteristics of roads and bridges are given in table III; the symbols for engineer characteristics appear in table IV. Symbols for certain other special road characteristics are given in table V.

TABLE III. *Symbols for General Characteristics of Roads and Bridges*

Symbol	Meaning
W	Followed by numeral indicates clearance width in feet (or meters) provided at most critical location.
Clr	Followed by numeral indicates clearance height in feet between surface of roadway and overhead obstruction.
Cl	Followed by numeral indicates the class of bridge.
mi or km	Preceded by numeral indicates distance in miles (or kilometers).

TABLE IV. *Symbols for Engineer Characteristics of Roads and Bridges*

Symbol	Meaning
	Roads
mi	Preceded by a numeral, indicates length of road in miles between 2 points identified by dots on the map or overlay.
km	Preceded by a numeral, indicates length of road in kilometers.
ft	Preceded by a numeral, indicates width of traveled way in feet at the narrowest point.
m	Preceded by a numeral, indicates width of traveled way in meters at the narrowest point.
k	Concrete.
b	Bituminous surface treatment. The symbol "b" may be used with any of the other surface symbols to denote a waterproof bituminous skin. For example: rb—bituminous macadam; kb—bituminous concrete.
p	Paving brick or stone.
r	Crushed rock, coral, or waterbound macadam.
gl	Gravel or lightly metaled surface.
n	Natural or stabilized soil, sand clay, shell, cinders, disintegrated granite, or other selected material.
v	Various other surfaces not itemized above (to be described in reconnaissance report).
	Bridges
k	Concrete, slab, or beam.
ka	Concrete arch.
sb	Steel beam.
st	Steel truss.
sg	Steel girder.
sa	Stone arch.
wo	Wood trestle.
wot	Wood truss.
l	Length.
ht	Height above stream bed.
p	Panel length (trusses).
	Condition—stated as "excellent," "good," "fair," or "poor."
Clr	Overhead clearance.

wo 3 @ 15′
st 1 @ 75′
k2W9 1 @ 20′
ht 22 $\overline{\text{Clr–15 Cl 110′}}$
Good
1450 9–15–54

TABLE V. *Symbols for Special Road Characteristics*

Rating	Meaning	Symbol
Alinement		
Good	Flat gradients and easy curves.	"A" in numerator.
Fair	Steep gradient (in excess of 6 percent).	"Ag" in denominator.
	Sharp curves with radius less than 150 ft.	"Ac" in denominator.
Bad	Steep gradients and sharp curves.	"Agc" in denominator.
Drainage		
Good	Adequate crown or superelevation with adequate ditches and culverts in good condition.	"D" in numerator.
Bad	Inadequate crown or superelevation; ditches or culverts blocked or otherwise in poor condition.	"D" in denominator.
Foundation		
Good	Stabilized, compact material of good quality.	"F" in numerator.
Bad	Unstable, loose, or easily displaced material.	"F" in denominator.
Surface		
Good	Free of potholes, bumps, or ruts likely to reduce convoy speed.	"S" in numerator.
Bad	Bumpy, rutted, potholed, or excessively cracked to an extent likely to reduce convoy speed.	"S" in denominator.

b. Method of Recording Road Symbols. In order to describe a road on a sketch, its characteristics must be determined. The general characteristics are given in table III and appear on the sketch shown in figure 86. Other special road characteristics and their symbols are given in tables IV and V, and are placed on the sketch, as shown in figure 86, in the form of a *road classification fraction.*

(1) *Road classification fraction.* Road classification is expressed in the form of a fraction, with the symbols for good characteristics placed in the numerator, and the

symbols for fair or bad characteristics placed in the denominator. The numerator contains, in addition to the "good" symbols, the road width and the surface type. The denominator contains, in addition to the "fair" or "bad" symbols, the road length. The construction of the fraction is as follows:

$$\frac{\text{good characteristics} \qquad \text{road width} \qquad \text{surface type}}{\text{fair or bad characteristics} \qquad \qquad \text{road length}}$$

(2) *Example of road classification fraction.*

$$\frac{\text{FD 20 ft rb}}{\text{Agc S 6.4 mi}}$$

This fraction describes a stretch of road 6.4 miles long and 20 feet wide at the narrowest point in the traveled way. The road has a good foundation and drainage system, but bad alinement, with grades in excess of 6 percent and sharp curves with radii less than 150 feet. The road also has a bituminous macadam surface in bad condition.

(3) When characteristics cannot be determined, their symbols must, of course, be omitted from the sketch.

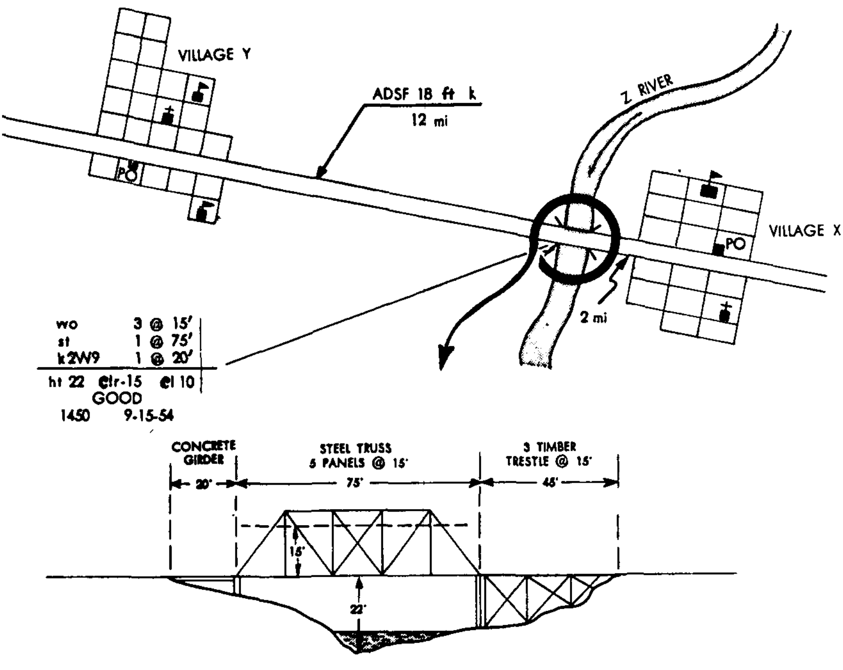


FIGURE 86. *Sketch demonstrating use of road and bridge data.*

c. Example of Road and Bridge Data Use on a Sketch. Figure 86 is a sketch showing road and bridge data between two villages, X and Y. One bridge and the road crossing it are involved. As observed at 1450 on 15 September 1954, the road has a good surface, foundation, alinement, and drainage; is 18 feet wide, and is an all-weather concrete road stretching 12 miles between Z and Y. The bridge is 2 miles from X and is a compound bridge over the Z river flowing south. It is 140 feet long and consists of a 45-foot wood trestle (three 15-foot sections), a 75-foot section of steel truss (five 15-foot panels), and a 20-foot concrete beam section, in order from X toward Y. The bridge has a 15-foot clearance, is 22 feet above the stream bed, and its capacity is class 10.

106. Types of Reconnaissance Sketches

Military sketches are divided into two main classifications, road sketches and area sketches.

a. Detailed Road Sketches. Road sketches cover the area along a line of movement, a path, a road, or even cross-country. All the features along the road are sketched to an average width of about 400 yards on each side. The width is dependent on many factors, including the particular purpose of the map and the time allowed for its completion. Generally, the width is governed by the nature of the terrain, combined with visibility to right and

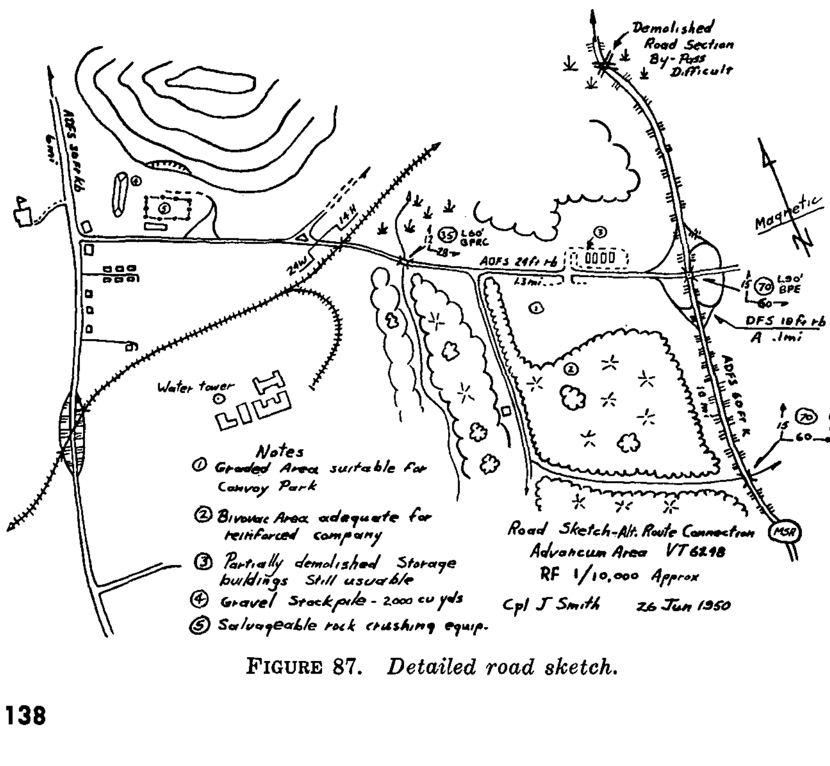


FIGURE 87. *Detailed road sketch.*

left. Therefore, sketches of roads through rather level areas, where features are sparse, tend to be of greater widths than sketches of roads through rough terrain. Figure 87 is a good example of a detailed road sketch, showing both tendencies.

b. Area Sketch. As the name implies, an area sketch covers a wide tract of land, rather than a strip of it. There are three classes of area sketches, based on the position of the sketcher.

(1) *Position sketch.* Such a sketch makes clear the relative positions of vantage points in any given area. To prepare the position sketch, it is necessary to have access to the entire area being shown, so that the vantage points may be selected, and significant distance may be paced. An example of a position sketch is shown in figure 88.

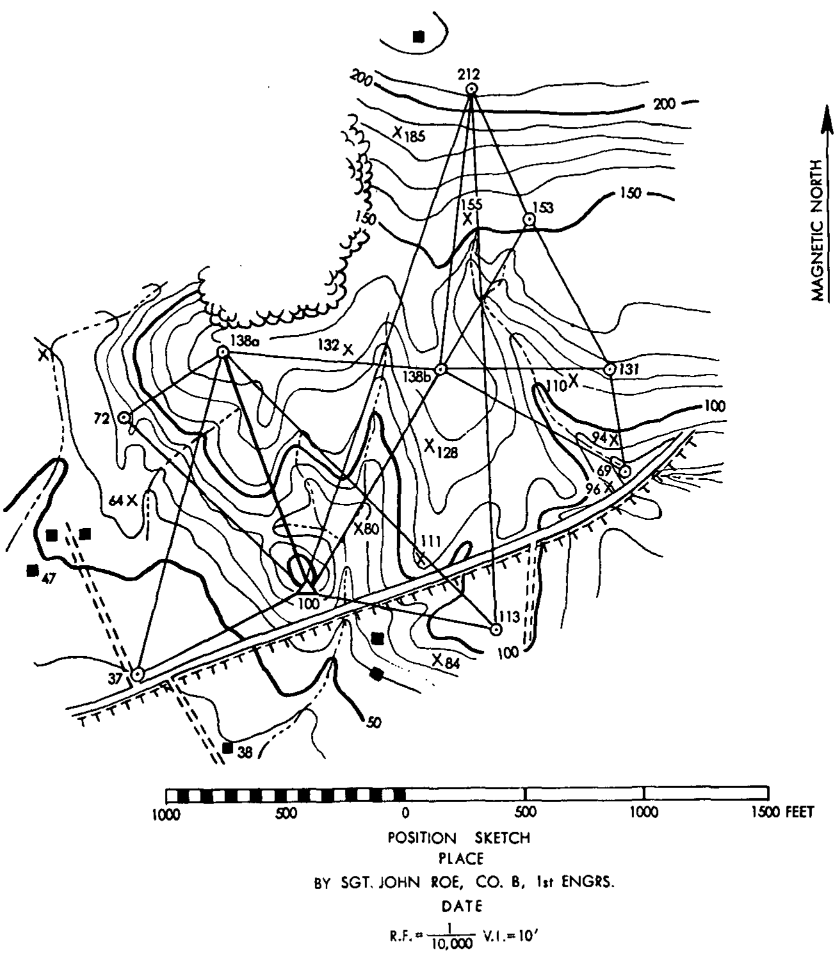


FIGURE 88. *Position sketch.*

(2) *Outpost sketch.* Outposts are usually connected by paths or boundaries beyond which it is not safe to go because of enemy action. The sketcher is forced to stay within this line while drawing and show only the features readily seen and for which distances can be easily estimated. An outpost sketch might be described as a base-line sketch.

(3) *Place sketch.* Such a sketch is made from one position, or a single vantage point of visibility. It may be made from an outpost, at the top of a cliff, or from any such position where movement is limited. It may be used as an extension to a route or area sketch, such as an extension into danger areas.

(4) *Panoramic sketching.* Sketches of this type are invaluable and are easily produced by observation posts and patrols. Panoramic sketch should indicate coordinates of position from which made, as well as distance and azimuth to at least one point on panorama. This type sketch can be made of enemy territory when others are impractical.

107. Basic Considerations in Reconnaissance Sketching

Once requirements and type are decided upon, other factors to be considered by the sketcher are scale selection and control. In addition, throughout the sketching process, care must be exercised in selection and proper positioning of detail.

108. Scale Selection

The principal factor in the selection of a proper scale for a sketch is the purpose for which it is being prepared. For example, a reconnaissance sketch to be used for planning engineer construction should be as detailed as possible, and the contour interval should be small, especially if earth movement might be involved. In this case, a large scale should be employed, 1:5,000 perhaps, with a 5-foot contour interval. Conversely, a sketch of a large area would need to show only the prominent features and could be drawn at 1:20,000 scale with 20-foot contours. The scales of sketches prepared for the use of any given military unit are governed by restrictions as to the size of the area over which the unit may maneuver. Time, available equipment, and trained personnel also influence the selection of scale, but only to a minor degree. In general, the best scales for sketches are large in comparison to those normally used for maps, and these may vary from 1 inch equals 100 feet, to 1 inch equals 1,500 feet. Once a scale is selected, the sketcher needs a graphic scale to correspond. This may be found in standard equipment, but if not, it should be prepared in advance of actual sketching.

109. Control and Attention to Detail

Elsewhere in this manual, it has been pointed out that a map is no better than the control on which it is compiled and the care exercised in the compilation procedure. This is also true of sketches. Basic control and care in its preparation are the essential requirements of a sketch, since accuracy and reliability depend upon them.

a. Control. It is always desirable to have at least one point of absolute control (major control) for each sketch, and as many secondary (minor control) points as are required to fulfill the mission. Control, as mentioned here, means both horizontal and vertical control, since the sketch portrays both the horizontal position of features and the topography or vertical picture of the whole area, usually by means of contours.

(1) *Major control.* A network of control of both types covers the United States. It is based on common origins known as datums, one for horizontal control and one for vertical control. Stations in the network are identified on the ground, usually by concrete monuments with brass nameplates affixed on top. Any and all of these stations are major control, and if all sketches are based on them, they are on a common datum. Furthermore, they are on the same datum as standard maps, which means that sketching data can be applied to, or used in conjunction with, maps. The difficulty in fulfilling the sketching principle of always having one or more major control points in the area covered by every sketch is that very seldom does an established station in the network fall within the area.

(2) *Minor control.* As work progresses, secondary control points are established throughout the area. These points are tied to the major control and become the minor control for the sketch. Collectively, they serve as the framework upon which the features and their details are placed. The methods used to position these points and carry elevations are described later in this chapter.

b. Attention to Detail. After control is established, the second basic principle of sketching is applied. Care is exercised in positioning features and relief on the control network, with speed and good judgment combined throughout the procedure. The ability to fill in suitable details on the sketch is a direct result of experience, and it constitutes at least half of the sketching activity. A good sketcher has developed a "feel" of the ground; selection of the important features or points is instinctive, these being points that

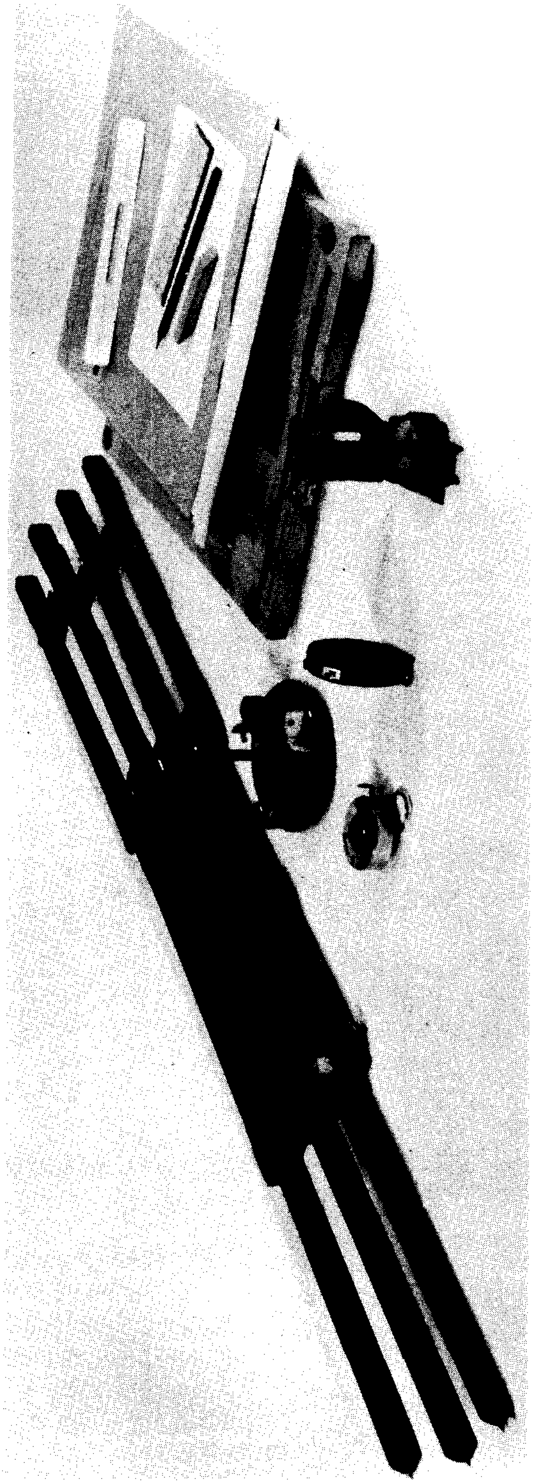


FIGURE 89. *Military sketching set.*

give the best advantage for locating other points and features. Care in preparation becomes automatic.

110. Sketching Equipment

There is a standard military sketching set containing all the items of equipment required for sketching. Figure 89 shows some of the equipment contained in a military sketching set. Certain of the items are expendable; others are not. The standard set contains the following items:

a. Equipment.

(1) Triangular boxwood scale.
(2) Sketching board with waterproof cover.
(3) Folding tripod.
(4) Clinometer with leather case.
(5) Lensatic compass with leather case.
(6) Pace tally.
(7) Rectangular protractor.

b. Supplies.

(1) One-half gross sketching paper ($12\frac{1}{2}'' \times 13\frac{1}{8}''$).
(2) Sixteen drawing pencils (3H).
(3) Four pencil erasers.
(4) Twelve thumbtacks.

111. Alidade

The triangular boxwood scale in the standard sketching set is also the alidade, or sighting device. It has a triangular cross-section, as shown in figure 90, and is used for plotting direction lines to objects being sketched. Figure 90 also shows the three surfaces of the scale with the many scales printed on them for use during the preparation of the sketch. Note the eyelet at one end, for use as a plumb bob (it has a lead plug in its center to add weight for better stability).

112. Alidade Scales

The use of the boxwood scale as a line-of-sight and plumb bob needs no explanation, but it is necessary to discuss the scales printed on its three flat surfaces. The scales shown in figure 90 are not necessarily standard. They do, however, represent the scales of average use in sketching. These are 1:20,000, 1:10,000, 1:5,000, a scale of yards, a slope scale, an inch scale, and a stride scale. Their purpose is for use in plotting distances on the sketch, and several are supplied in an attempt to answer all sketching needs.

113. The Sketching Board

This is the flat surface upon which the sketch is prepared. It is fabricated of wood and designed to withstand weather and a

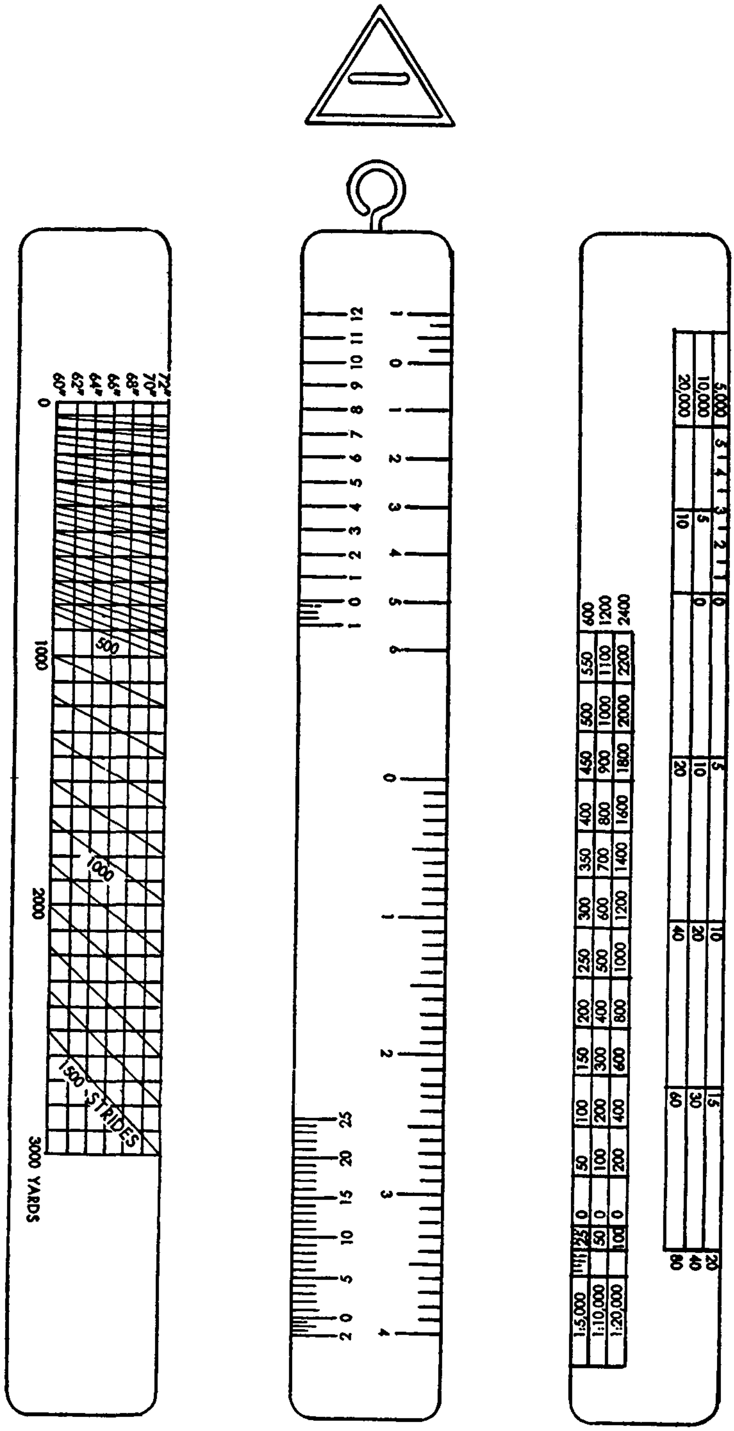


FIGURE 90. *Sketching alidade.*

certain degree of faulty handling. It is supported on a lightweight tripod with adjustable legs. A magnetic needle is inset on one edge of the board and scales are stamped into the other areas, as shown in figure 91, which pictures the board's upper or working surface. Four brass thumb-screws are provided at the corners for fastening the drawing paper to the board. Often, however, the use of scotch tape is preferred. The slope scale seen on the bottom edge is designed for emergency use when a clinometer or some other slope-measuring device is not available. The board is turned on

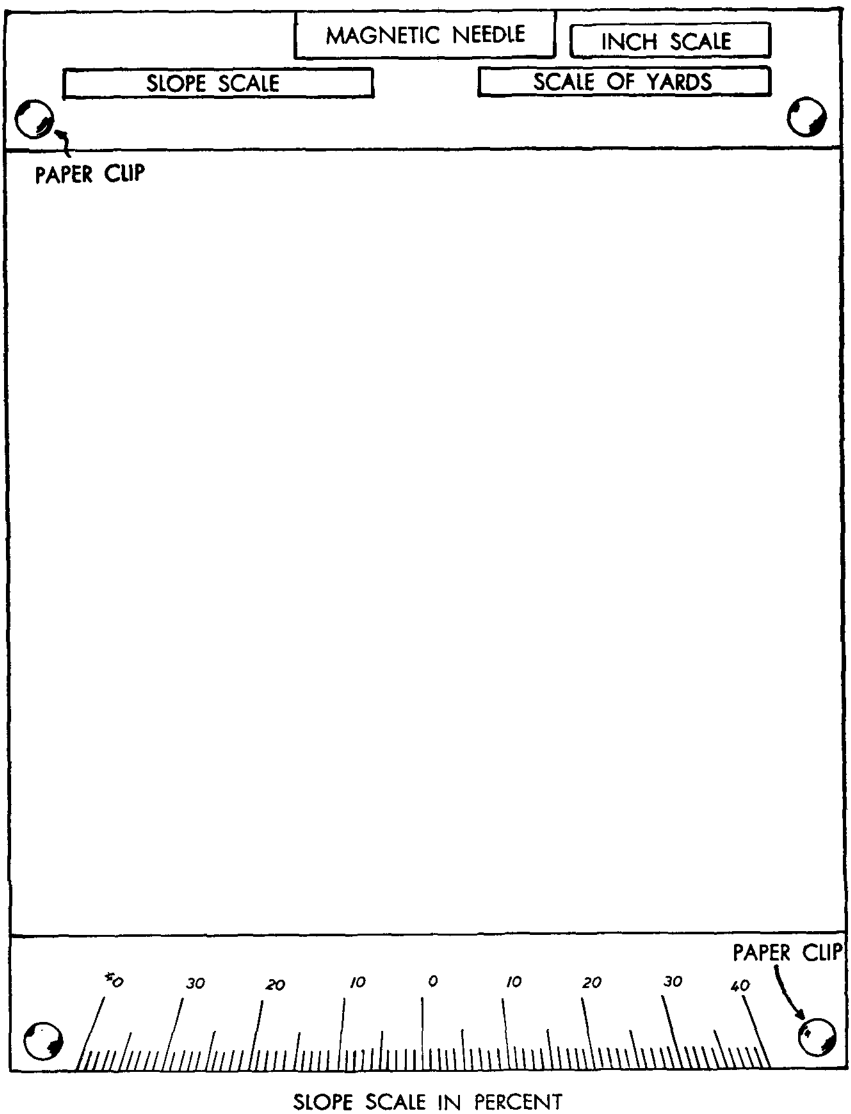


FIGURE 91. *Sketch board (top view).*

edge and used to determine slopes. Figure 92 shows an improvised slope board in use. At times the equipment in the sketching set will not be available when a sketch is desired. In such case, accurate sketching tools can be fabricated out of scrap materials if the sketcher properly understands construction of the alidade scales and slope board.

114. The Clinometer

This is a service instrument designed for reading slopes in percent. It operates on the pendulum principle, with the mecha-

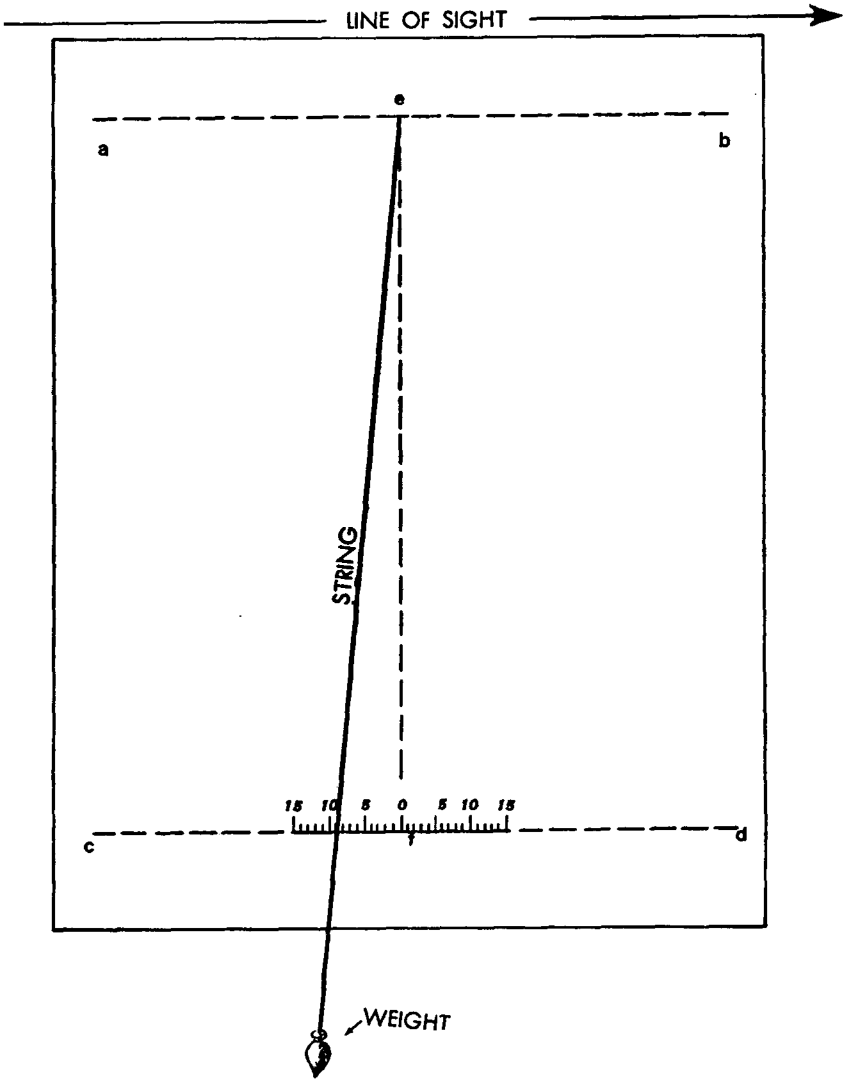


FIGURE 92. *Slope board.*

nism arranged in such a manner that the true slope is readable when the pendulum comes to rest. The observer sights through the instrument at a slope-point on the ground and reads the scale in the same glance. When the scale reads zero, the slope is also zero, and in this manner the instrument can be used as a hand level for determining elevation differences. Figure 93 shows, in cutaway, the working parts of the clinometer.

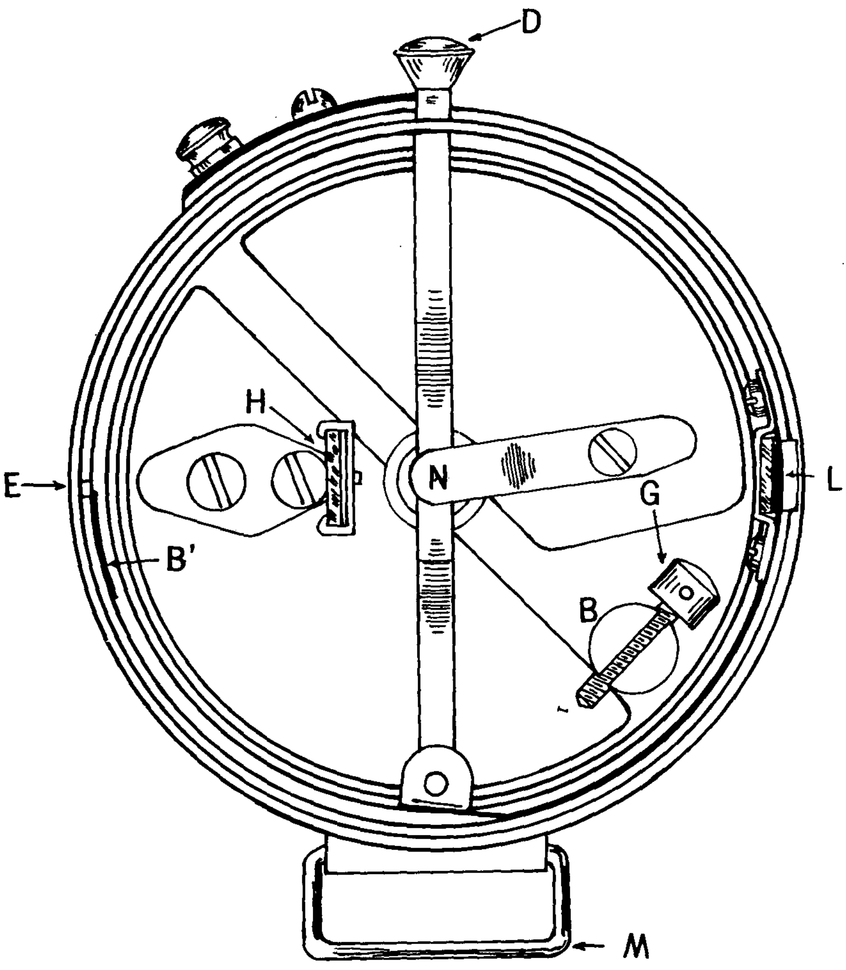


FIGURE 93. *Clinometer.*

115. Operating the Clinometer

The method of making observations with the clinometer is best presented in step form, as follows. Reference is made to figure 93, which shows the clinometer with the side of the case removed and the working parts labeled.

a. Place the clinometer upright against the cheek and aline E and L on the target by sighting through the instrument. To get an average slope, the target must be elevated by an amount equal to the height of the observer.

b. Release the pendulum by sliding the bar and pressing stop D. Bring the pendulum to rest by temporarily damping with the stop D.

c. Read the slope percent in mirror H, which magnifies the reflection from the scale B. Red figures indicate a plus or ascending slope, while black figures designate a minus or descending slope. It is extremely important to take readings only when the pendulum is at rest.

116. Calibrating the Clinometer

It is advisable for the sketcher to check the adjustment of his clinometer before using it, especially if it is a different one than previously used, or one unused for a considerably period of time. In other words, it must be proved that the instrument reads true slopes. This check can be made roughly by sighting on a level course such as a lake surface; the dial should read zero. However, a better method is to select a slope and read it from both ends. If the reading is the same value, but opposite in sign (plus, minus), the instrument is in adjustment. Otherwise, it is not in calibration and should be either adjusted or the error noted and a correction made accordingly on all readings. For example, if the foresight is plus 6 percent and the backsight over the same course is minus 4 per cent, the error is plus 1 percent, since it should have read 5 and 5. The plus 1 percent error can be subtracted from all plus slope readings and added to all negative slopes. But the chances of doubling the error rather than eliminating it are too great. It is better to take the time to adjust the instrument by turning screw G, as in figure 93, until the readings are equal and opposite by actual ground tests.

117. Using the Clinometer to Determine Elevation Differences

The percent-of-slope reading which a clinometer affords the sketcher can be used to quickly give the difference in elevation between the two points at the extremities of the slope. Knowing this value and the sea-level elevation of his occupied position, the sketcher determines the elevation of the foresight point by a simple addition or subtraction. The difference in elevation is obtained by multiplying the slope reading by the horizontal distance. Since 1 percent of slope means a rise of 1 unit in 100 units of horizontal distance, the elevation difference obtained is in the same units as those used for measuring the horizontal distance. Its value is determined by placing the decimal point properly, at

2 ciphers from the right. For example, a plus-3-percent slope, measuring 48 feet on the sketch, will show a (.03 × 48) 1.44-foot rise, and an 18-percent drop in a 260-yard horizontal distance will show a negative elevation difference of (.18 × 260) minus 46.80 yards. Figure 94 illustrates the measurement of a slope. A to B is a negative slope, and B to A is a positive slope.

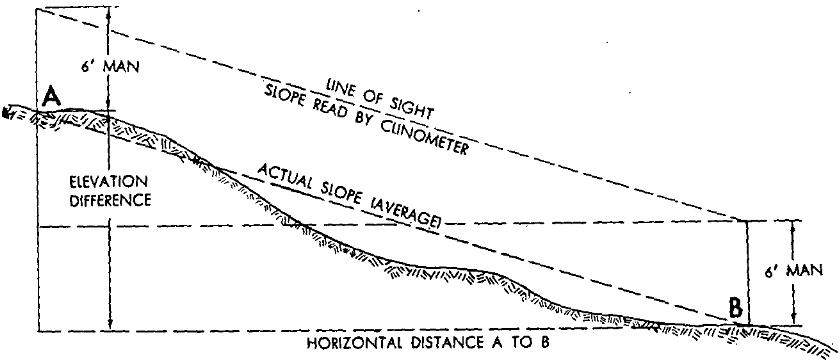


FIGURE 94. *Clinometer use in measuring slope elevations.*

118. The Compass

The lensatic compass is usually furnished as part of the standard sketching equipment, but any of the other service models may be substituted for it. The makeup and use of the lensatic compass is discussed in chapter 3, and its use for control in sketching is described later in this chapter.

119. The Pace Tally

The purpose of this device is, as the name implies, to record paces as they are stepped off. It is operated by pressing the trigger as each step is taken. The mechanism automatically records a total, which is read on the central dial.

120. The Rectangular Protractor

The tool is a rectangular piece of durable transparent material about 2 inches wide and 6 inches long. It is beveled on one surface at the four edges and is graduated to plot any azimuth, which is its primary function. However, it is very useful as a straightedge, a scale, a parallel ruler, and for many other purposes.

121. Assembly of the Sketching Equipment

Assembling sketching equipment means attaching the sketching board to the tripod to form the working surface or elevated table on which to prepare the sketch. The tripod legs are extended and secured, and a mechanical head is fastened at the top. To this head, the board is affixed and the sketching table is ready for use.

122. General Mechanics of Sketching

The two main principles of sketching are always adhered to, as discussed previously—control is established, and details are fitted to it. There are always time and accuracy requirements to be met. Greater accuracy requires more time, and more time taken should result in greater accuracy. When requirements conflict, time takes precedence. The basic control is made as accurate as possible and the time is saved on secondary control and detail in less important areas. The determination of where time can be saved and accuracy somewhat sacrificed is mostly a matter of experience. The expert can correctly choose the areas of importance, and can draw the balance of his sketch with regard to the detail requirements of the mission. He also saves time by doing several steps or portions of steps concurrently, thus shortening the completion phase. Therefore, the approved steps, developed as the mechanics of sketching, are not followed to the letter by the experienced sketcher, since he combines many of them as single operations. However, all are complied with before the sketch is complete. These steps are important to know, especially for the apprentice in sketching, and are listed below, with a discussion of each in subsequent paragraphs.

a. Tasks of Preparation.

(1) Selection of scale.

(2) Construction of graphic scales.

(3) Construction of magnetic north line.

(4) Plotting of major control.

b. Establishment of Minor Control in Field.

c. Compilation of Detail.

(1) Planimetry.

(2) Topography.

(3) Military information.

d. Reviewing, Checking and Labeling of Sketch.

123. Preparation for Field Sketching

Upon receipt of a sketching mission and after verifying the details, several steps are taken before beginning field operations. Equipment is checked for completeness and serviceability. Scales are secured or prepared to suit the requirements. Control, both horizontal and vertical, if available in the area, is searched out and plotted on the sketch sheet, and material for its field identification is assembled. This is done in accordance with principles for control, as discussed previously. The field sheet is prepared, as far as possible, to include the north arrow for a guide in field orientation. It is drawn parallel to magnetic north, and about 5 inches long, on the border of the sheet near the magnetic needle of the sketching board.

124. Importance of Minor Control

In the discussion of minor control (par. 109*a*(2)) it was stated that, in general, such control serves as the network from which the sketch is developed. This means that there is no feature in the area which cannot be plotted on the sketch from one of these control points, by intersection (ch. 5) or by azimuth and distance measurement. In other words, every distance and direction on the map corresponds to the identical distance and direction on the ground. This is the ideal condition of accuracy which can only exist when minor control is the best possible. To accomplish this condition, traverse is the method most commonly employed.

a. Traverse. A traverse is a series of directions and distances (represented by lines) measured and plotted concurrently, one following another in such a manner that the intersections of the courses become known, or plotted positions. These have the same relative positions as the ground points which they represent. A distant point is plotted by measuring its azimuth and distance on the ground, plotting it on the sketch, moving to that point, and continuing the process to other successive distant points. If the first line is plotted from a known point (major control point), then the other points are plotted on the same datum. An attempt is always made to "tie in" to another, or the same known point, for checking and adjusting purposes. When this is done, the work becomes a closed traverse. Otherwise, it is an open traverse. For example, figure 95 shows a closed traverse running from major control point HENRI to LUCAS, but if point LUCAS did not exist, the traverse would be open. Known points can be closed by reference. Note that points in between major control are numbered consecutively in order of establishment. They are traverse stations. Running a traverse with the sketching equipment is known as making a traverse, and the process is detailed in step form as follows:

(1) Set up the sketching board over the major control point on the ground and shift the length and position of the legs of the sketching board until it appears level.

(2) Orient the board with the north arrow on the prepared sketching paper pointing in the direction of magnetic north, as indicated by the magnetic needle set in the board. If a second known point is visible on the ground and has been plotted, a better orientation can be obtained. To do this, place the ruling edge of the alidade along the two plotted known points and rotate the board until the alidade is sighted on the second point. Select a ruling edge and sighting edge of the alidade, and use the

same edges for for all sights. Clamp the board in place when properly oriented.

(3) Select a route of traverse. For a route sketch there is little choice other than to follow the route. In area sketching, however, the most desirable route takes advantage of any road net for ease of travel, visibility along and on both sides of the individual courses or lines-of-sight, and the general shape of the area to be sketched. This is done in such a manner that all features can be plotted from the shortest route. This step requires some thought and perhaps a hasty reconnaissance.

(4) The first traverse station to be plotted along the route should be selected for its ease of identification and accurate measurement, rather than because it is a prominent feature. When doing so, it should be remembered that the station is to be the next point over which the sketching table will be set up, and that, if possible, good visibility from it will be required in all directions.

(5) Plot a foresight. Place a pin through the first known control point on the sketch. Using it as a pivot point, sight on the new station and draw the direction line to it. It is always better to keep both eyes open while sighting.

(6) With the clinometer, read the slope angle and record it on the foresight already drawn. This is done to establish the elevation of the point ahead, after the distance to it has been measured. Reading the slope angle is done as described in paragraph 114.

(7) Lock the sketching board needle, take up the sketching table, and stride the distance to the new station (No. 1), recording the paces on the tally. Be sure that the initial station is properly marked for backsighting before leaving it.

(8) Set up over station No. 1, repeat step (1) orient by compass and check by sighting back to the initial point as in step (2) and plot the horizontal distance to scale along the direction line from the initial point. The horizontal distance is obtained by use of the clinometer. This locates station No. 1. A pin placed in that point now becomes the hub or pivot point for any sighting from that station.

(9) With the clinometer, read the slope angle back to the initial station. It should be the same value as read in (6), but opposite in sign. An error of 2 percent of slope is allowable and is applied as an average error. More than

this is usually a mistake in reading and both readings should be repeated.

(10) Compute the elevation of station No. 1 and record it on the sketch near the station (par. 117).

(11) Check the orientation of the board. Then check the needle and proceed with the repetition of the above steps to locate and record an elevation for traverse station No. 2 (fig. 96).

(12) Repeat this process through the traverse to a closure on another known point, or to the initial point. The position and elevation carried through the traverse should agree exactly with the position and elevation of the closure station. A difference in either is an error of closure for that element and the amount of error is, to a great extent, a measure of the care exercised in running the traverse. A serious mistake is apparent if the error is greater in length than 3 per cent of the length of the total traverse, and the problem should be reworked from start to finish.

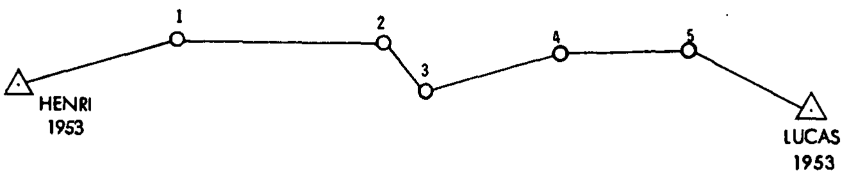


FIGURE 95. *Simple traverse (closed).*

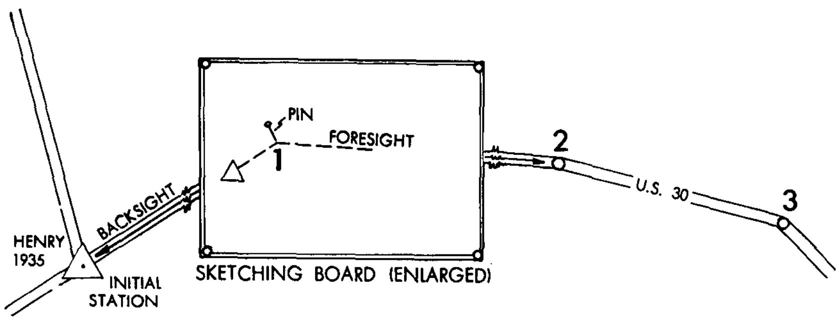


FIGURE 96. *Foresight and backsight.*

b. Keeping Field Traverse Notes. It is advisable to keep a set of field notes as the traverse progresses. In this way a gross error of closure or mistake in some observation can be discovered quickly by checking the notes. The field notes should include all of the readings that were taken and the values computed from them. A sample set of notes is shown in table VI.

TABLE VI. *Sample Traverse Notes*

Station	Foresight	Backsight	Paces	Distance	Elevation
Initial	....	....	......	......	660′
1	+4°	−4°	120	291′	672′
2	−9°	+8°	48	132′	660′
3	−3°	+3°	72	180′	655′
4	−1°	+1°	206	540′	601′
Closure	+13°	−15°	164	422′	660′

c. Adjustment of Position Errors for Traverse Closing on Initial Station. Any adjustment of horizontal error of closure must assume that the error is uniform throughout the length of the traverse. Therefore, the adjustment is a procedure for distributing the error uniformly. It can be done mathematically, but a graphic solution is preferred. An example of such a graphic

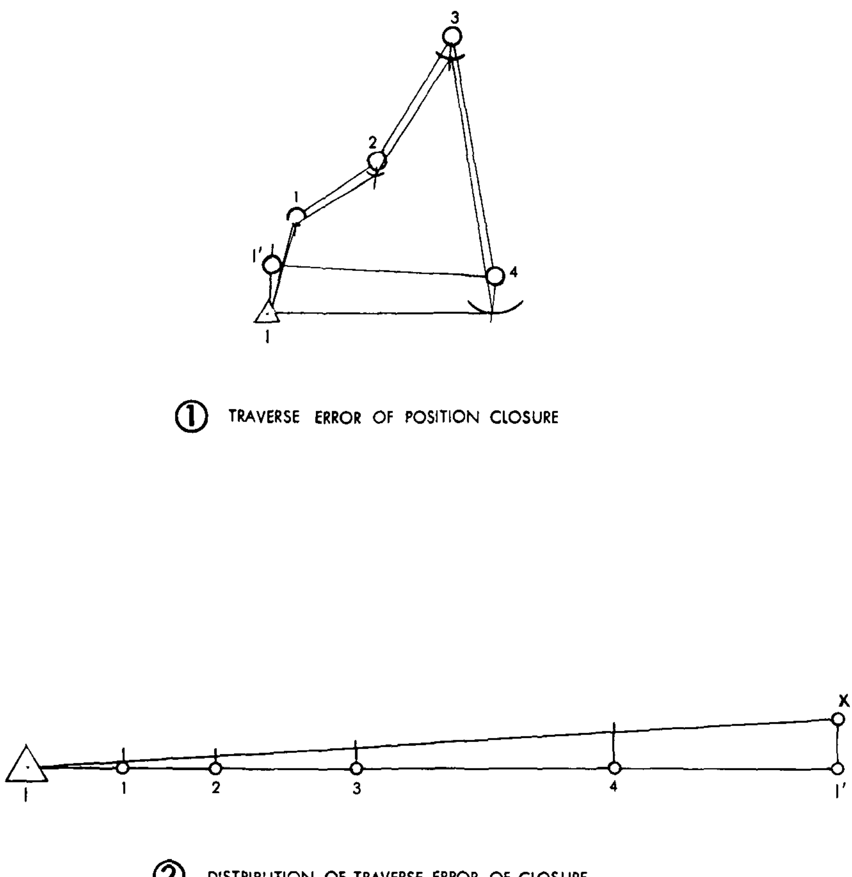


FIGURE 97. *Adjustment of position error of closure.*

adjustment is illustrated by figure 97, and the necessary steps of the procedure are listed. The field sketching sheet, showing the plotted traverse running from the initial station through traverse stations 1, 2, 3, 4, and connecting again with the initial station at I′ instead of I, is shown in (1), figure 97. A graphic representation of the distribution of the traverse error of closure is shown in (2), figure 97. The necessary steps of the procedure are listed below.

(1) Draw a straight line on a worksheet from I to I′ ((2), fig. 97). Beginning at I, lay off the length of the courses of the traverse consecutively, and label them 1 through 4, the last point being I′.

(2) Draw perpendiculars at all points except I, and lay off the line X—I′ equal to the length of the closure error I—I′ ((1), fig. 97). Lay off the line I—X. The segments of the perpendiculars thus formed at the station points represent the correction for each.

(3) On the plotted traverse ((1), fig. 97) draw lines through each station, parallel to I—I′ and in the direction in which the adjustment is to be made. Lay off the correction to each as determined in (2) above and as shown in (2), figure 97. Connect the corrected position points through the courses of the traverse. The network thus formed is the adjusted traverse.

d. Adjustment of Position Errors for Traverse Closing on a Second Major Control Station. In this case, also, the graphic method is preferred to the mathematical method. A sample problem is presented with the error uniformly distributed by steps. Figure 98 illustrates the problem showing the plotted traverse running from the initial station I through intermediate station points 1 through 4 and closing at station T′ instead of T. It further shows construction lines of the adjustment solution.

(1) Measure true distance I—T, and lay it off as I—t on a straight line drawn connecting I and T′.

(2) Draw radials from a convenient point O to stations and station points as shown, and draw T″—t parallel to O–I to establish T″.

(3) Draw T″—I′ parallel to I–T′ to establish I′.

(4) Beginning at I′, draw I′—1′ parallel to I—1, 1′—2′ parallel to 1—2, etc., and the result is the adjusted traverse, I′–T″.

e. Adjustment of Small Position Errors of Traverse Closure. When the error of closure is small, it may be adjusted by eye, using the same principles of uniform distribution as practiced in two different graphic solutions above. The amount and direction

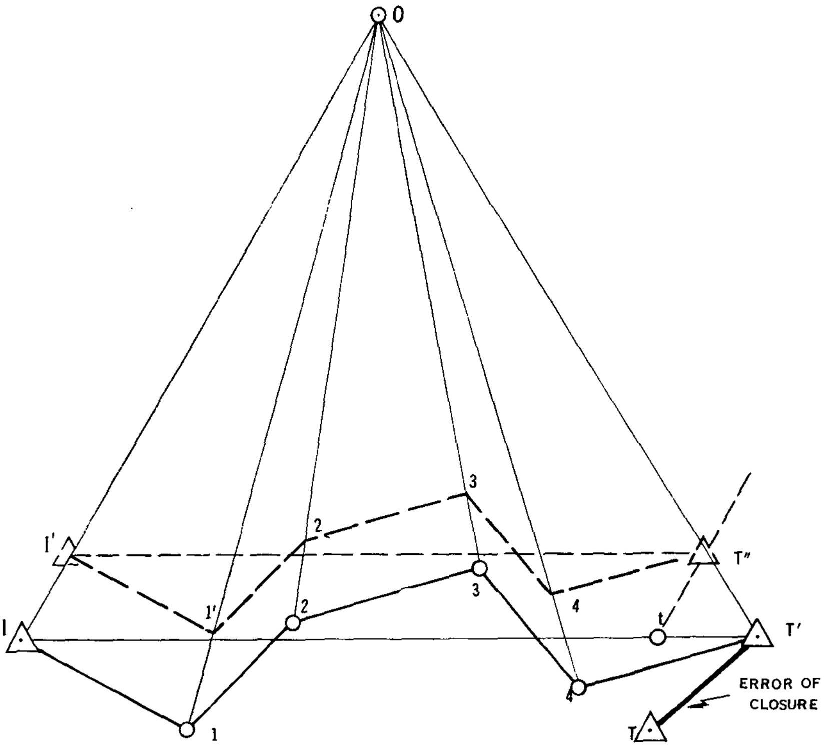


FIGURE 98. *Adjustment of position error of closure of traverse between two known points.*

of error is noted and distributed back through the traverse in proportion to the distance each point is from the initial station. Each point is marked at its proportionate corrective distance from the original plotting of the point, and in a direction parallel to that of the error of closure.

f. Adjustment of Vertical Control Closure Errors in Traversing. The sea-level elevation, carried from point to point through a traverse, is also subject to error. A gross error made during the operation can be discovered from the field notes, but the error of usual concern is one of accumulation over the entire procedure. This error is assumed to be proportionate to the number of courses, and therefore the adjustment is a matter of dividing the total error of closure by the number of courses and applying an equal amount to the elevation of each point established along the traverse. The sign of the closure error is noted and the correction is made by adding it algebraically to the original value. For example, the known elevation of station I in the traverse (fig. 98) is 400 feet above sea level, and that of Station T is 500 feet. The elevation of station T, as carried through the traverse, is 480 feet.

This implies an error of plus 20 feet. It is *plus*, because the 480 feet must be corrected in a plus direction to become 500 feet. There are 5 courses, and plus 20 feet, divided by 5, gives a correction at each point of plus 4 feet. Beginning at station 1, the plus 4 feet is added to the original value, plus 8 feet to station 2, plus 12 feet to station 3, plus 16 feet to station 4, and plus 20 feet to the 480 feet for station T. In this way, the desired closure is made. Had the error of closure been a *minus* 20 feet, or a reading of 520 instead of 480, the correction would have been the same, 4 feet. It would have been added algebraically which would mean a subtraction in each case, an accumulative reduction of the elevation values through the traverse. Both examples show an error which comes out in even numbers of feet for correcting each station. This is not usually the case; the error of closure is more often an odd figure, such as plus 23 feet, which is not evenly divisible by the number of courses involved. Larger corrections are applied to longer courses because it is natural to assume that more error is accumulated over their longer lengths. In the example used above, as illustrated by figure 98, the error applied to all courses would be plus 23 feet divided by 5 courses, which would equal 4 feet of correction to each elevation, with 3 extra feet left over to be distributed evenly to the 3 longer courses. Beginning at station 1, the plus corrections would be 5 feet, 9 feet (5 + 4), 14 feet (5 + 4 + 5), 18 feet (5 + 4 + 5 + 4), and 23 feet (5 + 4 + 5 + 4 + 5), respectively through the traverse to tie into the known elevation of 500 feet for station T.

g. Detail Compilation. As previously stated, the purpose of the control network, now established, is to serve as a basis for the positioning of all ground features in the area. Two methods of locating points were described in chapter 5, intersection and resection. Intersection was the method of locating distant points from two known points, and resection was the same operation in reverse. Several known points are made available by the traverse in planetable sketching, in order to make the intersection method feasible. Briefly, a direction line is drawn to almost all important features in all directions from each station point set up in such a manner that every feature has two or more direction lines drawn to it on the sketch. The intersections of these lines become the plotted positions of these features and the sight lines can be erased. The next step is to draw in the detail between the plotted features as it exists on the ground. At this stage, it is not difficult to imagine the importance of knowing just what features to select and include on the sketch; too many mean needless work, and too few mean a sacrifice in sketching accuracy. Again, experience is the best teacher in developing the judgment required of a

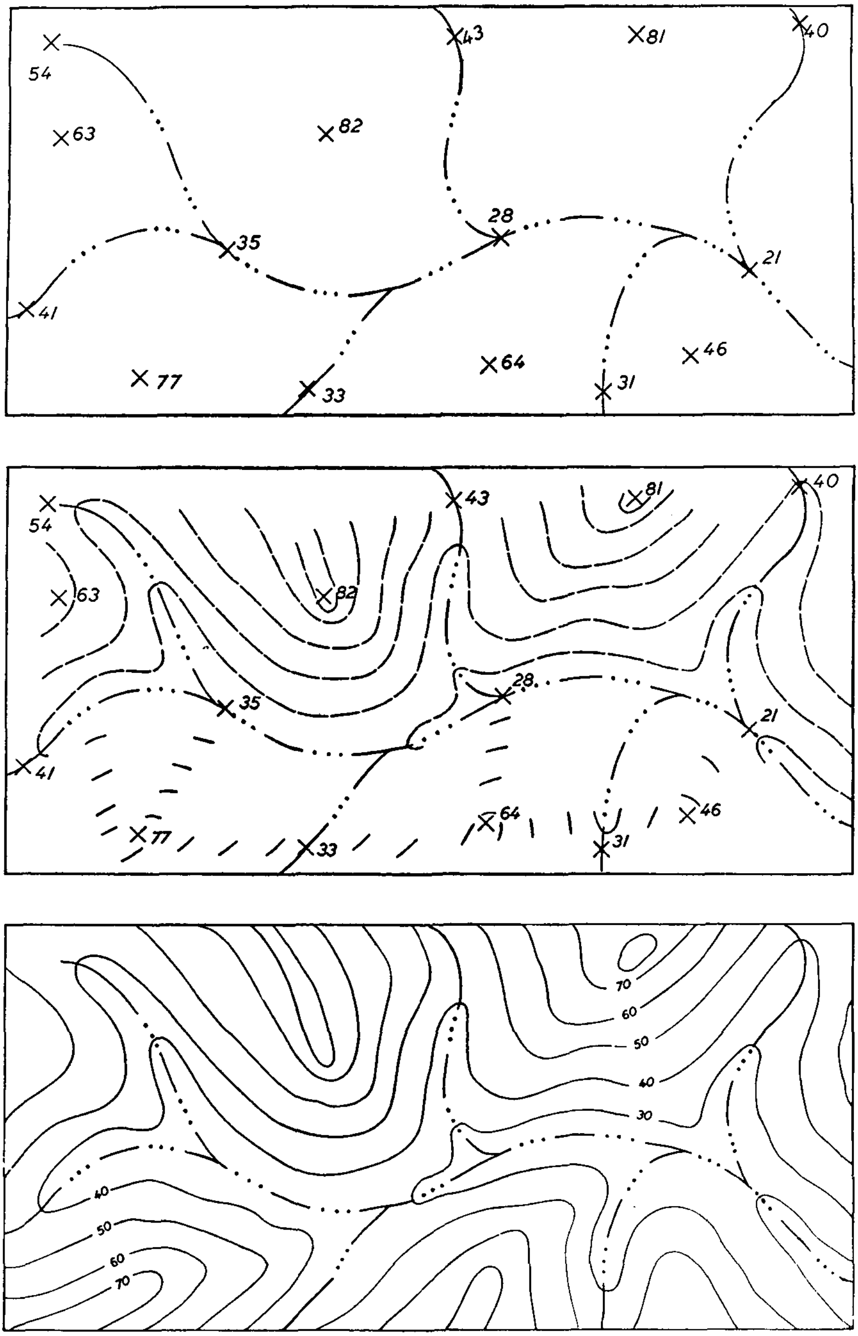


FIGURE 99. *The three stages in contour interpolation.*

sketcher. Even more experienced judgment is required in the adding of relief, or topography, to the sketch. Usually, this is done by the use of contours (par. 57). Contouring is accomplished on the sketch in the field, but only after establishing several critical elevations, called spot elevations or spots. These are described as the points where the slopes change, and where streams enter and leave the area. The contours are then sketched in by interpolation, which presupposes that all slopes are gradual between the spot elevations. Figure 99 shows three stages in contour sketching, the top view showing the spots and the stream network sketched in, the next view showing the contours being shaped by interpolation, and the bottom view showing the completed topography for the area. Naturally, up to a point, the more spots that are established, the easier the contour sketching becomes. Once this stage is reached, however, additional points do not add to the speed and accuracy. This, again, is a matter of experience and judgment.

125. Completing the Sketch

Following actual field operations, as much time should be spent in reviewing and checking the sketch work as is permissible under the time limitations. All important corrections should be made. The final step is to label the work for future reference by adding a title box to contain the information as shown on the sample sketches, figures 87 and 88.

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PART THREE

LAND NAVIGATION BY DEAD RECKONING

CHAPTER 7

GENERAL

126. Purpose

The purpose of part three is to familiarize military personnel with the problems of land navigation by dead reckoning and with some of the problems of air and marine navigation, as well as to serve as a text for the use of methods and equipment involved.

127. Dead Reckoning Defined

Dead reckoning is the process by which position at any instant is found by applying to the last determined position the direction and distance of the course or courses traveled.

128. Usefulness of Dead Reckoning

In areas where maps exist, even poor maps or sketch maps, travel is guided by them to a great extent. It is a matter of knowing one's position at all times through association of map features with ground features. The features are signposts along the route, and dead reckoning requires no special forethought to read them. But the greater portion of the globe is unmapped, hence the possibility that military forces may have to move overland without a map to guide them, and without time to make one. Although these areas could be anywhere, they are likely to be beyond the frontiers of civilization. Desert areas and frozen waste lands are examples of such areas. Many mapped areas, having wide regions of scant terrain relief and features for signposts, also require dead reckoning navigation.

129. Dead Reckoning Described

For many centuries, mariners have used dead reckoning to navigate their ships when out of sight of land, and during bad weather. It is the simplest system of navigation and is one on which the navigator relies most. Dead reckoning stems from the necessity to move from one geographic position to another, and is just as applicable to navigation over land, as by sea. The route of travel is not one course, but rather it is made up of several courses. An azimuth is established at the starting point for the first course to be followed and measurement of the distance of travel is begun with the departure. Measurement is continued through the first course which ends when a change in direction is made. A new azimuth for the second course is established and its measurement begins at the change of direction. Records of all data are kept and positions plotted. Naturally, the more accurate the data, the more correct are the plotted positions. In general, the procedure is the same regardless of the mode of travel or measurement.

CHAPTER 8

INSTRUMENTS OF LAND NAVIGATION

130. General

For some time, equipment has been available for automatically plotting a course on paper. There were two types, the *pedograph* and the *odograph*. Now, however, the former, which was developed for foot marches, has become obsolete. Instead two models of odograph exist, the original M1 which is the standard, and the M2 which is far superior in performance, but which is not provided in quantity because of its high cost.

131. M1 Odograph

This instrument automatically plots the course of a moving vehicle. It consists of three principal units: the compass, the plotting unit, and the power pack. All components are interconnected by electric cable and flexible shafts. It was designed for use in the ¼-ton truck, but can be used in other vehicles to include the M–29 cargo carrier and/or M–29 tow sled for operation in the far north. Qualified personnel are required for installation, maintenance, and adjustment. Once this is completed its operation is easy. The odograph plots at scales 1:20,000 to 1:80,000. To function, it depends on three separate factors—

a. Distance determined from an odometer or fifth-wheel.

b. Direction determined from a compensated magnetic compass.

c. Direction components from an integrator which converts the direction into its coordinate components for plotting purposes. This is necessary, since the plotting pencil is activated by two motions at right angles to each other, one motion representing the sum of all the north and south components of the vehicular movement, and the other, all the east and west components.

132. M2 Odograph

This instrument is much more accurate and convenient to use than the M1. It utilizes the miniature gyrocompass described in paragraph 135*b* for the input of direction. In fact, it is the miniature gyrocompass described in paragraph 135*b* with a position indicating attachment added. In normal operation, if the map coordinates of the starting point are set on the instrument, it will provide the true coordinates of any point along the course of travel. The miniature gyrocompass is very complex in construction, and for this reason its use with an odograph is limited.

CHAPTER 9

DIRECTION FINDING

133. Magnetic Compass

It is essential that every navigator be familiar with the magnetic compass and its use. New and better direction-finding instruments are being supplied, but they are not always available or in working order. The lensatic and the wrist-type are the two principal compasses of military issue. They are described, and their use is explained in paragraph 52.

134. Vehicular Magnetic Compass

A magnetic compass has been developed for mounting in all vehicles except armored ones. It has a compensating arrangement for correcting major deviations caused by induced magnetism of surrounting objects. The correction arrangement requires trained personnel to operate it. Normally, the compensation is made for the standard or regular loading of a given vehicle, and precautions are then taken not to change the loading and to avoid bringing additional metal near the compass. No compensation for declination changes is possible in the instrument, and magnetic charts must be relied upon for such data.

135. Vehicular Gyroscopic Instruments

The use of gyroscopic instruments in military vehicles has never been entirely successful, because the requirements of such instruments have been extremely difficult to assemble into the manufactured item. It must first be small in size and light in weight. It must be sufficiently accurate to be reliable in varying conditions of terrain and weather. It must be unaffected by the operation of the vehicle in which it is mounted, and it must be simple to maintain and easy to operate. It must be sturdy enough not to require frequent adjustment, and must develop a reputation for overall dependability. In spite of these severe requirements, two different instruments have been developed at different times and have been put into limited use. The directional gyro was developed first, but it is gradually being replaced by the miniature gyrocompass.

a. The Directional Gyro. The directional gyro is an instrument which indicates and maintains a fixed direction to which other directions may be referred. From a spinning wheel or rotor, it derives directional characteristics, the chief one being the tendency of the spin axis to retain a fixed direction in space. This tedency is due to the great inertia possessed by a rapidly rotating wheel or rotor. Although the directional gyro has several advantages over the magnetic compass, it does not, in itself, present a complete solution to the problem of direction indication. First, the directional gyro is not a compass. It does not seek any particular direction. Therefore, it must be manually oriented with respect to a chosen meridian, such as magnetic north, true north, or grid north. Second, the gyro is subject to a slow drift (precessional error) away from the heading at a rate of about 3 degrees to 5 degrees in 15 to 20 minutes. Consequently, periodic correction of the instrument is necessary. For these reasons, an independent directional reference must be provided for use in setting and correcting the directional gyro. The astrocompass is a simple means of providing this reference, but a magnetic compass may be used if readings are taken well away from the disturbing influence of the vehicle.

b. The Miniature Gyrocompass. The miniature gyrocompass, the first gyrocompass designed for and successfully used in military vehicles, is a further development of the directional gyro. It is a self-contained mechanism, which seeks true north. Rotation of the earth and gravity factors are inputs giving a dependable heading reference. The gyrocompass is free of the inherent limitations of the magnetic compass, because it does not depend on magnetic fields. Neither does it require compensation or calibration by the operator. It can be installed wherever its small bulk and weight (65 pounds) can be accommodated. Only the controls need be within reach of the operator. Other components can be stowed elsewhere. Repeaters, which have a dial indicating the heading, may be mounted for observation wherever required. Electrical current for the gyrocompass is furnished by a motor-generator unit which is activated by a 24-volt battery or by the electrical system of the vehicle. All major parts of each separate assembly unit are standard and readily accessible for quick and easy interchange requiring no calibration. It is a desirable instrument for vehicle navigation by dead reckoning, but its cost is high because of the necessary complexity it embodies. Among its more desirable characteristics are—

(1) Has average accuracy of better than ½ degree.

(2) Has average drift of ⅕ degree per hour when used as a free gyro.

(3) Operates between minus 65 degrees Fahrenheit and plus 130 degrees Fahrenheit, and up to 60 knots.

(4) Is designed for severest type of military service in general purpose vehicles, armored vehicles, amphibious landing craft, PT boats and others.
(5) Is dustproof and waterproof.
(6) Settles rapidly, is easy to maintain.
(7) Is durable and dependable, as proved by service tests.

CHAPTER 10

GROUND DISTANCE MEASUREMENT

136. Need for Ground Measurements

The navigator must have some means of obtaining course distances while actually moving along the course. Two general methods are in common military use, one while afoot and the other while riding in a vehicle.

137. Pacing Distances

Pacing is probably the most common method of measuring a distance. It is the simplest one, and consists of counting the number of paces in a measured course and converting this number into map units. At best, the distances measured this way are only approximate, but with practice, these distances are sufficiently accurate for the results desired. It is important that all personnel, subject to the use of dead reckoning navigation, establish the length of their average pace and become proficient in using it to plot courses.

a. Pace Length. An individual's average pace is determined by pacing a measured course many times and computing the mean. When pacing a course in the field the conditions that may affect pace length are many, and the average pace must be adjusted accordingly. Such varying conditions might be—

(1) *Slopes.* The pace lengthens on a downgrade, and shortens on an upgrade.

(2) *Winds.* A head wind shortens the pace, and a tail wind increases it.

(3) *Surfaces.* Sand, gravel, mud, and similar surface material tend to shorten the pace.

(4) *Elements.* Snow, rain, or ice cause the pace to be reduced in length.

(5) *Clothing.* Excess weight of clothing shortens the pace, while the type of shoes affects traction and, therefore, the pace length.

(6) *Stamina.* Fatigue affects the pace.

b. Pitfalls in Pacing. There are two precautions to be taken by the pacing navigator, as experience has shown that they are most often abused in dead reckoning duties.

(1) The tendency is to overestimate distance, and the pacer must guard against it.

(2) Distances on a map are always horizontal, and therefore the pacer should be cognizant of this fact and, while pacing, correct his pace lengths to represent horizontal distance. Otherwise, the plotted positions fall short of or further away from the actual location, depending upon the amount of pacing on the upgrade or downgrade.

c. Pace Counting and Recording. It is evident that a means of counting paces must be provided which is foolproof. Usually, paces are counted in hundreds, and the hundreds are counted in many different ways, by—

(1) Keeping notes in a record book.

(2) Counting on the fingers.

(3) Placing articles such as match sticks into an empty pocket with every hundred paces.

(4) Use of a mechanical hand counter.

(5) Use of a pedometer.

138. Odometer

Distances can be measured by use of the speedometer, or odometer, and is standard equipment on most vehicles. The speed indicator is disregarded and the odometer or distance indicator, which is graduated in tenths of miles, is used. Readings are recorded at the start and end of a course, and their difference is its length. When variations along the course from the horizontal are corrected, a more accurate reading is obtained.

139. Measuring Wheel

A special measuring wheel can be built for towing behind a vehicle or sleigh. As the wheel turns, the number of revolutions is recorded on an automatic counter, and the distance is computed later by knowing the circumference of the wheel. It is best to calibrate the wheel over different surfaces in order to find the best factors for each type.

CHAPTER 11

RECORDING AND MAINTAINING COURSE

140. Duties of the Navigator

The duties of a navigator are so important and exacting that he should not be burdened with any other duties. This is especially true in regard to vehicular movements. The march commander should not attempt to do the navigating himself, since his normal responsibilities would suffer as a result. The commander selects one person to be navigator and makes him responsible for all the details involved. In general, the navigator is responsible for—

a. Accumulating necessary equipment.

b. Keeping equipment serviceable.

c. Performing the detailed duties of taking and recording necessary data for precise location at all times.

d. Maintaining liaison with the commander.

e. Supplying data to keep the column on course.

141. Steering Marks Defined

A steering mark is any well-defined object on the ground in the direction of travel toward which a navigator may steer. It is easier to follow these than to steer continually by compass. The ideal condition would be to have a steering mark for each azimuth of travel.

a. Steering Marks by Day. Naturally, steering marks are more readily usable for daytime marches. Such objects as lone trees or buildings, timber corners, and shapes on the horizon are good examples. Even a cloud formation or wind direction may be used if checked periodically by compass.

b. Steering Marks by Night. By night, the stars are usually the single source of steering marks. The stars are continually moving and compass checks on azimuth are necessary. The length of the safe period between checks is largely dependent on the star selected. A star near the north horizon serves for about a half hour. The pole star is an ideal steering mark since it is less than 1 degree off true north, but above latitude 70 degrees it is too high in the sky to be useful. When moving south, azimuth checks on stars should be made every 15 minutes to be safe. When travelling east or west, the difficulty of staying on azimuth is not as much due to changing direction angle, as to the likelihood of the star climbing too high in the sky or losing itself behind the western horizon. In all the above cases, it is necessary to change to another guide star when one becomes useless. South of the equator, the above general directions for using north and south stars are reversed for safe use.

142. Compass Navigation on Foot

On foot, the hand compass is standard for navigation by dead reckoning. The starting point is known on the map, if a map is available, and if not, an assumed starting point is indicated on some sort of a plotting sheet. At this point on the ground, an azimuth is set on the compass for the first course, and the journey is started. At the first turn, a new azimuth is established and followed, and the process is repeated to the goal. A log of all values, azimuths, and distances is kept and the journey is plotted. Figure 100 is a pictorial illustration of the use of the compass in navigating on foot.

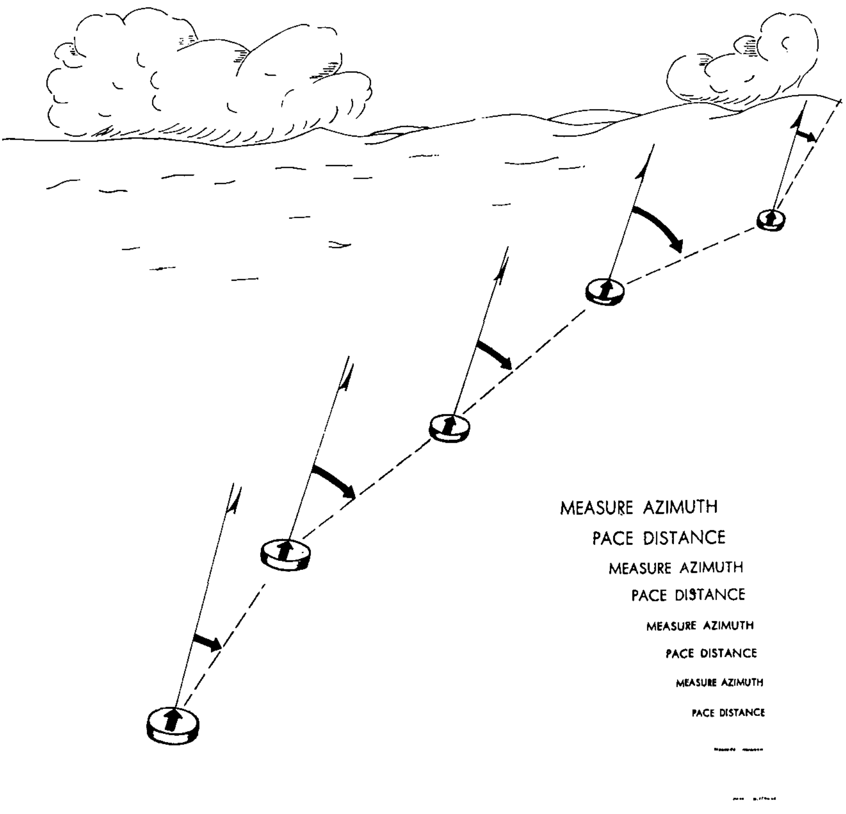

FIGURE 100. *Compass navigation on foot.*

143. Vehicular Navigation

In vehicular movement, the process of measuring angles and distances for plotting purposes is the same as for movement on foot. The difference lies in the methods employed to make the measurements. More often than not, the hand compass is the only compass available and in working order. This means much care must be taken to compensate for declination and deviation. It also means using a declination table and getting out of the vehicle periodically with the compass to eliminate outside magnetic attractions. The process of leaving the vehicle to establish a true azimuth can be somewhat confusing, and for this reason a good procedure is outlined.

a. Vehicular Navigation without Steering Marks. In very open country, where no steering marks are available, the vehicle is aimed in the direction of travel. The navigator gets out and walks 50 yards forward. An azimuth on the vehicle is then read and, by addition or subtraction of 180 degrees, the forward azimuth is obtained. This azimuth is used to plot the course. The vehicle is signaled and moves forward to join the navigator. Instructions are given to the driver to stay on as straight a course as possible. The navigator gets into the vehicle and proceeds to determine the magnetic declination from the true azimuth just obtained. The compass heading is read while the navigator is seated in the vehicle holding the compass in the same position as it is to be held while advancing. Further, it is read with the motor running and the ammeter showing normal charge, and with the brake and gear levers in running position. This azimuth is used to direct the movement only. The march is then started and held to the azimuth by the navigator who continually watches the compass. If the course changes more than 10 degrees, the procedure should be repeated. It should take only a few minutes to establish each new heading.

b. Vehicular Navigation Using Steering Marks. Vehicular navigation is much simpler when steering marks are available. When aiming the vehicle, the steering mark is selected and no azimuth is needed during the movement. However, an azimuth is needed for plotting the course, and this is obtained at each turn in the march by moving away from the magnetic influence of the vehicle to take the compass azimuth, as described above.

144. Navigation Record—the Log

The log (fig. 101) is essential in navigation by dead reckoning. It is a form on which all the distances and azimuths of a march are recorded. Note that it has a series of columns labeled in such a manner that the data are complete. The distances are in miles and the azimuths are true azimuths for direct plotting purposes. If the means of measurement does not record in miles, another column is set up for the conversion. For example, a measuring wheel records the number of revolutions it makes, and the number then has to be converted to miles for each course. Also, it might be preferable to plot grid azimuths rather than true azimuths, which would mean a different conversion factor after declination and

LOG						
1	2	3	4	5	6	7
ODOMETER READING AT START OF EACH COURSE	DISTANCE IN MILES	FORWARD AZIMUTH (MAGNETIC)	DECLINATION CORRECTION	DEVIATION CORRECTION	TRUE AZIMUTH	NOTES
A 4750						
	6	17°	+13°	+3°	33°	
B 4756						
	9	358°	"	+2°	13°	
C 4765						
	8	341°	"	+1°	355°	
D 4773						
	1	314°	"	0°	327°	
E 4774						
	1.5	341°	"	+1°	355°	
F 4775	5					
	1.5	322°	"	0°	335°	
G 4777						
	1	312°	"	0°	325°	
H 4778						
	12	300°	12°	−1°	311°	
I 4790						
	6	341°	"	+1°	354°	
J 4796						
	6	302°	"	−1°	313°	
K 4802						
	20	319°	"	0°	331°	
4810						Wahoo River
						Crossing—
4814						Cut 2 mi
L 4824		Base Camp (data)				

FIGURE 101. *Sample log.*

deviation corrections had been made. The last column is reserved for notes related to any particular course or courses. Such notes often clarify the log at a later date. A 3H pencil is used, always heavily enough to indent the paper and produce a record that will be clear and readable under all conditions. Often, relatively short stretches of a march cannot be traversed in a straight course because of some natural feature such as a river to be crossed, or a rather steep and rugged slope to be climbed. The break in the normal navigation procedure is shown on the log in order to assure a proper plotting. In the sample log in figure 101, a crossing of the Wahoo River cost 4 extra miles on the odometer, 2 miles of which were lost in a false attempt to cross. These were noted for deduction from the course length, by writing "cut 2 miles." The last course of the march, K–L, was continued after the river crossing. This might not be the case, and a new course would be desirable once the crossing has been made. If so, a separate odometer reading should be logged, both before and after the crossing. Also, if the crossing entails considerable linear distance, it should be entered as a separate course, with distance and azimuth to permit a more accurate plot. It may be necessary to estimate the distance and read an azimuth from the far side of the crossing area. In such a case, notes are made to clarify the operation and to account for the odometer mileage lost in its execution.

145. Plotting the March from the Log Data

The march is plotted directly on the face of the map, or on a separate piece of paper at the same scale as the map. If the latter method is chosen, the completed plot can be transferred to the map sheet, provided that at least one point of the plot is also shown on the map. The simplest transfer is by means of carbon paper, although many other ways exist. The actual plotting is done by protractor (par. 50*d*) and scale (par. 38). The degree of accuracy obtained is dependent upon the quality of draftsmanship, the physical conditions, and the care taken in obtaining the data while enroute. Figure 102 illustrates a separate paper plot of the data obtained for the log sample in figure 101. It should be noted that four of the courses from D to H are short and have been plotted as a single course, the mean of the four. This is recommended because it saves time and does not lose any appreciable amount of accuracy.

146. Adjusting a Plot

If at all possible, a plot should be adjusted to known points. This means that a plot should be tied in to at least one known point along the route of march. A known point is one on the ground

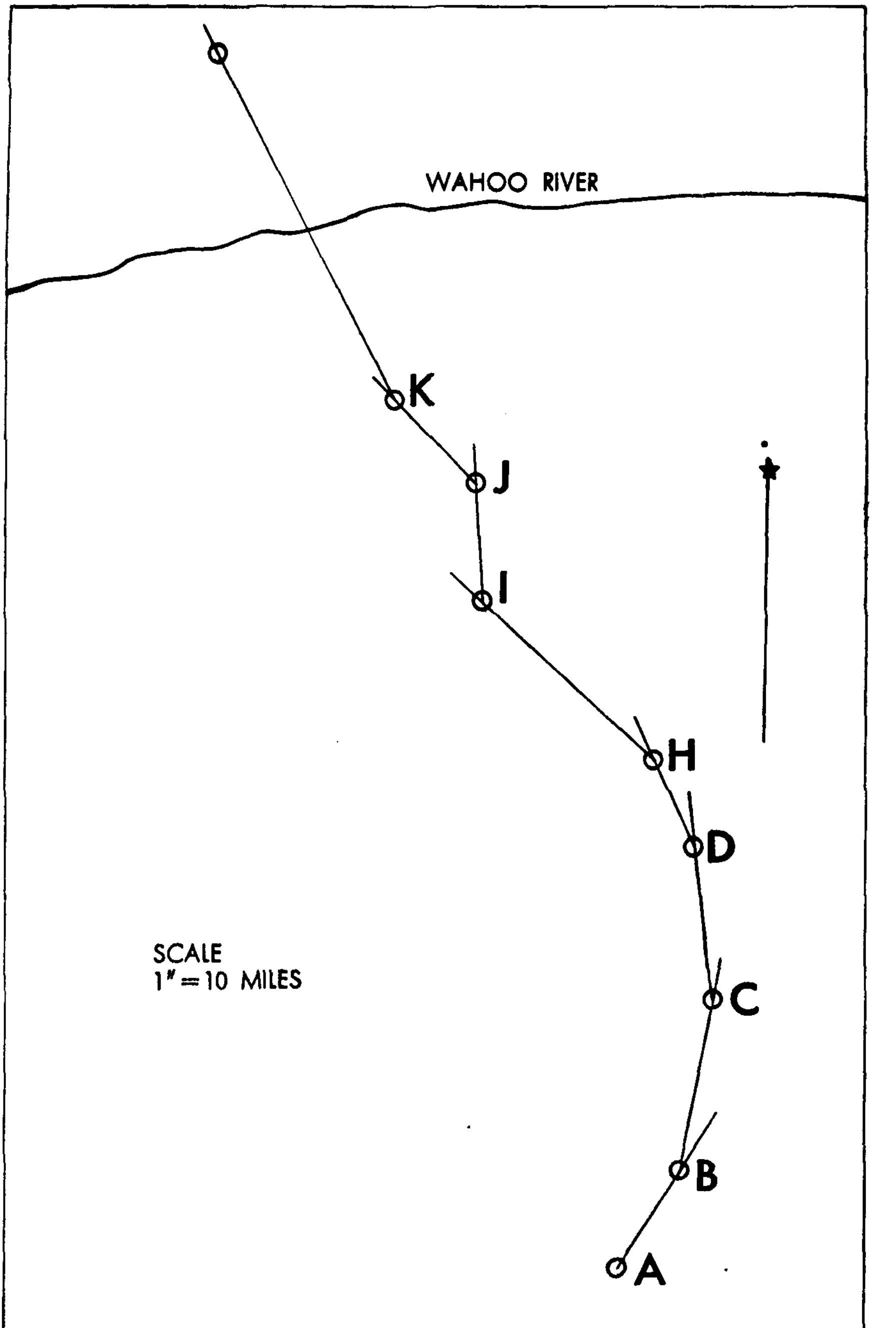

FIGURE 102. *Sample plot.*

which can be identified on the map. The tie-in is achieved by either directing the route to pass near or over such a point or feature, or by azimuth and distance from one or more turns in the route. An azimuth alone, from at least two adjacent turns, often serves the purpose. It is not even necessary for turns to be used, since any point along the route can be used if a distance reading is taken at the same time as the side azimuth is read. Notes in the log clarify the action and are a record of the data taken. Different plot adjustments are discussed, assuming each plot is drawn on a separate paper rather than on the face of a map.

a. Simple Adjustment of Plot. The simplest adjustment is made possible by identifying a point on the line of march and making it plottable by changing course at that point or by taking a mileage reading there. Assuming the initial point is known, two points are now known, and the plot is adjusted by pivoting it about the initial point until the second point falls on its correct map position. With this orientation held fast, all turning points of the traverse are pricked through onto the map sheet, or otherwise transferred. When connected by straight lines the adjusted plot is complete on the map.

b. Normal Plot-Adjustment Method. The above method is ideal, but seldom used, since it rarely occurs that two known points on a traverse fit exactly to the scale of the map. In revolving about the initial point as a pivot, the second point is likely to be long or short of falling on its map counterpart. This calls for a special type of adjustment, known as a straight-line adjustment. It is graphical and quickly applied. Figure 103 shows the solution to a problem in which the plot did not fit the map at known points X and P simultaneously. The route XABCD was plotted from the following log, as shown in figure 103(1), in which P did not fall on its known position at P′:

Line	Distance	True azimuth	Notes
X–A	14.2 miles	304	
A–B	6.1 miles	330	
B–C	7.8 miles	300	Point P at +3.2 mi.
C–D	21.00 miles	273	

Next, a straight-line plot was made ((2), fig. 103) by beginning at *X* and laying off successive course distances according to the log, with the known point *P* also plotted. Perpendiculars were drawn at each point on the straight line plot, P–P′ (p) was laid off from (1), figure 103, and another straight line was drawn from X through P′. The distance error at each turn of the route was then represented by distances *a, b, p, c,* and *d.* They were scaled, and transferred to the original plot by laying off the respective distances on lines drawn through each turning point parallel to P–P′. The last step was to connect the points by straight lines which produced the adjusted plot *X A′B′ C′ D′*.

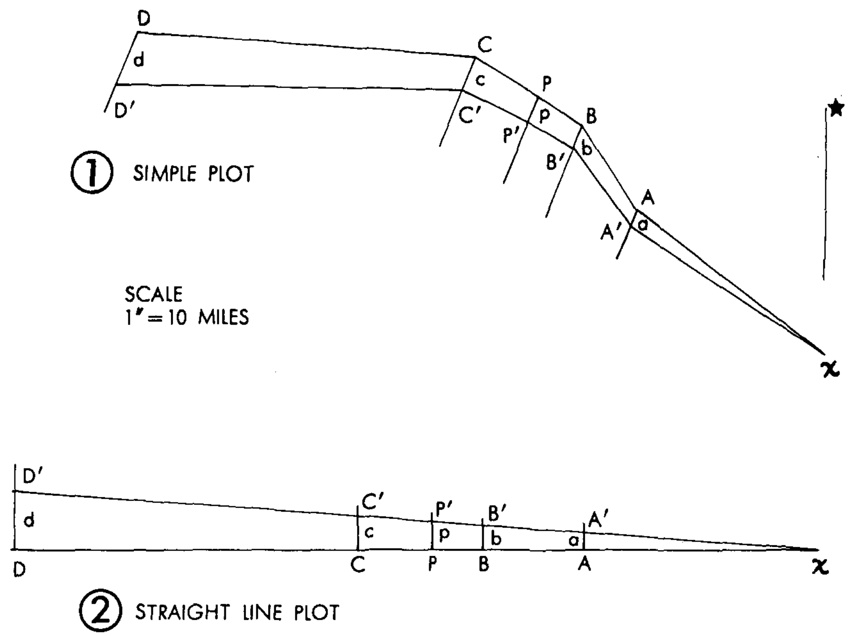

FIGURE 103. *Adjustment of traverse.*

c. Plot Accuracy. More often the second known point, *P*, of the straight-line adjustment above, is the last point on the plot, *D*, the route destination, in which case the adjustment by the straight-line method tends to be more accurate. Or, if both points are known, the accuracy is even greater, because two adjustments are made, one between *X* and *P* (fig. 103) and the other between *P* and *D*. Errors in the plot are inevitable, but if a navigator is conscientious in his work, a vehicle navigation problem over a long route should not be in error over 1½ degrees in azimuth and 3 percent in distance from beginning to end. On foot, the error is nearly doubled. Errors on foot are expected, but difficult to average because of varying field conditions under which land navigation by dead reckoning is usually performed. The primary factor determining the amount of accuracy obtained is the skill and experience of the navigator himself.

PART FOUR

MAP SUBSTITUTES AND SUPPLEMENTS

CHAPTER 12

IMORTANCE OF MAP SUBSTITUTES

147. Map Substitute Defined

A map has been defined as a line drawing of a portion of the earth's surface to a definite scale. The purpose of the map, as previously explained, is multifold. It is reasonable to assume that the purpose of map substitutes must also be multifold. An item may be a map substitute, or a supplement, depending on the use made of it. Many of the properties of a map are incorporated into map substitutes, and an item used as a map supplement must have certain necessary map characteristics which justify its use with a map. The map substitute, or supplement, may show a portion of the earth's surface as a camera image or freehand sketch, rather than as a line drawing. It may not be to an exact scale, but it does have a scale. In such ways, a map and a map substitute are very similar, although not identical.

148. General Use

Although the term map substitute implies that it is used only when a map is not available, such is not the case. It can be used instead of a map, as a map substitute; or along with a map, as a map supplement. For example, certain map uses do not depend heavily on scale and azimuth, but concentrate on the relative position of surrounding features. To an engineer field commander charged with maintaining an arterial road, a sketch or aerial photograph can be just as adequate as a map in pointing out the locations of gravel pits. It is primarily their existence in the vicinity which it is important to know. In such a case, a sketch or aerial photograph or other map substitute is sufficient and often more suitable. On the other hand, the photo-interpreter uses a map substitute as a supplement to a map. Such a case exists when the map substitute (airphoto) contains information of a nature that is not well defined on the map; then the two are used together to best satisfy the mission.

149. Map Substitutes

There are several general groups of map substitutes that are extensively used for military purposes. Each group has many variations of form in which the map substitute is prepared and reproduced for field use. Regardless of form, however, each map substitute is recognizable as belonging to one of the following groups:

a. Aerial photographs.
b. Mosaics and photomaps.
c. Sand table, terrain models, and plastic relief maps.

CHAPTER 13

AERIAL PHOTOGRAPHS

150. Definition and General Purpose

The aerial photograph is simply a photograph of a portion of the ground, taken from an airplane. It is exposed, developed, and printed in a similar manner to standard photographs, except that the whole process is much more elaborate and scientifically controlled. This is necessary in order to obtain photography possessing the qualities required for the general military application of an aerial photograph with, or as a substitute for, a topographic map. The primary military use is for the initial preparation of a map, map revisions, or military intelligence. However, for purposes of discussion, it must be assumed that the topographic maps are prepared and that the aerial photograph is still of important value to the armed forces. The ideal use of an aerial photograph is in conjunction with a map of the same area. Maps become outdated almost before they are printed, and therefore, a situation in which a map and recent photographs are available would produce the maximum possible information. For example, a five-year-old topographic map might not show new highways and bridges, certain wooded areas shown might have been burned or timbered, and many other features of military importance in the area could have changed. In such a case new photography would supply the missing information. It is the nature of a map to show detail by symbols, while the photograph is an eye view of the actual area. This eye view is, of course, helpful in planning military maneuvers. The many and varied types of vegetation can be better evaluated; heights and density of forests can be estimated, and open fields are very clearly outlined. Even without the map, the photograph can be used somewhat successfully for such operations as measuring distances, determining directions, and for planning routes. However, it must be remembered that certain characteristics of the map are not duplicated in the photograph. This must be considered when photographs, rather than maps, are available for use. Distance and direction cannot be scaled accurately on a photograph. Features of military importance which show very plainly on a map may be difficult to identify on a photograph. Many other disadvantages of a photograph as a replacement for a map become immediately apparent to the experienced mapreader who has had no opportunity to master the art of photograph reading. Nevertheless, recent aerial photography in an area of action should never be disregarded, even if the area is covered with the best of recent topographic maps. Skilled photo-interpreters are employed to obtain information of enemy terrain. For details see FM 30–5.

151. Photograph Classification by Camera

Cameras are of two types, the single-lens camera and the multiple-lens camera. Today, the single-lens camera is standard for all military and civilian uses in this country. However, multiple lens photography may be available under certain unusual conditions. The theory behind the multiple-lens camera is that it covers a much wider area in one exposure than does the single-lens camera. However, since the single-lens variety of aerial photograph is standard, it is so considered throughout the balance of part four.

152. Photographic Classification

For military use, only two types of photographs are normally available, but three other types are considered here also. The two usual types are vertical and oblique; the others are composite, trimetrogon, and sonné.

a. Vertical Photographs. Vertical photographs are taken with the camera aimed downward from the plane; the axis of the camera being perpendicular to the ground surface. This provides a photograph that is parallel to the ground below. However, it is difficult to control the airplane and camera in such manner as to obtain this ideal result without at least a small amount of tilting of the photograph. Tilt causes inaccuracy in map making and must be compensated accordingly. Two types of vertical photographs are pin-point and strip photographs, and area cover, (ch. 14).

b. Oblique Photographs. In contrast to the verticals, oblique photographs have their axes purposely tilted from the vertical. The amount of tilt, or angle away from the vertical, varies in accordance with the mission, but generally the angle is within a range of 30 to 60 degrees (fig. 104). An oblique photograph which includes the horizon is called a high oblique. One which does not have the horizon showing is called a low oblique. Figure 104 also shows that the altitude of the camera does not determine whether an oblique is high or low; in fact it shows that a low oblique can be exposed from a higher level. Obliques are more desirable than verticals in many instances because of the sideview characteristic they possess. They produce a more normal view of ground objects which makes them desirable for studying certain types of terrain or ground features having considerable relative relief, such as tall structures or slopes.

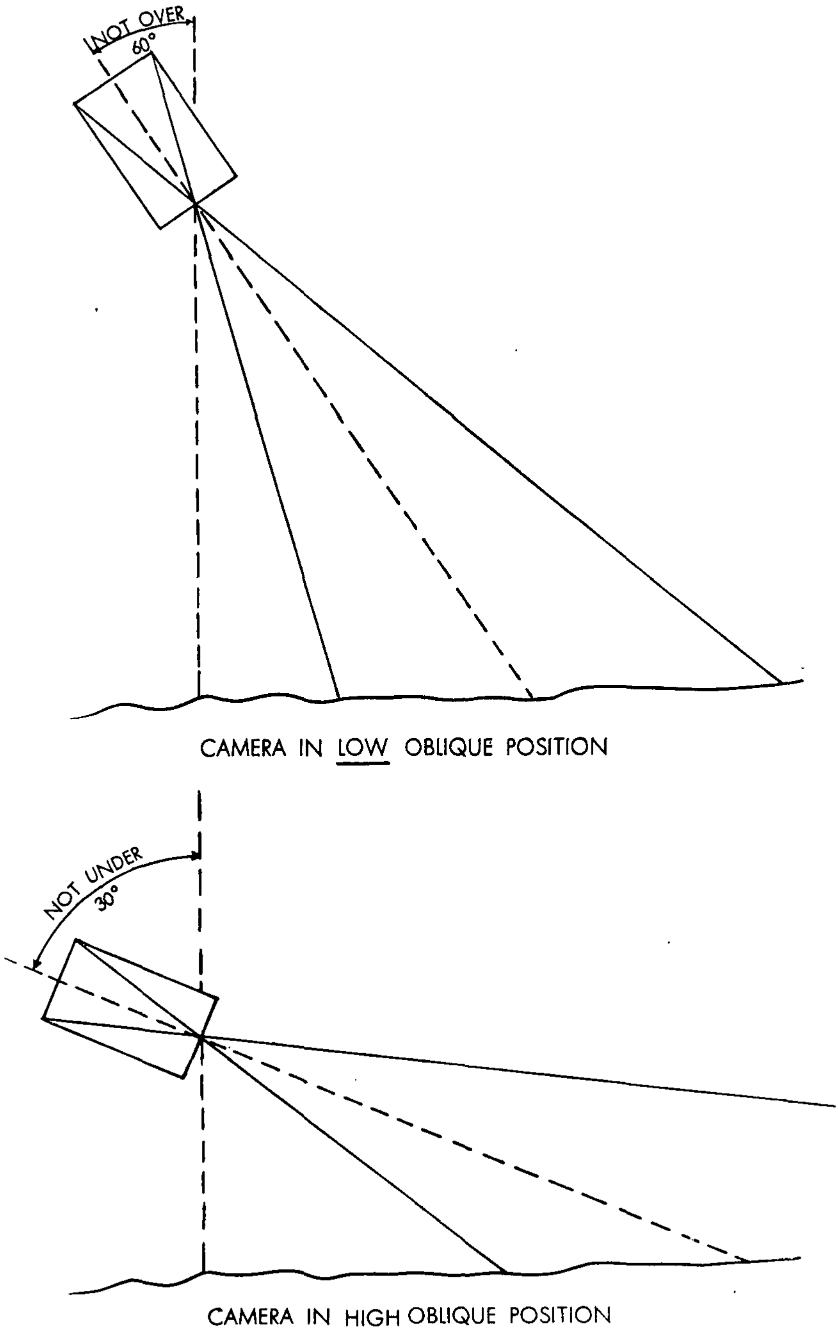

FIGURE 104. *Oblique photography.*

c. Composite Photographs. A composite photograph is printed from three or more separate negatives which are exposed simultaneously by a multilens camera. The multilens camera of usual construction has one lens aimed along a vertical line of sight, and other lenses arranged in pairs tilted away from, and on opposite sides of, the central lens. When printed, the tilt is reversed and the resulting photograph is all in one piece and in the same plane as the portion exposed by the central lens. The composite photograph can be either vertical or oblique, according to the definitions of the two preceding paragraphs, but it is generally used as a vertical photograph to take advantage of the great area of coverage it affords. This great area of coverage in a composite photograph is the most important reason for its design, and is called "angle of coverage" for purposes of discussion, since the area is dependent upon the size of the angle of coverage possessed by the

FIGURE 105. *Composite photograph.*

taking camera. Increasingly better air-camera lenses are being designed today with wider angles of coverage, thereby diminishing the advantage of the multilens cameras. The composite photograph is necessarily large and awkward to handle in the field, as compared to the single lens vertical or oblique, but it does provide

d. Trimetrogon Photograph. Trimetrogon photography employed. Figure 105 shows a mulitlens (9 lens) composite photograph.

d. Trimetrogon Photograph. Trimetrogon photography employs a combination of three separate photographs exposed simultaneously by three single lens cameras mounted in the same airplane. The central camera is vertical and the other two are arranged as obliques to the right and left of the line of flight, in such a manner that the entire area is photographed from right horizon to left horizon. But, the coverage is not printed as a composite photograph. Rather, it is used as three separate pictures, a vertical and two obliques, for a special mapping procedure, explained below, employed by the chart makers in and for the United States Air Force. However, for field use, any or all of the three pictures in a set can be used.

e. Sonné Photographs. The sonné camera photographs a continuous strip of terrain by allowing the negative to move continuously over a fixed slit. The speed with which the film moves across the slit is adjusted to the speed and height of the aircraft. Sonné strip photography is especially adopted to low altitude flying, but is not generally considered of value as a map substitute.

153. Marginal Data on Aerial Photographs

Every aerial photograph is given a title which is applied to the margin of the photograph and contains information that will identify the photograph and serve as a means of preserving its value for future use. The information is in code form and contains such items as time, date, camera type, altitude, and other pertinent facts without which technically excellent aerial photographs might well be valueless to the map user. The data is actually placed on the negatives by the Air Force unit making the photographic sortie, since it is a responsibility of the Air Force to perform the photographic mission and to title the photographs that are taken. AFR 95–7 governs the titling procedure. It specifies in detail how and where and when the data will be applied to the negatives. It outlines the sequence of date contained in the title, and gives a title similar to the following:

121 USAF 14RS 109 (12 Sep 50) 12″ 12,000 270–D30

(4302N–7607W) M 1630Z (50–1) Syracuse, N. Y. Unclassified

Figure 106 is an aerial photograph to which the above title has been applied properly. The meaning of each item is explained below:

Item	Example	Explanation
1	121	*Exposure Number.* The 121st consecutive exposure with a camera on a sortie.
2	USAF	*Service.* U. S. Air Force. Others are U. S. Navy (USN), U. S. Army Engineers (USE), British Air Force (RAF), Canadian Air Force (RCAF).
3	14RS 109	*Taking Unit and Sortie Number.* Denotes 14th Reconnaissance Squadron, sortie 109.
4	(12 Sep 50)	*Date* photography is accomplished.
5	12″	*Focal length* of camera lens.
6	12,000	*Altitude above sea level* at the time of exposure.
7	270–D30	*Position of Camera.* Denotes camera is pointed to left of direction of flight (270° azimuth) and is depressed (D) 30 degrees from the horizon.
8	(4302–7607W)	*Coordinates.* Geographic coordinates of Syracuse, N. Y. in degrees and minutes.
9	M	*Kind of Photography.* M is mapping photography; R is reconnaissance photography, etc.
10	1630Z	*Time of Exposure.* Always Greenwich Mean Time.
11	(50–1)	*Project Number.* Denotes the year of 1950, the first project.
12	Syracuse, N. Y.	*Descriptive Title.* Denotes general area of project.
13	Unclassified	*Classification* for security.

Not all of the above items are required on every negative of every sortie of all kinds of photography. AFR 95–7 states which of the twelve will be employed, by kinds of photography, and it further specifies which items are required on the first and last exposure of each sortie, and which ones make up the titles for intermediate photographs. In general, the kind of photography indicates which items are necessary in connection with its special use. For exam-

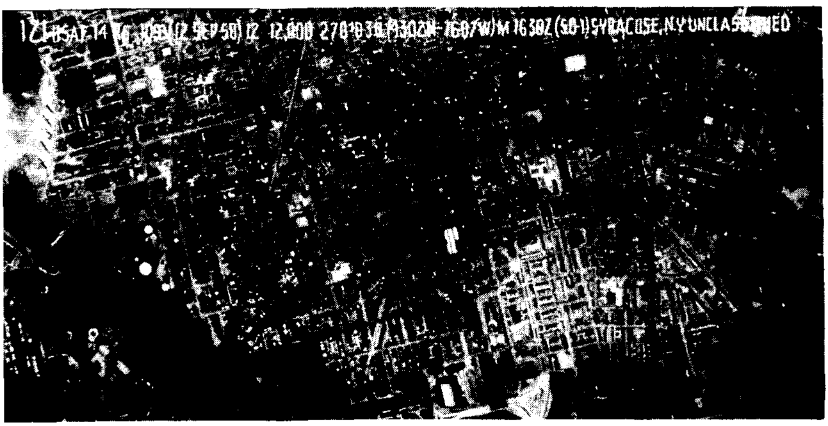

FIGURE 106. *Titling data on aerial photograph.*

ple, mapping photography must have all the items, less item 12, on the first and last exposure of each continuous flight strip; while only items 1 through 6 and item 13 are necessary on intermediate exposures.

154. Indexing Photographs

A photograph index serves as a catalog of available photography, and its preparation is a funtion of the agency performing the actual photographic flying missions. The purpose of the index is for ready access to available photographs and coverage data.

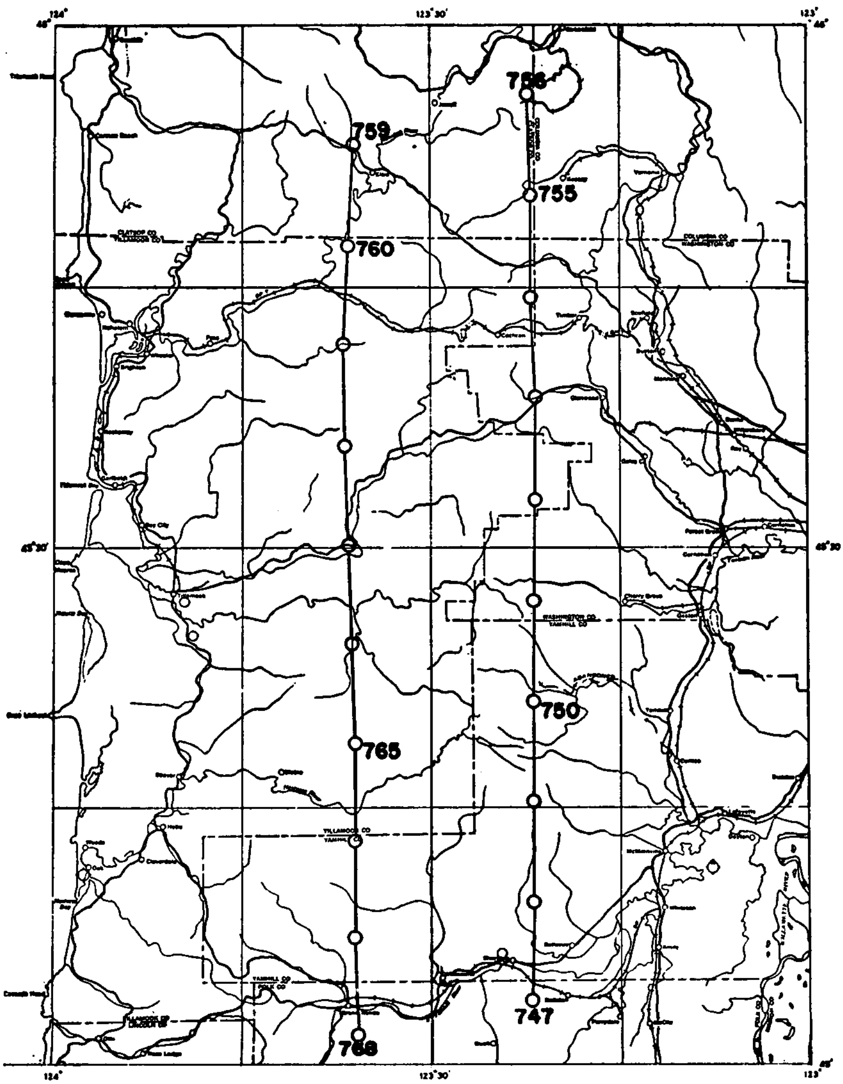

FIGURE 107. *Photograph indexing by centers.*

Physically, the ideal index is a staple mosaic which is described in chapter 14, but the usual form is a map on which the available photographs have been positioned. Time limitation and the extent of the area covered affect the method of placement. However, the two most popular methods of indexing photographs are by centers and by templet area.

a. Photograph Center Indexing. Photographic center indexing consists of plotting the approximate position of individual photograph centers (principal points), joining the points with straight lines along the lines of flight, and labeling the end photographs of each flight with its identifying number. Usually, the centers are plotted on an existing map of the area by comparison of map and photograph detail. Where no map or maps exist, it must be done by comparison of adjoining photograph detail, which makes it

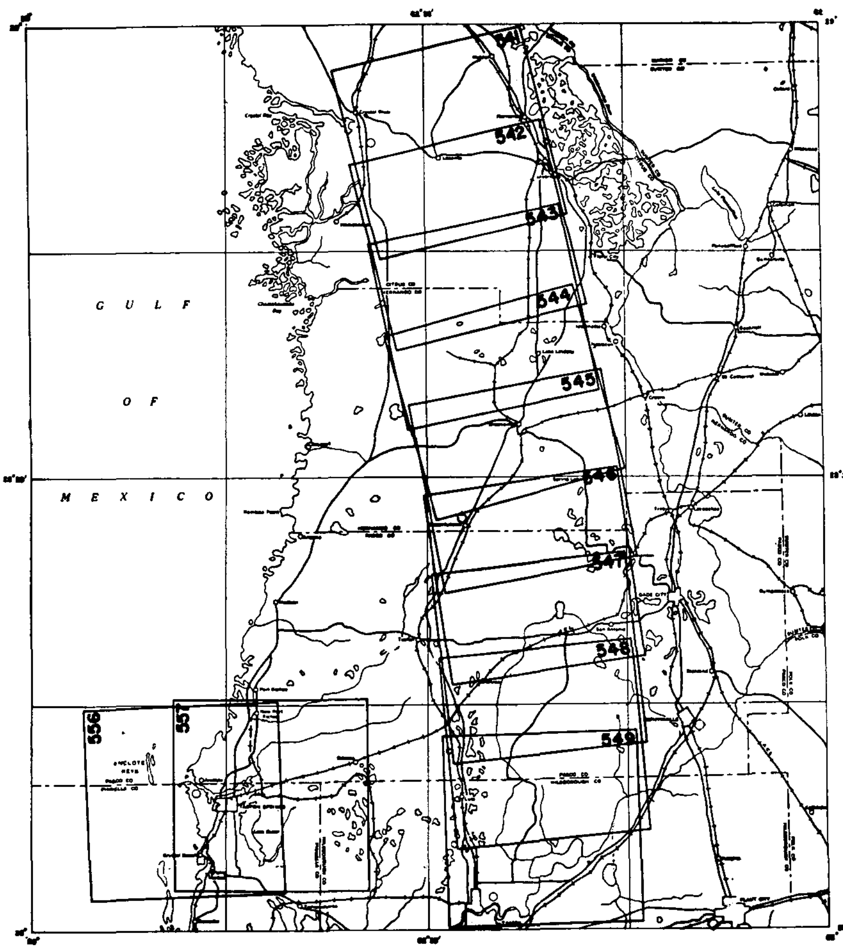

FIGURE 108. *Photograph indexing by area plotting.*

difficult to produce reliable indexes. The center method of indexing photographs is employed mostly in the cases of large area coverages involving a large number of photographs, and in cases when only a hasty index is required (fig. 107).

b. Photograph Indexing Area. For the photograph indexing area method, the ground area included in each photograph is actually outlined on a map sheet by the following procedure (fig. 108). A templet is prepared equivalent to the ground area of the photograph, both photograph and map scale being considered. The templet is placed on the map and oriented until it covers the identical area of the photograph, as identified by similar details on each, and the area indicated by the templet is outlined on the map. The last step is to identify each photograph area by its number. The templet method is employed only when map coverage exists and when a more accurate picture of photograph coverage and overlap is required.

155. Photograph Scale

It is just as important to know the scale of a photograph as it is to know the scale of a map, whether it be for field use or in map making. Photograph scale is the means of making measurements on the photograph. A photograph does not have a constant scale, as does a map, because of certain inherent geometrical and optical properties, but an average scale can be determined which suffices for field operations, especially when only the central portion of a photograph is used. There are several methods of determining photograph scale.

a. Flying Height Method. In general, the higher the airplane when pictures are taken, the smaller the scale, using the same camera and lens. Specifically, the scale is a function of the focal length of the taking camera and its distance above the ground surface, as follows:

$$\text{Scale} = \frac{\text{focal length of camera (inches)}}{\text{altitude above ground (inches)}} = \frac{f}{H}$$

The authenticity of this scale formula is illustrated by figure 112, where the scale is represented by the width of the negative (ab) divided by the corresponding ground coverage (AB). By proportion, ab/AB = f/H. Therefore, Ratio = f/H. For example, the scale of a photograph (fig. 109) taken at 10,000 feet altitude above the ground where f = 6-inch camera, would be:

$$\text{Scale} = \frac{6 \text{ (inches)}}{10{,}000 \times 12 \text{ (inches)}} = \frac{1}{20{,}000} \text{ scale}$$

The scale of a photograph of the same area at 20,000 feet would be:

$$\text{Scale} = \frac{f}{H} = \frac{6}{20{,}000 \times 12} = \frac{1}{40{,}000} \text{ scale}$$

Note that only altitudes above the ground elevation have been mentioned. Flying altitudes are always based on sea level, and therefore care should be taken to subtract the average sea level elevation of the area of photograph coverage from the flying altitude, before using it in the scale formula. For example, if the elevation of an area averaged 1,000 feet, then the height above the ground would be the flying altitude less 1,000 feet.

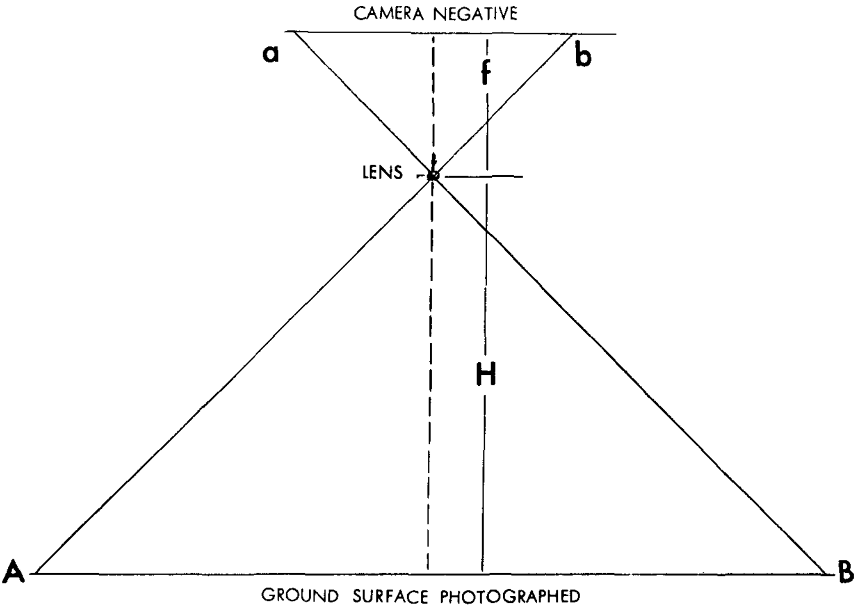

FIGURE 109. *Aerial photograph scale diagram.*

b. Map Distance Method. If a map of the same area as that covered in a photograph is available, the scale of the photograph can be determined. The principle used is the same as was in *a* above, except that instead of using the whole width of the photograph (ab), a shorter distance is actually selected on the photograph and the corresponding distance on the ground (AB) is scaled from the map. Two identifiable points are selected to determine the ends of this measured line of distance, as illustrated by (ab) in the photograph on figure 110. The line connecting these two points passes close to the center of the photograph, making them an almost equal distance from the center. It is advisable to select the points in this manner for a better average scale. The scale is improved if the two points are at about the same elevation on the ground. A further improved average scale is obtained if two or more scale distances are measured and the resulting scales averaged. To determine the scale, once the two comparable distances have been measured, the values are entered in the formula, Scale = Photo distance/Ground distance. For example, a photograph distance of 6 inches and a map distance of 10,000 feet would produce a photograph scale of—

$$\text{Scale} = \frac{\text{PD}}{\text{GD}} = \frac{6}{10{,}000 \times 12} = \frac{1}{20{,}000}.$$

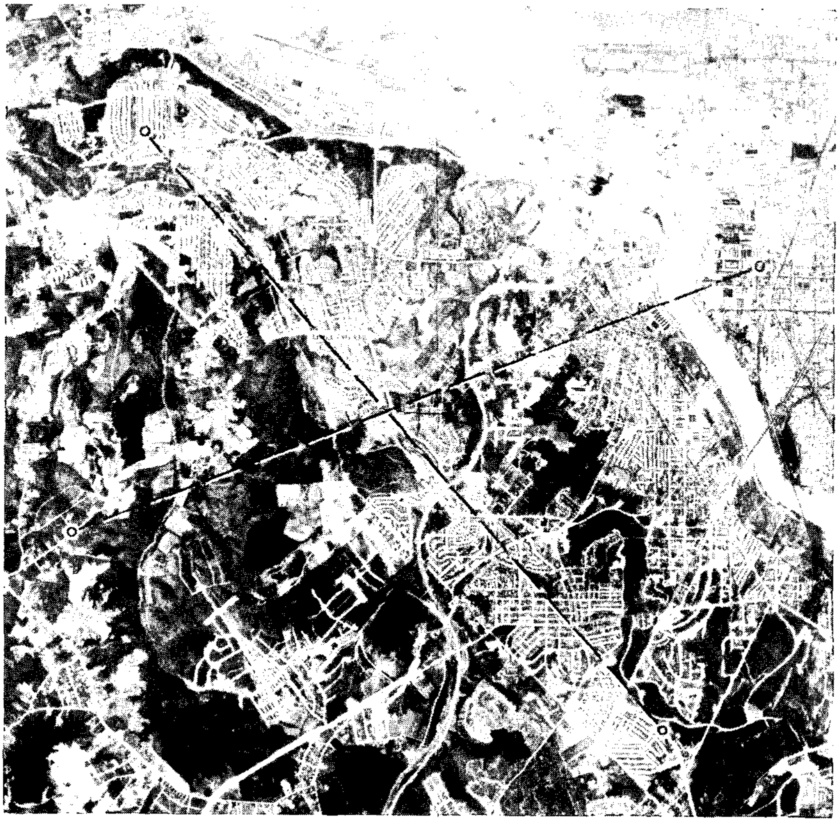

FIGURE 110. *Photograph scale determination.*

c. Ground Distance Method. This method is identical to the map-distance method of determining photograph scale, with one exception. The ground distance is actually measured or paced off on the ground for substitution in the scale formula. This method presupposes that the ground area is accessible and that no map of the area is available.

156. Measuring Distance on a Photograph

When the scale is known, it is easy to measure distances on a photograph. The distance is measured in inches and multiplied by the denominator of the scale fraction to determine the ground distance in inches. However, if many distances are to be measured, it is advisable to prepare a graphic scale and use the paper-strip method of reading off distances directly in ground units, as is explained in chapter 3 in the discussion on map measurements.

157. Measuring Azimuths on a Photograph

For all practical military purposes in the field, the same methods are used as prescribed for measuring and laying off azimuths with the compass and protractor on a map. Because of the geometry of a photograph, azimuths from a point near its center are more nearly correct than azimuths from a location near a margin. This fact should be carefully noted. If possible, work should be done in the center of the photograph only.

158. Photograph Orientation

a. General. In order to use the photograph to the best advantage, it must first be oriented like a map. This can be done in several ways, the simplest of which is by inspection, which involves rotating the photograph until the features imaged on it are alined with actual features on the ground, as described for map orientation in paragraph 24.

b. Orienting a Photograph with Map and Compass. A more accurate orientation is accomplished when, in addition to the photograph, a map of the same area and a compass are available. First, orient the map with the compass, as described in paragraph 50*e*; then, aline the photograph features similarly to the map features, and the photograph is oriented.

c. Establishing North by Shadows on Photograph. Often it is desirable to find the direction of north on a photograph when no map of the area is available. A different means of orientation is required. Under such circumstances, the shadows cast by objects are used to establish north on the photograph. In general, the method presupposes that the azimuth of shadows is known and can be applied as a correction angle to the shadows which are on the photograph to produce true north. The azimuth of shadows is dependent on two things, the time of day and the position on the globe north or south of the equator. Shadows on photographs are equally dependent on these two conditions. The time and place of the photograph are found in its marginal data (par. 153). Of course, the place thus indicated is quite general and must be defined in accordance with known directions of the sun. In the north temperate zone, rays of the morning sun will cast shadows to the northwest, the evening sun, to the northeast, and at 1200 noon the shadows will point to the true north. South of the equator, the directions are just the opposite. To measure the angle of the shadows from north is the problem. A typical problem and its solution follow and is illustrated in figure 111.

(1) True north is desired on a photograph taken at 1600 hours of an area north of the equator (fig. 111). In that area, a test is made on the ground to learn that the shadows move through an angle of 12½ degrees every hour. Therefore, the azimuth angle of the shadows on the photograph is (1600—1200) $\times$ 12½°, or 50° east of north.

(2) The 50° azimuth is laid off counterclockwise from a shadow on the photograph, and the direction to the true North Pole is drawn on the photograph (fig. 111).

(3) If the photograph had been taken four hours prior to noon, the shadow's azimuth would be 50° also, but it would have to be applied in a clockwise direction since the shadows would have fallen west instead of east of north. Figure 111 also shows this alternate solution.

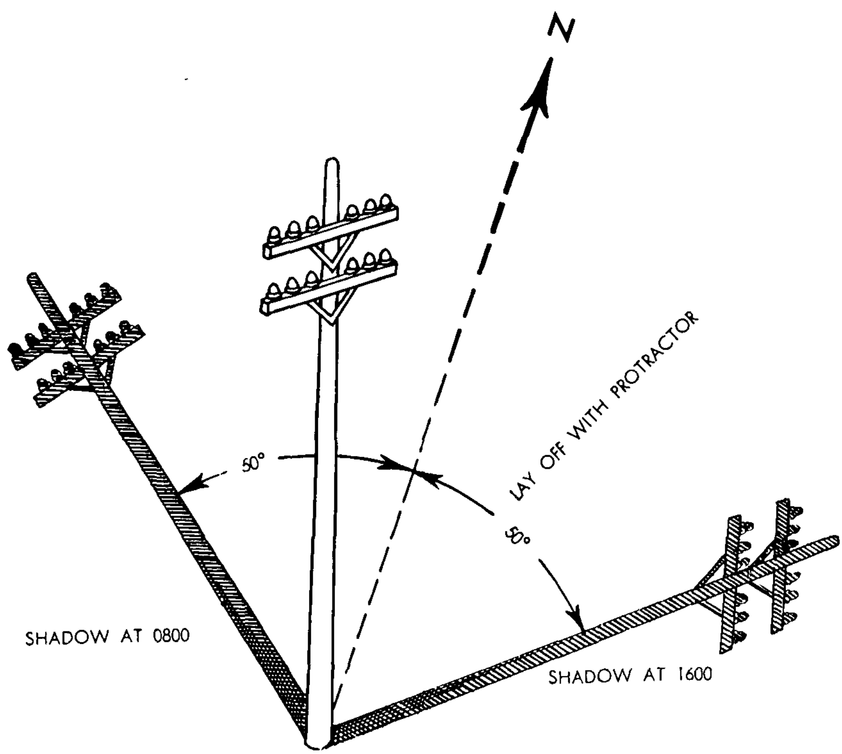

FIGURE 111. *Establishing north by shadows on photograph.*

159. Photograph Interpretation

The aerial photograph is non-selective—that is, it contains every detail picked up by the camera lens. For map reading purposes, the various features must be made meaningful by a specialized technique called photograph interpretation, which has been developed extensively for miltary use. It is not a simple procedure and the four rules of application described below are meant to be used as a guide while learning; adeptness will come only after much experience.

a. Size. The relative sizes of images on a photograph usually help in identifying them. For example, the smaller buildings are likely to be dwellings; the larger, to be commercial or community buildings such as churches, court houses, or schools.

b. Shape. Straight lines indicate manmade features; irregular lines tell of natural features. Ditches are straight, streams are meandering. Railroads strike long straight tangents across the photograph; trails and backroads follow the easy contour route blending with the landscape. Cultivated fields tend to be well-defined regular shapes, while shorelines and small bodies of water are usually irregular in design.

c. Shade. Shades of gray on the photograph, the contrast or tone, is also very useful in photograph interpretation. Tone is useful in the same way that color is, though to a lesser degree; the shades of gray serve as various colors. In general, the photograph reveals light-colored objects as light gray images, and darker objects as darker images. Smooth concrete pavements and shiny roofs show up light gray, while timbered areas and deep water appear darker.

d. Shadow. The fourth rule of photograph interpretation is concerned with using the shadows in the photograph to identify objects photographed. For example, tall features can be spotted directly by their long shadows. Further, the shape of the shadow is often a clue the identity of a feature. The clearance of a bridge, as well as the type of structure it is can often be interpreted from the shadow it throws. Military works often have unusual shapes and can be detected by their shadows. For tactical interpretation of aerial photographs, see TM 30-246.

160. The Stereoscopic Property of a Photograph

There is one property of a photograph that is valuable for nearly every use of the aerial photograph. This is stereopsis, the characteristic of third dimension which is achieved by blending into one image two pictures of the same object taken from different points. Viewing photographs stereoscopically gives the user a sense of being in the airplane from which the photographs are being taken. In this way, the user can see the ground more realistically, and this is an invaluable asset in obtaining the maximum information from aerial photographs.

a. Stereo-Pairs. The two overlapping photographs required are called a stereo-pair, and are so placed for study that they are in the same relative positions as when they were taken. The left eye sees only one photograph and the right sees only the other photograph. The overlapping ground area in the center is seen by both, simultaneously. Figure 112 offers two samples of such overlapping areas. Normally, an instrument called a stereoscope is employed to view these pictures. There are a great many varieties of stereoscopes, ranging from pocket models to large encased models. Some use mirrors, but the more desirable ones use lenses which magnify the picture.

b. Use of the Stereoscope. In viewing a stereo-pair, the photographs are placed beneath the stereoscope so the detail viewed under the lens on the left-hand photograph is identical to that being viewed under the other lens on the right-hand photograph. The best way to arrange the photographs is to place a finger on the same feature on each photograph, place the instrument over the stereo-pair and, while viewing through the lenses, move the pictures until the two fingertips coincide. On removing the fingers, the viewer should experience the feeling that the features are elevated. If two images of the features on the photographs are still visible, move the photographs slightly until the images merge into one, to get the three dimensional effect. For a detailed discussion see TM 5–230.

c. Stereovision. It is difficult for some individuals to grasp stereovision instantly, while others never do. However, the majority of people develop better facility with practice. The eyes must become sufficiently flexible to act separately instead of together as nature intended. Certain aids or eye exercises are prescribed to help obtain this flexibility when necessary. These are used when the exercise cannot be obtained by practice with a stereoscope. The simplest exercise is the finger exercise in which the two forefingers are placed end-to-end at arm's length before the eyes, while viewing a distant object, then drawn slowly apart. A third finger appears when the correct placement is obtained, and the eye exercise is extended by moving the fingers as far as possible while still holding the third finger in view. Another simple and similar exercise is obtained by placing two dots on a piece of paper about 2 inches apart and viewing them in such a way as to see another dot form in between them. It is obvious that stereopsis is valuable to nearly every military mission in which photographs are employed. In general, stereo-pairs and a stereoscope should always be considered as a unit, by the map or photo-

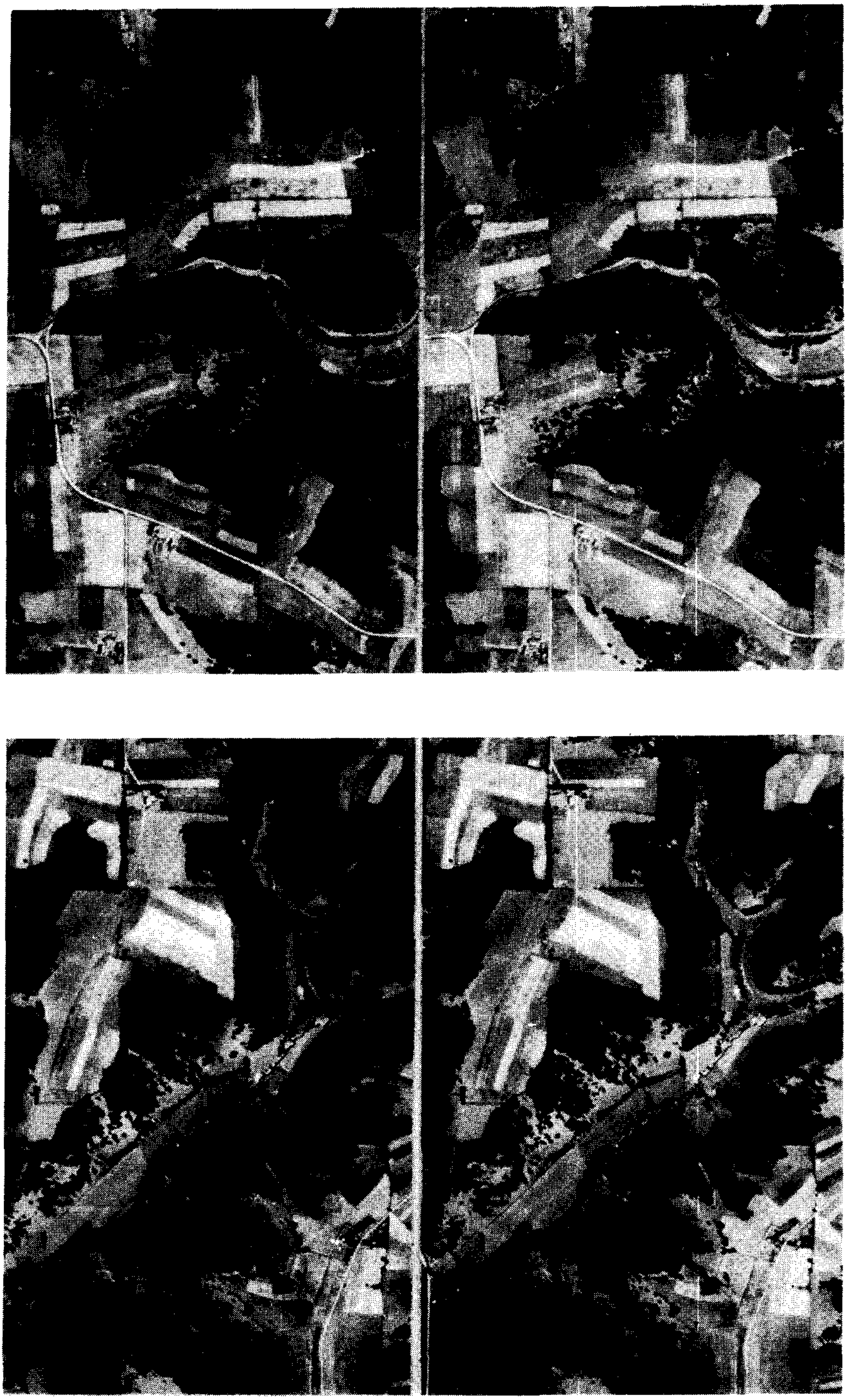

FIGURE 112. *Stereo-pairs.*

graph reader. There are many special uses for this combination, and there are many techniques by which it can be used to develop special information. More detailed discussion about the use of photographs and stereoscopes is to be found in TM 5–244.

CHAPTER 14

MOSAICS AND PHOTOMAPS

161. Definition and Comparison

A mosaic is a combination of two or more overlapping photographs, so joined as to give a single continuous picture of the entire area. When grid lines, names, and marginal data are placed on the face of the mosaic, and the result is reproduced in quantity, it becomes a photomap. Naturally, the photomap is no better than the accuracy maintained in controlling it with ground control points. Mosaics are produced under two classifications which are based on expected accuracy, but either class has a wide accuracy range, dependent on the workmanship employed. The two classes are controlled and uncontrolled mosaics.

162. Uncontrolled Mosaic

As the name implies, an uncontrolled mosaic is not based on plotted ground control points. Rather, it is produced by matching detail as each photograph is added to the mosaic. As the match lines are never perfect throughout, it is a matter of spreading the error as evenly as possible by trial and error. At least two types of uncontrolled mosaics are produced. These are staple mosaics and paste mosaics.

a. Staple Mosaic. This type of mosaic is produced to serve as an index, primarily of the photographs themselves. It is also used for many other indexing requirements, such as for location of units in the field, supply points, and control stations. It is prepared by stapling each photograph successively to a stable base, in such a manner as to leave exposed the edge of each photograph containing the marginal information described in paragraph 153. Photographic details must be matched in the necessary overlap procedure in order for it to qualify as an uncontrolled mosaic. Although the staple mosaic has no worthwhile overall scale, its use in indexing photographs justifies its construction. A staple mosaic can be seen in figure 113.

b. Paste Mosaic. This is the commonly used type of uncontrolled mosaic. It differs from the staple mosaic in that only the center areas of each photograph are used and the balance discarded. They are joined together and pasted to the stable base

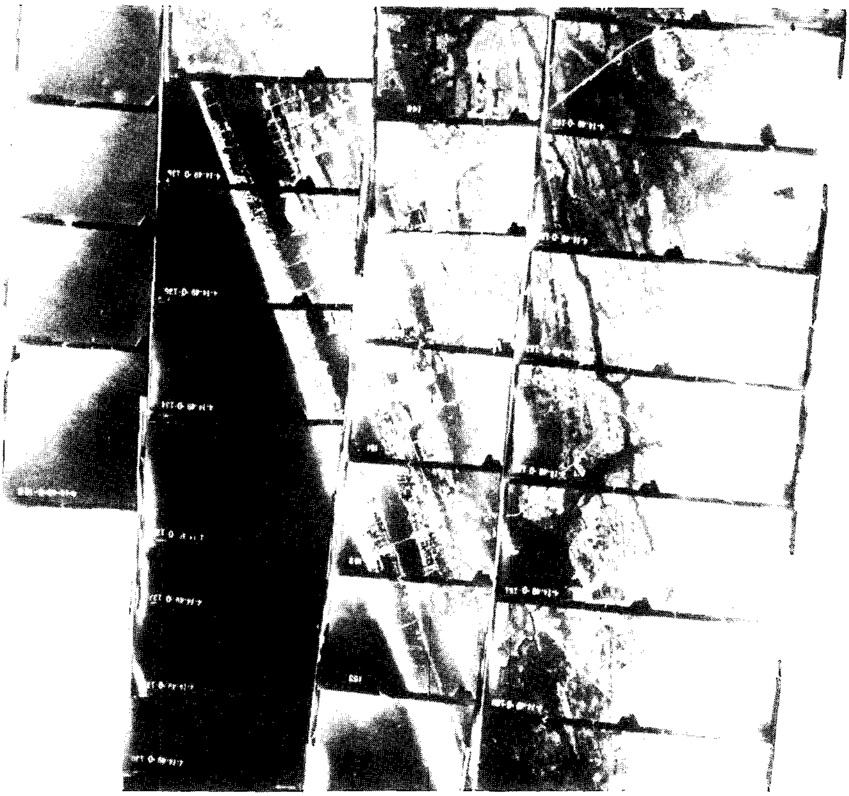

FIGURE 113. *Staple mosaic.*

to form the mosaic. Much more time is required to prepare this type of mosaic, but the result affords a practical scale and direction quality, making it useful where scale and direction are desirable for the purposes of the mission. It forms a much better pictorial representation of an area than the staple mosaic and its inherent errors are not harmful if the user is aware of their existence.

163. Controlled Mosaic

A controlled mosaic has a comparatively accurate scale and direction value because it is fitted to established ground control points. The control is plotted to the average scale of the photographs on the mounting surface just as it is prepared for map compilation. The center areas of the photographs are mounted directly over the control points. Distortions in the photographs may not permit exact matching of details across photographic junctions, but the errors are normally insignificant, allowing the desired accuracy to be maintained. The controlled mosaic has many uses, but its primary military use is to serve as a basis for photomap production.

164. Semicontrolled Mosaic

The semicontrolled mosaic can qualify as a controlled mosaic of low accuracy. However, because of its usefulness and relative merit in a military capacity, it is treated separately from the controlled mosaic group. Its name implies that it is only partially controlled by accurate ground positions. This is true for several reasons. Perhaps sufficient positions do not exist, data for them is not available, or to establish them in the field would be too hazardous and time consuming. However, the semicontrolled mosaic has value for field preparation and use, because it can be produced rapidly by relatively inexperienced personnel, and yet provide the field commander with required information.

165. Strip Mosaic

This type of uncontrolled mosaic may be either paste or staple, but usually staple. It is made from a single strip of photographs, normally, because only one strip was flown and only one strip was needed. The need has a direct bearing on the purpose of the strip mosaic. For example, the strip mosaic provides a fine substitute for a map when used as a guide for flying cross-strip photography. It gives the navigator ground features by which to determine the proper spacing of flight lines. Two such strip mosaics, one placed across each end of an unmapped area, provide an ideal means of obtaining good photograph coverage. Strip mosaics also could be very useful to military forces operating in narrow areas, or across the front of a stabilized position.

166. Photomaps

A photomap is a reproduction of a photograph or mosaic on which grid lines, marginal data, and place names are added. A single vertical photograph with a point-designation grid might be considered a photomap. Normally, however, the military photomap is a map size reproduction of a mosaic, either controlled or uncontrolled. As a map substitute, it is reproduced in quantity and is printed on a press using standard map paper. The addition of a grid transforms a mosaic into a photomap and this gives it the same properties of point designation contained in a gridded map. For obvious reasons, the grid used on the photomap is the map grid, the UTM grid. A photomap made from an uncontrolled mosaic gives a good picture of the terrain and can be prepared quickly, although it will have errors in scale and direction. A photomap made from a controlled mosaic takes much longer to prepare, but it can be scaled accurately. The actual preparation of the photomap is detailed in TM 5–244, which also describes the application of names and marginal data in addition to that required for using the grid. Figure 114 is a photograph of a military photomap. Often it is printed on the reverse side of the regular map of the same area.

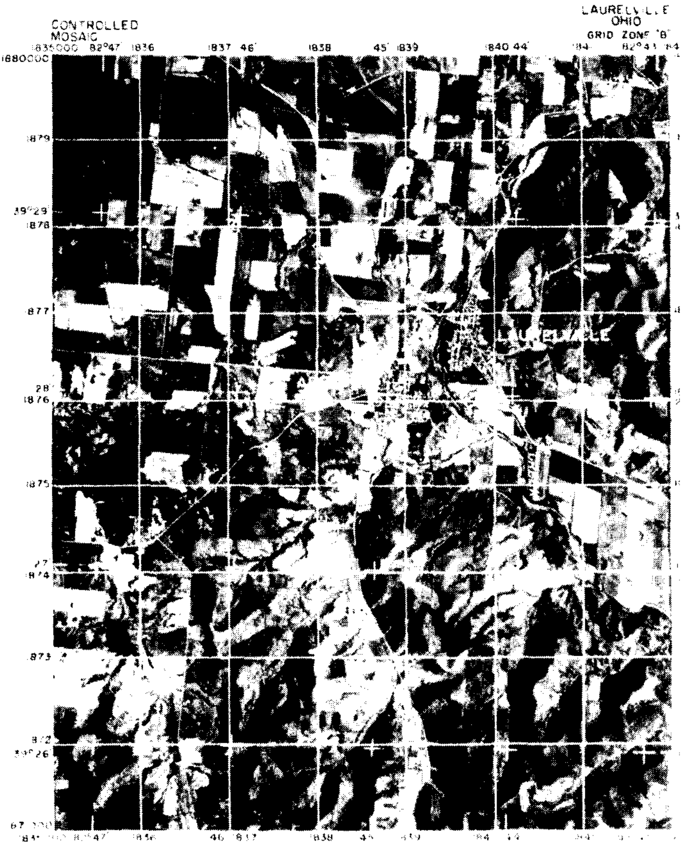

FIGURE 114. *Military photomap.*

CHAPTER 15

OVERLAYS AND OVERPRINTS

167. Definition and Purpose

An overlay carries the information on a separate medium which has marks for registering it to a certain map, and the overprint is the map itself on which the information has been specially printed in an obvious color and/or symbol.

168. Overlays

An overlay is a transparent or semi-transparent sheet giving special information not ordinarily shown on maps. When the overlay is laid over the map on which it is based, its details supplement the map. An overlay is a graphical method of explaining a situation which would otherwise require many pages of writing.

a. Use. When a unit is ready to move into a new area, maps are normally issued to each officer and enlisted man entitled to receive one. Later whenever the unit headquarters wants to convey some special information to all or part of its personnel, an overlay is prepared instead of a map. Thus, any number of overlays can be based on the same map.

b. Advantages.

(1) The overlay permits the transmission of information without actual transmission of maps. For example, a patrol leader wanting to report the location of an enemy position, makes an overlay, dispatches it to his commanding officer by messenger, and continues his patrol without having to give up his map.

(2) Placing the desired map information on an overlay aids in clarity. If the symbols were drawn directly on a map, the added symbols might obscure printed details. The reader of an overlay can first read the symbols, and then place the overlay on the map to determine the proper location of the objects. Overlays are comparatively easy to reproduce; they can be made in the field and can reduce the number and bulk of maps required for field operations.

c. Overlay Materials. Overlays are usually drawn on tracing paper or on transparent acetate. Tracing paper is normally easier to obtain, can be folded, and can be used for reproducing copies in quantity. The principal advantage of acetate is that symbols can be drawn on it with a china-marking pencil and easily erased; acetate is usually used on situation maps at headquarters where changes in the situation are posted on the map whenever information is received. Acetate is waterproof, can be rolled, but cannot be folded.

169. Preparing Overlays in the Field

Overlays are commonly used by personnel on patrols or in making reconnaissances to record information or to transmit information to higher headquarters. Figure 28 shows a typical overlay prepared in the field. Procedure for preparing such overlays is normally as follows:

a. Orient Map. Before objects are sketched in, the map should be oriented (placed so that magnetic north on the map coincides with magnetic north on the ground). It should be oriented on a hard, flat surface to make writing easier.

b. Place Overlay Paper on Map. Transparent material is placed over the map. The overlay is fastened securely to the map at the top so that it will remain in place while the sketch is drawn. It is allowed to remain loose at the bottom, however, so that it can be raised from time to time to locate points on the map more clearly.

c. Draw Register Marks. Register marks are traced on the overlay paper. A register mark consists of a cross traced over the intersection of a vertical and a horizontal grid with the identifying grid numbers placed along side. The register mark is not complete without the grid numbers. Obviously, two register marks are necessary to fix the correct position of the overlay. One register mark is usually drawn in the lower left corner; the other, in the upper right corner.

d. Sketch in Objects. The desired objects are sketched on the paper. The size of the military symbols depends on the scale of the map and the density of detail. The more symbols used, the smaller they are drawn. Certain features already found on the map, such as roads and streams, are sometimes traced on the overlay paper, to permit limited use of the overlay without placing it over a map. If explanatory notes are necessary, they are written in the margin of the overlay, with arrows pointing to the objects mentioned.

e. Indicate Sender's Position. When the overlay constitutes a message or report from the field, the sender's position at the time he made the overlay is usually given. Also, the route he has followed is shown.

f. Draw a Title Box. A title box, which contains the information required by the person who receives and uses the overlay, is usually placed in the lower right corner. This information must include—

(1) *Title and scale of map used.* This is essential because the receiver must place the overlay over the same map as the sender used.

(2) *Time the overlay was drawn.* This tells the receiver exactly when the situation was as shown on the overlay.

(3) *Signature, grade, and organization.* This shows the source of the information.

170. Overprints

When the urgent need for new and special information calls for a great many copies, the overprint may be chosen instead of the overlay. By definition, the overlay is useless without the map to which it adds suplemental information and, therefore, it is usually easier and quicker to prepare a press plate containing the special information, and overprint it on the regular issue map, usually in a distinguishing color. A typical example of information of this nature would be the pre-invasion condition of the roadnet in an area of military importance. The overprint is used to deliver many other types of information pertinent to the activities of large forces.

CHAPTER 16

THIRD DIMENSION MAP SUBSTITUTES

171. General

There is a type of map substitute or supplement which actually employs the third dimension to depict relief. One or more of this type of map substitute has been in popular military use throughout the history of warfare, but the oldest still in use today is the sandtable. The sandtable is a model of an area in three dimensions: elevation, as well as length and width. Only a relatively small area of ground can be represented at a large scale, and this limitation is the chief disadvantage of all three-dimensional map substitutes, modern types of which are the terrain model and the embossed model. However, in comparison to a map, this type of representation provides a more objective method of showing relief, which complements and accentuates the picture shown by contours. Since the three-dimensional models have definite value for military use, each of the popular types is described below.

172. The Sandtable

The sandtable can be built easily and quickly, but the area it can depict is limited. Its bulkiness and weight preclude its use as a map substitute in the field, or even in a theater of war. Therefore, it is utilized principally as a training aid, where it can be effectively employed.

173. The Terrain Model

The terrain model (fig. 115), like the sandtable, is built up physically to show relative differences in elevation for the area it portrays. The materials used vary from papier maché to rubber or plaster of Paris, and the terrain details are pictured on the finished model by painting or other color process. The terrain model is not intended for movement because of its size and bulk, but does cover larger areas and shows more detail than the sandtable.

174. The Plastic Relief Map

The plastic relief map is a form of embossed relief model which is offered as an improvement over other types of three-dimensional map substitutes. The embossed model in general is a conventional map which has had its relief accentuated by embossing. Of neces-

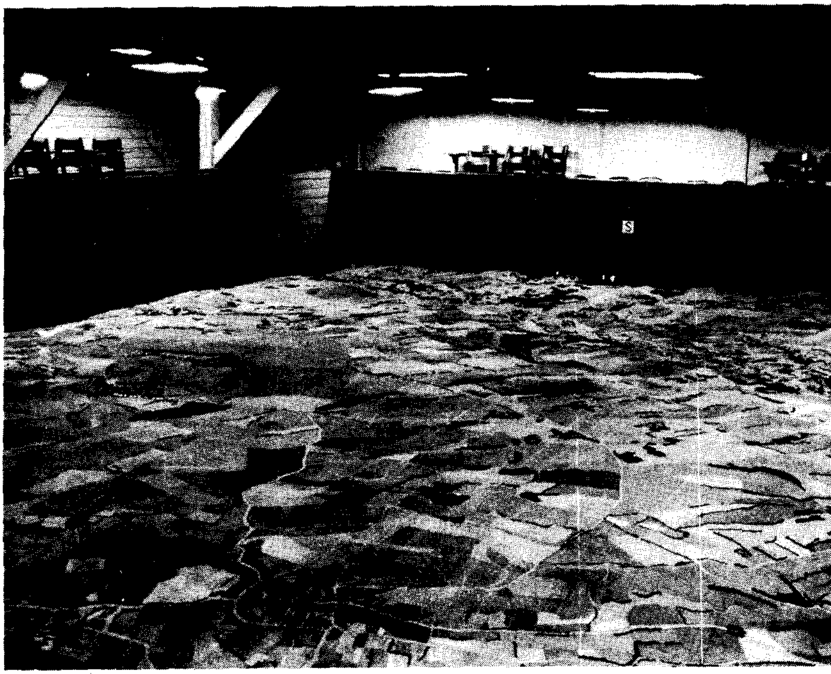

FIGURE 115. *Terrain model.*

sity the material used is not ordinary map paper, and experiments have been made with many different materials ranging from impregnated paper to aluminum. Plastic, however, has special advantages in being light in weight, and the plastic relief map can be produced in quantity for distribution to troops in the field. This map, like other relief maps, is identified by its symbolized representation of the terrain, with the added feature of the third dimension.

175. Third Dimension Map Practices

"Shaded relief" as described in paragraph 60, and "layer tints" as described in paragraph 61, are additional practices for reflecting third dimensional relief. These practices are not map substitutes, inasmuch as, when used, they are included as component features of topographic maps.

APPENDIX I

REFERENCES

Pam 108–1	Index of Army Motion Pictures and Film Strips
SR 117–5–1	Topographic Service (mapping and survey)
Pam 310 series	Military Publications (as applicable)
SR 320–5–1	Dictionary of United States Army Terms
SR 320–50–1	Authorized Abbreviations
FM 5–5	Engineer Troop Units
FM 5–6	Operations of Engineer Troop Units
FM 5–34	Engineer Field Data
FM 5–35	Engineer's Reference and Logistical Data
FM 21–5	Military Training
FM 21–8	Military Training Aids
FM 21–30	Military Symbols
FM 21–31	Topographic Symbols
FM 30–5	Combat Intelligence
TM 5–230	General Drafting
TM 5–231	Mapping Functions of the Corps of Engineers
TM 5–232	Elements of Surveying
TM 5–233	Construction Surveying
TM 5–238	60-Degree Star Graphs
TM 5–240	A Guide to the Compilation and Revision of Maps
TM 5–241	The Universal Grid System (Universal transverse mercator and universal polar stereographic)
TM 5–245	Map Reproduction in the Field
TM 5–248	Foreign Maps
TM 30–245	Photographic Interpretation Handbook
TM 30–246	Tactical Interpretation of Air Photos

APPENDIX II

GENERAL MAP INFORMATION

1. Definitions and Terms

The glossary at the end of this manual contains definitions and terms relative to maps and map reading, including the definition of a map which is purposely repeated here—A map is a graphic representation of a portion of the earth's surface drawn to a scale upon a plane surface. This is also the definition of a nautical chart, an aeronautical chart, and all special-purpose maps and charts produced throughout the world. In this manual, the term *map* refers to any and all maps or charts that are produced for military use. It is assumed that they have the military grid, even though many special-purpose maps and charts are not gridded.

2. Maps of the U. S. Armed Services

The information contained in this manual refers, unless otherwise stated, to maps made for or used by the U. S. Armed Services. Map requirements are dictated by their individual needs. Each service may have a map requirement peculiar to its primary mission which is not satisfied by the regular issues of military maps. In general, the Army needs topographic maps representing terrain features in detail. In addition, certain distinctive operations may call for special-purpose maps or map supplements. The Army delegates map responsibility to the Corps of Engineers, which is charged with all aspects of the Army's map supply.

3. Foreign Military Maps

Foreign military maps often contain much valuable information and may be used as supplements to, or in place of, inadequate United States maps of certain foreign areas. However, extreme care must be taken in their use, as the geographic lines of longitude may have a meridian of origin other than that of Greenwich. The grid may often be based on a local grid system and the scales may be different from those used on United States military maps. Further, the symbols used on foreign military maps must be carefully differentiated from similar United States mapping symbols. Foreign military maps may be quite accurate, in which case United States symbols and grids may be overprinted on them to a certain extent. In any case, before using foreign military maps, the accuracy and reliability of the maps must first be established. When sufficient time is available for this evaluation, and they are found to be accurate, foreign military maps may be reproduced for United States military use. In most cases the grid and grid reference information must be changed, the legend translated, glossary and reliability statement or digaram added, and the series and edition identifications corrected. For military maps that are inaccurate and not up to date a revision of major features or a complete revision must be made. In many instances, foreign military maps are the only extant source of information on certain foreign areas, and, as such, must be used when and as required. Therefore some understanding of foreign military maps by United States personnel is desirable. Foreign maps are discussed in greater detail in TM 5–248.

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APPENDIX III

CLASSIFICATION OF MAPS

1. Methods of Classification

There are three methods of classifying military maps—by type, by scale, and by military use. Classification by type organizes into groups those maps whose natural and manmade features are similarly represented. Maps which are relatively the same as to size of area covered are classified into groups by scale. By the third method, maps are classified together according to the military purposes for which they are suitable. This appendix outlines the specific characteristics by which a map is classified under these three categories.

Section I. CLASSIFICATION BY TYPE

2. Topographic Maps

A topographic map portrays natural and manmade features of a section of the earth's surface in both the horizontal and vertical planes. Horizontal distances between features are true distances at map scale, because the features are in true relative position. Vertical distances between features are measurable as normally represented by contours.

3. Planimetric Maps

A planimetric map shows only the relative horizontal position of features. It provides no means of measuring elevation.

4. Photomaps

A photomap shows the earth's features as seen from above, as from an airplane, with grid lines, marginal data, and place names added. The photomap provides a wealth of detail impossible to a topographical map. On the other hand, important military features are sometimes obscured by physical features. A photomap made from a controlled mosaic can be accurately scaled, but relative relief is not readily apparent.

Section II. CLASSIFICATION BY SCALE

5. Small-Scale Maps

Any map having a scale of 1:600,000 or smaller falls in the category of a small-scale map. While the size of area covered is comparatively great, the amount of detail shown is necessarily limited and generalized.

6. Medium-Scale Maps

All medium-scale maps are within a scale range of larger than 1:600,000 and smaller than 1:75,000. Since the size of area covered is less than in small-scale maps, the amount of detail shown is proportionally greater.

7. Large-Scale Maps

This group includes all maps whose scales are 1:75,000 or larger. They cover greatly reduced areas and can show every detail of value to any military mission.

Section III. CLASSIFICATION BY MILITARY USE

8. General Maps

This name is given to any map of a scale smaller than 1:1,000,000. The extremely small scale indicates that it portrays only the large ground features such as mountain ranges and major drainage systems, and that it covers a very large portion of the earth's surface. World maps are good examples of this classification. Their use is for general planning purposes on a nation- or world-wide scale where forces are separated by thousands of miles. These maps are usually associated with joint operations.

9. Strategic Maps

Strategic maps have a scale of 1:1,000,000. Like general maps, their principal use is in planning, but for planning of a more concentrated military effort. The strategic map is especially useful for planning the movement of troops and supplies in a single campaign or continental theater of operations. It is most used in higher headquarters in the field, where the planning may be in terms of armies or joint operations.

10. Strategic-Tactical Maps

The strategic-tactical map is a larger planning map and has a scale of 1:250,000 or 1:500,000. As its name implies, it serves a dual purpose. It substitutes for strategic maps when the latter are unsuitable or not available. It also acts as a makeshift larger-scale map for planning tactical maneuvers. While the strategic-tactical map is not used for normal military operations, upon occasion it may be more suitable for a purpose than the map designated by classification. Furthermore, the large difference in scale between strategic and tactical maps necessitates a map whose scale is midway between them, and which can be used for possible future developments in any extended military operation. The strategic-tactical map is primarily a transportation and communications map, which is used mainly for logistic planning and operations, and for infantry and armored operations.

11. Tactical Maps

Tactical maps have a large scale of 1:50,000 or 1:25,000. Because they show nearly all the planimetry and relief, they are very useful in planning the tactics of smaller combat units such as battalions. The principal purpose of a tactical map is to serve as a guide to these units prior to, and during a movement anywhere in the vicinity of the front lines. It may also aid in directing these units from higher headquarters. The company commander, the platoon commander, and particularly the squad leader use a tactical map to guide every move. The patrol leader designates his route on a tactical map. The same map is then used to guide him in the actual operation. The tactical map is equally useful to all arms and services because of its considerable detail. Where a tactical map of large scale is not available, a smaller 1:100,000 scale map may be substituted.

a. Situation Maps. A situation map is not a map of specific classification, and may be any appropriate map marked to show the tactical or administrative status of a unit at a specified time. For this purpose, a map is chosen of a scale appropriate to the amount of detail required. It may be used for staff study or as an annex to a staff report. When used by intelligence, such a map is known as the intelligence situation map or the enemy situation map, and shows the location and disposition of enemy forces and installations. The situation map can be readily interpreted by intelligence personnel and is used for the dissemination of intelligence information. It is frequently prepared by overprinting special information on a standard map or by printing overlays to be used with standard maps.

b. Artillery Maps (other uses). For purposes of planning and conducting fires, the artillery requires a large scale tactical map. Maps of scale 1:25,000 provide the necessary amount of detail and accuracy. A military grid is necessary to permit accurate location of targets. For normal use in lower infantry units the 1:25,000 scale map is most suitable. Positions and routes thereto can be accurately located. Detailed study of the terrain is possible for both offensive and defensive operations.

12. Photomaps

Although primarily a map substitute, photomaps are mentioned because of their wide use in theaters of operation. A photomap may be a printed reproduction of a single photograph. It may also be a mosaic composed of several photographs upon which are drawn such information as an approximate north-arrow, the names of places, an arbitrary grid, marginal data, and various other aids. The scale is varied according to the scales of the available photography. These scales may range between 1:5,000 and 1:60,000. The preferred scale is near the midpoint of this range, or 1:25,000, although 1:12,500 (half scale) is often considered adequate for photomaps. The over abundance of detail in photomaps decreases their usefulness as artillery maps and the limited coverage decreases their suitability for planning purposes. Among troops there is a strong tendency to use photomaps as tactical maps because of the large degree of detail, rather than in spite of it. Photomaps are frequently printed upon the reverse side of tactical maps as an additional aid to the user.

13. Town Plans and Cadastral Maps

Two types of planimetric maps which are sometimes useful for military purposes are the town plan and the cadastral map.

a. Town Plan. Detailed plans are available for many cities and towns in the United States and also in foreign areas. These plans generally have only supplementary map value and are best used for aid in interpretation and for information on place names. They may be helpful in determining a route by indicating through streets, and for certain other obvious tactical information, but caution must be exercised in their use, since their scale is often distorted, with positions exaggerated, even though they are normally at a larger scale even than large-scale military maps.

b. Cadastral Map. Detailed plans of political subdivisions such as counties, based on surveys made to determine the site, size, and distribution of real estate value and ownership, are known as cadastral maps. These maps are extremely detailed. They show fences and hedges; the sizes and arrangement of all structures within the confines of each holding, and in some cases, specialized data such as electric power lines and connections and communications lines. As terrain maps, cadastral maps are not of much value, the information to be gained on them is of tactical value in the way of general military intelligence.

APPENDIX IV

MAP STANDARDS

1. Accuracy

It is not possible to draw a map showing every object in perfect relative position. Errors are existent, even though they may not be noticeable. Plotting perfection is more nearly realized in large-scale maps than in the smaller scales. Yet, it is the human eye that measures the errors, and therefore the accuracy standards have been established accordingly, regardless of scale. These standards are defined in terms of horizontal and vertical accuracy.

a. Horizontal Accuracy Standards. Ninety percent of all features are shown within 1/50 inch of their true geographical positions, and the remaining ten percent are within 1/20 inch.

b. Vertical Accuracy Standards. Ninety percent of all contours on large-scale maps are shown within ½ the contour interval of the map, and all spot elevations are correct to within ¼ of the interval. On medium-scale maps, ninety percent of all contours are shown within one full interval of the basic contour interval, and all spot elevations are correct to within one-half of the interval.

2. Symbols

Map symbols fall into several categories. One refers to the features normally existing on the area that is mapped. Another is the representation of military units, installations, and operational areas. These symbols are the subject of two separate manuals, FM 21–31 and FM 21–30, which deal with mapping symbols and military symbols respectively. A third category of symbols is that concerned with the graphic description of roads and bridges. These symbols are shown in part in tables III, IV, and V and are more fully covered in FM 5–36.

3. Mapping Abbreviations

The authorized list of abbreviations for map use is given below. It does not necessarily agree with approved lists of abbreviations for other military uses, and for this reason it has been given the name of "mapping abbreviations" as a means of distinction.

A ....Army
Aband ....abandoned
ACIC ....Aeronautical Chart and Information Center
AF ....Air Force
AFB ....Air Force Base
Ala ....Alabama
Align ....alignment

Alt ....Alternate
AMS ....Army Map Service
Anc ....ancient
Anch ....anchorage
Approx ....approximate
Apr ....April
Arch ....archipelago
Ariz ....Arizona
Ark ....Arkansas
ASE ....Army Survey Establishment (Canada)
Aug ....August
Ave ....Avenue

B ....bay
Bdry ....boundary
Bk ....brook
Bldg ....building
Blvd ....boulevard
BM ....benchmark
Br ....branch
Brg ....bridge
Byp ....bypass

C ....cape
Calif ....California
Cath ....cathedral
CE ....Corps of Engineers
Cem ....cemetery
CG ....Coast Guard
CH ....courthouse
Ch ....church
Chan ....channel
Chy ....chimney
Co ....county
Col ....college
Colo ....Colorado
Comm ....Commission
Conn ....Connecticut
Const ....construction
CR ....crossroads
Cr ....creek
Cus Ho ....customhouse

DC ....District of Columbia
Dec ....December
Deg ....degree
Del ....Delaware
Dept ....department
Div ....division
DSvy ....Directorate of Military Survey (Great Britain).

E ....east
Elec ....electric, electrified
Elev ....elevated

Fd ....ford
Feb ....February
Fl ....flood
Fla ....Florida
Fld ....field
Fm ....fathom
For ....forest
Ft ....fort
Fy ....ferry

G ....gulf
GA ....Georgia
Gas ....gasoline
GN ....grid north
Govt ....government
Grd ....ground
GSGS ....Geographic Section, General Staff (Great Britain).

Hbr ....harbor
Hosp ....hospital
HS ....high school
Hy ....highway

I ....island
Ill ....Illinois
In ....inlet
Ind ....Indiana

Jan ....January
Jul ....July
Jun ....June
Junc ....junction

Kans ....Kansas
Km ....kilometer
Kn ....knot
Ky ....Kentucky

L ....lake
La ....Louisiana
Lat ....latitude
Ldg ....landing
LH ....lighthouse
Long ....longitude

M ....meter (s)
Mag ....magnetic
Mar ....March
Mass ....Massachusetts
Md ....Maryland
Mi ....mile (s)
Mich ....Michigan
Mil ....Military
Min ....minute (s)
Minn ....Minnesota
Miss ....Mississippi

Mo ....Missouri
Mon ....monument
Mont ....Montana
Mt ....mount, mountain
Mts ....mountains

N ....north
Natl ....national
Nav ....navigable
NC ....North Carolina
N Dak ....North Dakota
Nebr ....Nebraska
Nev ....Nevada
HN ....New Hampshire
NJ ....New Jersey
N Mex ....New Mexico
No ....number
Nov ....November
NY ....New York

Obs ....obstacle
Obstr ....obstruction
Oct ....October
Okla ....Oklahoma
Oreg ....Oregon

P ....protractor point (pivot point).
Pa ....Pennsylvania
Pen, Pena ......peninsula
PK ....peak
Pky ....parkway
PO ....post office
Pt ....point
PT ....post and telegraph office.

Quar ....quarantine

R ....range (public lands)
Rd ....road
Res ....reservation
Res ....reservoir
RI ....Rhode Island
RR ....railroad
RS ....radio station
Ry ....railway

S ....south
SC ....South Carolina
Sch ....school
S Dak ....South Dakota
sec ....second (s)
Sept ....September

St ....Saint
St ....street
Sta ....station
Ste ....Sainte
Str ....stream
Subm ....submerged

T ....telegraph office
T ....township tier (public lands).
Tel ....telephone or telegraph line.
Temp ....temporary
Tenn ....Tennessee
Tex ....Texas
Tnpk ....Turnpike
Tr ....tower
TVA ....Tennessee Valley Authority.

Univ ....university
US ....United States
USC&GS ....United States Coast and Geodetic Survey.
USDA ....United States Department of Agriculture.
USFS ....United States Forest Service.
USGS ....United States Geological Survey.
USNHO ....United States Navy Hydrographic Office.
USLS ....United States Lake Survey.

Va ....Virginia
VABM ....vertical angle bench mark.
Vil ....village
Vt ....Vermont

W ....west
Wash ....Washington
Wdm ....windmill
Wis ....Wisconsin
WM ....water mill
WT ....water tank, water tower.
W Va ....West Virginia
Wyo ....Wyoming

Yd ....yard
Yds ....yards

4. Marginal Data

Before one can hope to use a map to the fullest extent, it is essential that the information on a map be completely understood. The best source of this information is on the borders of the map itself and is therefore known as "marginal data." This refers to United States military mapping only. It is intended to tell the user every detail of information about the United States military map that he may need.

a. Example. Figure 116 is a reproduction of a typical large-scale military map showing, by means of circled numerals, the positions of the many items or marginal data with which the map user must be familiar. The circled numbers on the figure correspond to the item numbers listed and described in *b* below.

b. Items.

(1) *Sheet Name.* A means of identifying a map sheet is by its name, which is taken from a prominent cultural or geographical feature that appears on the map. The feature which is better known is usually chosen. It is found on the map in two places: in the center of the upper margin, and in the right side of the lower margin preceding the name of the next large geographical subdivision in which the map is located, for example, "Alexandria, Virginia."

(2) *Sheet Number.*

(*a*) Another means of identifying a map is by its number which is found in the *upper right corner.* The number of a map at 1:100,000 scale and larger is recognized as having one of three different forms representing 100,000, 50,000, and 25,000 scale maps. Army doctrine establishes a system for numbering military maps which is not only convenient, but which fixes map limits in such a way that the series of maps smaller in scale will cover the same area included on four maps of the larger scale series. The map numbering system is illustrated in figure 117.

(*b*) An arbitrary geographic coordinate system is set up covering the area to be mapped. The system has latitude and longitude lines so spaced that each rectangle formed by their intersections is the exact area to be mapped at 1:100,000 scale, not too large or too small to be drawn on a regular size sheet of map paper. Axes of origin are selected outside the limits of the area and a positive four-digit number is assigned each rectangle or map, the first two digits representing the column and the other two the row. The upper portion of figure

1 SHEET NAME
2 SHEET NUMBER
3 MAP SCALE
4 GRAPHIC SCALE
5 SERIES NUMBER
6 SERIES NAME
7 EDITION NUMBER
8 CREDIT NOTE
9 INDEX TO ADJOINING SHEETS
10 INDEX TO BOUNDARIES
11 INDEX TO SOURCE MATERIAL COVERAGE
12 PROJECTION NOTE
13 GEOGRAPHIC COORDINATES
14 GRID NOTE
15 GRID REFERENCE NOTE
16 VERTICAL DATUM NOTE
17 HORIZONTAL DATUM NOTE
18 LEGEND
19 DECLINATION DIAGRAM
20 PROTRACTOR SCALE
21 USER'S NOTE
22 UNIT IMPRINT

1 Nomenclature.

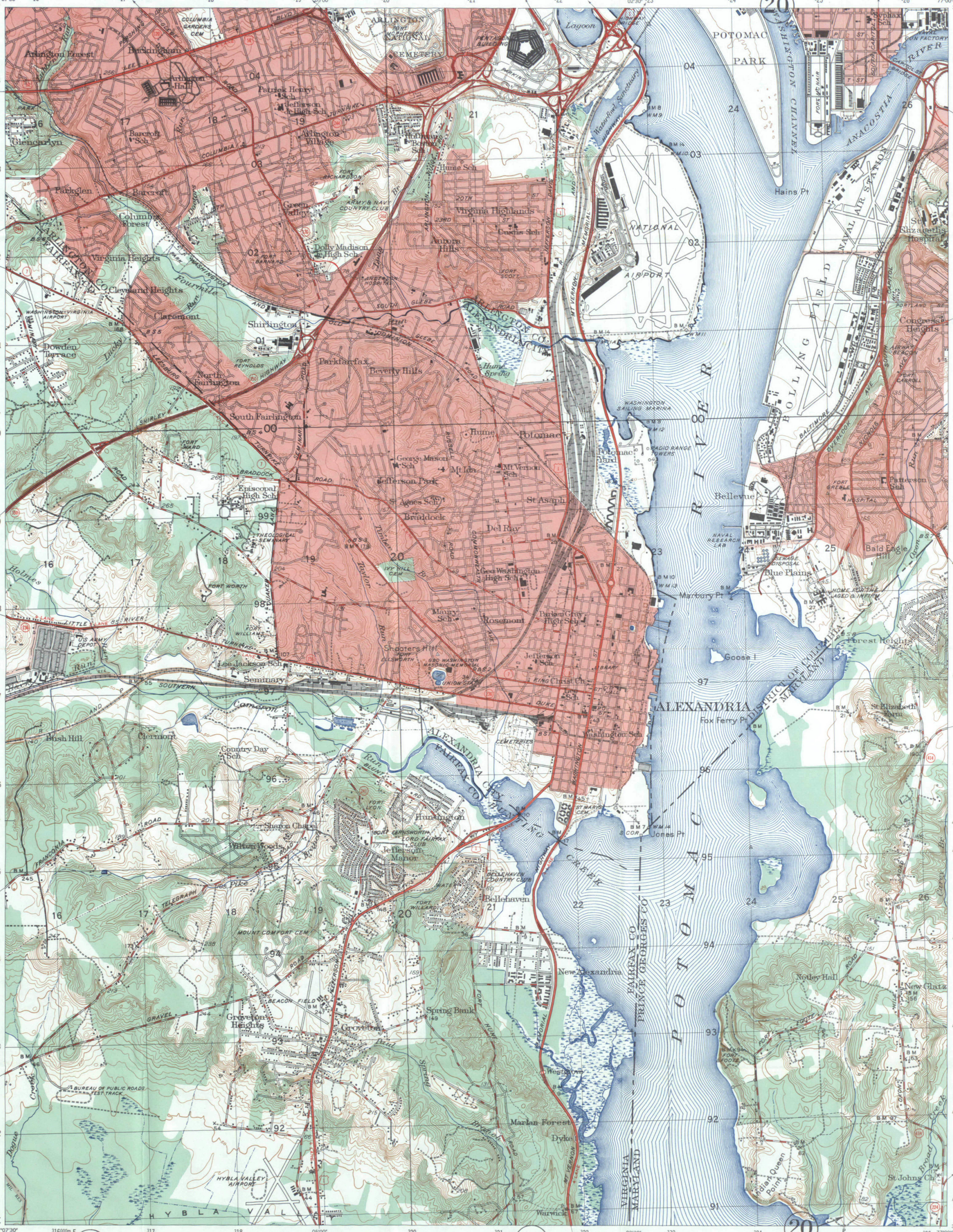
FIGURE 116. *Typical large-scale military map.*

VIRGINIA 1:25,000

EDITION 2–AMS

ALEXANDRIA

REFER TO THIS MAP AS:
SHEET 5561 I SE
SERIES V834



V834
Edition 2–AMS

Prepared by the Army Map Service (AM), Corps of Engineers, U. S. Army, Washington, D. C. Copied in 1949 from Virginia, 1:31,680, USGS, Alexandria, 1945. Boundary between District of Columbia and Virginia is not indicated where yet undetermined. Scale changed, marginal data revised and Universal Transverse Mercator Grid added, 1949. Recopied in 1952 from Virginia 1:24,000, USGS, Alexandria, 1951, with planimetric detail revised by plane-table methods and from aerial photography dated 1949.

Scale 1:25,000

CONTOUR INTERVAL 10 FEET
VERTICAL DATUM: MEAN SEA LEVEL

TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM: 1927 NORTH AMERICAN DATUM

BLACK NUMBERED LINES INDICATE THE 1,000 METER UNIVERSAL TRANSVERSE MERCATOR GRID, ZONE 18

THE LAST THREE DIGITS OF THE GRID NUMBERS ARE OMITTED

USERS NOTING ERRORS OR OMISSIONS ON THIS MAP ARE URGED TO MARK HEREON AND FORWARD DIRECTLY TO COMMANDING OFFICER, ARMY MAP SERVICE, WASHINGTON, D. C. MAPS SO FORWARDED WILL BE RETURNED OR REPLACED IF DESIRED.

PRINTED BY ARMY MAP SERVICE, CORPS OF ENGINEERS, 11-58 .113956

LEGEND

Tint indicates areas in which only landmark buildings are shown
ROAD DATA 1951
In developed areas, only through roads are classified

- Hard surface, heavy duty road, more than two lanes wide
- Hard surface, heavy duty road, two lanes wide; Federal route marker
- Hard surface, medium duty all weather road, two lanes wide; State route marker
- Loose surface, graded or narrow hard surface
- Improved dirt, dry weather road
- Unimproved dirt, dry weather road; Trail

GRID ZONE DESIGNATION: 18S

100,000 M. SQUARE IDENTIFICATION

TO GIVE A STANDARD REFERENCE ON THIS SHEET TO NEAREST 100 METERS

SAMPLE POINT: MAURY SCH

1. Locate first VERTICAL grid line to LEFT of point and read LARGE figures labeling the line either in the top or bottom margin, or on the line itself:
Estimate tenths from grid line to point:
2. Locate first HORIZONTAL grid line BELOW point and read LARGE figures labeling the line either in the left or right margin, or on the line itself:
Estimate tenths from grid line to point:

INDEX TO BOUNDARIES

Virginia
A. Arlington County
B. Alexandria City
C. Fairfax County
District of Columbia
Maryland
D. Prince Georges County

INDEX TO ADJOINING SHEETS

5561 I NW	5561 I NE	5661 IV NW
5561 I SW	5561 I SE	5661 IV SW
5561 II NW	5561 II NE	5561 III NW

Sheet 5561 I SE falls within NJ 18-4
V501, 1:250,000

5°30′ OR 98 MILS
1°18′ OR 23 MILS

APPROXIMATE MEAN DECLINATION 1953
FOR CENTER OF SHEET
ANNUAL MAGNETIC CHANGE 1′ EASTERLY

Use diagram only to obtain numerical values. To determine magnetic north line, connect the pivot point "P" on the south edge of the map with the value of the angle between GRID NORTH and MAGNETIC NORTH, as plotted on the degree scale at the north edge of the map.

ALEXANDRIA, VA., D. C., MD.

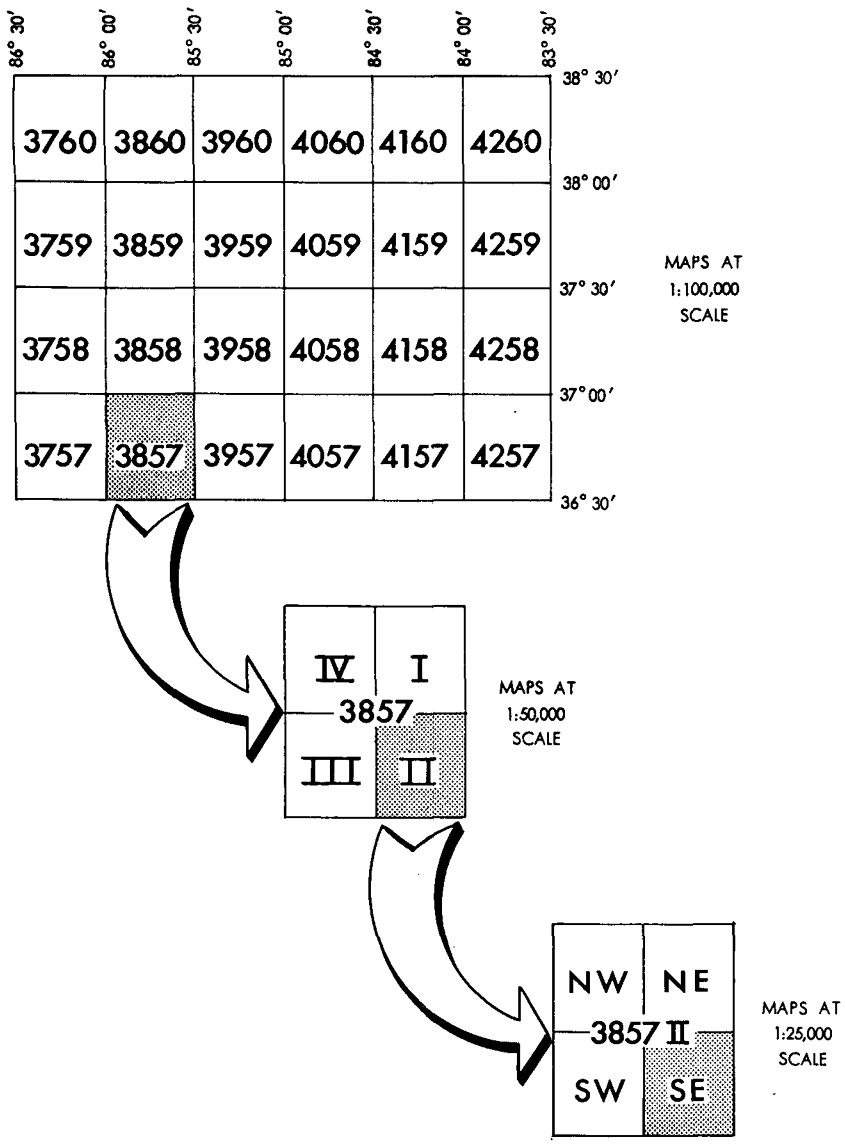


FIGURE 117. *Examples of the sheet numbering system.*

117 illustrates an area subdivided into areas for mapping at 1:100,000 scale, and the map sheets have been properly numbered. Note that the numbers are derived using the basic method for reading coordinates, that is, READ RIGHT UP.

(*c*) The second type of map number to be understood is the one for maps at 1:50,000 scale. In part it bears the same number as the 1:100,000 scale map inside which it falls. But it has a Roman numeral added to it to distinguish which of the four quarters of the 1:100,000 scale area is covered by the 1:50,000 scale map. Figure 117 also shows a 1:100,000 scale map subdivided into four 1:50,000 scale map sheets. Note that the roman numerals begin with the sheet in the upper right corner and run clockwise around the rectangle. The four 1:50,000 scale maps are numbered 3859 I, 3859 II, 3859 III, and 3859 IV.

(*d*) In turn the 1:25,000 scale map covers only ¼ the area covered by the 1:50,000 scale map, both on the same sized sheet of map paper. Another number is added to distinguish each of the four 1:25,000 scale maps. It is by the geographical quarter it falls in, NE, NW, SE, or SW. Figure 117 also illustrates the subdivision of the 1:50,000 scale map 3857 II and the numbering of the 1:25,000 scale maps within it. 3857 II SE is a number that would be found on a 1:25,000 scale map.

(*e*) The numbering of maps at 1:1,000,000 scale is the same as the numbering system established for International Maps of the World (IMW). Sheet numbers for 1:250,000 scale maps are established as breakdowns of the IMW numbering system.

(3) *Map Scale.* In addition to recognizing the scale of a map through its number, the scale is always shown in the upper left and lower center margins. It is expressed as a ratio of map distance to ground distance, that is, as a representative fraction such as 1/25,000.

(4) *Graphic Scale.* A graphic scale is usually printed on a map in the center of the lower margin. It is actually three scales, one a mile scale, one a meter scale, and the other a yard scale. The use of a graphic scale in measuring map distances is explained in chapter 6.

(5) *Series Number.* Another important number found on a map is the series number which is always located in the lower left and upper right margins.

(*a*) This number has to do with identifying the large and larger areas of which a map may be drawn. Several maps could have the same series number because they cover the same large area. But every area is a part of a larger area and therefore the numbers are necessary.

(*b*) The series number is a three-digit number preceded by a letter. The letter represents the larger regional area, the first digit specifically identifies the scale group, as: 5 = 1:250,000; 6 = 1:100,000; 7 = 1:50,000;

8 = 1:25,000 scale. The next digit indicates the subarea; and the final digit, the number of the series.

(6) *Series Name.* Each map has a series name which identifies it as being located in a large geographic or political division of area. In this country the name of a State would be the series name for all maps within that State's area. The series name is shown in the upper left corner.

(7) *The Edition Number.* This number is found in the lower left corner and to the left of the sheet name in the upper margin. It is shown as "Third Edition" and represents the age of the map, relative to other editions of the same map. Maps become out of date and are revised and republished as another edition with the next larger number.

(8) *Credit Note.* The credit note is very often referred to by map users. It is found in the lower left corner, and it explains what agency prepared the map, how, when, and what source materials were used. One who uses maps considerably has a definite idea of the quality of a map immediately upon reading this credit note, and he will depend on the map accordingly. The credit note also includes pertinent statements which clarify any unusual conditions, for which no explanation exists elsewhere on the map.

(9) *Index to Adjoining Sheets.* In the lower margin of a map is found a diagram which pictures all the maps that border on the one in question. Sometimes it will extend beyond the bordering maps and index other maps of the series, depending on the space available for the diagram. On 1:250,000 scale maps, this index is called a location diagram.

(10) *Index to Boundaries.* This index is also in the form of a diagram and is located in the lower margin. It depicts all the political boundaries that fall on the map, such as county lines and State boundaries. On 1:250,000 scale maps, this information is included in the location diagram.

(11) *Index to Source Material Coverage.* This is a diagram of the map in consideration showing the areas of different source materials separated graphically. Naturally, this index is not required when the coverage is singular; the credit note is sufficient. However, it is useful for example when the map is compiled by more than one method. When more than one basic source of compilation materials is used, when aerial photos are used from

photo missions that are separated by more than one year, or even when photographs of more than one type are used.

(12) *Projection Note.* The projection on which each map is constructed is named in the lower margin. 1:50,000 and larger scale maps are drawn on the Universal Transverse Mercator projection between 80° North and South latitude. Between 80° and the poles, the Polar Stereographic Projection is used as a base for these same scale maps.

(13) *Geographic Coordinates.* The Geographic Coordinates of each of the four corner points of a map are indicated near their respective locations in the margin. When a map is referred to by geographic coordinates instead of by name or number, all four corner coordinates are not quoted. Only one corner is used and it is always the one nearest the equator and zero longitude.

(14) *Grid Note.* In the lower center margin is the grid note or notes, there being one for each grid printed on the map. Each note is usually printed in the same color as the grid on the map to which it refers, and it contains the following items of information concerning that grid:

- (*a*) Name of the grid system.
- (*b*) Spheroid of grid system (when map is not in North America where the Clarke Spheroid of 1866 is used).
- (*c*) Grid interval.
- (*d*) Color note.
- (*e*) Guide for reading grid values.

(15) *Grid Reference Note.* In the lower center margin is a boxed-in instruction for referring to a point on the map. It includes an example using a specific point.

(16) *Vertical Datum Note.* This note is located in the lower margin and establishes the elevation datum of the map. The 1929 datum has been designated as basic in the United States, and the note on maps covering the area should read: VERTICAL DATUM: SEA LEVEL DATUM OF 1929.

(17) *Horizontal Datum Note.* The basic horizontal datum is set forth in this note which is located in the lower center margin. United States maps compiled today carry this note: HORIZONTAL DATUM: 1927 NORTH AMERICAN DATUM.

(18) *Legend.* The legend is usually found in the lower left margin of the sheet. It illustrates the symbols used for more prominent features on the map.

(19) *The Declination Diagram.* It is in the lower margin and it pictures three arrows radiating from a single pivot

point. The diagram shows the true relationship between true north, magnetic north, and grid north at the center of the map for the major grid. A note directly below the diagram gives the annual magnetic change. On 1 : 250,000 scale maps, a diagram is not shown, but the information is contained in a note appearing in the lower margin.

(20) *Protractor Scale.* A scale for measuring and laying off small angles is built into the map. One of the north-south lines of the major grid is selected as the zero line with the pivot of the protractor (P) being at the intersection of this line with the south neat line. A degree scale is laid off along the north neat line and labeled. Full instructions for the use of this protractor scale are printed as a note in the lower margin of the map. This scale is not included on maps smaller than 1 : 50,000 scale.

(21) *User's Note.* A note to users of a map is printed in the center of the lower margin. It reads—"Users noting errors or omissions on this map are urged to mark hereon and forward directly to the Commanding Officer, Army Map Service, Washington, D. C. Maps so forwarded will be returned or replaced if desired."

(22) *Unit Imprint.* It is located in the lower right margin of the sheet and designates the agency and date of printing of the map. In addition to the unit imprint, maps printed by the Army Map Service will show a key number which serves to facilitate filing and ordering.

APPENDIX V

CONVERSION FACTORS OF MEASUREMENT

TABLE VII. *Conversion Factors of Degrees to Mils*

$$360^\circ = 6{,}400 \text{ mils}$$

$$1^\circ = \frac{6{,}400}{360} = 17.8 \text{ mils (or 18 approx.)}$$

$$1 \text{ mil} = \frac{360}{6{,}400} = .056^\circ \text{ (or 3.48 approx.)}$$

$$1 \text{ mil} = 0.056^\circ \text{ approximately}$$

$$= 3 \text{ minutes } 22.2 \text{ seconds}$$

$$\text{Mils} = 17.8 \times \text{degrees}$$

TABLE VIII. *Conversion Factors of Degrees to Grade*

$$360^\circ = 400 \text{ grade}$$

$$\frac{\text{Number of degrees*}}{0.9} = \text{grade}$$

$$\text{Grade} \times 0.9 = \text{degrees*}$$

* Minutes and seconds converted to decimal parts of a degree.

TABLE IX. *Conversion Factors for English-Metric Equivalents*

Units	Miles	Kilometers	Yards	Meters	Feet	Centimeters	Inches
1 mile	1	1.609	1,760	1,609	5,280	160,935	63,360
1 km.	0.621	.1	1,094	1,000	3,282	100,000	39,384
1 yard	—	—	1	0.914	3	91.44	36
1 meter	—	—	1.094	1	3.28	100	39.36
1 foot	—	—	—	0.305	1	30.48	12
1 cm.	—	—	—	—	—	1	0.394
1 inch	—	—	—	—	—	2.54	1

Meters into yards		Yards into meters	
1 meter =	1.093 611 1 yards	1 yard =	0.914 401 8 meters
2	2.187 222 2	2	1.828 803 7
3	3.280 833 3	3	2.743 205 5
4	4.374 444 4	4	3.657 607 3
5	5.468 055 6	5	4.572 009 1
6	6.561 666 7	6	5.486 411 0
7	7.655 277 8	7	6.400 812 8
8	8.748 888 9	8	7.315 214 6
9	9.842 500 0	9	8.229 616 5

TABLE IX. *Conversion Factors for English-Metric Equivalents*—Continued.

Meters into feet		Feet into meters	
1 meter =	3.280 833 3 feet	1 foot =	0.304 800 6 meters
2	6.561 666 7	2	0.609 601 2
3	9.842 500 0	3	0.914 401 8
4	13.123 333 3	4	1.219 202 4
5	16.404 166 7	5	1.524 003 0
6	19.685 000 0	6	1.828 803 7
7	22.965 833 3	7	2.133 604 3
8	26.246 666 7	8	2.438 404 9
9	29.527 500 0	9	2.743 205 5

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APPENDIX VI

PROJECTIONS

1. General

a. A map projection is a systematic representation of a portion of the earth's surface upon a plane. The geographic system of parallels and meridians can be easily drawn on a globe, but the surface of the globe cannot be stripped and flattened into a map without distortion. A perfect map representation, therefore, is impossible although there are many ways of getting approximate representations on a flat sheet. The simplest of these is to envelop the globe with a cylinder or cone or to lay a tangent plane against it, and to project upon the cylinder, cone, or plane a part of the geographic coordinate system of the globe. The cylinder or cone is then cut open and laid out flat. The system of parallels and meridians on the flattened paper is then the framework, or projection, upon which the map is constructed. A projection, then, is any orderly system of parallels and meridians on which a map is drawn.

b. Many kinds of projections have been devised. Some are particularly good for one purpose and some for another; no one projection is best suited for all purposes. Of the many types of projections in use today, those chosen as bases for United States military maps are the Universal Transverse Mercator projection, which is an adaptation of the Mercator projection, and the Universal Polar Stereographic projection. Another projection used by United States mapping agencies and also by the British is the Lambert Conformal Conic projection.

c. Following are brief explanations of these projections. For more detailed information, see TM 5–230.

2. Mercator Projection

a. This is a cylindrical projection in which parallels and meridians are projected onto a cylinder tangent to the earth at the equator (fig. 118). When the cylinder is laid out flat the meridians appear as vertical straight lines, evenly spaced, and true to scale on the equator (fig. 119) but true scale may be established at any latitude. The parallels are horizontal straight lines spaced so that

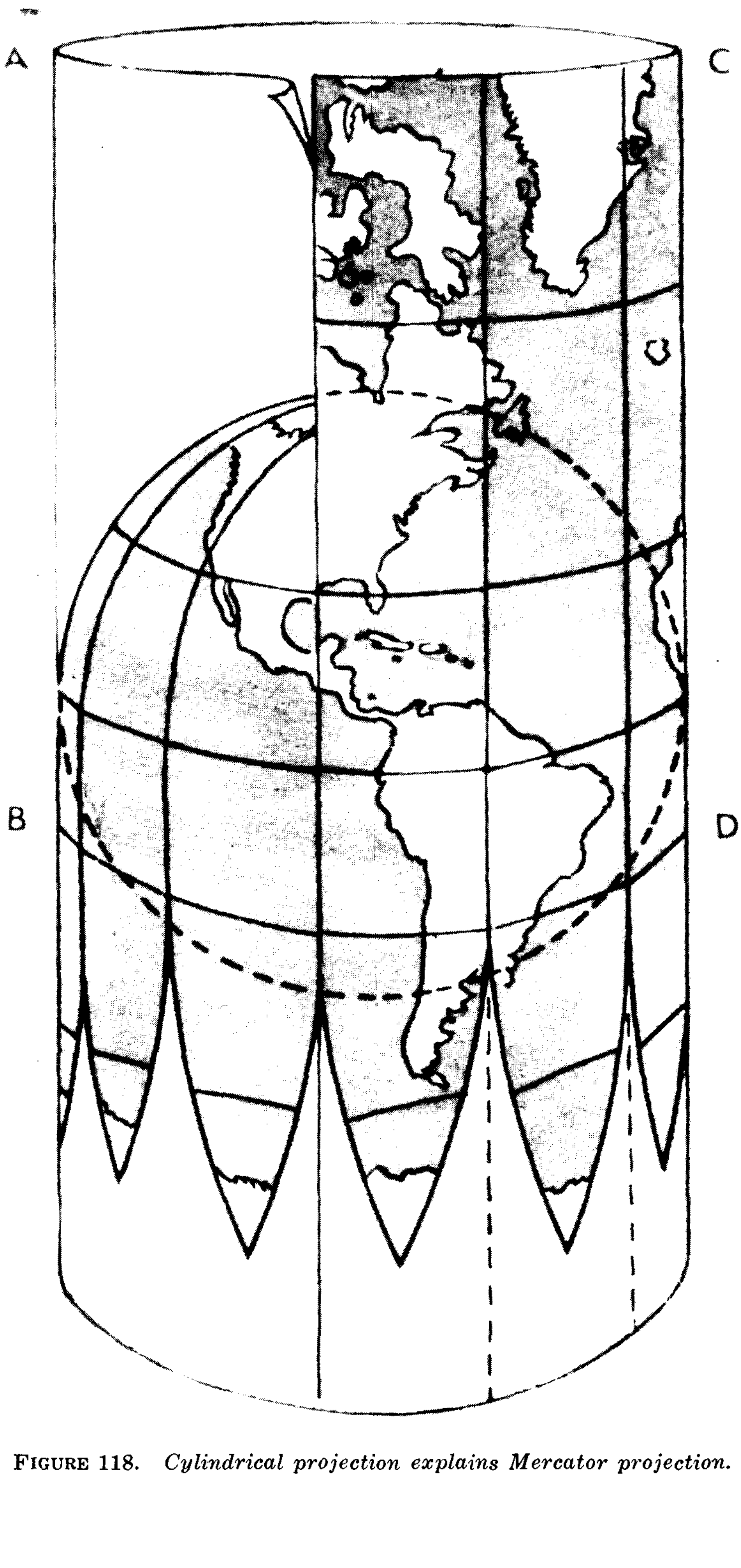

FIGURE 118. *Cylindrical projection explains Mercator projection.*

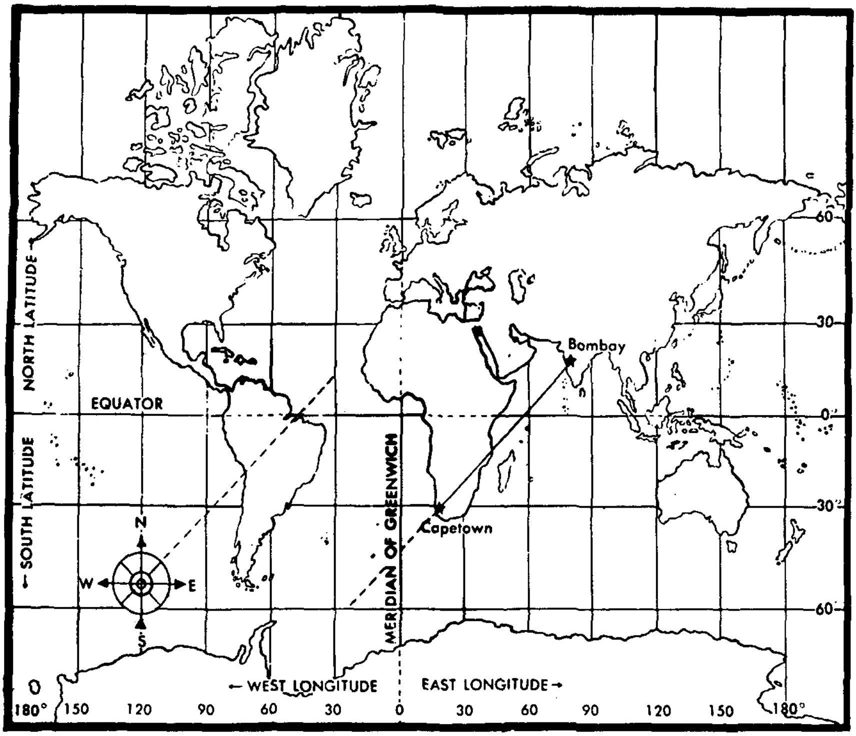

FIGURE 119. *Mercator projection.*

for any small area the relation of scale along the meridians and along the parallels is the same as on the globe. For example, at latitude 60° the parallels are twice as far apart as at the equator. Therefore, since the meridians on the map are the same distance from each other at every latitude, the scale of the map is doubly exaggerated at 60°. At 80° the exaggeration is sixfold. It is obvious that the poles cannot be shown in this projection, because the expansion would be infinite. Therefore, maps on Mercator projections seldom are extended much beyond 80° of latitude.

b. The advantages of the Mercator projection are ease of plotting or reading geographic coordinates because the parallels and meridians form a rectangular grid; and, ease of plotting and reading navigation courses of ships or aircraft. A compass course between any two points can be shown by a straight line connecting them (fig. 119). Thus, the path of a ship or plane following a constant compass bearing appears as a straight line. Because the Mercator projection is used in instrumental navigation of ships and planes it is the standard projection for hydrographic charts (U. S. Navy), Navy air-navigation charts, and USAF long-range navigation charts of small scale.

c. One disadvantage of the Mercator projection is the increasing exaggeration toward the poles. On a Mercator map Greenland shows larger than South America though, in reality, South America is nine times larger than Greenland. Small-scale Mercator maps have the additional disadvantage that because of polar distortion usual type scales cannot be used to measure distance. However, this limitation does not apply to large-scale maps of small areas.

3. Universal Transverse Mercator Projection

The Universal Transverse Mercator projection is shifted 90 degrees from the regular Mercator projection making the cylinder tangent to a meridian instead of the equator. The Mercator projection has true scale along the equator, and is best suited to regions elongated in an east-west direction. Transversely, the UTM projection has true scale along the meridian of tangency, making it a better map base for areas extended in a north-south direction. It is used extensively for British military maps and has been adapted by the United States Army as a basis for map production at scales of 1: 250,000 and larger, because of its important advantage to all users of numerical values of the Universal Transverse Mercator grid which is based on it.

4. Universal Stereographic Polar Projection

The Universal Stereographic Polar projection is a combination of two types of projection, the conformal and the perspective, with

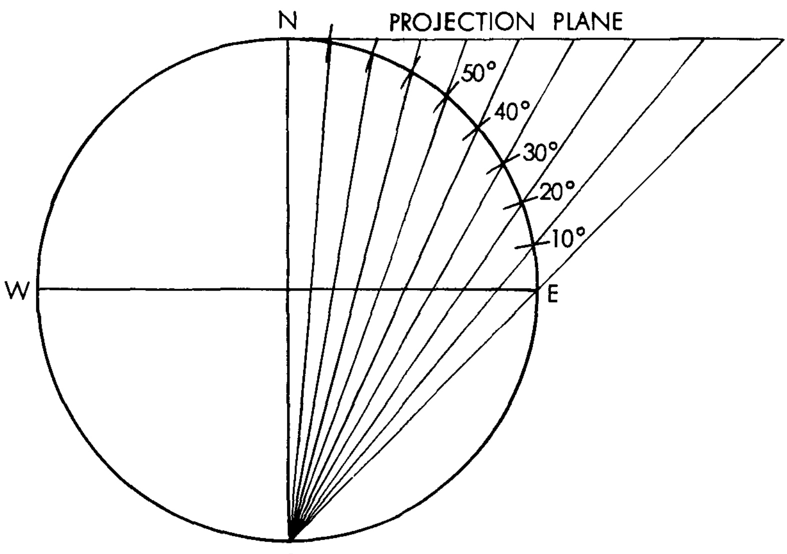

FIGURE 120. *Perspective of the Universal Stereographic Polar projection.*

the point of perspective being the South Pole when the Arctic is being projected. It is so named because it shows the North Pole (or South Pole) in its center, and it is constructed with this pole as its center of rotation. It is especially adapted for mapping polar regions since it is quite accurate near the pole. As the map extends farther from the pole, the error is increased, and therefore, its use

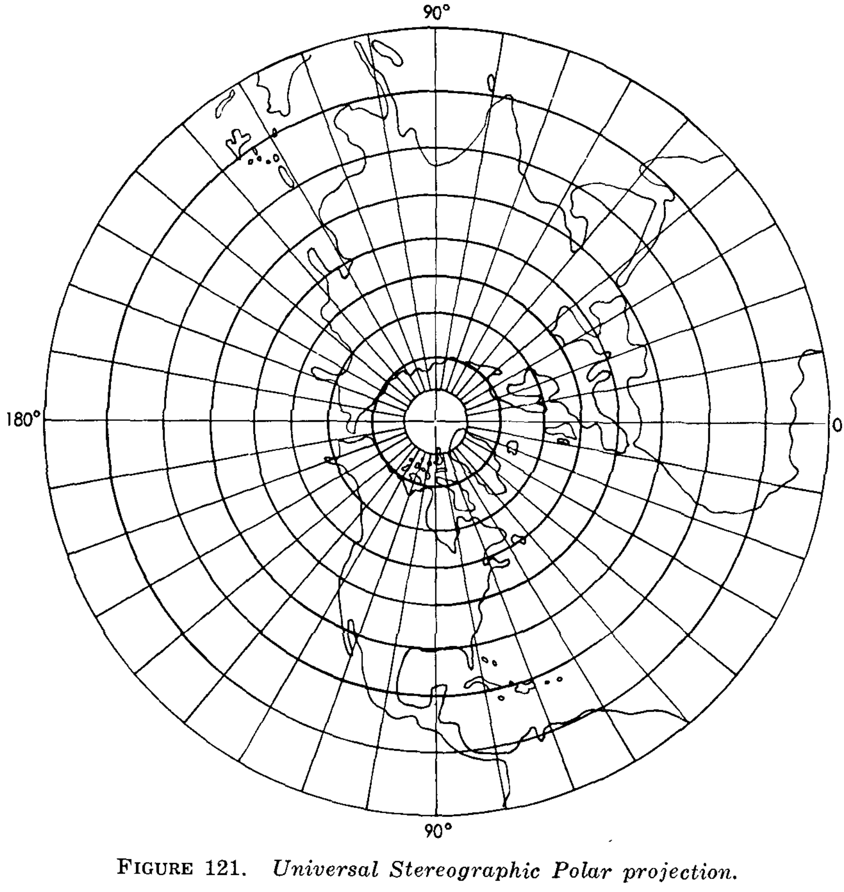

FIGURE 121. *Universal Stereographic Polar projection.*

is generally limited to only a few degrees of latitude. For example, the USAF World Aeronautical Chart at 1:1,000,000 scale, uses this projection between 80 degrees north latitude and the North Pole. The plane of the projection is usually the equatorial plane. A plane, tangent to the globe at the North Pole would be equally usable, and it is used to demonstrate the construction. In figure 120 the circle is a meridian on which north and south represent the poles. Straight lines from south through parallels, spaced along arc NE, intersect the projection plane at points representing the corresponding parallels on the projection. In the plane of the projection, the parallels are concentric circles about the North Pole, and the meridians are represented by straight lines radiating from the same point as shown in figure 121.

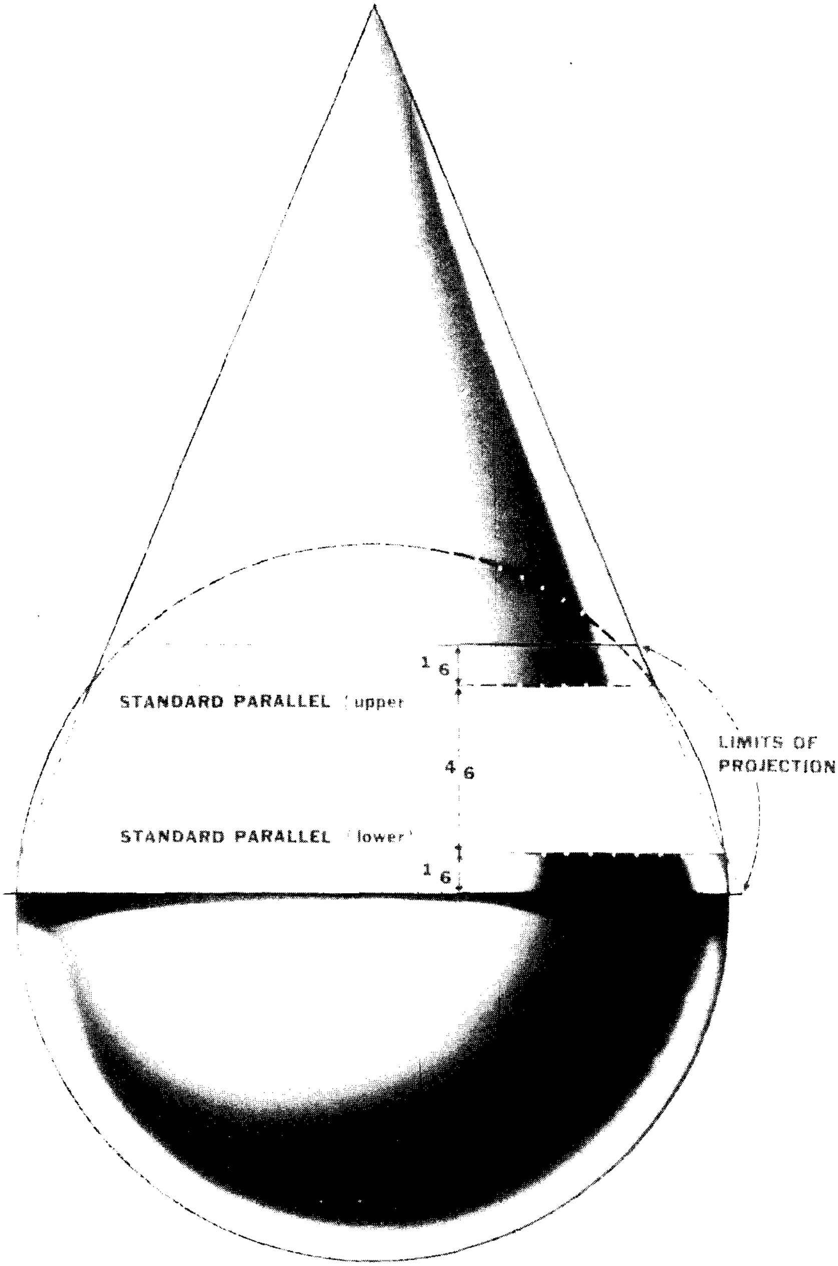

FIGURE 122. *Lambert conformal conic projection.*

5. Lambert Conformal Conic Projection

a. The Lambert conformal conic projection employs a simple cone tangent to the earth along a single parallel or intersecting the earth at two parallels known as the standard parallels for the area to be mapped (fig. 122). All meridians are converging straight lines that meet in a common point beyond the limits of the map. All parallels are concentric circles whose center is at the point of intersection of the meridians. Parallels and meridians intersect at right angles, and the angles formed by any two lines on the earth's surface are correctly represented on this projection.

b. To distribute scale error when two standard parallels are used, the standard parallels are chosen at one-sixth and five-sixths of the length of the central meridian to be represented. Between these parallels the scale will be too small, and beyond them too large. On military maps maximum scale error ordinarily does not exceed one-half of one percent.

c. This projection is specially suited for maps having a predominating east-west dimension. It was widely used in World Wars I and II and is used currently for many British maps. Because of its correct azimuth, it is also used for the Sectional Airway Maps of the United States.

GLOSSARY

Aerial camera—A camera especially designed for use in aircraft.

Aerial photograph—A photograph of a portion of the earth's surface taken by a camera mounted in an aircraft.

Aeronautical chart—A map especially designed for the aviator, on which, in addition to essential topography, are shown obstructions, aids to navigation, and other information to assist in navigating.

Agonic line—A line on a map joining places at which the magnetic needle points true north; a point having a magnetic declination of zero degrees.

Alidade—An instrument used in surveying and mapping to determine the direction and distance of a point by a combined sight and straightedge ruler. For sketching, a triangular boxwood scale with three faces used in determining direction lines of points to be plotted during the construction of the sketch.

Angle of coverage—The apex angle of the cone of rays passing through the front nodal point of a lens.

Angular measure—The procedure necessary to determine the angle between two directions.

Approximate contour—(*See also* Contour.) A contour substituted for a normal contour whenever there is any question as to its reliability.

Area sketch—(*See also* Sketch.) One of two types of military sketches which confine the sketcher to a given area.

Artillery map—(*See also* Map.) A large-scale map, usually 1:25,000, required for the direction of artillery fire, frequently gridded.

Auxiliary contour—(*See* Supplemental contour.)

Azimuth—A term that expresses horizontal direction, as an angle from north. It is measured clockwise from north.

Azimuthal projection—(*See also* Map projection.) A map projection which portrays the azimuth or direction of all points on the map as seen from some central point to be the same as the corresponding azimuths or directions on the earth.

Backsight—(*See also* Foresight.) A direction line determined in reverse order to a foresight for the purpose of establishing a base direction from which to measure a new direction.

Base direction—The direction of a line expressed as a bearing or an azimuth from which other points or directions may be located.

Bearing—A term that expresses horizontal direction in degrees or mils from a line extending north and south through the observation point. The north-south line may be true, magnetic, or grid north. Since the angle is measured east or west either from north or south, whichever gives the smaller angle, a bearing is never greater than 90 degrees or 1600 mils.

British grid—(*See also* Grid.) One of the several grids designated by the British for military map use.

British grid reference system—(*See also* Reference system.) The reference system provided by the British grids.

Cadastral map—A map of a political subdivision, such as a county, drawn to extremely large scale and showing the exact positions and dimensions of real property.

Calibration—The process of determining certain specific measurements in an instrument or device, for comparison with a standard, or for the purpose of recording.

Chart—(*See* Aeronautical chart and Nautical chart.)

Clinometer—A hand instrument for the purpose of direct reading of slope percent.

Closed traverse—(*See also* Traverse.) A traverse which ends at the starting point or at a point the position and elevation of which are known in respect to the starting point.

Compartment—(*See also* Corridor and Cross compartment.) A terrain area bounded on at least two opposite sides by natural features.

Compass—An instrument for determining directions by a magnetized needle or bar which indicates the magnetic north and south.

Compass north—(*See also* Magnetic north.) The base direction indicated by the north-seeking end of the compass needle.

Compilation—The gathering together of source material such as existing maps, photographs, surveys, etc., and the symbolization on a map of the physical and cultural features of the earth or a section thereof as defined by the source materials.

Composite photograph—(*See also* Aerial photograph.) A photograph made by assembling the separate photographs made by each lens of a multiple-lens aerial camera during simultaneous exposure into the equivalent of a photograph taken with a single-lens wide-angle aerial camera.

Concave slope—(*See also* Slope.) A slope having a caved-in profile.

Conformal projection—(*See also* Map projection.) A projection in which the shape of any small section of the surface mapped is preserved on the map.

Contour—A line on map representing an imaginary line on the earth's surface, all points of which, within permissible tolerances are of the same elevation above a fixed datum, usually mean sea level.

Contour interval—The difference in elevation between adjacent contours on a map.

Control—A system of relatively accurate measurements to determine the distances and directions or differences in elevation between points on the earth, and upon which depends a system of lesser accuracy.

Controlled mosaic—(*See also* Mosaic.) A mosaic laid on ground control to improve the accuracy of representation as to distance and direction.

Conventional projection—(*See also* Map projection.) A projection that is arranged arbitrarily because it conforms sufficiently to law to permit its expression analytically or, sometimes more easily, by geometric principles.

Convex slope—(*See also* Slope.) A slope having a bulging profile.

Coordinates, geodetic—A system for the location of a point or points on a spheroid.

Coordinates, geographic—A system for describing the true latitudes and longitudes of points on the earth's surface.

Coordinates, grid—A system for locating points on the earth's surface by means of a rectangular grid superimposed upon and keyed to a map projection. Grid coordinates are sometimes called plane or rectangular coordinates.

Corridor—(*See also* Cross compartment.) A long natural compartment of terrain which runs in the direction of troop movement.

Credit note—A note printed in the margin of a map including, as a minimum, the following information: direction of authority; designation of the preparing agency; method of preparation; years of preparation; an abridged list of source materials; added references for revised sheets; any explanatory notes. Proper reading of credit notes is extremely important to the map user in evaluating the accuracy of the map.

Cross compartment—(*See also* Corridor.) A compartment of terrain whose longest dimension runs perpendicular or oblique to the direction of troop movement.

Datum—Also *datum plane*—(*See* Vertical datum and Horizontal datum.) *Vertical datum* is any level surface taken as a surface of reference from which to reckon elevations, as for example, mean sea level. *Horizontal datum* is the latitude and longitude of an initial point, the azimuth to a given point, and the spheroid on which the system of horizontal control is computed.

Dead reckoning—The procedure used to produce a plot from which a navigator's position can be determined.

Declination—(*See* Magnetic declination.) (*See also* Grid declination).

Declination diagram—(*See* Magnetic declination.) (*See also* Grid declination.) A diagram showing graphically the relationship of true north and magnetic north to grid north for the area included on the map on which it is printed in the lower margin. The values of the declinations are indicated.

Defilade—(*See also* Mask area.) A condition of not being visible in a position to which the line of sight is cut off by an obstruction.

Degree—A unit of angular measure established as the angle subtended at the center of a circle by 1/360th of its circumference.

Delineation—In mapping, the distinguishing of worthy features by outlining the features on the source material or by visual selection, as when operating a stereoscopic instrument.

Depression contour—(*See also* Contour.) A closed contour inside of which the ground is at a lower elevation than outside.

Depth curve—(*See also* Contour.) A contour showing points of equal elevation below the level of the shoreline of any body of water.

Depth perception—(*See* Stereovision.)

Details—In mapping, the small items or particulars of information shown on the map by lines, symbols, and lettering, which, when considered together, furnish the comprehensive representation of the physical and cultural features. The fewer the details, the more generalized is the map.

Developed surface—A geometric figure which has been spread out in a plane without any stretching or tearing, for example, the cone and the cylinder.

Directional gyro—An instrument for indicating and maintaining a fixed direction to which other directions may be referred.

Drift—The horizontal displacement of an aircraft under the action of the wind from the track it would have followed in still air.

Easting—The distance east of the north-south grid line which has been assigned a value of zero in a grid system. It may also be considered as any north-south grid line on a military map. The eastings and northings of a given point are its grid coordinates.

Elevation—The vertical distance from the datum, usually mean sea level, to a point or object on the earth's surface.

Embossed model—A standard topographic map usually printed on a plastic base and deformed to produce the vertical relief, as indicated by the contour lines, at an exaggerated scale.

End lap—(*See also* Overlap.) The overlap between adjacent photographs in the same flight strip.

Engineer scale—A triangular boxwood scale, one foot long, having three faces and six separate and distinct decimal scales.

Equal area projection—(*See also* Map projection.) A projection which preserves the ratio of areas constant; that is, any given part of a map bears the same relation to the area that it represents as the whole map bears to the whole area represented.

Equator, geodetic—An imaginary circle on the spheroid midway between its poles of revolution. The geodetic equator is the line of zero degrees of latitude from which geodetic latitudes are reckoned north and south, to 90 degrees at the poles.

Flight strip—A succession of overlapping aerial photographs taken along a single course of flight.

Foresight—(*See also* Backsight.) A direction line determined in connection with a plot to serve as a point reference.

Form lines—(*See also* Contour.) Dashed lines resembling contours and having the same purpose, but which have been sketched from visual observation or from inadequate or unreliable map sources, to show collectively the shape of the terrain rather than the elevation.

General maps—(*See also* Map.) Maps having scales smaller than 1:1,000,000. They are used for general planning purposes.

Geodetic—A term signifying basic relationship of the earth to the curvature of its sea-level surface.

Geodetic position—The position of a point on the surface of the earth expressed in terms of geodetic latitude and longitude. A geodetic position implies an adopted geodetic datum. In a complete record of a geodetic position, the datum must be stated.

Geographic position—The latitude and longitude of a given position on the earth.

Gnomonic projection—(*See also* Map projection.) A projection developed by projecting lines from the center of the sphere and drawing them an a map plane tangent to the sphere.

Grad—A unit of angular measurement based on the centesimal system. One grad equals 1/400th of a circle.

Grade—(*See also* Slope.) The degree of inclination from horizontal of the surface of roads and railroads.

Graphic scale—A graph for direct measurement of ground distances on the map for which it was prepared.

Graticule—A system of meridians and parallels intended to facilitate the measurement of latitude and longitude on a map.

Great circle—A circle on the earth's surface formed by the intersection of the earth's surface with a plane which passes through the center of the earth.

Grid—A system of straight lines representing a rectangular coordinate system, superimposed on maps, charts, aerial photos, and similar graphics, as a means of uniquely expressing location of ground points or relationship between points with respect to the grid system.

Grid azimuth—(*See also* Azimuth.) An azimuth referenced to grid north.

Grid data—Information related to the grid appearing in the margin of the map; includes declination diagram, protractor scale, zone-identification note, and reference box.

Grid declination—(*See also* Magnetic declination.) The difference between true north and grid north at any point. It changes with grid and location.

Grid north—A base direction for angular measurement as indicated by the vertical grid lines on a map.

Ground control—(*See* Control.)

Ground speed—The velocity of a craft with relation to the ground; the resultant of the heading and speed of the craft and the direction and velocity of outside forces such as wind and tide.

Hachure—(*See also* Contour.) A map symbol used to indicate significant ground formations not normally revealed by contours.

Heading—The angular direction of the longitudinal axis of a craft with respect to the true meridian. It is the course with drift correction applied, and is the true heading unless otherwise designated.

High oblique—(*See also* Oblique photograph.) An oblique photograph in which the apparent horizon is shown.

Horizontal accuracy—The degree of conformity with standards established for horizontal measurements.

Horizontal control—(*See also* Control.) Control which determines horizontal positions only, as with respect to parallels and meridians, or to other lines of reference.

Horizontal datum—The latitude and longitude of an initial point, the azimuth to a given point, and the spheroid on which the system of horizontal control is computed.

Horizontal scale—The ratio of a distance on a map or map substitute to a corresponding distance on the ground.

Index contour—(*See also* Contour.) Normally, every fifth contour; drawn with a heavier line to aid the map user.

Intermediate contour—(*See also* Contour.) The four contours normally found between index contours.

Intersection—A graphic means of plotting the horizontal position of a point not occupied by the person doing the plotting, by drawing two direction sight lines that intersect at the point.

Isogonic line—A line joining positions that have the same magnetic declination.

Lambert conformal projection—(*See also* Map projection.) A simple conic projection developed so that all small areas on the earth's surface retain their original shapes on the projection. It is best suited for use when mapping areas extend predominately along an east-west axis.

Land navigation—The process of plotting a course from one known land position to another by the use of direction-finding and control instruments.

Large-scale map—A map having a scale of 1: 75,000 or larger.

Latitude—A distance, linear or angular, measured north and south from an east-west reference line such as the equator.

Layer-tint—A method of accentuating the elevation expressed by contours on a map by the use of colors or different tones of the same color to show different zones of elevation.

Lensatic compass—(*See also* Compass.) A compass that is read through a magnifying lens in the eyepiece.

Longitude—A distance, linear or angular, measured east or west from a north-south reference line such as the line passing through Greenwich, England, from pole to pole.

Low oblique—(*See also* Oblique photograph.) An oblique photograph in which the horizon is not shown.

Magnetic azimuth—(*See also* Azimuth.) An azimuth referenced to magnetic north.

Magnetic compass—(*See* Compass.)

Magnetic declination—(*See also* Grid declination.) The difference between true north and magnetic or grid north at any point. See the declination diagram on each map sheet for variations for time and place.

Magnetic deviation—The error in a compass whose needle does not point directly to the magnetic North Pole because of the magnetism of surrounding objects.

Magnetic north—(*See also* Compass north.) A base direction for angular measurement as established by the magnetic North Pole.

Magnetic variation—(*See* Magnetic declination.)

Major control—(*See also* Minor control.) In sketching, points of known position and elevation.

Map—A graphic representation of a portion of the earth's surface drawn to a scale upon a plane surface. A representation on a plane surface, at an established scale, of the physical features, both natural and artificial, of a part or the whole of the earth's surface, by means of signs and symbols, and with the means of orientation indicated.

Map azimuth—(*See also* Azimuth.) An azimuth measured on a map, true, grid, or magnetic.

Map projection—An orderly system of lines on a plane representing a corresponding system of imaginary lines on an adopted terrestrial or celestial datum surface. Also the mathematical concept of such a system.

Map scale—(*See* Horizontal scale.)

Map substitute—(*See also* Map.) A representation of a portion of the earth's surface which portrays desired information, when used in place of, or in conjunction with, a map.

Mapping photography—Aerial photography primarily for mapping purposes, and distinguished from aerial photography for reconnaissance or other purposes.

Marginal data—The information shown on a map outside the neat line, such as the series name and number, scale, sheet name, "for use by" note, edition note, sheet number, projection note, officer's note, declination diagram and note, contour intervals note, grid diagram and note, credit note, legend, imprint, key number, index to adjoining sheets, glossary, and conversion graph.

Mask—A ground feature that stands between two ground points and obstructs the view of one from the other.

Mask area—(*See also* Mask.) The area hidden from view by the mask.

Mean sea level—(*See also* Datum.) Reference plane for elevations.

Measuring wheel—A special wheel with attached recorder for counting its revolutions, to be used in computing the distance traveled by the vehicle or sledge towing it.

Medium-scale map—(*See also* Map.) A map having a scale larger than 1: 600,000 and smaller than 1: 75,000.

Mercator projection—(*See also* Map projection.) A projection showing increments of latitude and longitude on the map in the same relation as on the earth's surface.

Meridians—The great circles of the earth which pass through the poles; lines of longitude.

Mil—A unit of measure for angles based on the angle subtended by 1/6400th of the circumference of a circle. It is the angle subtended by one unit at one thousand units.

Military crest—The highest point near the top of a slope from which the entire valley below is visible. It is differentiated from the topographic crest which is the highest point.

Military grid—(*See also* Grid.) A grid specified for military use.

Military symbol—(*See* Symbol.)

Minor control—(*See also* Major control.) In sketching, a system of points serving as a framework upon which the detail of the sketch is hung. Minor control is established by the sketcher from major control.

Model—(*See* Relief model.)

Mosaic—An assemblage of aerial photographs forming a continuous photographic representation of a portion of the earth's surface.

Multiple-lens camera—A camera with two or more lenses, the axes of the lenses being systematically arranged at a fixed angle in order to cover a wide field by simultaneous exposures in all chambers.

Multiple-lens photograph—A photograph made with a multiple-lens camera.

Nautical chart—A hydrographic or marine map. A map of a portion of the earth's surface which includes navigable waters and the adjacent or included land, if any, and on which are indicated depths of water, marine obstructions, aids to navigation, and other information to aid the mariner in navigating.

Neat line—The line which surrounds the map itself; it differs from the margin in that the margin is outside the neat line. The neat line defines the limits of the geographic coordinates of the map area.

Northing—The distance north of the east-west grid line which has been assigned a value of zero in a grid system.

Oblique photograph—A photograph taken with the camera axis tilted.

Odograph—An instrument which automatically plots the course taken by a moving vehicle.

Odometer—A device for measuring distance traveled by a vehicle.

Open traverse—(*See also* Traverse.) As opposed to a closed traverse, the open traverse does not end at the starting point or at a point of known position and elevation.

Outpost sketch—A form of area sketch showing military features of ground along a friendly outpost line and as far toward the hostile position as may be sketched from the rear of and along the line of observation.

Overlap—(*See also* Flight strip.) The amount by which one photograph overlaps the area covered by another photograph. Overlap is customarily expressed as a percentage.

Overlay—A record on a transparent medium to be superimposed on another record, for example, the names overlay for a map manuscript.

Overprint—(*See also* Map.) A map which has data of importance or special use superimposed by printing on the original printed map.

Pace—In walking, the length of a step.

Pace tally—Device for counting paces while walking.

Pacing—Measuring distance by walking and counting the paces.

Parallels—Lines of latitude represented by circles on the earth parallel to the equator.

Paste mosaic—(*See also* Mosaic.) An uncontrolled mosaic prepared by cutting away the borders and assembling the center portions of adjacent photographs on a base to which the whole is affixed by a paste adhesive.

Percent of slope—(*See also* Slope.) A measurement of slope expressed as a ratio in terms of vertical rise as compared to horizontal distance.

Perspective projection—(*See also* Map projection.) A projection based on the principle of direct projection of points on the earth's surface by straight lines drawn through them from some given point to a map plane tangent to the sphere.

Photographic interpretation—The determination of the nature and description of objects that are imaged on a photograph.

Photomap—A reproduction of an aerial photograph or a mosaic made from a series of aerial photographs, upon which arbitrary grid lines, marginal data, place names, route numbers, important elevations, boundaries, approximate scale, and approximate direction have been added.

Pin-point photography—A single aerial photograph, purposely exposed, of an area of special importance.

Place sketch—A form of area sketch covering the area before a single point of observation.

Planimetric map—A map presenting only the horizontal position for the detail plotted. It is distinguished from a topographic map by omission of relief in a measurable form.

Point designation grid—(*See also* Grid.) A special grid for point designation on photographs.

Polar Stereographic grid—(*See also* Grid.) A grid based on the polar stereographic projection.

Polar Stereographic projection—(*See also* Map projection.) A projection having the center of the projection located at a pole of the sphere.

Polyconic projection—(*See also* Map projection.) A projection having the central meridian represented by a straight line, and the parallels represented by arcs of circles that are not concentric, but the centers of which all lie in the extension of the central meridian.

Position sketch—A form of area sketch which implies that the sketcher has access to all parts of the area sketched.

Profile—A line drawing showing the side view of a slope as in mechanical drawing.

Projection—(*See* Map projection.)

Protractor—A device for plotting or reading angular measurements on a plane surface, such as a map.

Provisional map—A map that sacrifices accuracy for haste of preparation; it differs from the planimetric or topographic map in that it does not necessarily have accuracy requirements to meet.

Relief—(*See also* Elevation.) Tha portion of the earth's surface that has elevation. The characteristic of variability in the earth's surface.

Relief forms—(*See also* Relief and Elevation.) The shapes taken by relief as developed by the actions of nature, and which, taken as a whole indicate the presence of each other, as ridges indicate valleys.

Relief model—A map substitute physically providing the effect of three dimensions to its representation of terrain.

Resection—A graphic means of plotting the position of a point occupied by the person doing the plotting, by drawing two direction sight lines to corresponding points of known position.

Roadmap—(*See also* Map.) A map having a scale usually from 1:200,000 to 1:1,000,000 giving approximate locations of towns and roads, and distinguishing between the various types of roads, road surfaces, and road capacities.

Route sketch—(*See also* Sketch.) As distinguished from an area sketch, a route sketch covers the area along a line of movement.

Scale—(*See* Horizontal scale.)

Scale ratio—(*See* Horizontal scale.)

Semicontrolled mosaic—(*See also* Mosaic.) A mosaic laid on insufficient ground control to meet the accuracy requirements of a controlled mosaic.

Side lap—(*See also* Overlap.) The overlap between photographs in adjacent parallel flights.

Simple conic projection—(*See also* Map projection.) This projection is the development of a right circular cone tangent to the spheroid along a single parallel of latitude, with spacings laid out on the parallel and a central meridian in proportion to relative distances on the spheroid. Straight lines are drawn from the apex through the spacings on the base parallel, and circles are drawn with the apex as a pivot to form the lines of latitude.

Single-lens camera—A camera having only one lens.

Single-lens photograph—(*See also* Single-lens camera.) A photograph made with a single-lens camera.

Situation map—(*See also* Map.) A map showing the tactical or administrative situation of a unit at a specified time, in a scale appropriate to the amount of detail required.

Sketch—A hasty pictorial drawing showing only desired map features and objects in relative position, usually for a specific use.

Slope—Any ground surface inclined with the horizontal, as shown on a profile drawing of the inclined surface.

Small-scale map—(*See also* Map.) A map with a scale of 1:600,000 or smaller.

Sortie—Individual flight in accomplishment of photographic mission.

Spheroid—An assumed size and shape of the earth, differing little from a sphere, used for computing geodetic positions.

Spot elevation—A point which is located on the map along with its elevation to aid in interpreting relief.

Standard military maps—(*See also* Map.) Includes all maps produced by the armed forces, or under their direction, for specific uses of the military. For example, ground force requirements include maps at 1:25,000, 1:50,000, 1:100,000, 1:250,000 and 1:1,000,000.

Staple mosaic—(*See also* Mosaic.) An uncontrolled mosaic stapled together with photograph information showing, usually used as an index of photograph coverage.

Steering mark—A reference point used as a guide for land navigation; a natural object or feature serving as a signpost.

Stereo-pair—(*See also* Stereo-vision.) Two overlapping photographs taken at the same altitude from separated camera stations.

Stereopsis—(*See also* Stereo-vision.) The property of three-dimensional effect achieved by blending into one image two pictures of the same object or area taken from different camera stations.

Stereoscope—(*See also* Stereo-vision.) An optical instrument for assisting the observer to view two properly placed photographs, a stereo-pair, to obtain the mental impression of a three-dimensional model.

Stereo-vision—That particular binocular application of the property of stereopsis which enables the observer to view an object, or two different perspectives of an object, a stereo-pair, so as to obtain therefrom the mental impression of a three-dimensional model.

Strategic map—(*See also* Map.) A map having a scale of 1:1,000,000, used for planning purposes to include movement, concentration, and supply.

Strategical-tactical map—(*See also* Map.) A map having a scale of 1:250,000 used when maps having other scales are unsuitable or unavailable. A 1: 500,000-scale map may serve as a substitute.

Strip photography—(*See also* Flight strip.) The procedure of covering a ground area with aerial photographs by accomplishing the required number of parallel and overlapping flight strips.

Supplemental contour—(*See also* Contour.) A contour representing a half-interval, used to produce a more complete picture of relief.

Symbol—A diagram, design, letter, or abbreviation, placed on maps and charts, which by convention, usage, or reference to a legend, is understood to stand for or represent a specific characteristic or object.

Tactical map—(*See also* Map.) A map having a scale of 1: 50,000, used for tactical and administrative purposes by all arms and services.

Terrain—An area of ground under consideration as to extent and topography.

Terrain model—(*See* Relief model.)

Topographic crest—(*See also* Military crest.) The point of highest elevation, as opposed to the military crest.

Topographic map—(*See also* Map.) A map showing the natural and manmade features of the earth's surface in measurable form, showing both their horizontal and their vertical positions. The vertical positions, or relief, are normally presented by contours. The elevations are usually referred to a mean sea-level datum plane.

Topography—The features of the actual surface of the earth, considered collectively as to form.

Town plan—A planimetric map made to a large scale showing city blocks, through streets, and civic features.

Track—(*See also* Ground speed.) The actual path of a craft over the surface of the earth or water.

Transverse Mercator projection—(*See also* Map projection and Universal Transverse Mercator grid.) A conformal projection adopted as a basis of map production at scales of 1: 250,000 and larger.

Traverse—A series of consecutive lines running from point to point, with the distances and angles being accurately known.

Trimetrogon photography—A method of obtaining aerial photographic coverage wherein three single-lens camera exposures are made at each normal single-lens camera station, one exposure being a vertical photograph and the other two being 60-degree oblique photographs to the left and right of the flight strip. This type of photography is obtained exclusively for use in a special process of small-scale map compilation.

True azimuth—(*See also* Azimuth.) An azimuth referenced to true north.

True north—A base direction for angular measurement as indicated by the direction of the geographic North Pole.

Uniform slope—(*See also* Slope.) A constant slope, as indicated on a topographic map by contours that are evenly spaced.

Universal Polar Stereographic grid—(*See also* Grid.) A military grid system in which the grid network is applied to stereographic projections of zones of the earth's surface covering from 80° north latitude to the North Pole, and from 80° south latitude to the South Pole, with a ½-degree overlap with the Universal Transverse Mercator grid, thereby extending valid and overlapping grid coordinates to 79°30′ north and south latitude.

Universal Transverse Mercator grid—(*See also* Grid.) A military grid system in which the grid network is applied to transverse mercator projections of zones of the earth's surface covering from 80° north latitude to 80° south latitude, 6 degrees of longitude wide, with 1 degree of overlap, ½ degree on each side. It is authorized by the Department of the Army for all military maps, replacing the world polyconic grid. As a gradual long-range action, the UTM grid is gradually replacing existing British grids, with the ultimate aim of establishing The UTM grid as the world-wide grid on military maps.

Vertical accuracy—The degree of conformity with standards established for vertical measurements.

Vertical control—(*See also* Control.) Control which determines positions with respect to elevations only, specifically leveling.

Vertical datum—(*See also* Datum.) Any level surface taken as a surface of reference from which to reckon elevations, as, for example, mean sea level.

Vertical photograph—An exposure made with an aerial camera with its axis held as nearly vertical as possible.

Wide-angle camera—An aerial camera having a lens which provides an unusually wide angular field of coverage, generally greater than 90 degrees.

World map—(*See also* Map.) A map of very small scale, usually 1:10,000,000 and smaller, which includes a large portion of the earth's surface, as, for example, the Western Hemisphere.

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NG: State AG (6); units—same as Active Army except allowance is one copy to each unit.

USAR: Same as Active Army except allowance is one copy to each unit.

For explanation of abbreviations used, see SR 320–50–1.