Section
5

INTRODUCTION TO LAND NAVIGATION

Key Points

1 Understanding Azimuths

2 Converting Azimuths

3 Determining Elevation

4 Calculating Distance on a Map

Introduction

To accomplish your mission, you must be in the right place at the right time. Being in the right place requires you to navigate well. Knowing how to read a map is one thing—knowing how to use a map to navigate requires that you understand how to use azimuths, elevation, and map distance.

In the previous section, you learned how to identify and interpret topographic symbols, colors, contour lines, and marginal information found on a military map. You also learned about the military grid reference system and how to plot grid coordinates using a military map and protractor.

This section will expand your map-reading skills and introduce you to how the military navigates using a map, compass, and protractor. You will learn what an azimuth is and how to convert azimuths in order to navigate using a compass and map. You will also learn how to determine the elevation of the terrain by analyzing the contour lines and contour interval data from the marginal information on a military map. Lastly, you will learn to compute straight-line and road distance using the scale in the margin of the military map. Coupled with your learning from your orienteering and map reading lessons, you will have the basic knowledge to navigate from one point to another and arrive safely at your destination.

In the following vignette, COL John Zierdt Jr., commander of the 1st Support Command during the first Gulf War, remembers how a group of Soldiers paid a serious price when they decided to rely on familiarity rather than put into practice basic map-reading and land-navigation skill required of all Soldiers.

Captured During Desert Storm

The driver had been on a particular route two or three times and thought he knew where he was going. Then instead of turning left, he kept going straight. They even saw the water on their right, which was a dead giveaway that they were going north rather than west. There were two HETs [heavy trucks] following each other. The guy, the one that was eventually captured, was in the lead vehicle, and stopped. And the guys behind him said, "You're going the wrong way and we need to turn around." He said, "I am not." He says, "I'm going straight. You can follow me or turn around if you want."

So, they kept going straight. The next thing you knew they were in the middle of a firefight. The second vehicle got turned around in time [and] got out of there; the [first] vehicle got stuck and didn't get turned around, and the two of them got captured.

Department of the Army, XVIII Airborne Corps and
US Army Center of Military History

Critical Thinking

If the drivers of the two vehicles had looked at and oriented their maps, what might have told them they were headed in the wrong direction?

What would you have done if you were in the second vehicle? Would you have continued to follow the first vehicle after you decided it was going the wrong way?

What could you have said over the radio to the Soldiers in the first vehicle that may have triggered in their minds that they were, in fact, going in the wrong direction?

Understanding Azimuths

azimuth

the horizontal angle, measured clockwise by degrees or mils between a reference direction and the line to an observed or designated point—there are three base (reference) directions or azimuths: true, grid, and magnetic azimuth

Everything in land navigation begins with an **azimuth**. An azimuth is a horizontal angle measured clockwise by degrees or mils between a reference direction and a line to an observed or designated point. There are three base directions or azimuths: true, grid, and magnetic.

The Army uses azimuths to express direction. Direction is determined from your start point, or where you are, outward toward your desired destination, or your intended target. Because you use north (0 or 360 degrees) as your base line, 270 degrees away from north will always be due west.

Think of yourself as standing in the middle of a Nebraska cornfield. You are facing north. The horizon stretches around you in a great 360-degree circle. If you travel an azimuth of zero degrees—or 360 degrees—or due north—you will wind up in Canada.

If you turn to your right and travel on an azimuth of 90 degrees—due east—you will wind up in the Atlantic Ocean, probably off the coast of New Jersey.

An azimuth of 180 degrees—due south—will take you into Mexico, and an azimuth of 270 degrees—due west—will take you to the Pacific, just off the coast of Northern California.

*The terms **azimuth** and **direction** are interchangeable.*

Determining a Grid Azimuth Using a Protractor

There are two ways you can determine an azimuth. You can use a map to determine a grid azimuth, or you can use a compass to determine a magnetic azimuth. Regardless of the technique, you will learn in this chapter how to convert a grid azimuth to a magnetic azimuth and a magnetic azimuth to a grid azimuth. You will first use a map and learn how to determine a grid azimuth. The steps in this process should be very familiar if you have ever taken a geometry class.

grid azimuth

the angle between grid north and a line drawn on the map

To begin, select a start point on the map. Mark it as point A. Identify an end point on your map. Mark it as point B. Using the edge of your protractor, draw a straight pencil line between points A and B. The line is your azimuth. Now you must determine the **grid azimuth** of that line—the angle between the line and grid north.

When you lay your protractor down on your map, make sure you place it right side up; verify this by checking to see that the writing on the protractor is not backward. If your protractor is wrong side up, you will get grid azimuths that are 180 degrees off from the

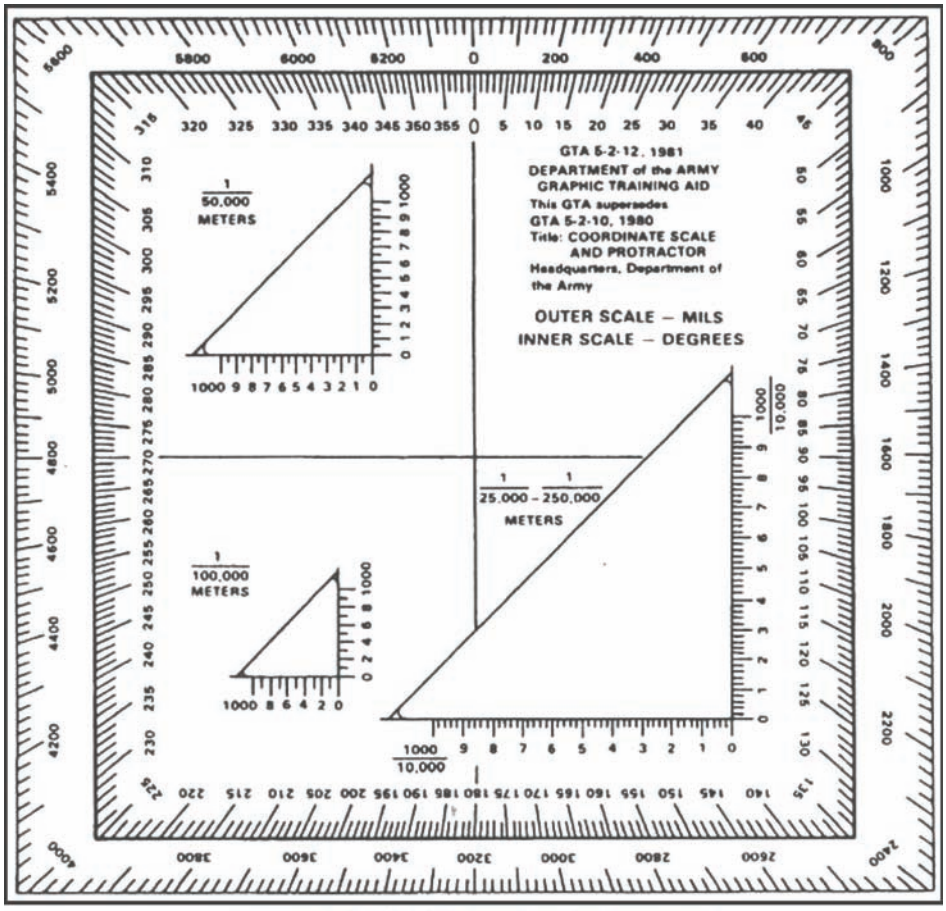

Figure 5.1 Army Protractor (GTA 5-2-12, 1981)

Although having the mils scale on the outside of the protractor may seem confusing now, don't get into the habit of cutting the mils scale off your protractor. Later in your military career, your military occupational specialty (MOS) may require you to state azimuths in mils as well as degrees.

correct grid azimuth. Also, make sure the 0- or 360-degree mark of your protractor is toward the top (or north) of your map, and make sure the 90-degree mark is toward the right (or east) of your map. *If you place your protractor down incorrectly on your map, the grid azimuth that you determine will be a minimum of 90 degrees off and as much as 270 degrees off the actual azimuth.*

Follow these three steps to determine your grid azimuth from the arbitrary points A and B (Figure 5.2):

1. Place the index of your protractor (the place where the etched vertical line and the etched horizontal line meet) at the point where the line you drew on your map crosses a vertical, north-south grid line.
2. Keeping the index at this point, line up the 0-to-180-degree line, or base line, of the protractor on the vertical, north-south grid line.
3. Follow your line outward to the degree scale of your protractor. Read the value of the angle from the protractor. This is your grid azimuth from point A to point B expressed in degrees.

Next, you will plot an azimuth from a known point on a map. Imagine you receive an order to move from your current position in a given direction. Plotting the azimuth on your map will allow you to see the terrain and objects you will need to navigate through along the entire length of your azimuth. The steps are as follows:

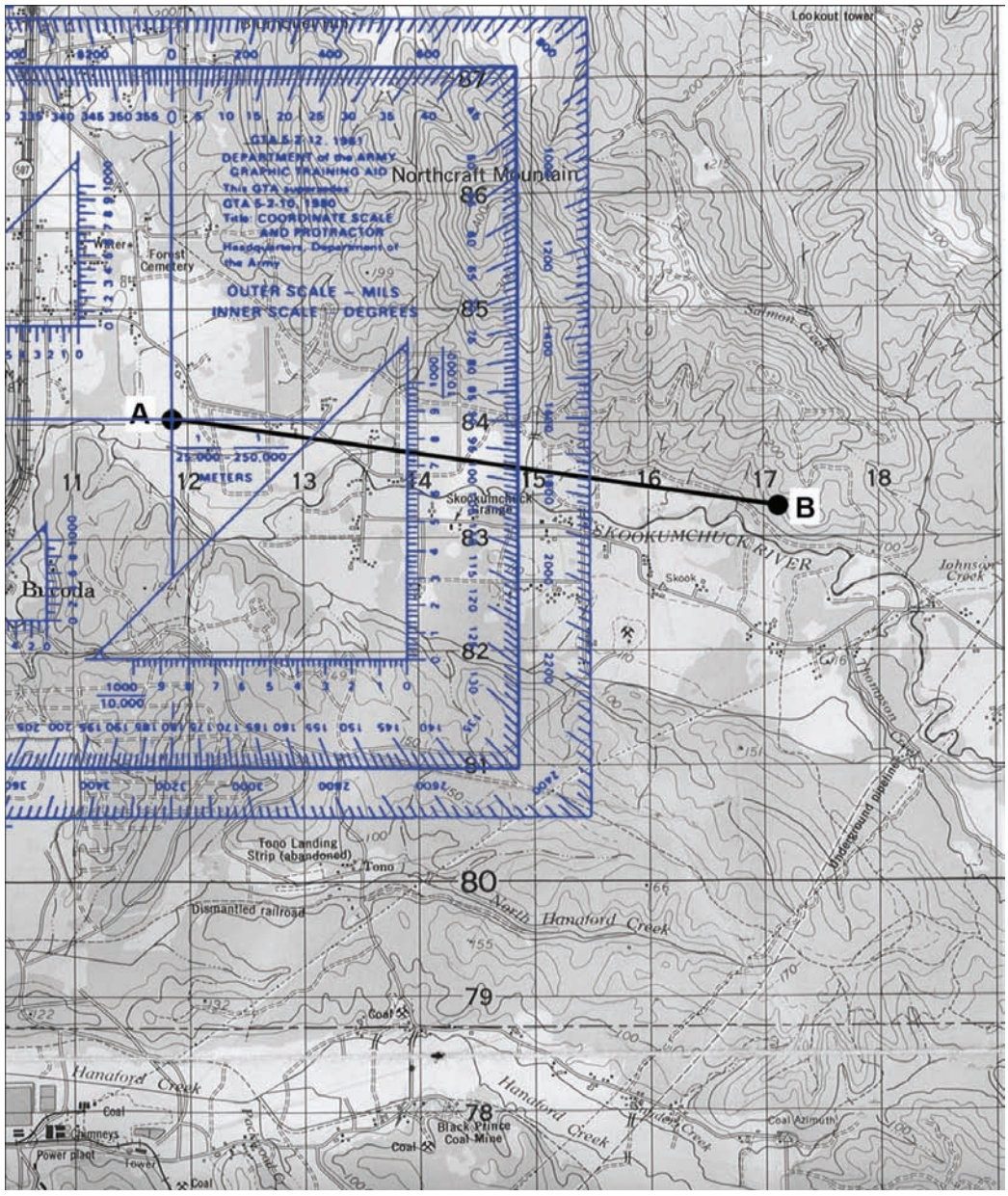

Figure 5.2 Measuring an Azimuth

This is the same method you will use to determine the grid azimuth between any two points on the map.

1. Place your protractor on the map with the index mark at the center of the known point and the base line parallel to a vertical, north-south grid line.
2. Using your pencil, make a small tick mark on the map at the edge of the protractor at the desired azimuth. Remember that your protractor will have degrees on the inner scale and mils on the outer scale. Ensure the tick mark on the map is beside the desired azimuth in degrees and not mils.
3. Lift and reposition the protractor so you can use its side as a straightedge. Draw a line connecting the known point and the tick mark on the map. This is your grid direction line—your azimuth.

Determining a Back Azimuth

back azimuth

the opposite direction of an azimuth—to obtain a back azimuth from an azimuth, add 180 degrees if the azimuth is 180 degrees or less, or subtract 180 degrees if the azimuth is 180 degrees or more

A **back azimuth** is simply the opposite direction to your azimuth. A simple example is when you get on the interstate going north when you wanted to go south. At the next exit, you get off the interstate, turn around, and get back on the interstate going south. You just took a back azimuth, or in slang, you just "did a 180."

To compute a back azimuth from an azimuth, simply add or subtract 180 degrees to or from your original azimuth. Remember that a circle has 360 degrees, so if your azimuth is greater than 180 degrees, adding 180 degrees to determine your back azimuth will give you an azimuth that is more than 360 degrees. For example, if your azimuth were 200 degrees, adding 180 degrees would result in a back azimuth of 380 degrees, whereas subtracting 180 degrees would result in a back azimuth of 20 degrees. The back azimuth 380 degrees is obviously greater than the number of degrees in a circle—20 degrees greater. Sure, you could subtract 360 degrees from 380 degrees and still get the same correct back azimuth of 20 degrees. But this simply adds another step to the process. So, subtracting 180 degrees from azimuths greater than 180 degrees simplifies determining back azimuths.

Determining a Magnetic Azimuth to an Object

A *magnetic azimuth* is an azimuth determined using magnetic instruments, such as a compass. The Army uses two types of compasses: the M2 compass and the lensatic compass. Soldiers use the M2 compass primarily for positioning indirect fire weapons such as mortars. The lensatic compass, pictured in Figure 5.3, is the compass the Army uses for land navigation.

To determine a magnetic azimuth using a compass:

1. Open your compass to its fullest so the cover forms a straightedge with the base. Move the lens (the rear sight) to the rearmost position. This allows the dial to float freely.
2. Place your thumb through the thumb loop, form a steady base with your third and fourth fingers, and extend your index finger along the side of the compass.
3. Place the thumb of your other hand between the lens (rear sight) and the bezel ring; extend your index finger along the remaining side of the compass, and your remaining fingers around the fingers of your other hand. Tuck your elbows into your sides. This will place the compass between your chin and your belt.
4. Turn your body toward the object that you wish to get an azimuth to, pointing your compass cover directly at the object.
5. Look down and read the azimuth from beneath the fixed black index line on the compass face.

Critical Thinking

1. Why is it important for you to understand how to determine a back azimuth?
2. When would you use a back azimuth?

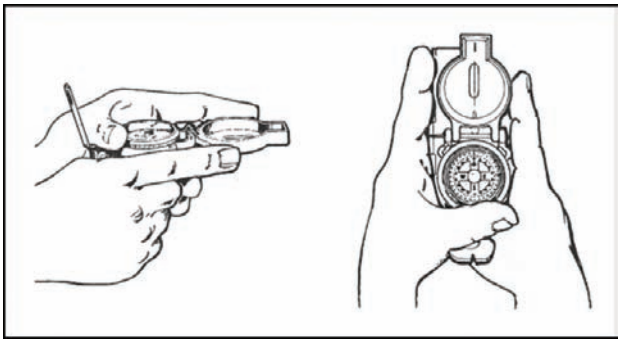

Figure 5.3 Centerhold Technique With a Lensatic Compass

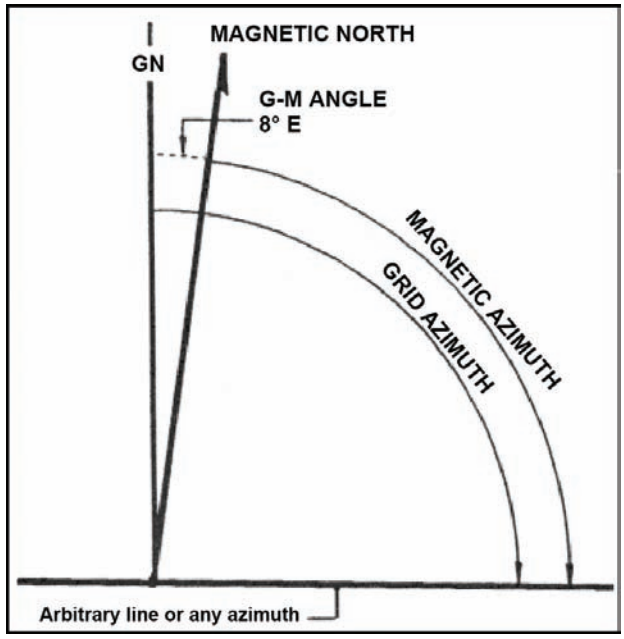

Figure 5.4 True, Magnetic, and Grid North

Shooting an Azimuth with a Compass

When you already know the magnetic azimuth that you want to navigate along, you follow the above steps, but reverse steps 4 and 5. You look down at the compass bezel and slowly turn your body until you see the azimuth you wish to take. Once you see your azimuth on the bezel, look up, and identify an easily recognizable object off in the distance that is in line with your azimuth. Once you have identified the object on your azimuth, you can put your compass away and move to that object. As long as you continue to move to your identified object, you will be on your desired azimuth. This method is known as "shooting an azimuth."

Converting Azimuths

Two problems complicate your easy use of a map and compass:

First, the surface of the earth is curved, while the surface of your map is flat. This creates problems between what your map shows as north (grid north) and what really is north (true north).

Second, the earth's magnetic pole is not the same as the earth's axis. This creates a difference between what your compass shows as north (magnetic north) and what really is north (true north).

declination diagram

the chart in the map legend that tells you the differences in angle between true north, grid north, and magnetic north

Your map contains information to help you overcome these problems. The **declination diagram** in your map's legend gives you the information you need to compensate for the differences—declination—between grid north, true north, and magnetic north.

The declination diagram (Figure 5.4) shows you the difference in angle between any of these norths. Since you will navigate with a magnetic compass and a grid map, your primary concern is the difference between grid north and magnetic north. The difference between grid north and magnetic north is known as the G-M angle (grid-magnetic angle).

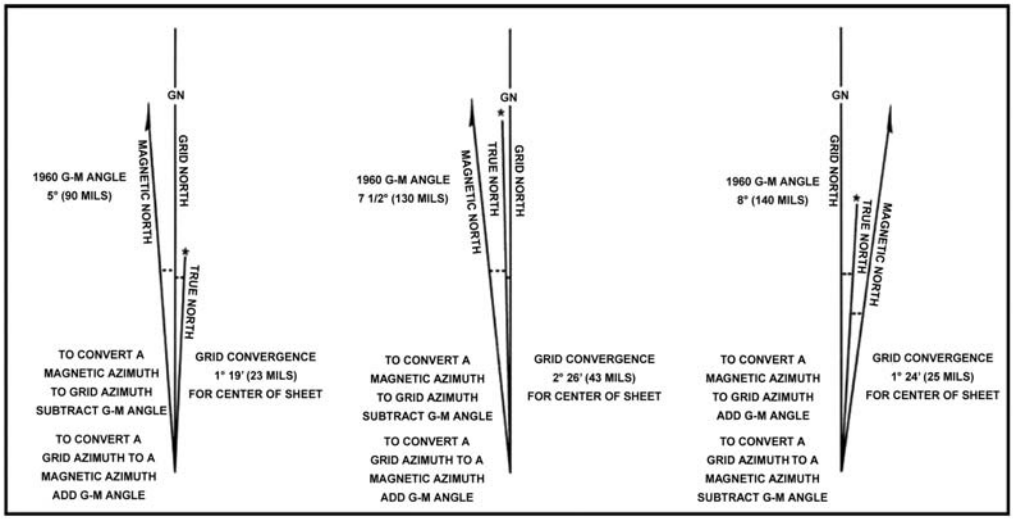

Figure 5.5 Map Declination Diagram

The G-M angle will be shown in the declination diagram and will be expressed in degrees. The G-M angle will either be to the west of grid north (westerly G-M angle) or to the east of grid north (easterly G-M angle). To reduce the confusion of converting easterly and westerly G-M angles from grid to magnetic or magnetic to grid, the mapmakers now include easy-to-understand instructions on the declination diagram so you can quickly convert azimuths without remembering formulas (Figure 5.5).

The three vectors that make up the declination diagram (true north, grid north, and magnetic north) are not drawn to scale. Use the written value for the G-M angle and do not try to measure the vectors to determine the G-M angle.

Most military maps will display the declination diagram in the lower margin. Some maps may not display the declination diagram and will only list the declination information as a note in the map margin.

Adjusting for the Grid-Magnetic (G-M) Angle

The G-M angle value is the size of the angle between grid north and magnetic north. You will see it as an arc, indicated by a dashed line, connecting the grid-north and magnetic-north vectors.

The G-M angle is important because if you don't adjust for the G-M angle, your grid azimuth translated from your map to your compass will be wrong by the size of the angle and vice versa. For example, if your G-M angle is 8 degrees *and you don't adjust for that angle*, your grid or magnetic azimuth will be off by 8 degrees. The farther you move away from your start point on your incorrect azimuth, the farther off you will be from your objective. The angular error increases the farther you move. Not using the G-M angle when converting from a grid azimuth to a magnetic azimuth can cause you to miss your objective. Likewise, if you forget to use the G-M angle when you convert a magnetic azimuth to a grid azimuth, you will plot the wrong azimuth on your map. This could result in passing on incorrect information or calling in inaccurate indirect fire missions.

Look at the notes that accompany the G-M angle diagram (Figure 5.5). One note tells you how to convert your magnetic azimuth to a grid azimuth; another tells you how to convert your grid azimuth to a magnetic azimuth.

A typical note may read "To convert a magnetic azimuth to grid azimuth, subtract G-M angle." If you have a magnetic azimuth of 270 degrees, and the G-M angle is 8 degrees, your grid azimuth will be 262 degrees.

The conversion (whether to add or subtract) depends on whether your map has an easterly or westerly G-M angle. If your magnetic north is to the right (east) of the grid north, then your map has an easterly G-M angle. If your magnetic north is to the left (west) of the grid north, then your map has a westerly G-M angle.

You will learn more about azimuths and land navigation as you progress through ROTC. By the end of your MSL III year, you must master land navigation in order to succeed at the Leader Development and Assessment Course (LDAC), which you will attend at Fort Lewis, Wash., after your MSL III year.

Determining Elevation

You can determine the elevation of any location on your map without any special equipment using two things on your map that you learned about in the previous Map Reading section—contour lines and the contour interval. Before you can determine the elevation of any point on your map, you must first know the contour interval for the map you are using. As you read previously, you can find the contour interval in the margin of your map—usually in the middle of the lower margin. Recall that the contour interval is a measurement of the vertical distance between adjacent contour lines.

Refer to Figure 5.7 to learn how to determine the specific elevation of a point on a map:

1. Identify the contour interval and the unit of measure used (feet, meters, or yards) from your map's marginal information at Figure 5.6 (most military maps use meters).

   Using the map example at Figure 5.7, if you wanted to determine the elevation to point A, you would find the numbered index contour line nearest point A. In Figure 5.7, the closest numbered contour line to point A is the 500-meter contour interval.

   Determine if point A is above (higher in elevation) the 500-meter contour line, or if point A is below (lower in elevation) than the 500-meter line. Since point A lies between the 500-meter contour line and the 600-meter contour line, moving from the closest contour line (500-meter) to point A would be traveling uphill to a higher elevation.

2. Determine the elevation of point A by starting at the index contour line numbered 500 and counting the number of intermediate contour lines (the unmarked contour lines) to point A.

   Point A is on the second intermediate contour line above the 500-meter index contour line. Since the contour interval is 20 meters (Figure 5.6), each intermediate contour line crossed to get to point A adds 20 meters to the 500-meter index contour line. The elevation of point A is 540 meters.

3. Determine the elevation of point B by going to the nearest index contour line. In this case, it is the upper index contour line, numbered 600. Point B is located on the intermediate contour line immediately below the 600-meter index contour line.

   Therefore, point B is located at an elevation of 580 meters. Remember, if you are increasing elevation, add the contour interval to the nearest index contour line. If you are decreasing elevation, subtract the contour interval from the nearest index contour line.

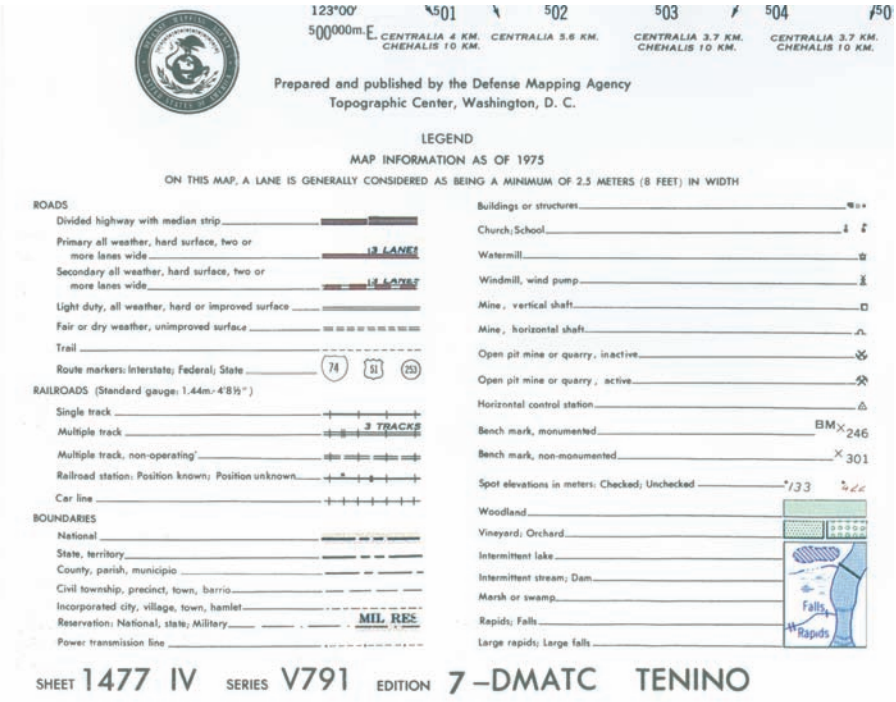

Figure 5.6 Example of a Contour Interval Note

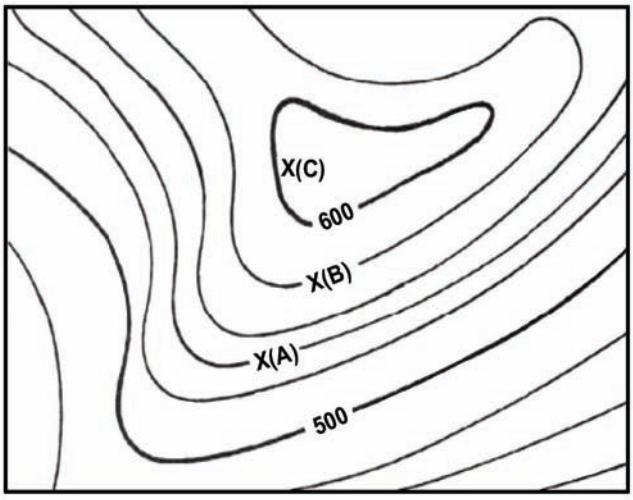

Figure 5.7 Points on Contour Lines

Critical Thinking

Why is it important for you to know how to determine elevation on a military map? Think about the azimuth you will plot on your map in order to travel from point A to point B. How will knowing elevation help you when navigating from point A to point B? Can knowing the elevation help you decide which azimuths or routes to take to your destination?

4. Estimate the elevation of the hilltop, point C, by adding one-half of the contour interval to the elevation of the last contour line. In this example, the last contour line before the hilltop is an index contour line numbered 600. Add one-half the contour interval, 10 meters, to the index contour line. The elevation of the hilltop would be 610 meters. You use the same process to estimate the elevation of a depression, except you subtract half of the contour interval to estimate the elevation at the bottom of the depression.

Calculating Distance on a Map

Now you know how to plot and determine azimuths on your map, and you understand how to determine elevation on your map or along your plotted azimuth. But how far is it from your start point to your destination? The marginal information on your map allows you to determine both straight-line distance and road distance. You can use the graphic scale—located in the lower center portion of the map margin—as a ruler to convert distances on the map to distances on the ground (Figure 5.8).

The graphic scale is divided into two parts. To the right of the zero, the scale is marked in full units of measure and is called the primary scale. To the left of the zero, the scale is divided into tenths and is called the extension scale.

Most maps have three or more graphic scales, each with a different unit of measure, such as meters, yards, statute miles, and nautical miles. When you use the graphic scale, be sure that you use the appropriate unit of measure.

Straight-Line Distance

To calculate the straight-line distance between two points on your map:

1. Lay a straight-edged piece of paper on the map so the edge of your paper touches both points and extends past them.
2. Make a tick mark on the edge of the paper at each point (Figure 5.9).
3. Then move your paper to the graphic bar scale, and use the scale to measure the distance between the two points. Note that you should align the tick mark on the right with a printed number in the primary scale so that the left tick mark falls within the extension scale (Figure 5.10).

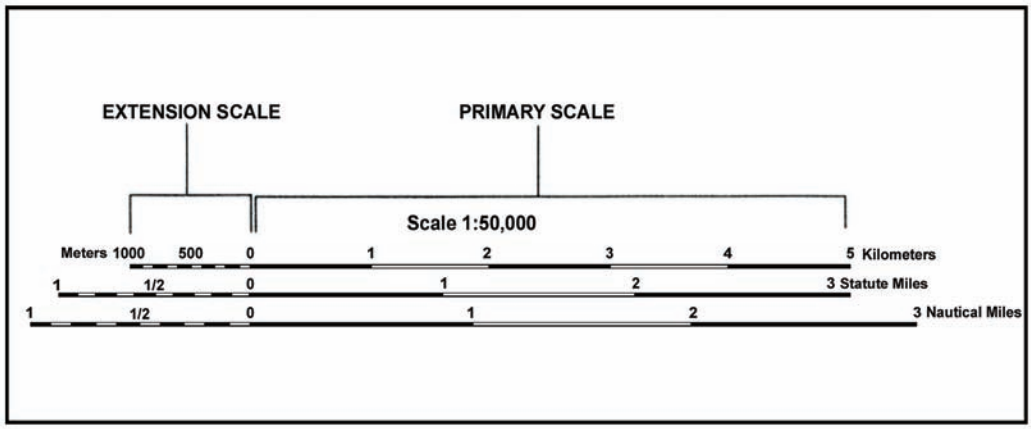

Figure 5.8 Using a Graphic (Bar) Scale

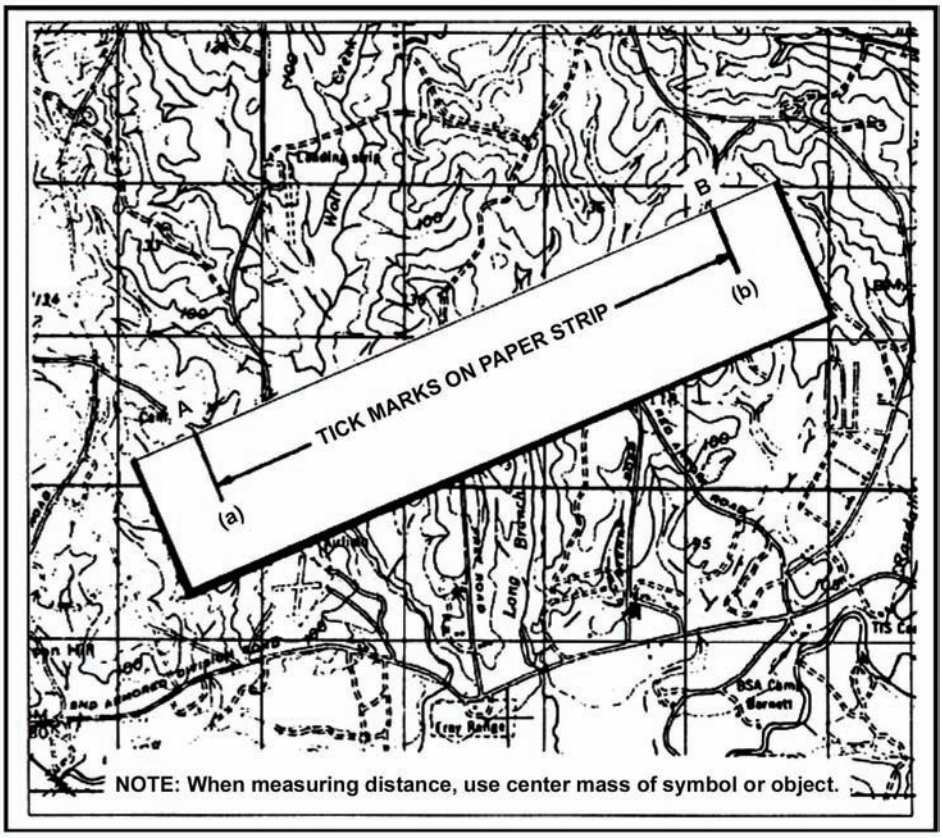

Figure 5.9 Transferring Map Distance to Paper Strip

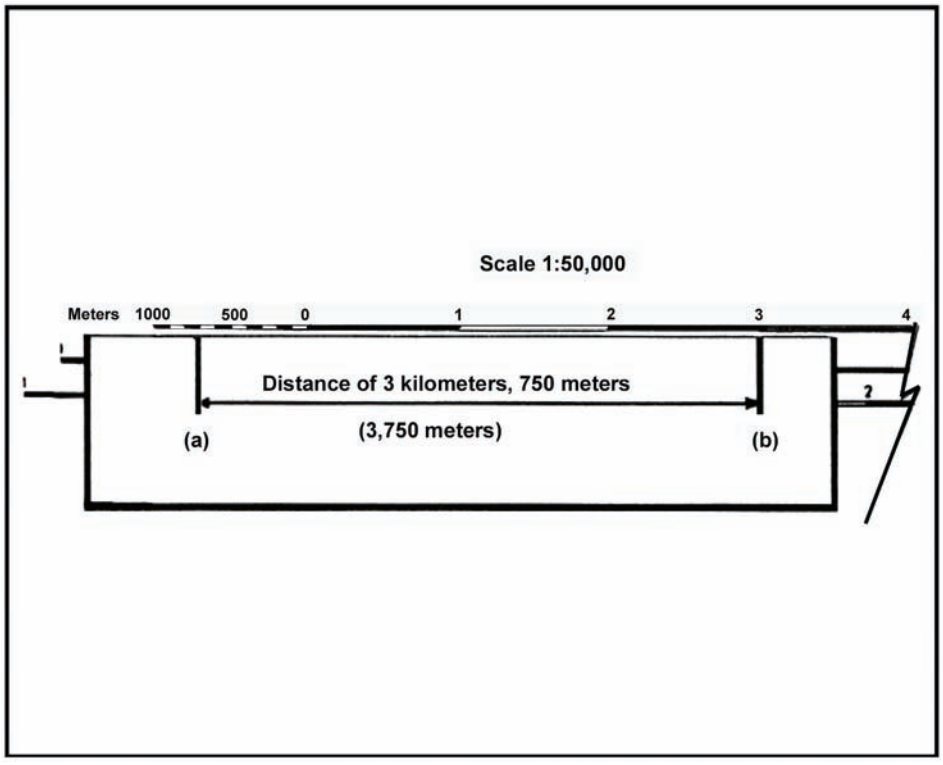

Figure 5.10 Measuring Straight-Line Map Distance

The more tick marks you make when measuring your curved route, the more accurate your final distance will be. This is especially true when measuring along curves.

Curved-Line Distance

To measure the distance along a curved route, such as a road, trail, waterway, or other curved line:

Put a straight-edged piece of paper on your map with the edge next to your starting point. Place a tick mark on the paper and on your map.

Line up the straight edge of the paper with the straight portion of the curved route you are measuring. Make a tick mark on both map and paper when the edge of the paper leaves the straight portion of the line you're measuring. (See View A in Figure 5.11.)

Pivot the paper until another straight portion of the curved line lines up with the edge of the paper. Continue in this manner until you have completed the distance you want to measure. (See View B in Figure 5.11. Notice the number of small ticks on the edge of the paper and that the last is labeled tick mark B.)

Move the paper to the graphic scale to determine the ground distance. The only tick marks you need to measure are tick marks A and B. (See View C in Figure 5.11.)

In order to maintain accuracy when measuring curved distance, it is important to keep the straight edge of your paper on the same side of the curve you are measuring. If you start off measuring a curved road on one side of that road, then keep your paper on that side of the road and mark all of your tick marks on that same side of the road. Do not cross over and start making tick marks on the opposite side of the road.

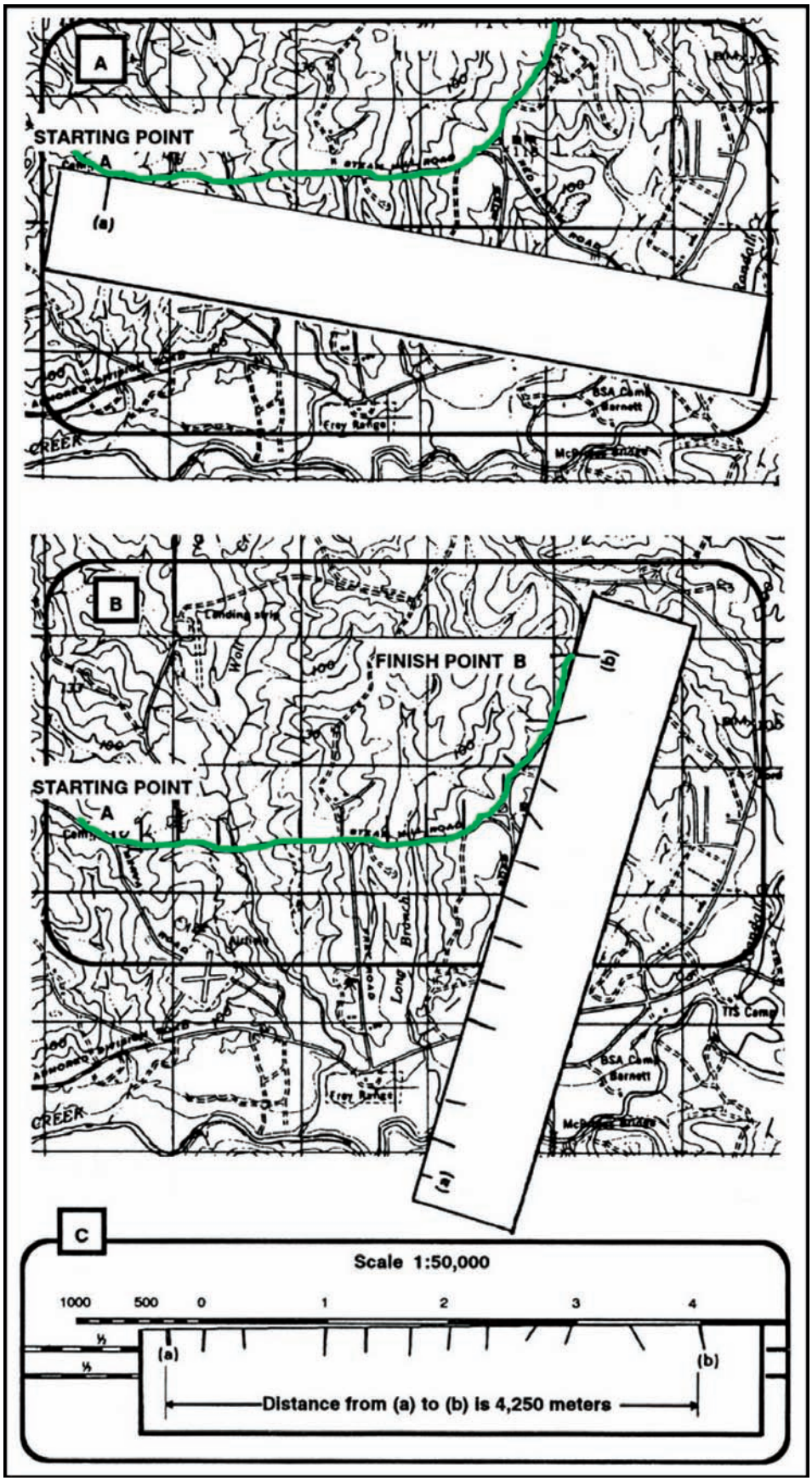

Figure 5.11 Measuring a Curved Line

CONCLUSION

You are a Cadet now. In the not-too-distant future, you may be an Army second lieutenant leading a platoon. Perhaps, in the distant future, you will be a lieutenant colonel commanding a battalion, a colonel commanding a brigade, or even a major general commanding a division. Whatever your position and rank, you will always need to get your Soldiers from one point to another. If you can't do so, you endanger your mission and perhaps the lives of your Soldiers.

It's impossible to overemphasize the importance of map reading and land navigation. They are critical leadership skills. They are also perishable skills—they require constant practice and review, regardless of a Soldier's rank or experience. Start now to develop your expertise and work to keep your skills honed and at the ready.

Learning Assessment

1. What is an azimuth?
2. Explain how to determine a grid azimuth.
3. Explain how to determine a magnetic azimuth.
4. Explain the differences between the three norths.
5. Explain how to use the G-M angle to convert grid and magnetic azimuth.
6. What is a contour interval?
7. Explain how to determine elevation on a map.
8. Explain how to measure the straight line and curved distance between two points on a map.

Key Words

azimuth
grid azimuth
back azimuth
declination diagram

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