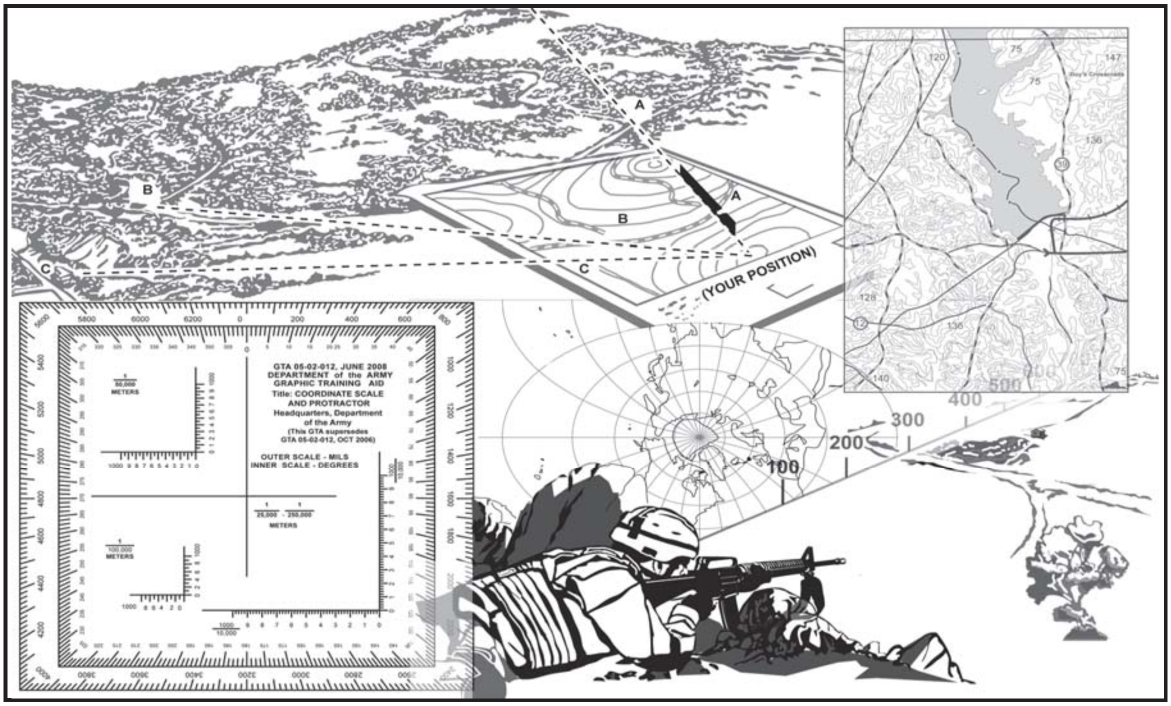
TC 3-25.26 (FM 3-25.26)

Map Reading and Land Navigation



November 2013

Headquarters, Department of the Army

DISTRIBUTION RESTRICTION: Distribution authorized to U.S. government agencies and their contractors only (this publication addresses current technology in areas of significant or potentially significant military application). This determination was made on September 13, 2004. Other requests for this document will be referred to: Commandant; U.S. Army Infantry School; ATTN: ATSH-INB-O; Fort Benning, GA 31905-5593.

DESTRUCTION NOTICE: Destroy by any method that will prevent disclosure of contents or reconstruction of the document.

Training Circular
No. 3-25.26

Headquarters
Department of the Army
Washington, DC 15 November 2013

Map Reading and Land Navigation

Contents

DISTRIBUTION RESTRICTION: Distribution authorized to U.S. Government agencies and their contractors only (this publication addresses current technology in areas of significant or potentially significant military application). This determination was made on September 13, 2004. Other requests for this document will be referred to: Commandant; U.S. Army Infantry School; ATTN: ATSH-INB-O; Fort Benning, GA 31905-5593.

DESTRUCTION NOTICE: Destroy by any method that will prevent disclosure of contents or reconstruction of the document.

***This publication supersedes FM 3-25.26, 18 January 2005.**

Figures

Tables

Preface

Training Circular (TC) 3-25.26 contains doctrine and training guidance on map reading and land navigation. Part One addresses map reading and Part Two, land navigation. The appendixes include an introduction to orienteering and a discussion of several devices that can assist the Soldier in land navigation. This TC provides a standardized source document for Armywide reference on map reading and land navigation. It applies to every Soldier in the Army regardless of service branch, MOS, or rank.

The primary target audience for this publication is the platoon leader and other leaders within a reconnaissance platoon. The secondary audience includes training developers involved in developing training support materials for professional military education (PME).

This TC applies to the Active Army, the Army National Guard (ARNG)/Army National Guard of the United States (ARNGUS), and the United States Army Reserve (USAR) unless otherwise stated.

The proponent for this publication is the United States Army Training and Doctrine Command (TRADOC). The preparing agency is the Maneuver Center of Excellence (MCoE). Send comments and recommendations by any means: U.S. mail, email, fax, or telephone, following the format of DA Form 2028 (*Recommended Changes to Publications and Blank Forms*). You may phone for more information. Point of contact information is as follows:

E-mail:	benn.29IN.229-S3-DOC-LIT@conus.armyl.mil
Phone:	Commercial: 706-545-8623 or DSN: 835-8623
Fax:	Commercial: 706-545-8600 or DSN: 835-8600
U.S. Mail:	Commandant, MCoE ATTN; ATSH-INB 6850 Barron Ave, Bldg. 85 Fort Benning, GA 31905-5593

Unless this publication states otherwise, masculine nouns and pronouns do not refer exclusively to men.

PART ONE

MAP READING

Chapter 1

Training Strategy

This manual responds to an Armywide need for a new map reading and land navigation training strategy based upon updated doctrine. This chapter describes and illustrates this approach for teaching these skills.

BUILDING BLOCK APPROACH

1-1. Institution courses are designed to prepare the Soldier for a more advanced duty position in the unit. The critical soldiering skills of move, shoot, and communicate require training, practice, and sustainment at every level in the schools and in the unit. Map reading and land navigation skills are critical to the duty position for which Soldiers are being trained, and a prerequisite for critical skills at a more advanced level. This includes:

- A Soldier completing initial-entry training prepares to become a team member proficient in basic map reading and dead reckoning skills.
- After completing the Warrior Leader Course, a Soldier should be ready to be a team leader. This duty position requires expertise in map reading, dead reckoning, and terrain association.
- A Soldier completing the Advanced Leader Course receives training for the squad leader position. Soldiers at skill level 3 are expected to be proficient in map reading and land navigation, and have developed the knowledge and skills to support route selection and squad tactical movement.
- The Senior Leader Course prepares skill level 4 Soldiers to assume the duty position of platoon sergeant or operations noncommissioned officer (NCO). Soldiers at this level are expected to have the knowledge and skills required to plan and lead tactical movements.
- Officers follow a similar progression. A new second lieutenant masters map reading and land navigation skills, and has an aptitude for dead reckoning and terrain association.
  - The Basic Officer Leader Course prepares officers to assume the duties and responsibilities of a platoon leader. Commanders require leaders to execute their orders and operations. Map reading and land navigation at this level require development of the problem-solving skills of route selection and tactical movement.
  - Completion of the Captain's Career Course prepares officers to assume the duties and responsibilities of a company commander or primary staff officer. The commander plans and executes operations with full consideration for all aspects of navigation. The staff officer recommends battlefield placement of all administrative, logistical, and personnel resources. These recommendations are tactically sound when the estimate process includes a detailed analysis of the area of operations. This ability requires expertise in all map reading and navigation skills, including the use of nonmilitary maps, digitized terrain, and terrain analysis (with respect to friendly and enemy forces). The commander/staff officer plans and executes a program to develop the unit's train-the-trainer program for land navigation.

- A program of demonstrated proficiency of all the preceding skill levels is a prerequisite for the successful implementation of a building-block training approach. This approach reflects duty position responsibilities in map reading and land navigation. An understanding of the fundamental techniques of dead reckoning or field-expedient methods is a basic survival skill that each Soldier develops at the initial-entry level. This skill provides a support foundation for more interpretive analysis at intermediate skill levels 2 and 3, with final progression to level 4. Mastery of all map reading and land navigation tasks required in previous duty positions is essential for the sequential development of increasing proficiency levels.

ARMYWIDE IMPLEMENTATION

1-2. The United States Army Training and Doctrine Command service schools and United States Army Forces Command professional development schools receive a mandatory core of critical map reading, land navigation tasks, and a list of electives. Standardization is achieved through the mandatory core requirements.

SAFETY

1-3. Unit leaders brief and enforce all safety regulations established by local range operations. They coordinate the mode of evacuation of casualties through the appropriate channels and review all installation safety regulations. Unit leaders complete a thorough terrain reconnaissance looking for dangerous terrain, heavily trafficked roads, water obstacles, wildlife, and training debris before using an area for land navigation training.

MOBILE ELECTRONIC DEVICES

1-4. Units should consider current mobile applications (apps) and those under development to supplement individual land navigation training. Mobile electronic devices may allow Soldiers to download and use training apps to learn and practice basic task steps, such as plotting a grid, determining a distance, or finding the location of map data. Some apps may have a Global Positioning System (GPS) mode that allows use of the mobile device as a navigation tool.

CAUTION

This TC does not produce or support current approved apps or interactive multimedia programs. The Army has several official online sites to access apps and multimedia training programs. However, the navigational aid or training information provided by these apps and programs may not be accurate or relevant for the intended unit training.

CAUTION

When using the GPS mode of an approved app, the mobile electronic device being used needs additional verification checks by the training unit to ensure applicable changes in data are correct (such as change the Universal Transverse Mercator [UTM] coordinate system to the military grid reference system [MGRS]).

SIMULATORS

1-5. No individual land navigation simulation trainers are currently being fielded, but there are a multitude of virtual ground vehicle and air mobile training platforms available. The scope of training depends upon the system and software packages available.

1-6. Simulators are standard training platforms, providing Soldiers the opportunity to replicate training with vehicles such as the—

- M1 Abrams tank.
- M2 Bradley fighting vehicle.
- M3 cavalry fighting vehicle.
- Bradley fire support team vehicle.
- M113 armored personnel carrier heavy expanded mobility tactical truck.
- High mobility multipurpose wheeled vehicle.

1-7. To maximize the training effort, units should consider including land navigation skills in training. Simulation programs including the Virtual Combat Convoy Trainer, AH64A Combat Missions Simulator, and the Close Combat Tactical Trainer, allow the possibility of leaders to designate routes and control movement in the virtual environment. .

This page intentionally left blank.

Chapter 2

Maps

Cartography is the art and science of expressing the known physical features of the earth graphically by maps and charts. No one knows who drew, molded, laced together, or scratched the first map in the dirt, but an historical study reveals that the most pressing demands for mapping accuracy and detail are a result of military needs. Today, due to the complexities of tactical operations and deployment of troops, it is essential for all Soldiers to be able to read and interpret their maps in order to move quickly and effectively on the battlefield. This chapter includes the definition and purpose of a map and describes map security, types, categories, and scales.

General George Washington

"The want of accurate maps of the Country which has hitherto been the Scene of War, has been a great disadvantage to me. I have in vain endeavored to procure them and have been obliged to make shift with such sketches as I could trace from my own Observations…"

General George Washington, according to John C. Fitzpatrick,
Writings of George Washington from the Original Manuscript Sources, 1745-1799

DEFINITION OF MAPS

2-1. A map is a graphic representation of a portion of the earth's surface drawn to scale, as seen from above. It uses colors, symbols, and labels to represent features found on the ground. The ideal representation shows the true shape of every feature in the area being mapped. Obviously this is unfeasible, and an attempt to plot each feature true-to-scale would result in a product impossible to read even with the aid of a magnifying glass.

2-2. To be understandable, features are represented by conventional signs and symbols. To be legible, many of these are exaggerated in size, often far beyond the actual ground limits of the feature represented. On a 1:250,000-scale map, the prescribed symbol for a building covers an area about 500 square feet on the ground; a road symbol is equivalent to a road about 520 feet wide on the ground; the symbol for a single-track railroad (the length of a cross-tie) is equivalent to a railroad cross-tie about 1,000 feet on the ground.

2-3. The portrayal of many features requires similar exaggeration. Therefore, the selection of features shown, as well as their portrayal, is according to the guidance established by the National Geospatial-Intelligence Agency (NGA).

PURPOSE

2-4. A map provides information on the existence of the location and the distance between ground features, such as populated places and routes of travel, and communication. It also indicates variations in terrain, heights of natural features, and the extent of vegetation cover. With our military forces dispersed throughout the world, it is necessary to rely on maps that provide information to our combat elements and resolve logistical operations far from our shores. Planning using maps allows units to transport, store, and place Soldiers and materiel into operation at the proper time and location. All operations require maps; however, the finest maps available are worthless unless the map user knows how to read them.

PROCUREMENT

2-5. Military units are authorized a basic load of maps. Local command supplements to Army Regulation (AR) 115-11 provide tables of these initial allowances. Routine ordering of NGA maps and products are made through the Defense Logistics Agency's mapping customer operations. All Department of Defense activities and federal agencies submit electronic orders via military/federal standard requisitioning and issue procedures through the Defense Automatic Addressing System Center. The mapping customer operations website, http://www.aviation.dla.mil/rmf/ Division G-2 section is responsible for maps:

- To order a map, refer to the NGA catalog located in the intelligence/G-2 shop. Part 3 of this catalog, Topographic Maps, has five volumes. Use the delineated map index to find map information needed based upon the location of the nearest city. With this information, order maps using the following forms:
  - Department of Defense (DD) Form 1348 (*DOD Single Line Item Requisition System Document [Manual]*). Order only one map sheet on each form.
  - DD Form 1348M (*Single Line Item Requisition System Document, DOD [Mechanical]*). This is a punch card form for ordering via the Automatic Digital Network.
- The numbered sections of all forms are the same. For example, in block 1, Soldiers stationed in the continental United States (CONUS), enter "AOD;" those stationed overseas, enter "AO4." In block 2, use one of the following codes depending upon location. The supply section can help with the rest of the form.

LOCATION	CODE
Europe	CS7
Hawaii	HM9
Korea	WM4
Alaska	WC1
Panama	HMJ
CONUS	HM8

- Stock numbers are also listed in map catalogs, which are available at division and higher levels (and occasionally in smaller units). A map catalog consists of small-scale maps with delineated outlines of the individual sheets of a map series. Another document that is an aid to the map user is the gazetteer. This lists all the names appearing on a map series of a geographical area, a designation that identifies anything located at that place name, a grid reference, a sheet number of the map upon which the name appeared, and the latitude and longitude of the named features. Gazetteers are prepared only for maps of foreign areas.

SECURITY

2-6. All maps are considered to be documents that require special handling. If a map falls into unauthorized hands, it could easily endanger military operations by providing information of friendly plans or areas of interest to the enemy. Even more important is a map marked which shows the movements or positions of friendly Soldiers. It is possible to determine marking and information on maps even after they have been erased. *Maps are documents that must not fall into unauthorized hands.*

- When maps are no longer needed, they are given to the proper authority. Maps that are in danger of being captured are destroyed. The best method of destruction is burning it and scattering the ashes. If burning is not possible, the map can be torn into small pieces and scattered over a wide area.
- Maps of some areas of the world are subject to third party limitations. These are agreements that permit the U.S. to make and use maps of another country provided these maps are not released to a third party without permission of the country concerned. Such maps require special handling.
- Care and handle classified maps according to AR 380-5. If applicable, follow other local security directives.

CARE

2-7. Maps are documents printed on paper that requires protection from water, mud, and tearing. Whenever possible, carry maps in a waterproof case, pocket, or some other place where it is handy for use but still protected. (Appendix A shows two ways to fold a map.) Other considerations include:

- Take care when using a map since it may have to last a long time. Use a pencil if marking a map becomes necessary. Use light lines to make erasing easier without smearing, smudging, or leaving marks that may cause confusion later. If trimming map margins is necessary, it is essential to note marginal information such as grid data and magnetic declination for possible future use.
- Take special care when using a map in a tactical mission, especially in small units; the mission may depend on that map. All members of such units should know the map's location at all times.

CATEGORIES OF MAPS

2-8. The NGAs mission is to provide mapping, charting, and all geodesy support to the armed forces, and all other national security operations. NGA produces four categories of products and services: hydrographic, topographic, aeronautical, and digital. Military maps are categorized by scale and type.

2-9. Knowing the mathematical scale used is important to the user. The scale determines the ground distance between objects or locations on the map, the size of the area covered, and the amount of detail being shown. The mathematical scale of a map is the ratio or fraction between the distance on a map and the corresponding distance on the surface of the earth. The representative fraction (RF) is the scale, with the map distance as the numerator and the ground distance as the denominator.

$$\text{Representative fraction (scale)} = \frac{\text{map distance}}{\text{ground distance}}$$

2-10. As the denominator of the representative fraction gets larger and the ratio gets smaller, the scale of the map decreases. NGA maps are classified by scale into three categories: small-, medium-, and large-scale maps. (See Figure 2-1.) The terms *small scale*, *medium scale*, and *large scale* may be confusing when read in conjunction with the number. However, when viewing the number as a fraction, it quickly becomes apparent that 1:600,000 of something is smaller than 1:75,000 of the same thing. Therefore, the larger the number after 1, the smaller the scale of the map. Maps can be categorized as—

- **Small**. Maps with scales of 1:1,000,000 and smaller are used for general planning and for strategic studies (bottom map in Figure 2-1). The standard small-scale map is 1:1,000,000. This map covers a large land area at the expense of detail.
- **Medium**. Maps with scales between 1:1,000,000 and 1:75,000 are used for operational planning (center map in Figure 2-1). They contain a moderate amount of detail, but terrain analysis is best done with the large-scale maps. The standard medium-scale map is 1:250,000. Medium-scale maps of 1:100,000 are encountered frequently.
- **Large**. Maps with scales of 1:75,000 and larger are used for tactical, administrative, and logistical planning (top map in Figure 2-1). These are the maps a Soldier or junior leader are most likely to encounter. The standard large-scale map is 1:50,000; however, many areas have been mapped at a scale of 1:25,000.

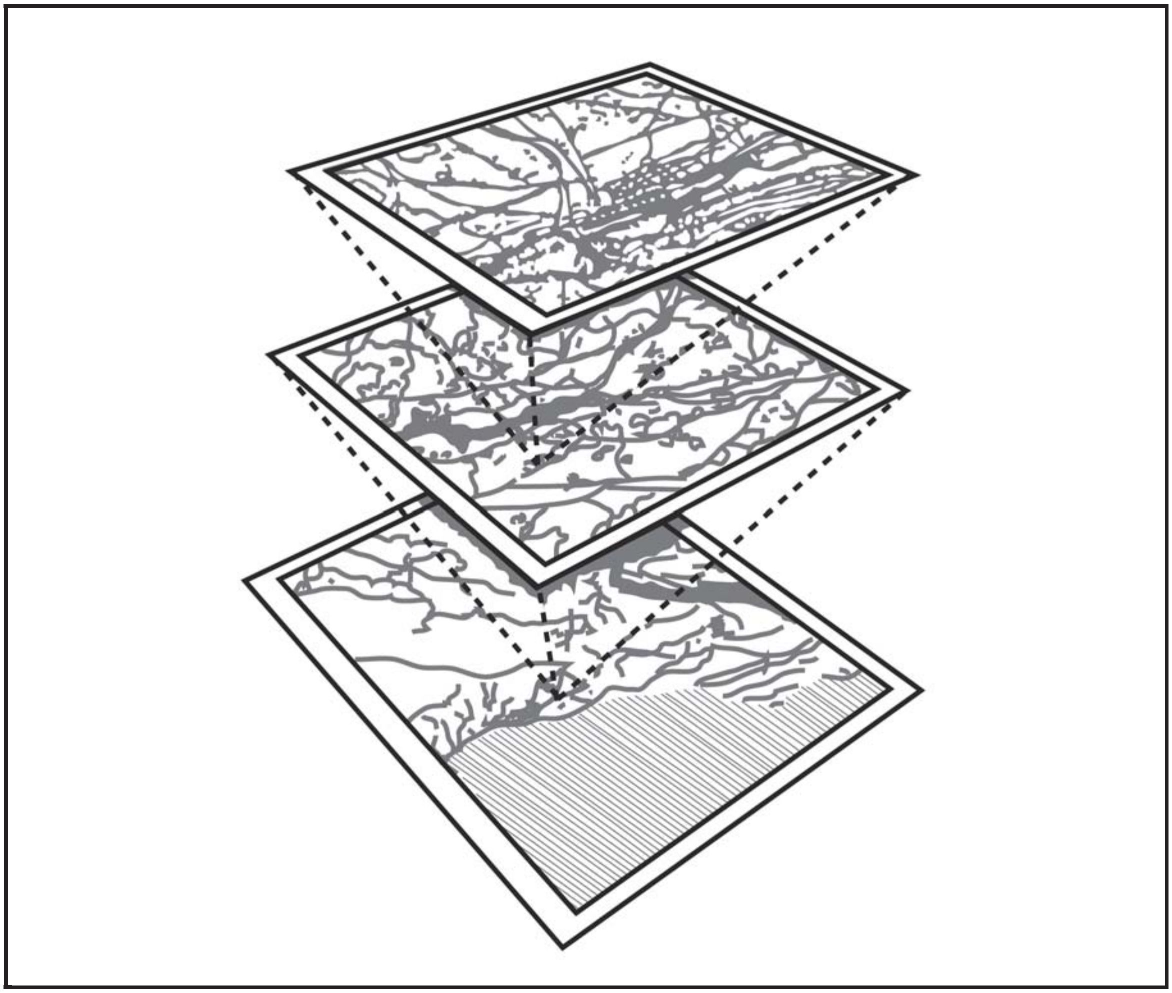


Figure 2-1. Scale classifications

- **Types**. The map of choice for land navigators is the 1:50,000-scale military topographic map. When operating in foreign places, some NGA map products may not cover a particular area of operations due to a lack of production, or may not be available to a unit when required. Therefore, units may find it necessary to use maps produced by foreign governments that may or may not meet the standards for accuracy set by NGA. These maps often use symbols that resemble those found on NGA maps but have completely different meanings. There may be other times units use obtained maps such as tourist maps or other commercially produced maps. (In Grenada, many of our troops used a British tourist map.) It is also important to know how to use the many other products available from the NGA:
  - **Planimetric map.** A planimetric map presents only the horizontal positions for the features represented. It is distinguished from a topographic map by the omission of relief, normally represented by contour lines. Sometimes it is called a line map.
  - **Topographic map.** A topographic map portrays terrain features in a measurable way, as well as the horizontal positions of the features represented. The vertical positions, or relief, are normally represented by contour lines on military topographic maps. On maps showing relief, the elevations and contours are measured from a specific vertical datum plane, usually mean sea level.
  - **Digital maps.** A digital map (also called digital cartography) is the visual representation of a point on the earth as depicted by electronic data that is compiled and formatted into a virtual image. Early digital maps had the same basic functionality as paper maps, providing a virtual view based on scanned images of paper maps already in use. Virtual views of topographic maps are only part of the current digital mapping capabilities. In many cases,

Soldiers can choose from virtual maps, satellite images, and hybrid views (with or without mission command overlays). Often, displays may be layered, and the Soldier can choose from one or multiple layers using a dropdown menu.

- **Digital city graphic.** The features of a digital city graphic include important buildings, airfields, military installations, industrial complexes, embassies, government buildings, hospitals, schools, utilities, and places of worship. A guide to numbered buildings and an index to street names are provided in the margin. Contour lines are in sufficient detail to identify spurs, draws, saddles, hill tops, and concave/convex slopes. Digital city graphic maps can be used for mission planning and navigation, and are often used in military operations in urban terrain, noncombatant evacuation operations, attaché support, and civil disturbance missions.
- **Controlled image base.** A controlled image base is an unclassified seamless dataset of geometrically corrected orthophotos, or aerial images, made from rectified grayscale images. It supports various weapons, mission command theater battle management, mission planning, digital moving map, terrain analysis, simulation, and intelligence systems. Controlled image base data are produced from digital source images, and are compressed and reformatted to conform to the national imagery transmission format. It may be derived from a grayscale image, one band of a multispectral product, or from a combination of several multispectral bands. Applications for the controlled image base include rapid overview of areas of operations, map substitutes for emergencies and crisis, metric foundation for anchoring other data in mission command systems or image exploitation, correct positional images for draping in terrain visualization, and image backgrounds for mission planning and rehearsal.
- **Compressed arc digitized raster graphic.** This is a joint services' standard map background product produced in multiple scales that support systems with map background display, coordinates selection, and provides perspective view generation capabilities. It is a common compression of arc digitized raster graphic for use in any application requiring rapid display of a map image, manipulation of the image, or manipulation of the image of a map in raster form.
- **Digital terrain elevation data.** The digital terrain elevation data (DTED) is a uniform matrix of terrain elevation values providing basic quantitative data for all military systems that require terrain elevation, slope, and gross surface roughness information. Data density depends on the level produced. DTED0 post spacing is 30 arc seconds (approximately 1000 meters). This corresponds to a small scale hardcopy map product. DTED1 post spacing is three arc seconds (approximately 100 meters). This corresponds to a medium scale hardcopy product. DTED2 post spacing is one arc second (approximately 30 meters), corresponding to large scale hardcopy products.
- **TalonView.** The National Geospatial-Intelligence Agency uses the TalonView, a computer-based mapping application that displays various types of maps and geographically referenced overlays. Many types of maps and imagery files are supported, but the primary ones of interest to most users are aeronautical, hydrographic, topographic maps and charts, satellite images, and elevation maps. TalonView supports the GeoPDF format with a large number of overlay types that can be displayed and printed over any map background. It does not include flight mission planning components and threat analysis capabilities. TalonView was designed to be distributed to other federal agencies, first responders, and foreign partners so they have a software program that utilizes NGA digital mapping and imagery products, along with applications for geospatial intelligence data interpretation, scene visualization, and situational awareness. NGA also provides the TalonView software on the SECRET Internet Protocol Router Network and Joint Worldwide Intelligence Communications System.
- **Vector maps.** A vector map (VMap) Level 0 is the low resolution component of the VMap family of products and has a comprehensive 1:1,000,000-scale vector base map of the world. It consists of geographic, attribute, and textual data stored on CD-ROMs. VMap Level 1 contains medium resolution data at the 1:250,000 scale. The data is separated into ten thematic layers consistent throughout the VMap program. The VMap Level 2 program

is designed to provide vector-based geospatial data at high resolution. It is separated into ten thematic layers, with each layer containing thematically consistent data.

- **Photomap.** A photomap is a reproduction of an aerial photograph upon which grid lines, marginal data, place names, route numbers, important elevations, boundaries, approximate scale, and direction have been added.
- **Joint operations graphics.** Joint operations graphics are typically based upon the format of standard 1:250,000 medium-scale military topographic maps, but they contain additional information needed in joint air-ground operations. Along the north and east edges of the graphic, detail is extended beyond the standard map sheet to provide overlap with adjacent sheets. The map is identified in the lower margin as joint operations graphic (ground) or joint operations graphic (air). The topographic information is identical on both, but the ground version shows elevations and contours in meters and the air version shows them in feet. Layer (elevation) tinting and relief shading are added as an aid to interpolating relief. Both versions emphasize air-landing facilities (shown in purple), but the air version has additional symbols to identify aids and obstructions to air navigation. (See Appendix B for additional information.)
- **Photomosaic.** This is an assembly of aerial photographs that is commonly called a mosaic in topographic usage. Mosaics are useful when time does not permit the compilation of a more accurate map. The accuracy of a mosaic depends upon the method employed in its preparation, and may vary from a good pictorial effect of the ground to that of a planimetric map.
- **Terrain model.** A terrain model is a scale model of the terrain showing features. Large-scale models also depict industrial and cultural shapes. It provides a means to visualize the terrain for planning or indoctrination purposes, and for briefing on assault landings.
- **Military city map.** A military city map is a topographic map (usually at 1:12,550-scale, and sometimes up to 1:5,000-scale) showing the details of a city. It delineates streets and shows street names, important buildings, and other elements of the landscape significant to navigation and military operations in urban terrain. The scale of a military city map depends upon the importance and size of the city, density of detail, and available intelligence information.
- **Special maps.** Special maps are for special purposes such as trafficability, communications, and assaults. They are usually in the form of an overprint in scales larger than 1:1,000,000 but smaller than 1:100,000. A special purpose map is one that has been designed or modified to give information not covered on a standard map. The wide range of subjects covered under the heading of special purpose maps prohibits (within the scope of this manual) more than a brief mention of a few important subjects, such as—
  - Terrain features.
  - Drainage characteristics.
  - Vegetation.
  - Climate.
  - Coasts and landing beaches.
  - Roads and bridges.
  - Railroads.
  - Airfields.
  - Urban areas.
  - Electric power.
  - Fuels.
  - Surface water resources.
  - Ground water resources.
  - Natural construction materials.

  - Cross-country movements.
  - Suitability for airfield construction.
  - Airborne operations.

MILITARY MAP SUBSTITUTES

2-11. If military maps are not available, use substitute maps. These can range from foreign military or commercial maps, to field sketches. The NGA can provide black and white reproductions of many foreign maps, and produce its own maps based upon intelligence.

- **Foreign maps.** Foreign maps have been compiled by nations other than our own. When used, change the marginal information and grids to conform to U.S. standards, if time permits. The scales may differ from our maps, but they do express the ratio of map distance to ground distance and are used in the same way. Use the legend since the map symbols almost always differ from ours. Before issuing to the troops, foreign maps are usually evaluated in regard to established accuracy standards, because their accuracy varies considerably. (See Appendix C for additional information.)
- **Atlases.** Atlases are collections of maps of regions, countries, continents, or the world. Such maps are accurate only to a small degree and are used for general information only.
- **Geographic maps.** Geographic maps provide an overall idea of the mapped area in relation to climate, population, relief, vegetation, and hydrography. They also show the general location of major urban areas.
- **Tourist road maps.** Tourist road maps are maps of a region where the main means of transportation and areas of interest are shown. Some of these maps depict secondary networks of roads, historic sites, museums, and beaches in detail. They may contain road and time distance between points. Carefully consider the scale when using these maps.
- **City/Utility maps**. City/utility maps are maps of urban areas showing streets, water ducts, electricity and telephone lines, and sewers.
- **Field sketches.** Field sketches are preliminary drawings of an area or piece of terrain. (See Appendix D.)

STANDARDS OF ACCURACY

2-12. Accuracy is the degree of conformity that horizontal positions and vertical values are clearly represented on a map in relation to an established standard. The NGA determines the standard based upon user requirements. Unless otherwise specified in the marginal information, consider maps to meet accuracy requirements.

This page intentionally left blank.

Chapter 3

Marginal Information and Symbols

It is important that Soldiers know how to read maps, and the place to begin is the marginal information and symbols, where useful information about the map is located and explained. All maps are not the same, so it is necessary to examine the marginal information carefully each time a different map is used.

MARGINAL INFORMATION ON A MILITARY MAP

3-1. Figure 3-1 shows a reduced version of a large-scale topographic map. The circled numbers indicate the items of marginal information that the map user needs to know. These circled numbers correspond to the following:

- **Sheet name (1).** The sheet name is found in bold print at the center of the top and in the lower left area of the map margin. A map is generally named for the largest settlement contained within the area covered by the sheet, or for the largest natural feature located within the area at the time the map was drawn.
- **Sheet number (2).** The sheet number is found in bold print in the upper right and lower left areas of the margin, and in the center box of the adjoining sheets diagram found in the lower right margin. To link specific maps to overlays, operations orders, and plans, use the sheet number as reference. For maps at 1:100,000-scale and larger, the sheet numbering system is arbitrary and makes possible the ready orientation of maps at scales of 1:100,000, 1:50,000, and 1:25,000.
- **Series name (3).** The map series name is found in bold print in the upper left corner of the margin. The name given to the series is generally that of a major political subdivision such as a state within the United States or a European nation. A map series usually includes a group of similar maps at the same scale and on the same sheet lines or format. They are designed to cover a particular geographic area and may be a group of maps that serve a common purpose, such as military city maps.
- **Scale (4).** The scale is found in the upper left margin after the series name and in the center of the lower margin. The scale note is a representative fraction that gives the ratio of a map distance to the corresponding distance on the earth's surface. For example, the scale note 1:50,000 indicates that one unit of measure on the map equals 50,000 units of the same measure on the ground.
- **Series number (5).** The series number is found in the upper right margin and the lower left margin. It is a sequence reference expressed either as a four-digit numeral (1125) or as a letter followed by a three- or four-digit numeral (M661, T7110).
- **Edition number (6)**. The edition number is found in bold print in the upper right area of the top margin and the lower left area of the bottom margin. Editions are numbered consecutively; if there is more than one edition, the highest numbered sheet is the most recent. Most military maps are now published by the NGA, but older editions of maps may have been produced by the U.S. Army Map Service. Still others may have been drawn, at least in part, by the U.S. Army Corps of Engineers, the U.S. Geological Survey, or other agencies affiliated or not with the United States or allied governments. The credit line, revealing who produced the map, is just above the legend. The map information date is found immediately below the word "LEGEND" in the lower left margin of the map. This date is important when determining how accurately the map data might be expected to match what is encountered on the ground
- **Index to boundaries (7).** The index to boundaries diagram appears in the lower or right margin of all sheets. This diagram, which is a miniature of the map, shows the boundaries that occur within the map area such as county lines and state boundaries.

- **Adjoining sheets diagram (8).** Maps at all standard scales contain a diagram that illustrates the adjoining sheets. On maps at 1:100,000 and larger scales and at 1:1,000,000-scale and smaller, the diagram is called the index to adjoining sheets. It consists of as many rectangles representing the adjoining sheets as are necessary to surround the rectangle that represents the sheet under consideration. The diagram usually contains nine rectangles, but the number may vary depending on the locations of the adjoining sheets. All represented sheets are identified by their sheet numbers. Sheets of an adjoining series, whether published or planned, that are at the same scale are represented by dashed lines. The series number of the adjoining series is indicated along the appropriate side of the division line between the series.
- **Elevation guide (9).** The elevation guide is normally found in the lower right margin. It is a miniature characterization of the terrain shown. The terrain is represented by bands of elevation, spot elevations, and major drainage features. The elevation guide provides the map reader with a means of quick recognition of major landforms.
- **Declination diagram (10).** The declination diagram is located in the lower margin of large-scale maps and indicates the angular relationships of true north, grid north, and magnetic north. On maps at 1:250,000-scale, this information is expressed as a note in the lower margin. In recent edition maps, there is a note indicating the conversion of azimuths from grid to magnetic and from magnetic to grid next to the declination diagram.
- **Bar scales (11).** Bar scales are located in the center of the lower margin. They are rulers used to convert map distance to ground distance. Maps have three or more bar scales, each in a different unit of measure. Care should be exercised when using the scales, especially in the selection of the unit of measure that is needed.
- **Contour interval note (12)**. The contour interval note is found in the center of the lower margin normally below the bar scales. It states the vertical distance between adjacent contour lines of the map. When supplementary contours are used, the interval is indicated. In recent edition maps, the contour interval is given in meters instead of feet.
- **Spheroid note (13).** The spheroid note is located in the center of the lower margin. Spheroids (ellipsoids) have specific parameters that define the X Y Z axis of the earth. The spheroid is an integral part of the datum.
- **Grid note (14).** The grid note is located in the center of the lower margin. It gives information pertaining to the grid system used and the interval between grid lines, and it identifies the UTM grid zone number.
- **Projection note (15).** The projection system is the framework of the map. For military maps, this framework is of the conformal type; small areas of the surface of the earth retain their true shapes on the projection; measured angles closely approximate true values; and the scale factor is the same in all directions from a point. The projection note is located in the center of the lower margin. (Refer to NGA for the development characteristics of the conformal-type projection systems.) The three types of projection notes are:
  - Between 80 degrees south and 84 degrees north, maps at scales larger than 1:500,000 are based on the transverse Mercator projection. The note reads TRANSVERSE MERCATOR PROJECTION.
  - Between 80 degrees south and 84 degrees north, maps at 1:1,000,000 scale and smaller are based on standard parallels of the Lambert conformal conic projection. The note reads, for example, LAMBERT CONFORMAL CONIC PROJECTIONS 36 DEGREES 40 MINUTES NORTH AND 39 DEGREES 20 MINUTES NORTH.
  - Maps of the polar regions (south of 80 degrees south and north of 84 degrees north) at 1:1,000,000 and larger scales are based on the polar stereographic projection. The note reads POLAR STEREOGRAPHIC PROJECTION.
- **Vertical datum note (16).** The vertical datum note is located in the center of the lower margin. The vertical datum or vertical-control datum is defined as a level surface taken as a surface of reference from which to determine elevations. In the United States, Canada, and Europe, the vertical datum refers to the mean sea level surface. However, in parts of Asia and Africa, the vertical-control datum may vary locally and is based on an assumed elevation that has no connection to the sea level surface. Map readers should habitually check the vertical datum note

on maps, particularly if the map is used for low-level aircraft navigation, naval gunfire support, or missile target acquisition.

- **Horizontal datum note (17).** The horizontal datum note is located in the center of the lower margin. The horizontal datum or horizontal-control datum is defined as a geodetic reference point (of which five quantities are known: latitude, longitude, azimuth of a line from this point, and two constants, which are the parameters of reference ellipsoid). These are the basis for horizontal-control surveys. The horizontal-control datum may extend over a continent or be limited to a small local area. Maps and charts produced by NGA are produced on 32 different horizontal-control data. Map readers should habitually check the horizontal datum note on every map or chart, especially adjacent map sheets, to ensure the products are based on the same horizontal datum. If products are based on different horizontal-control data, coordinate transformations to a common datum is performed. UTM coordinates from the same point computed on different data may differ as much as 900 meters (m).
- **Control note (18).** The control note is located in the center of the lower margin. It indicates the special agencies involved in the control of the technical aspects of all the information that is disseminated on the map.
- **Preparation note (19).** The preparation note is located in the center of the lower margin. It indicates the agency responsible for preparing the map.
- **Printing note (20).** The printing note is also located in the center of the lower margin. It indicates the agency responsible for printing the map and the date the map was printed. The printing data should not be used to determine when the map information was obtained.
- **Grid reference box (21).** The grid reference box is normally located in the center of the lower margin. It contains instructions for composing a grid reference.
- **Unit imprint and symbol (22).** The unit imprint and symbol is on the left side of the lower margin identifies the agency that prepared and printed the map and its respective symbol. This information is important to the map user in evaluating the reliability of the map.
- **Legend (23).** The legend is located in the lower left margin. It illustrates and identifies the topographic symbols used to depict some of the more prominent features on the map. The symbols are not always the same on every map. Always refer to the legend to avoid errors when reading a map.

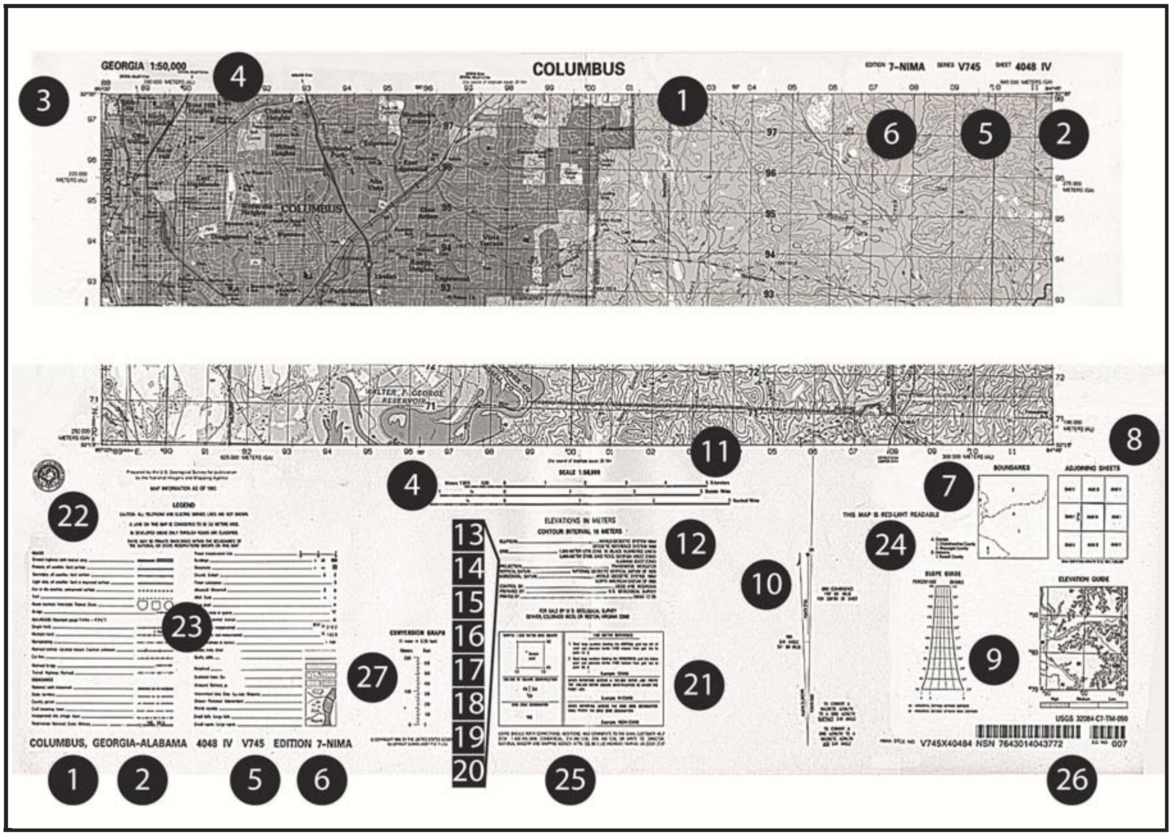


Figure 3-1. Topographical map

ADDITIONAL NOTES

3-2. Not all maps contain the same items of marginal information. Under certain conditions, special notes and scales may be added to aid the map user.

- **Glossary.** The glossary is an explanation of technical terms or a translation of terms on maps of foreign areas where the native language is other than English.
- **Classification.** Certain maps require a note indicating the security classification. This is shown in the upper and lower margins.
- **Protractor scale**. The protractor scale may appear in the upper margin on some maps. It is used to lay out the magnetic-grid declination for the map, which, in turn, is used to orient the map sheet with the aid of the lensatic compass.
- **Coverage diagram**. On maps at scales of 1:100,000 and larger, a coverage diagram may be used. It is normally in the lower or right margin and indicates the methods by which the map was made, dates of photography, and reliability of the sources. On maps at 1:250,000-scale, the coverage diagram is replaced by a reliability diagram.
- **Special notes (24).** A special note is a statement of general information that relates to the mapped area. It is normally found in the lower right margin. For example, a particular note could be “this map is red-light readable.”
- **User’s note (25).** The user’s note is normally located in the lower right-hand margin. It requests cooperation in correcting errors or omissions on the map. Errors should be marked and the map forwarded to the agency identified in the note.
- **Stock number identification (26).** All maps published by the NGA that are in the Department of the Army map supply system contain stock number identifications that are used in requisitioning map supplies. The identification consists of the words “STOCK NO” followed by a unique designation that is composed of the series number, the sheet number of the individual map, and on recently printed sheets, the edition number. The designation is limited to 15 units

(letters and numbers). The first 5 units are allotted to the series number; when the series number is less than 5 units, the letter "X" is substituted as the fifth unit. The sheet number is the next component; however, Roman numerals, which are part of the sheet number, are converted to Arabic numerals in the stock number. The last 2 units are the edition number; the first digit of the edition number is a zero if the number is less than 10. If the current edition number is unknown, the number 01 is used. The latest available edition is furnished. Asterisks are placed between the sheet number and the edition number when necessary to ensure there are at least 11 units in the stock number.

- **Conversion graph (27).** Normally found in the right margin, the conversion graph indicates the conversion of different units of measure used on the map.

TOPOGRAPHIC MAP SYMBOLS

3-3. The purpose of a map is to visualize an area of the earth's surface with pertinent features properly positioned. The map's legend contains the symbols most commonly used in a particular series or on that specific topographic map sheet. The legend should be referred to each time a new map is used. Every effort is made to design standard symbols that resemble the features they represent. If this is not possible, symbols are selected that logically imply the features they portray. For example, an open-pit mining operation is represented by a small black drawing of a crossed hammer and pickax.

3-4. Ideally, all the features within an area would appear on a map in their true proportion, position, and shape. This is not practical because many of the features would be unimportant and others would be unrecognizable because of their reduction in size.

3-5. The mapmaker (known professionally as a cartographer) is forced to use symbols to represent the natural and man-made features of the earth's surface. These symbols resemble the actual features as viewed from above. They are positioned in such a manner that the center of the symbol remains in its true location. An exception to this would be the position of a feature adjacent to a major road. If the width of the road has been exaggerated, then the feature is moved from its true position to preserve its relation to the road.

MILITARY SYMBOLS

3-6. In addition to the topographic symbols used to represent the natural and man-made features of the earth, military personnel require some method for showing identity, size, location, or movement of Soldiers, military activities, and installations. These are known as military symbols and are not normally printed on maps because the features and units they represent are constantly moving or changing; military security is also a consideration. They do appear in special maps and overlays. The map user draws them in, according to proper security precautions. (Refer to FM 1-02 for more information.)

COLORS ON A MILITARY MAP

3-7. By the fifteenth century, most European maps were carefully colored. Profile drawings of mountains and hills were shown in brown, rivers and lakes in blue, vegetation in green, roads in yellow, and special information in red. A look at the legend of a modern map confirms that the use of colors has not changed much over the past several hundred years. To facilitate the identification of features on a map, the topographical and cultural information is usually printed in different colors. These colors may vary from map to map. On a standard large-scale topographic map, the colors used and the features they represent are:

- **Black.** Black indicates cultural (man-made) features such as buildings and roads, surveyed spot elevations, and all labels.
- **Red-Brown**. The colors red and brown are combined to identify cultural features, all relief features, non-surveyed spot elevations, and elevation such as contour lines on red-light readable maps.
- **Blue**. Blue identifies hydrography or water features such as lakes, swamps, rivers, and drainage.
- **Green.** Green identifies vegetation with military significance such as woods, orchards, and vineyards.
- **Brown.** Brown identifies all relief features and elevation such as contours on older edition maps, and cultivated land on red-light readable maps.

- **Red.** Red classifies cultural features such as populated areas, main roads, and boundaries on older maps.
- **Other**. Occasionally, other colors may be used to show special information. As a rule, these are indicated in the marginal information.

Chapter 4

Grids

This chapter covers how to determine and report positions on the ground in terms of locations on a map. Knowing where one is (position fixing) and being able to communicate that knowledge is crucial for successful land navigation, effective employment of direct and indirect fire, tactical air support, and medical evacuation. It is essential for valid target acquisition; accurate reporting of various danger areas, and nuclear, biological, and chemical contamination areas; and obtaining emergency resupply. Few factors contribute as much to the survivability of troops and equipment, and to the successful accomplishment of a mission, as always knowing one's location. This chapter includes explanations of geographical coordinates, Universal Transverse Mercator (UTM) grids, the military grid reference system, and the use of grid coordinates.

REFERENCE SYSTEM

4-1. In a city, it is quite simple to find a location; the streets are named and the buildings have numbers. The only thing needed is the address. However, finding locations in undeveloped areas or in unfamiliar parts of the world can be a problem. To cope with this difficulty, a uniform and precise system of referencing has been developed.

GEOGRAPHIC COORDINATES

4-2. One of the oldest systematic methods of location is based upon the geographic coordinate system. By drawing a set of east-west rings around the globe (parallel to the equator), and a set of north-south rings crossing the equator at right angles and converging at the poles, a network of reference lines is formed from which a point on the earth's surface can be located.

- The distance of a point north or south of the equator is known as its latitude. The rings around the earth parallel to the equator are called parallels of latitude, or simply parallels. Lines of latitude run east-west but north-south distances are measured between them.
- A second set of rings that run around the globe at right angles to the lines of latitude and passing through the poles are known as meridians of longitude, or simply meridians. One meridian is established as the prime meridian. The prime meridian of the system we use runs through Greenwich, England and is known as the Greenwich Meridian. The distance east or west of a prime meridian to a point is known as its longitude. Lines of longitude (meridians) run north-south but east-west distances are measured between them. (See Figures 4-1 and 4-2.)

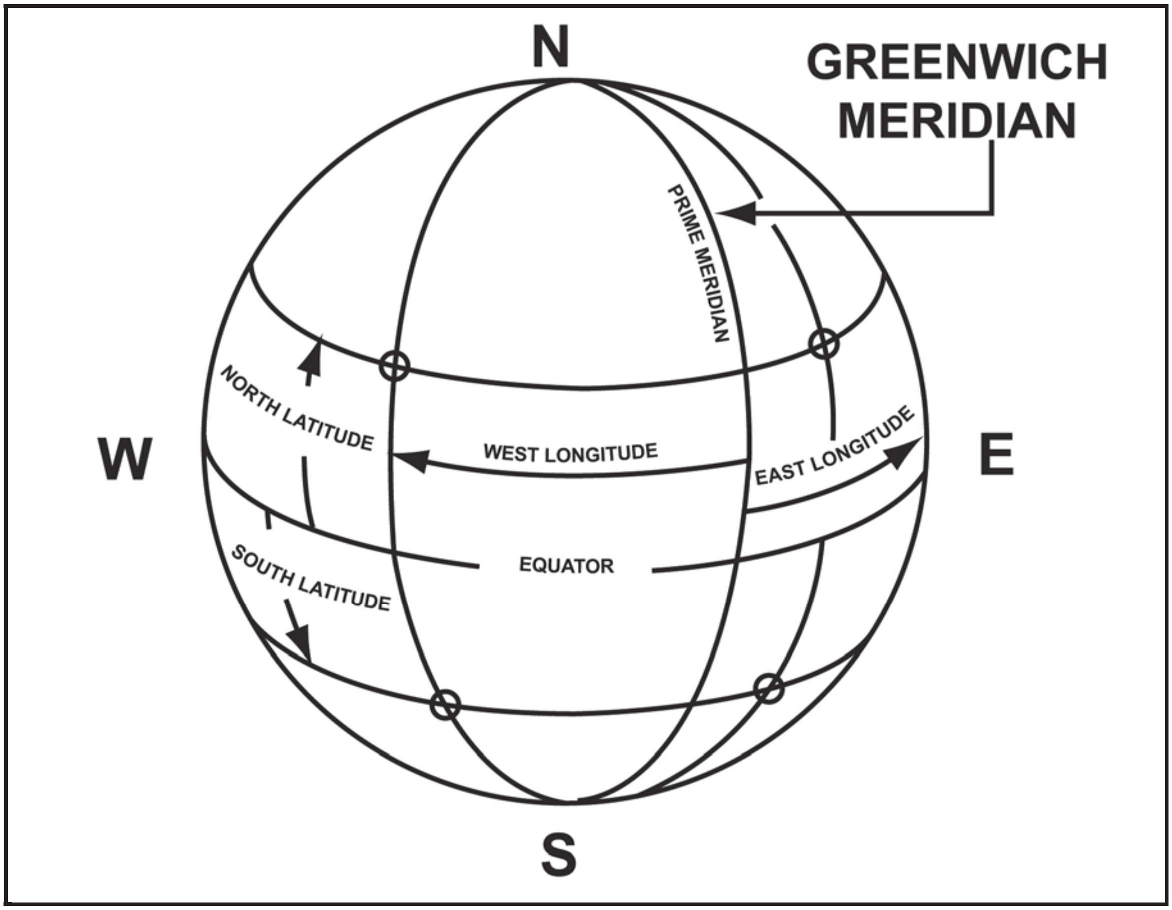


Figure 4-1. Prime meridian and equator

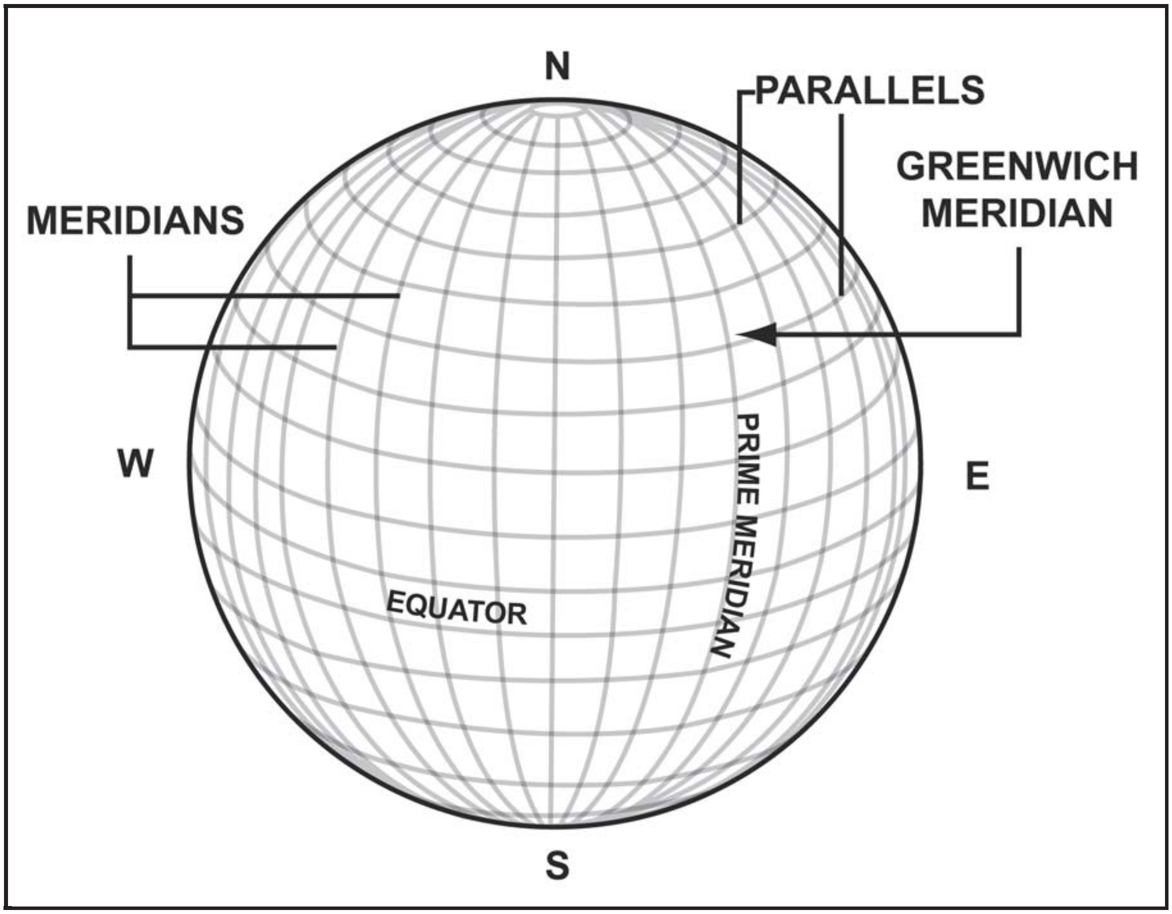


Figure 4-2. Reference lines

- Geographic coordinates are expressed in angular measurement. Each circle is divided into 360 degrees, each degree into 60 minutes, and each minute into 60 seconds. The degree is symbolized by °, the minute by ′, and the second by ″.
  - Starting with 0° at the equator, the parallels of latitude are numbered to 90° both north and south. The extremities are the North Pole at 90° north latitude and the South Pole at 90° south latitude. Latitude can have the same numerical value north (N) or south (S) of the equator, so the direction N or S is always given.
  - Starting with 0° at the prime meridian, longitude is measured both east (E) and west (W) around the world. Lines east of the prime meridian are numbered to 180° and identified as east longitude; lines west of the prime meridian are numbered to 180° and identified as west longitude. The direction E or W is always given. The line directly opposite the prime meridian, 180°, may be referred to as either east or west longitude.
  - The values of geographic coordinates, being in units of angular measure, mean more if they are compared with more familiar units of measure. At any point on the earth, the ground distance covered by one degree of latitude is about 111 kilometers (km) or 69 miles; one second is equal to about 30 m (or 100 feet). The ground distance covered by one degree of longitude at the equator is also about 111 km, but decreases as one moves north or south, until it becomes zero at the poles. For example, one second of longitude represents about 30 m at the equator; but at the latitude of Washington, D.C., one second of longitude is about 24 m (78 feet). Latitude and longitude are illustrated in Figure 4-3.

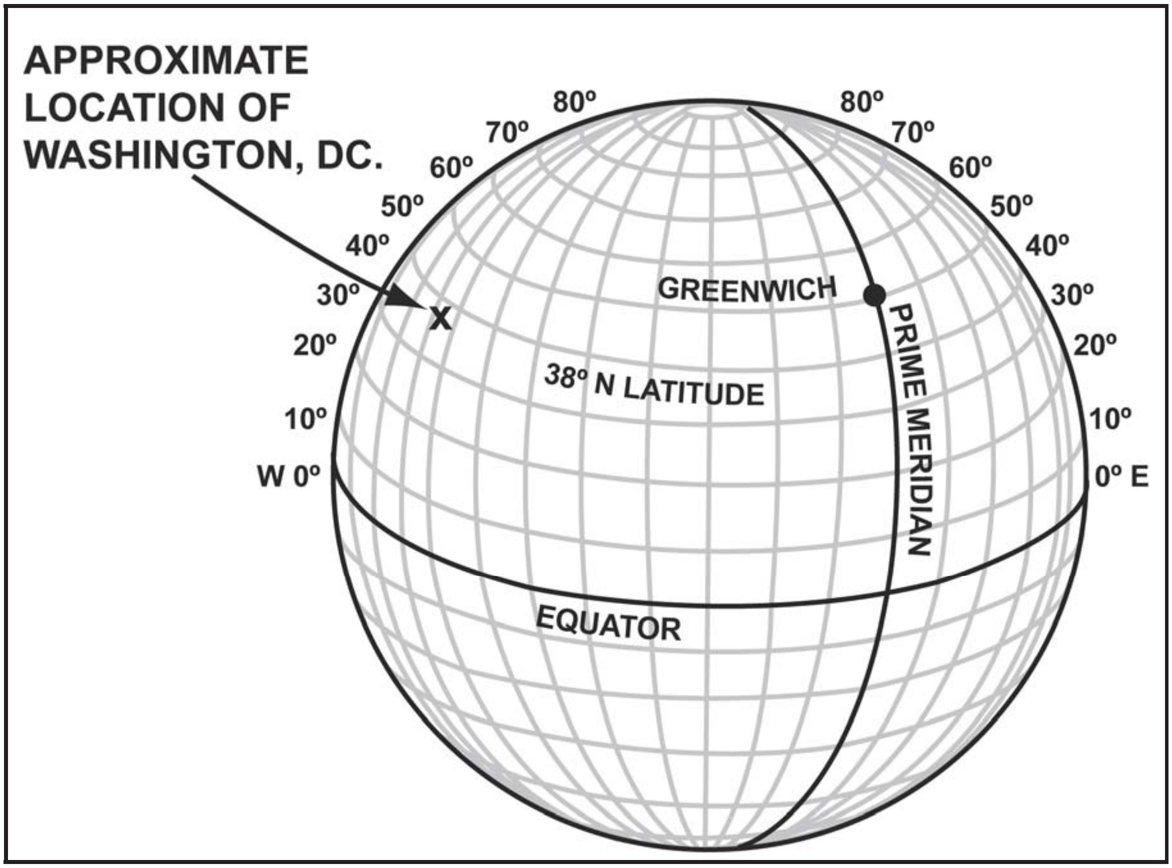


Figure 4-3. Latitude and longitude

- Geographic coordinates appear on all standard military maps; on some they may be the only method for locating and referencing the location of a point. The four lines that enclose the body of the map (neatlines) are latitude and longitude lines. Their values are given in degrees and minutes at each of the four corners.
  - On a portion of the Columbus, Georgia, map (see Figure 4-4), the figures 32°15' and 84°45' appear at the lower right corner. The bottom line of this map is latitude 32°15'00"N, and the line running up the right side is longitude 84°45'00"W.
  - In addition to the latitude and longitude given for the four corners, there are small tick marks at regularly spaced intervals along the sides of the map, extending into the body of the map. Each of these tick marks is identified by its latitude or longitude value.
  - Near the top of the right side of the map is a tick mark with the number 20'. The full value for this tick marks is 32°20'00" of latitude. At one-third and two-thirds of the distance across the map from the 20' tick mark is found a cross tick mark (grid squares GL 0379 and FL 9679) and at the far side another 20' tick mark. By connecting the tick marks and crosses with straight lines, a 32°20'00" line of latitude can be added to the map. This procedure is also used to locate the 32°25'00" line of latitude. For lines of longitude, the same procedure is followed using the tick marks along the top and bottom edges of the map.
- After the parallels and meridians have been drawn, the geographic interval (angular distance between two adjacent lines) is determined. Examination of the values given at the tick marks gives the interval. For most maps of scale 1:25,000, the interval is 2'30". For the Columbus map and most maps of scale 1:50,000, it is 5'00". The geographic coordinates of a point are found by dividing the sides of the geographic square in which the point is located into the required number of equal parts. If the geographic interval is 5'00" and the location of a point is required to the nearest second, each side of the geographic square is divided into 300 equal parts

(5’00” = 300”), each of which would have a value of one second. Any scale or ruler that has 300 equal divisions and is as long (or longer) than the spacing between the lines may be used.

- The following steps determine the geographic coordinates of Wilkinson Cemetery (northwest of the town of Cusseta) on the Columbus map:
  - Draw on the map the parallels and meridians that enclose the area around the cemetery.
  - Determine the values of the parallels and meridians where the point falls.

    Latitude 32°15’00” and 32°20’00”.
    Longitude 84°45’00” and 84°50’00”.

  - Determine the geographic interval (5’00” = 300”).
  - Select a scale that has 300 small divisions or multiples thereof (300 divisions, one second each; 150 divisions, two seconds each; 75 divisions, four seconds each, and so forth).
  - Using Figure 4-4 to determine the latitude:
    - Place the 0 of the scale on the latitude of the lowest number value (32°15’00”) and the 300 of the scale on the highest numbered line (32°20’00”) (labeled 1).
    - Keeping the 0 and 300 on the two lines, slide the scale (labeled 2) along the parallels until the Wilkinson Cemetery symbol is along the edge of the numbered scale.
    - Read the number of seconds from the scale (labeled 3). This is about 246.
    - Convert the number of seconds to minutes and seconds (246” = 4’06”) and add to the value of the lower numbered line (32°15’00” + 4’06” = 32°19’06”) (labeled 4).
    - The latitude is 32°19’06”, but this information alone is not enough. The latitude 32°19’06” could be either north or south of the equator, so the letter N or S is added to the latitude. To determine whether it is N or S, look at the latitude values at the edge of the map and find the direction in which they become larger. If they are larger going north, use N; if they are larger going south, use S. The latitude for the cemetery is 32°19’06”N.
  - To determine the longitude, repeat the same steps but measure between lines of longitude and use E and W. The geographic coordinates of Wilkinson Cemetery should be about 32°19’06”N and 84°47’32”W. (See Figure 4-5.)
- Many of the same steps are followed to locate a point on the Columbus map when knowing the geographic coordinates. (See Figure 4-6.) To locate 32°25’28”N and 84°50’56”W, first find the geographic lines within which the point falls: latitude 32°25’00” and 32°30’0”; and longitude 84°50’00” and 84°55’00”. Subtract the lower latitude or longitude from the higher latitude or longitude.
  - Place the 0 of the scale on the 32°25’00” line and the 300 on the 32°30’00”. Make a mark at the number 28 on the scale (the difference between the lower and higher latitude).
  - Place the 0 of the scale on the 84°50’00” line and the 300 on the 84°50’55”. Make a mark at the number 56 on the scale (the difference between the lower and higher longitude).
  - Draw a vertical line from the mark at 56 and a horizontal line from the mark at 28; they intersect at 32 25’28”N and 84 50’56”W.

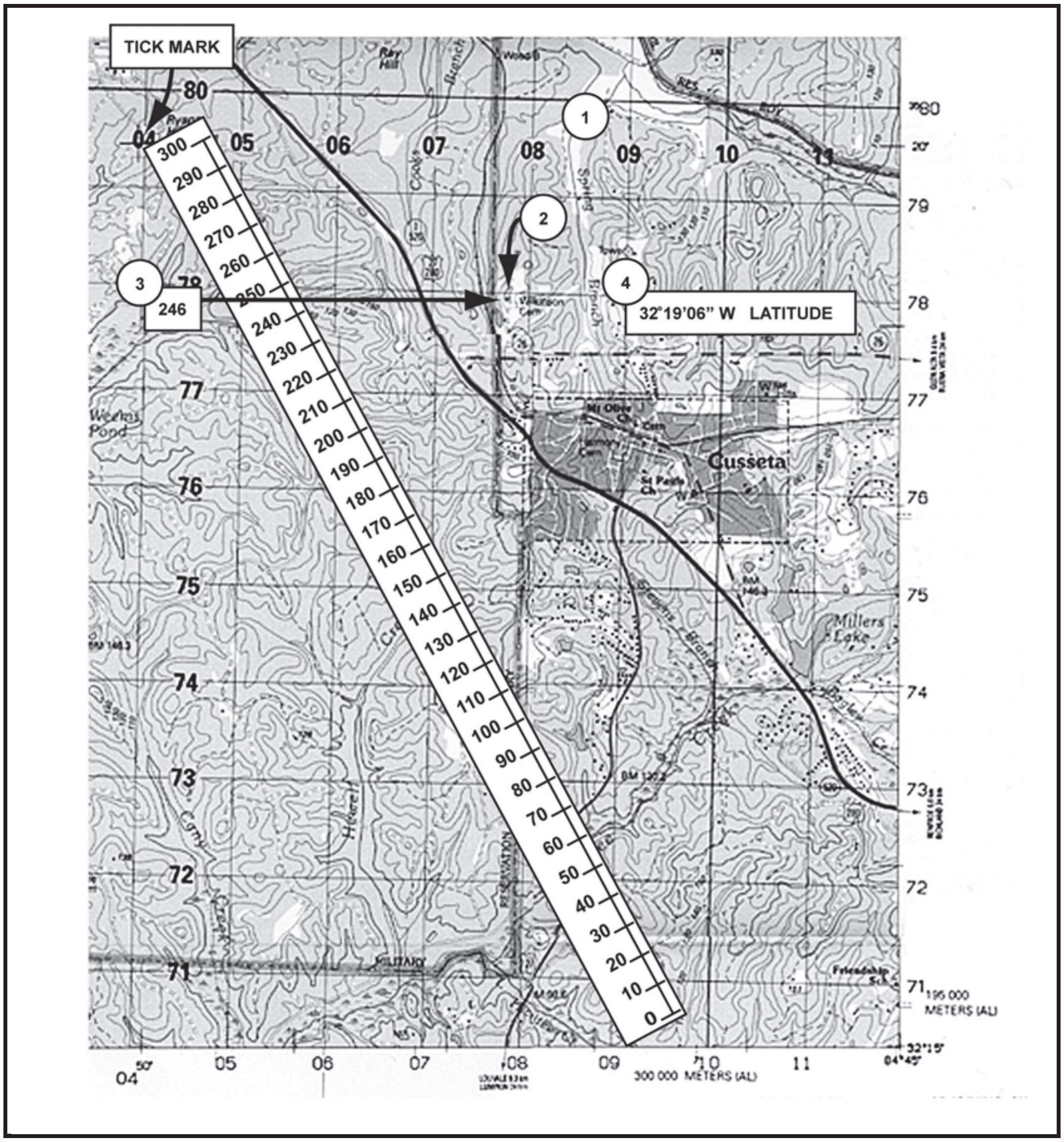


Figure 4-4. Determining latitude

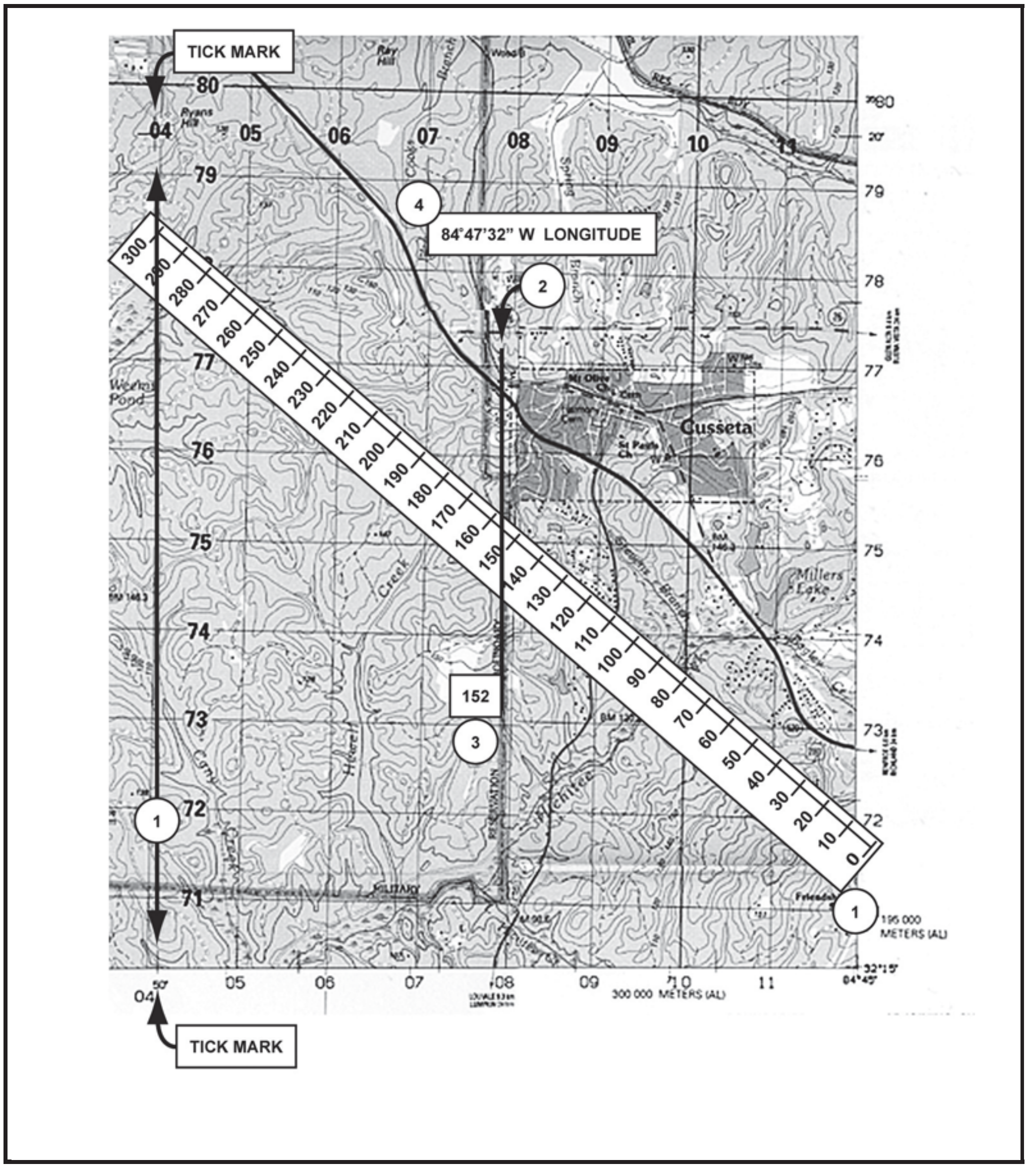


Figure 4-5. Determining longitude

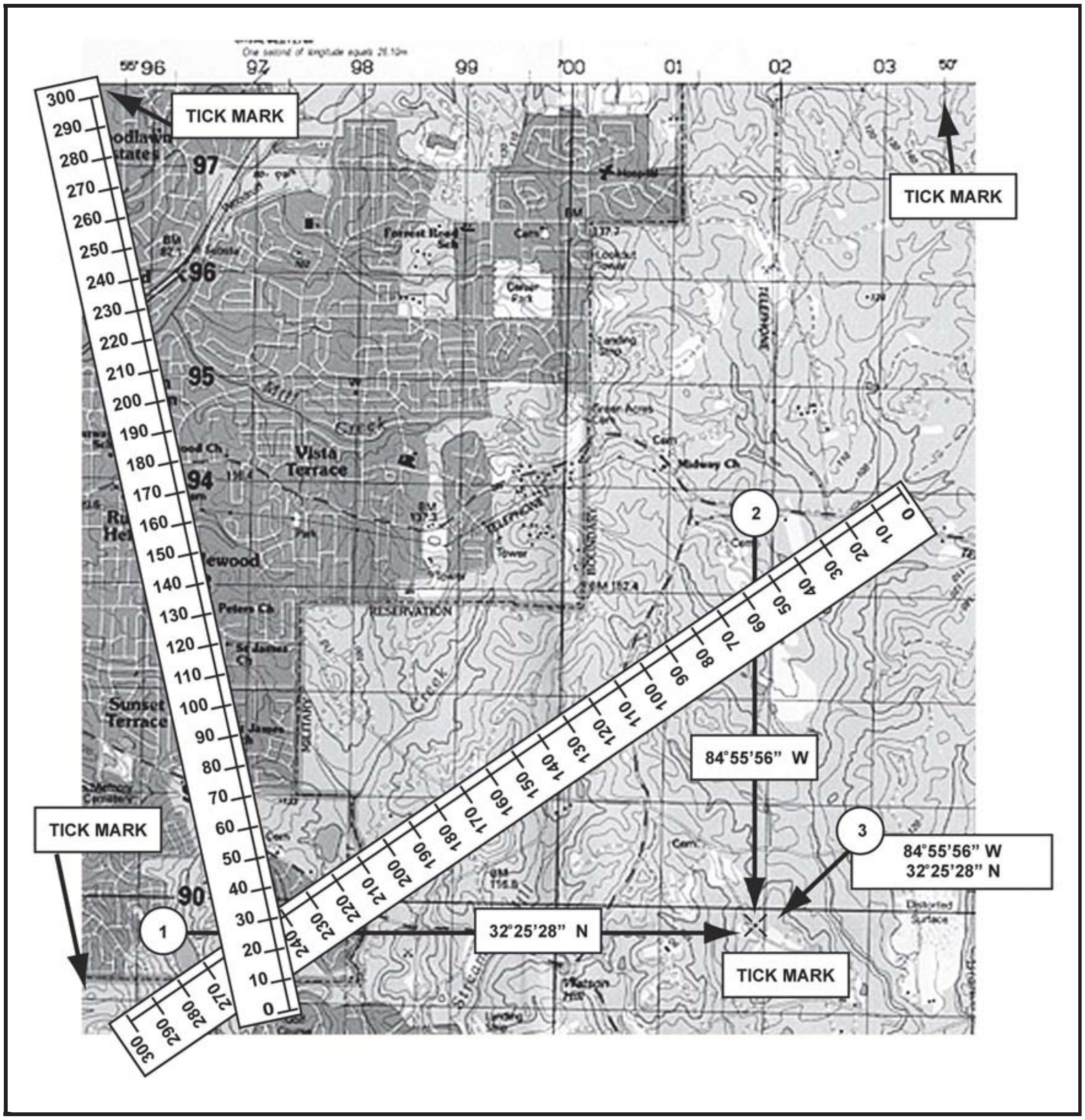


Figure 4-6. Determining geographic coordinates

- If there is no scale or ruler with 300 equal divisions or a map whose interval is other than 5'00", use the proportional parts method. The following steps determine the geographic coordinates of horizontal control station 141:
    - Locate horizontal control station 141 in grid square (GL0784). (See Figure 4-7.)
    - Find a cross in grid square GL0388 and a tick mark in grid square GL1188 with 25'.
    - Find another cross in grid square GL0379 and a tick mark in grid square GL1179 with 20'.
    - Enclose the control station by connecting the crosses and tick marks. The control station is between 20' and 25'.
    - With a boxwood scale, measure the distance from the bottom line to the top line that encloses the area around the control station on the map (total distance).

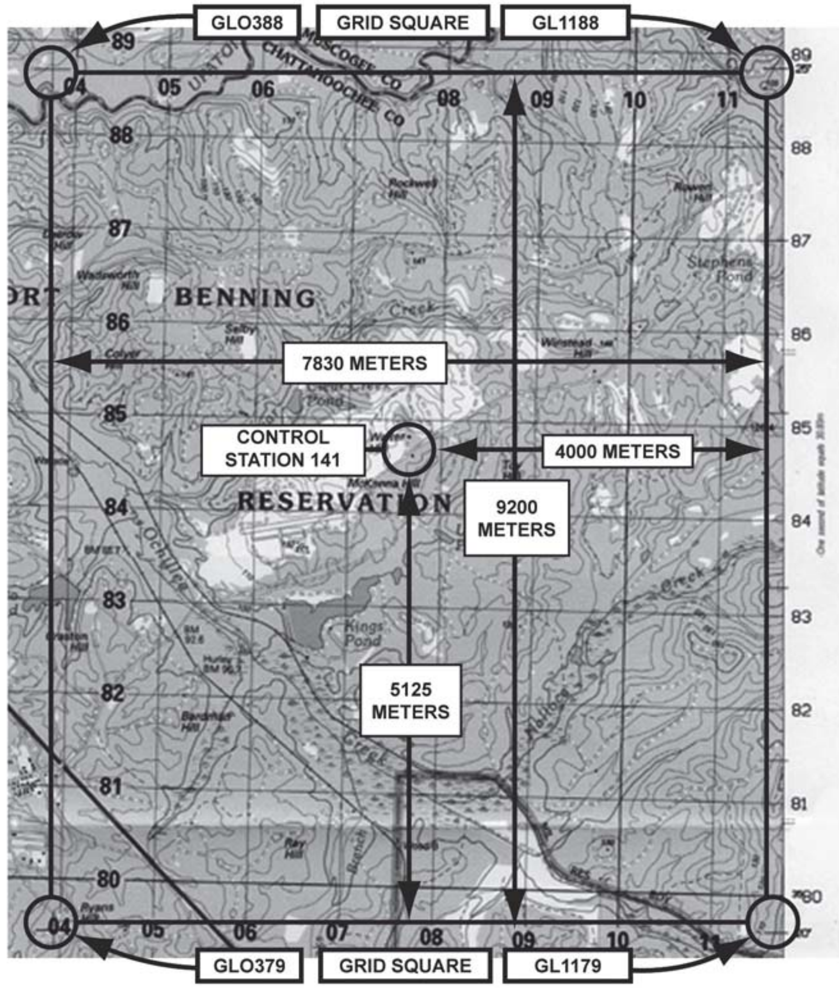


Figure 4-7. Using the proportional parts method

- Measure the partial distance from the bottom line to the center of the control station. These straight-line distances are in direct proportion to the minutes and seconds of latitude and are used to set up a ratio.
- The total distance is 9200 m, and the partial distance is 5125 m.
- With the two distances and the five-minute interval converted to seconds (300"), determine the minutes and seconds of latitude using the following formula:
    - 5125 x 300 = 1,537,500
    - 1,537,500 ÷ 9200 = 167
    - 167 ÷ 60 = 2.78 convert fraction (see note below) = 2'47"
    - Add 2'47" to 32°20'00" = 32°22'47"
- Follow the same procedures to determine minutes and seconds of longitude.

- The total distance is 7830 m, and the partial distance is 4000 m.
  - 4000 x 300 = 1,200,000
  - 1,200,000 ÷ 7830 = 153
  - 153 ÷ 60 = 2.55 convert fraction (see note below) = 2'33"
  - Add 2'33" to 84°45' = 84°47'33"N
- The geographic coordinates of horizontal control station 141 in grid square GL0784 are 32°22'47"N latitude and 84°47'33"W longitude.

Note. When computing formulas, round off totals to the nearest whole number in step 2. In step 3, convert the fraction to seconds by multiplying the fraction by 60 and rounding off if the total is not a whole number.

- The maps made by some nations do not have their longitude values based on the UTM prime meridian that passes through Greenwich, England. Table 4-1 shows the prime meridians that may be used by other nations. When these maps are issued to our Soldiers, a note usually appears in the marginal information giving the difference between our prime meridian and the one used on the map.

Table 4-1. Table of prime meridians.

City, Country	*Prime Meridian*
Amsterdam, Netherlands	4°53'01"E
Athens, Greece	23°42'59"E
Batavia (Djakarta), Indonesia	106°48'28"E
Bern, Switzerland	7°26'22"E
Brussels, Belgium	4°22'06"E
Copenhagen, Denmark	12°34'40"E
Ferro (Hierro), Canary Islands	17°39'46"W
Helsinki, Finland	24°53'17"E
Istanbul, Turkey	28°58'50"E
Lisbon, Portugal	9°07'55"W
Madrid, Spain	3°41'15"W
Oslo, Norway	10°43'23"E
Paris, France	2°20'14"E
Pulkovo, Russia	30°19'39"E
Rome, Italy	12°27'08"E
Stockholm, Sweden	18°03'30"E
Tirane, Albania	19°46'45"E

MILITARY GRIDS

4-3. Gerardus Mercator developed the Mercator projection (see Figure 4-8) in 1569 as an aid for naval navigators. The straight lines of the Mercator projection are loxodromes, or rhumb lines, that represent the lines of a constant compass bearing, which is perfect for determining "true" direction. Mercator projection is a poor projection for world maps, but its rectangular grid and shape make it an appealing choice for wall maps, atlas maps, and other maps in books and newspapers published by nongeographers. Its popularity caused it to become the most identifiable map projection for most Americans.

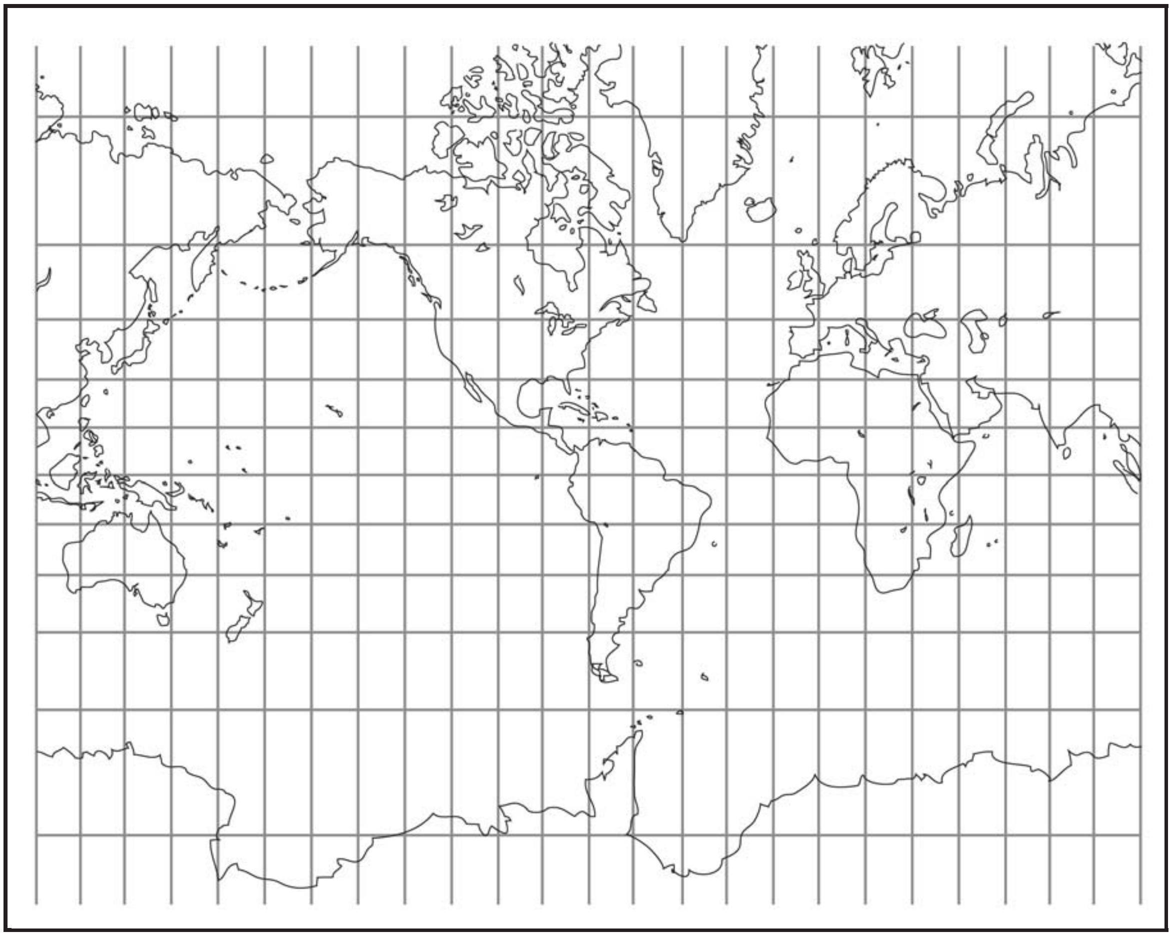


Figure 4-8 Regular Mercator projection.

4-4. In the standard Mercator projection, meridians are vertical, parallel, and equally spaced lines cut at right angles by straight horizontal parallels. The parallels have increasingly larger spaces between them as they approach the poles; these spaces are proportional to the earth's radius at a given latitude.

4-5. While the standard Mercator projection has a constant scale around the equator, the transverse Mercator projection (Figure 4-9) has a constant scale along a chosen central meridian. The meridians and parallels of the transverse Mercator projection are no longer straight lines (with the exception of the equator, the chosen central meridian, and each meridian 90 degrees away from the central meridian); instead, they are complex curves. When using the transverse Mercator projection, the scale along the chosen central meridian remains constant. This makes the projection ideal for regions extending predominantly north and south. The constant scale along the central meridian may be true to scale or deliberately reduced so that the mean scale of the entire map is more accurate.

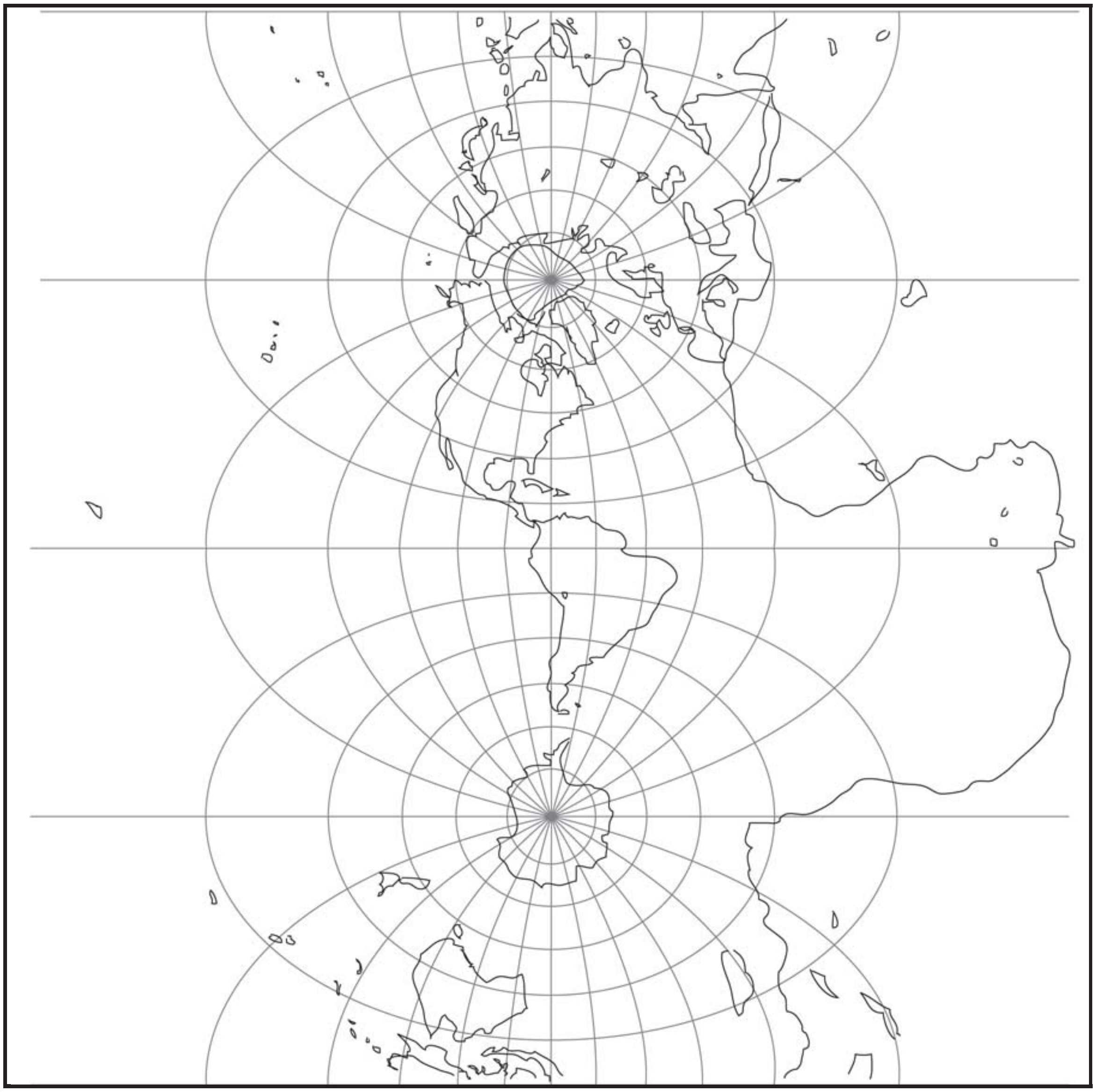


Figure 4-9. Transverse Mercator projection

4-6. An examination of the transverse Mercator projection, which is used for large-scale military maps, shows that most lines of latitude and longitude are curved lines. The quadrangles formed by the intersection of these curved parallels and meridians are of different sizes and shapes, complicating the location of points and the measurement of directions. To aid these essential operations, a rectangular grid is superimposed upon the projection. This grid (a series of straight lines intersecting at right angles) furnishes the map reader with a system of squares similar to the block system of most city streets. The dimensions and orientation of different types of grids vary, but three properties are common to all military grid systems: they are true rectangular grids; they are superimposed on the geographic projection; and they permit linear and angular measurements.

- **Universal transverse Mercator grid.** The UTM grid system was adopted by the U.S. Army in 1947 for designating rectangular coordinates on large-scale military maps. The UTM is currently used by the U.S. and North Atlantic Treaty Organization armed forces. With the advent of inexpensive GPS receivers, many other map users are adopting the UTM grid system for coordinates that are simpler to use than latitude and longitude. The UTM grid was designed to cover that part of the world between latitude 84°N and latitude 80°S, and, as its name implies, is imposed on the transverse Mercator projection. Each of the 60 zones (6-degrees wide) into which the globe is divided for the grid has its own origin at the intersection of its central meridian and the equator. (See Figure 4-10.) The grid is identical in all 60 zones. Base values (in meters) are assigned to the central meridian and the equator, and the grid lines are drawn at regular intervals parallel to these two base lines. With each grid line assigned a value denoting its distance from the origin, the problem of locating a point becomes progressively easier. Normally, it would seem logical to assign a value of zero to the two base lines and measure outward from them, but this would require that directions N, S, E, or W always be given with distances, or that all points south of the equator or west of the central meridian have negative values. This inconvenience is eliminated by assigning "false values" to the base lines, resulting in positive values for all points within each zone. Distances are always measured RIGHT and UP (east and north as the reader faces the map), and the assigned values are called "false easting" and "false northing." (See Figure 4-11.) The false easting value for each central meridian is 500,000 m, and the false northing value for the equator is 0 m when measuring in the northern hemisphere and 10,000,000 m when measuring in the southern hemisphere.

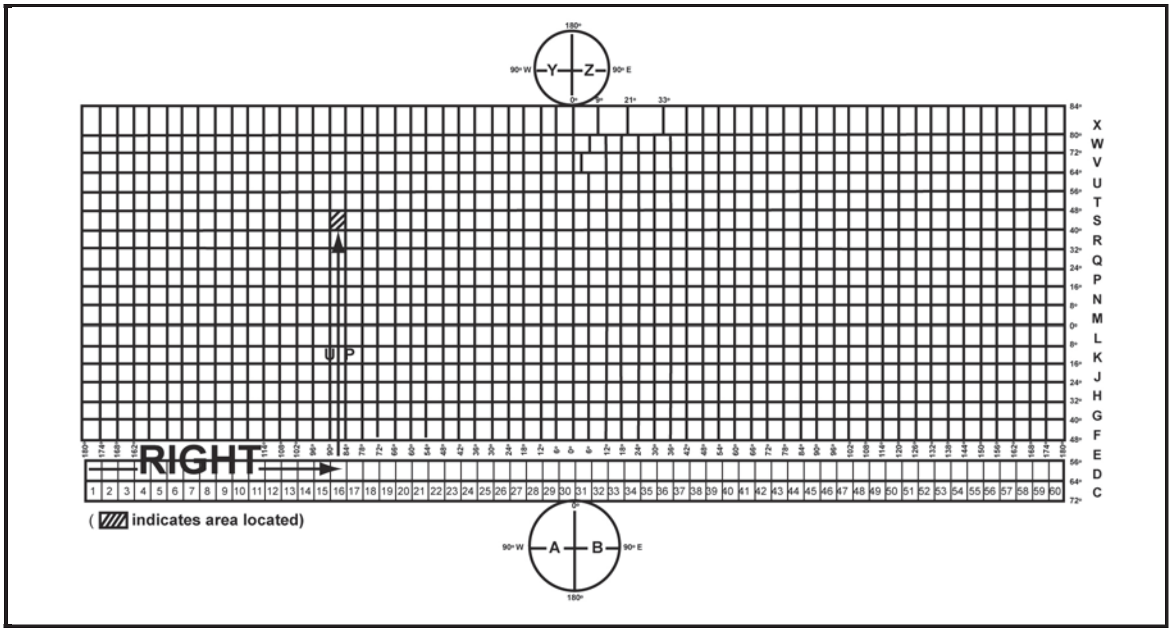


Figure 4-10. UTM grid zone location

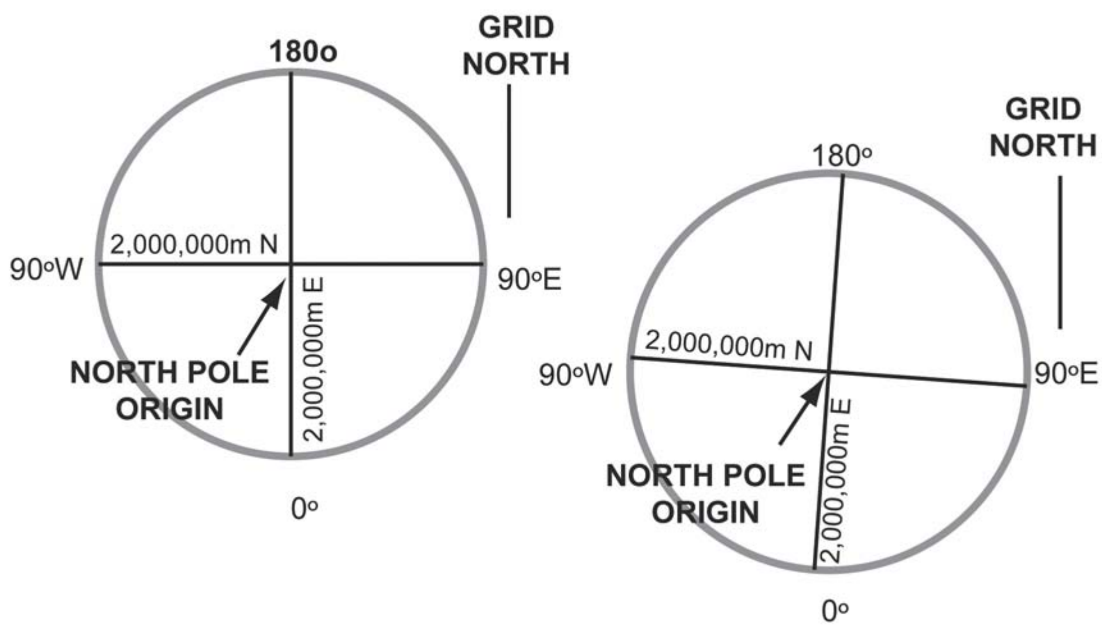


Figure 4-11. False eastings and northings for the UTM grid

- **Universal Polar Stereographic (UPS) grid**. The UPS grid is used to represent the polar regions. (See Figure 4-12.)
  - **North polar area**. The origin of the UPS grid applied to the north polar area is the North Pole. The "north-south" base line is the line formed by the 0 degree and 180-degree meridians; the "east-west" base line is formed by the two 90-degree meridians.
  - **South polar area**. The origin of the UPS grid in the south polar area is the South Pole. The base lines are similar to those of the north polar area.

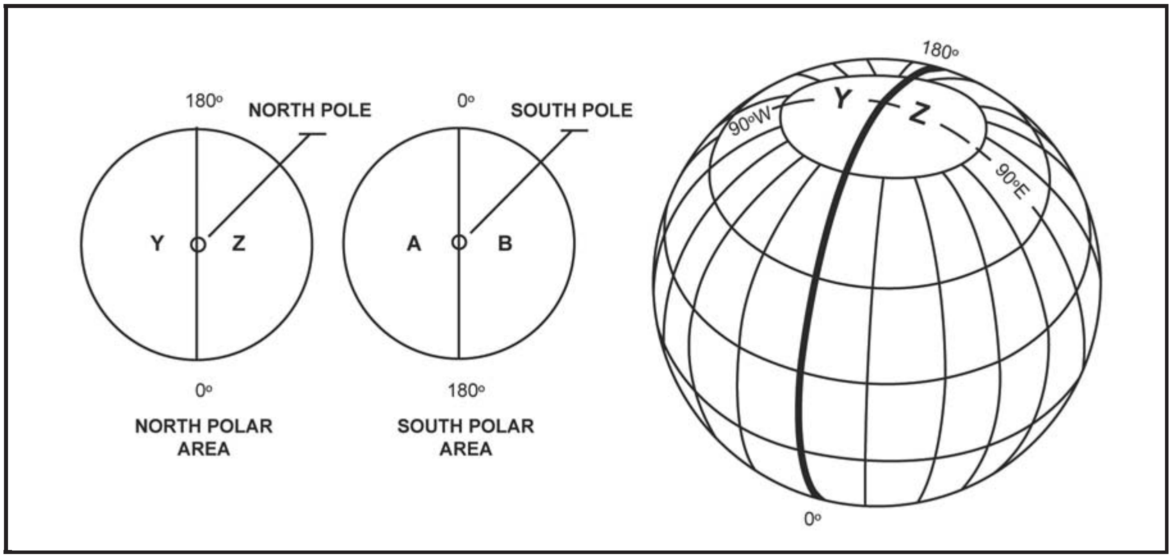


Figure 4-12. Grid zone designation for UPS grid

UNITED STATES ARMY MILITARY GRID REFERENCE SYSTEM

4-7. This grid reference system is used with the UTM and UPS grids. The coordinate value of points in these grids could contain as many as 15 digits if numerals alone were used. The U.S. military grid reference system reduces the length of written coordinates by substituting single letters for several numbers.

4-8. Using the UTM and the UPS grids, it is possible for the location of a point (identified by numbers alone) to be in many different places on the surface of the earth. With the use of the military grid reference system, there is no possibility of this happening.

4-9. The world is divided into 60 grid zones, which are large, regularly shaped geographic areas, each having a unique identification called the grid zone designation. The two grids are:

- **UTM grid.** The first major breakdown is the division of each zone into areas 6-degrees wide by 8-degrees high or 6-degrees wide by 12-degrees high. Remember, for the transverse Mercator projection, the earth's surface between 80°S and 84°N is divided into 60 north-south zones, each 6-degree wide. These zones are numbered from west to east, 1 through 60, starting at the 180-degree meridian. This surface is divided into 20 east-west rows, in which 19 are 8-degrees high and 1 row at the extreme north is 12-degrees high. These rows are then lettered, from south to north, C through X (I and O are omitted). Any 6-degrees-by-8-degrees zone or 6-degrees-by-12-degrees zone is identified by giving the number and letter of the grid zone and row in which it lies. These are read RIGHT and UP so the number is always written before the letter. This combination of zone number and row letter constitutes the grid zone designation. Columbus is in zone 16 and row S, or in grid zone designation 16S. (See Figure 4-10.)

UPS grid. The remaining letters of the alphabet—A, B, Y, and Z—are used for the UPS grids. Each polar area is divided into two zones separated by the 0 to 180-degrees meridian. In the south polar area, the letter A is the grid zone designation for the area west of the 0- to 180-degrees meridian, and B for the area to the east. In the north polar area, Y is the grid zone designation for the western area and Z for the eastern area. (See Figure 4-12.)

4-10. Between 84°N and 80°S, each 6-degrees-by-8-degrees or 6-degrees-by-12-degrees zone is covered by 100,000-m squares in each zone that are identified by the combination of two alphabetical letters. This identification is unique within the area covered by the grid zone designation. The first letter is the column designation; the second letter is the row designation. (See Figure 4-13.) The north and south polar areas are covered by 100,000-m squares in each zone by columns and rows. The 100,000-m square identification letters are located in the grid reference box in the lower margin of the map.

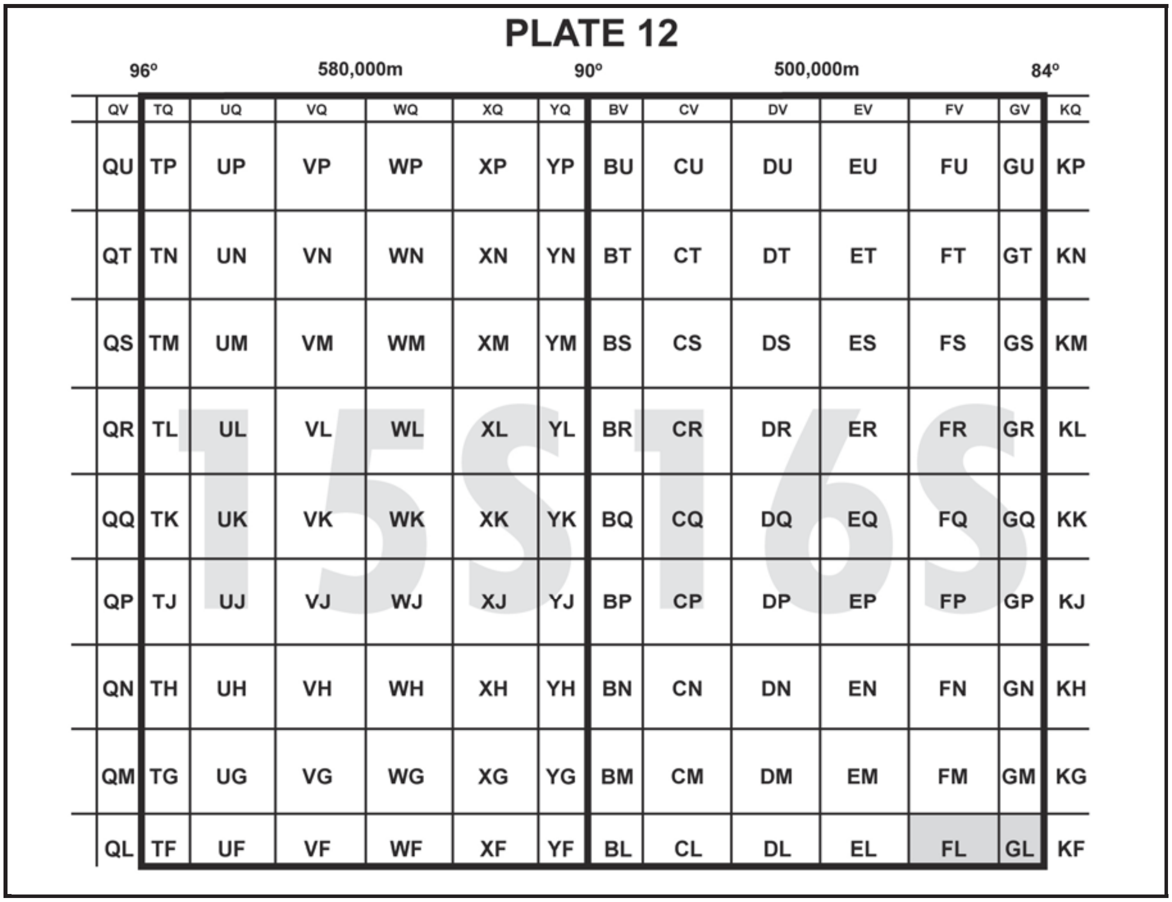


Figure 4-13. Grid zone designation and 100,000-m square identification

4-11. Grid coordinates divide the earth's surface into 6-degrees-by-8-degrees quadrangles, covered with 100,000-m squares. The military grid reference of a point consists of the numbers and letters indicating where in the 100,000-m grid zone areas the point lies, plus the coordinates locating the point to the desired position within the 100,000-m square. The next step is to tie in the coordinates of the point with the larger areas. To do this, it is important to understand—

- **Grid lines**. The regularly spaced lines that make up the UTM and UPS grid on large-scale maps are divisions of the 100,000-m square. The lines are spaced at 10,000-m or 1000-m intervals. (See Figure 4-14.) Each of these lines is labeled at both ends of the map with its false easting or false northing value, showing its relation to the origin of the zone. Two digits of the values are printed in large type, and these same two digits appear at intervals along the grid lines on the face of the map. These are called the principal digits, and represent the 10,000 and 1000 digits of the grid value. They are of major importance to the map reader because they are the numbers used most often for referencing points. The smaller digits complete the UTM grid designation.

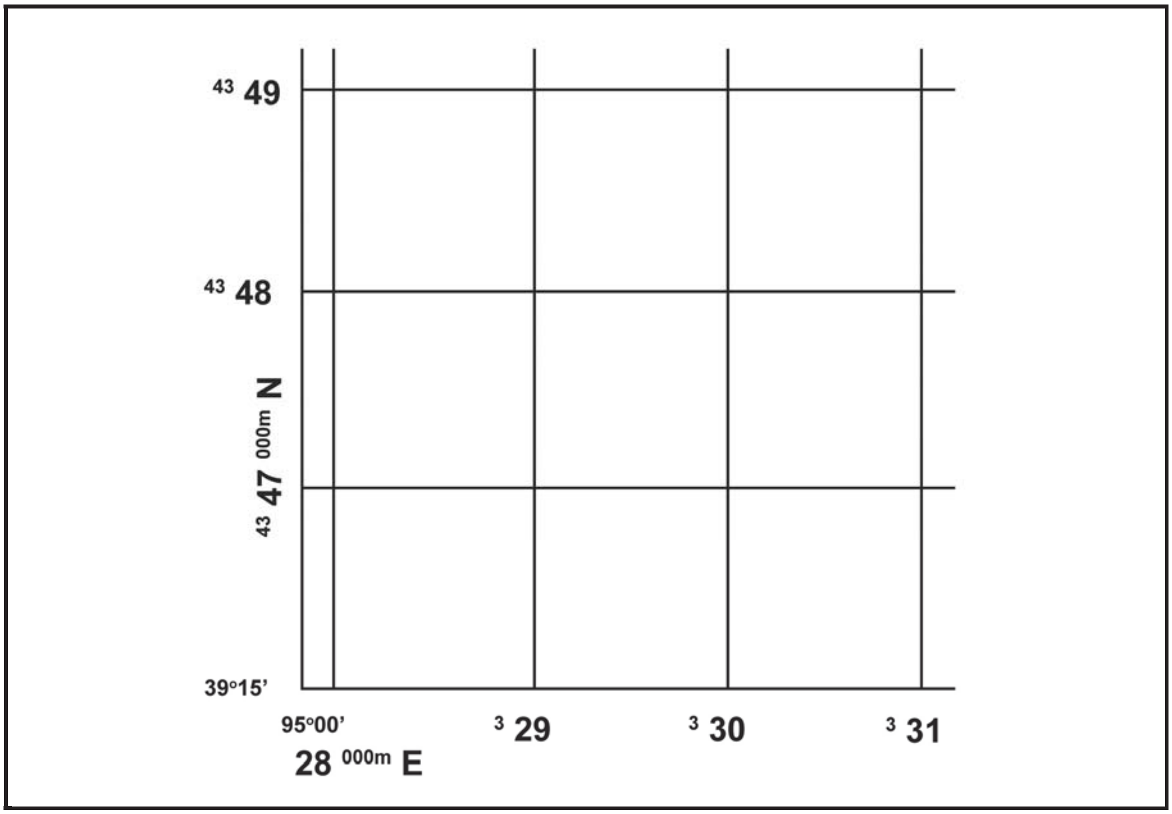


Figure 4-14. Grid lines and principle digits

Note. As an example, the first grid line north of the south-west corner of the Columbus map is labeled 3570000m N. This means its false northing (distance north of the equator) is 3,570,000 m. The principal digits, 70, identify the line for referencing points in the northerly direction. The smaller digits, 35, are part of the false coordinates and are rarely used. The last three digits, 000, of the value are omitted. Therefore, the first grid line east of the south-west corner is labeled 689000m E. The principal digits, 89, identify the line for referencing points in the easterly direction. (See Figure 4-15.)

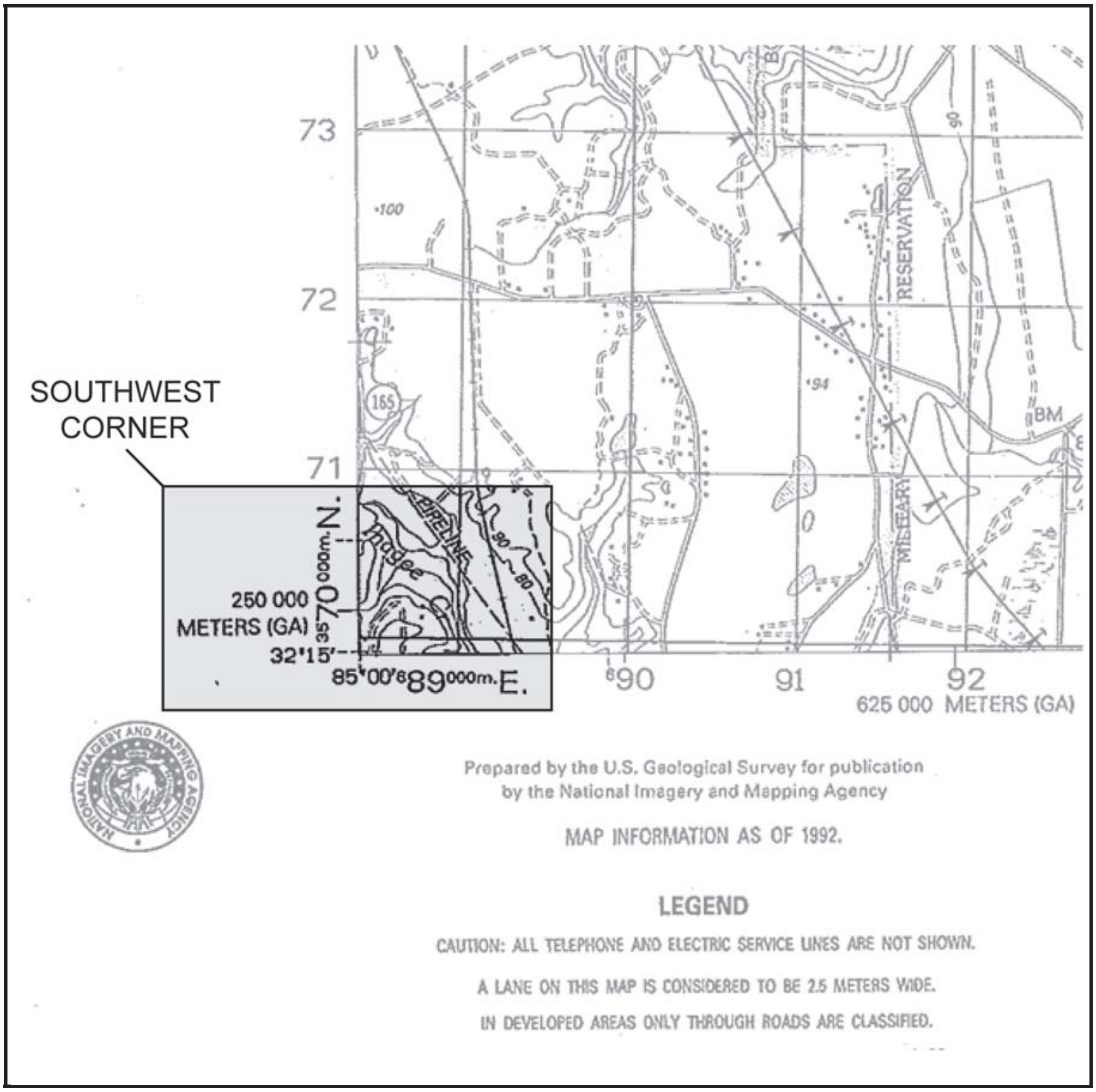


Figure 4-15. Southwest corner of the Columbus, Georgia, map

- **Grid squares.** The north-south and east-west grid lines intersect at 90 degrees, forming grid squares. Normally, the size of one of these grid squares on large-scale maps is 1000 m (1 km).
- **Grid coordinate scales.** The primary tool for plotting grid coordinates is the grid coordinate scale. This scale divides the grid square more accurately than can be done by estimation and the results are more consistent. When used correctly, it presents less chance for making errors. GTA 5-2-12 contains four types of coordinate scales. (See Figure 4-16.)

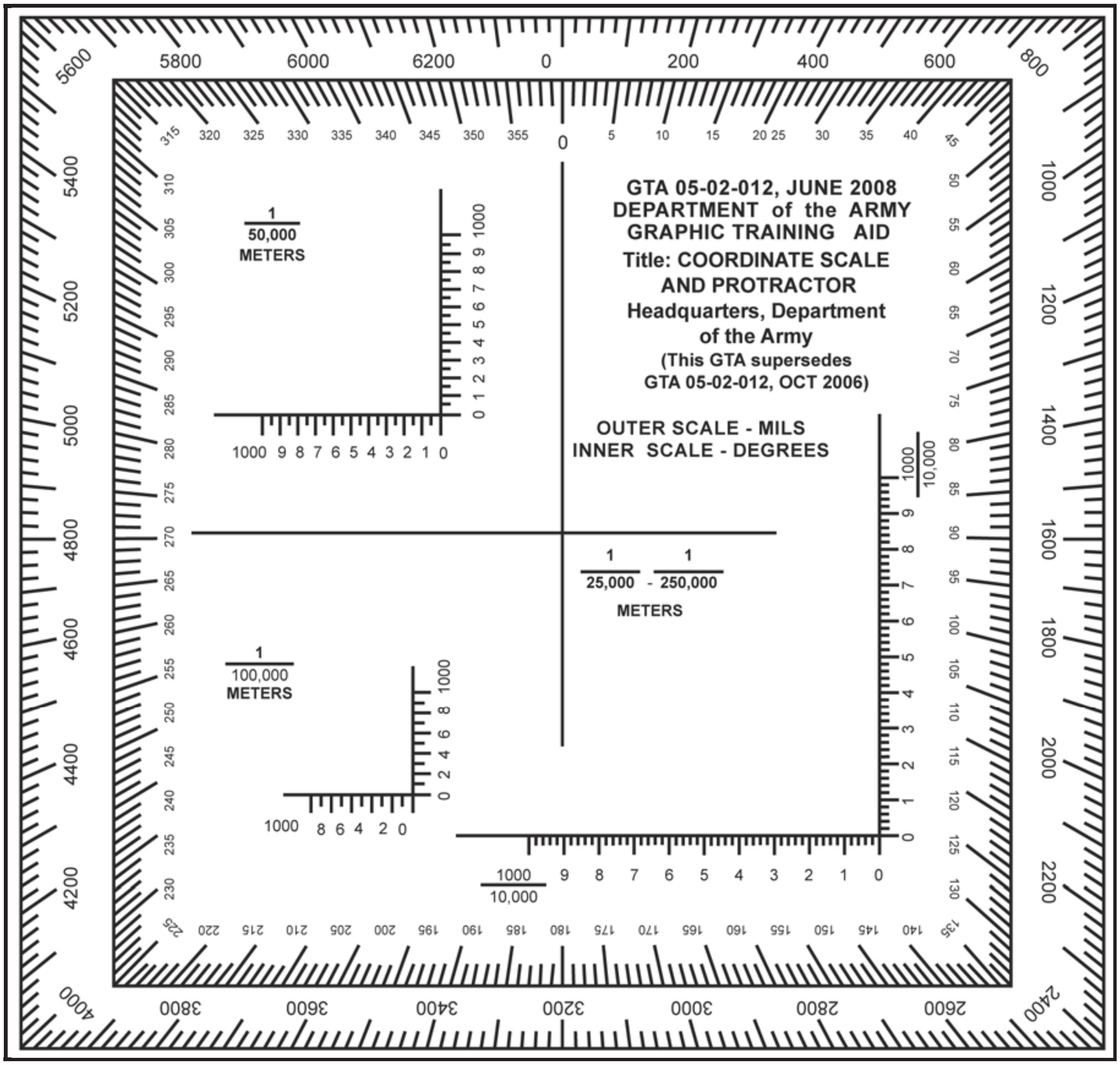


Figure 4-16. Coordinate scales

> ***Note.*** The 1:50,000-scale (upper left in Figure 4-16) subdivides the 1000-m block into 10 major subdivisions, each equal to 100 m. Each 100-m block is then divided in half. Points falling between the graduations are estimated to the nearest 10 m for the fourth and eighth digits of the coordinates.
>
> The 1:100,000-scale (lower left in Figure 4-16) subdivides the 1000-m grid block into five major subdivisions of 200 m each. Each 200-m block is then divided in half at 100-m intervals.
>
> The 1:25,000/1:250,000 (center, lower right in Figure 4-16) can be used in two different scale maps; 1:25,000 or 1:250,000. The 1:25,000-scale subdivides the 1000-m grid block into 10 major subdivisions, each equal to 100 m. Each 100-m block has five graduations; each equal to 20 m. Points falling between the two graduations can be read accurately by using estimation. These values are the fourth and eighth digits of the coordinates. The 1:250,000-scale is subdivided into 10 major subdivisions, each equal to 1000 m. Each 1000-m block has five graduations; each equal to 200 m. Points falling between two graduations can be read approximately by using estimation.

LOCATING A POINT USING GRID COORDINATES

4-12. Based on the military principle for reading maps RIGHT and UP, locations on the map can be determined by grid coordinates. The number of digits represents the degree of precision to which a point has been located and measured on a map. More digits mean the measurement is more precise.

DETERMINE GRIDS WITHOUT A COORDINATE SCALE

4-13. In order to determine grids without a coordinate scale, the reader refers to the north-south grid lines numbered at the bottom margin of a map. Then read RIGHT to the north-south grid line that precedes the desired point (this first set of two digits is the RIGHT reading). Then, by referring to the east-west grid lines numbered at either side of the map, the map reader moves UP to the east-west grid line that precedes the desired point (these two digits are the UP reading). In Figure 4-17, coordinates 1484 locate the 1000-m grid square in which point X is located; the next square to the right would be 1584; the next square up would be 1485, and so forth. To locate the point to the nearest 100 m, use estimation. By mentally dividing the grid square in tenths, estimate the distance from the grid line to the point in the same order (RIGHT and UP). Give complete coordinate RIGHT, then complete coordinate UP. Point X is about two-tenths or 200 m to the RIGHT into the grid square and about seven-tenths or 700 m UP. The coordinates to the nearest 100 m are 142847.

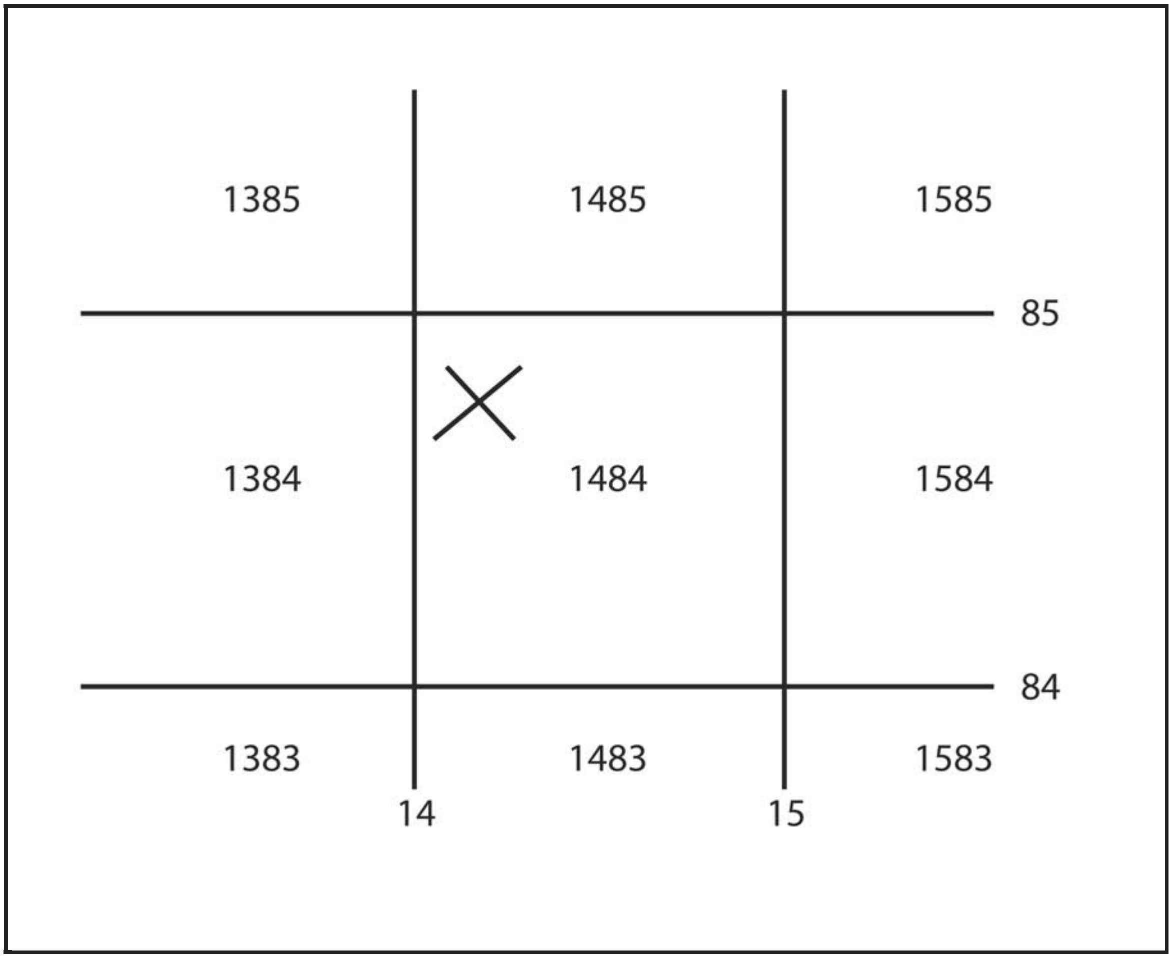


Figure 4-17. Determining grids without coordinate point

DETERMINE GRIDS WITH A COORDINATE SCALE

4-14. In order to use the coordinate scale for determining grid coordinates, the map user has to make sure that the appropriate scale is being used on the corresponding map, and that the scale is right side up. To ensure the scale is correctly aligned, place it with the zero-zero point at the lower left corner of the grid square. Keeping the horizontal line of the scale directly on top of the east-west grid line, slide it to the right until the vertical line of the scale touches the point for which the coordinates are desired. (See Figure 4-18.) When reading coordinates, examine the two sides of the coordinate scale to ensure that the horizontal line of the scale is aligned with the east-west grid line, and the vertical line of the scale is parallel with the north-south grid line. The scale is used when precision of more than 100 m is required. To locate the point to the nearest 10 m, measure the hundredths of a grid square RIGHT and UP from the grid lines to the point. Point X is about 21-hundredths or 210 m RIGHT and 73-hundredths or 730 m UP. The coordinates to the nearest 10 m are 14218473.

RECORDING AND REPORTING GRID COORDINATES

4-15. Coordinates are written as one continuous number without spaces, parentheses, dashes, or decimal points; they always contain an even number of digits. Therefore, whoever is to use the written coordinates knows where to make the split between the RIGHT and UP readings. It is a military requirement that the 100,000-m square identification letters be included in a point designation. Normally, grid coordinates are determined to the nearest 100 m (six digits) for reporting locations. With practice, this can be done without using plotting scales. The location of targets and other point locations for fire support are determined to the nearest 10 m (eight digits).

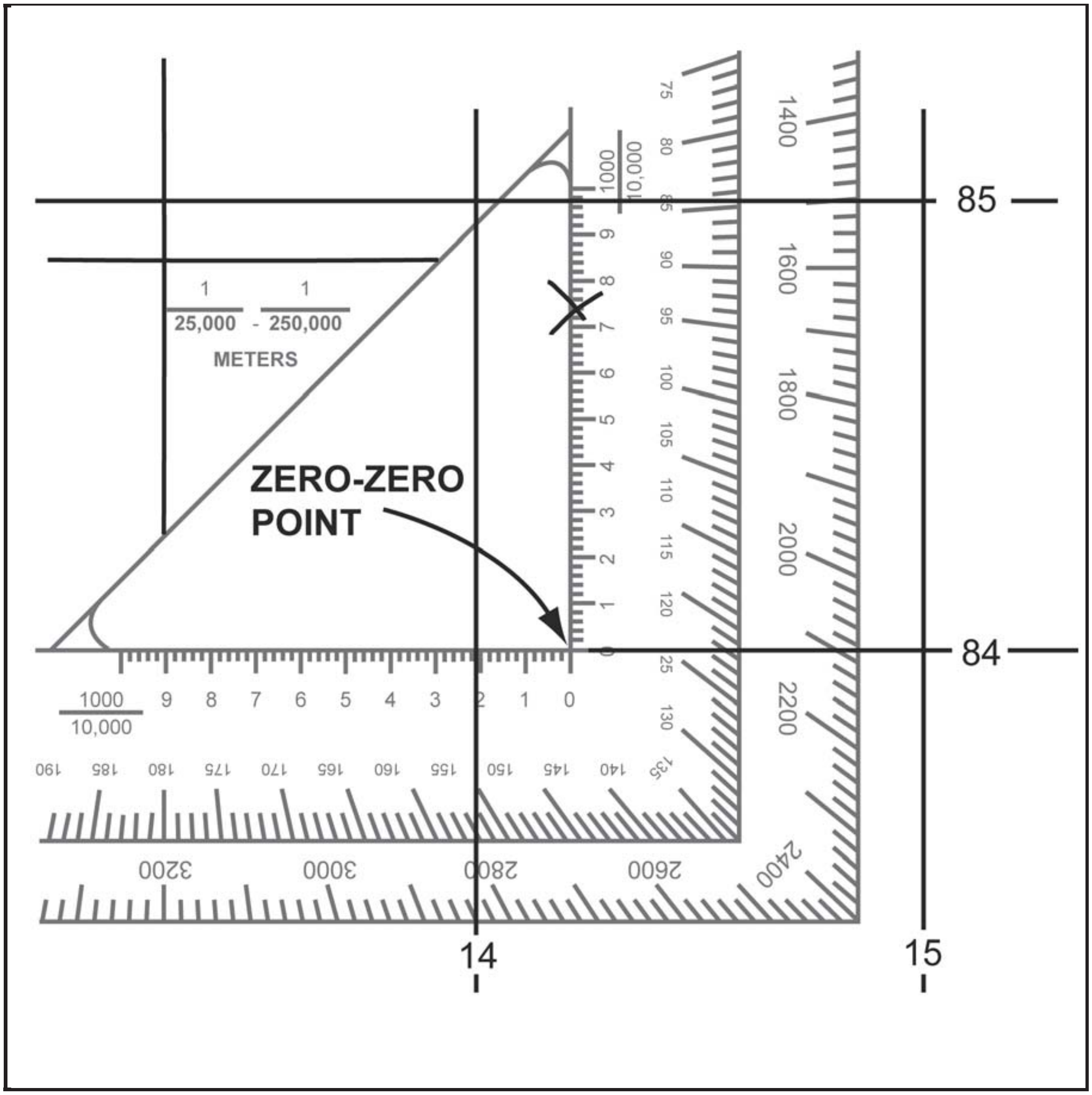


Figure 4-18. Placing a coordinate scale on a grid

> ***Note.*** Care should be exercised by the map reader using the coordinate scale when the desired point is located within the zero-zero point and the number 1 on the scale. Always prefix a zero if the hundredths reading is less than 10. In Figure 4-19, the desired point should be reported as 14838425.

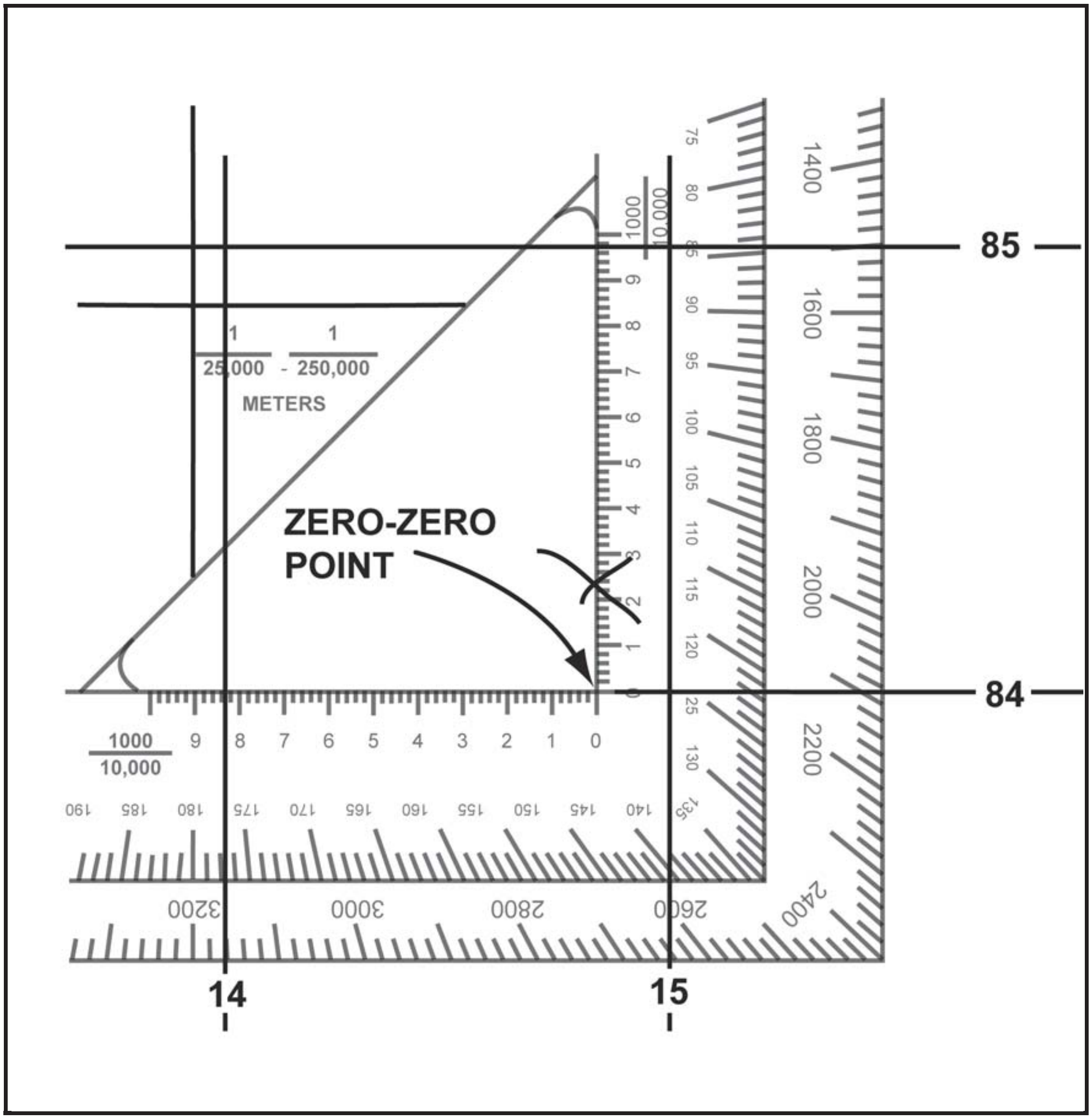


Figure 4-19. Zero-zero point

Note. Special care should be exercised when recording and reporting coordinates. Transposing numbers or making errors could be detrimental to military operations.

LOCATING A POINT USING THE U.S. ARMY MILITARY GRID REFERENCE SYSTEM

4-16. There is only one rule to remember when reading or reporting grid coordinates—always read to the RIGHT and then UP. The first half of the reported set of coordinate digits represents the left-to-right (easting) grid label, and the second half represents the label as read from the bottom-to-top (northing). The grid coordinates may represent the location to the nearest 10-m, 100-m, or 1000-m increment. These coordinates are found by taking the following steps:

- **Grid zone**. The number 16 locates a point within zone 16, which is an area 6-degrees wide and extends between 80°S latitude and 84°N latitude. (See Figure 4-10.)
- **Grid zone designation**. The number and letter combination 16S, further locates a point within the grid zone designation 16S, which is a quadrangle 6-degrees wide by 8-degrees high. There are 19 of these quads in zone 16. Quad X, which is located between 72°N and 84°N latitude, is 12-degrees high. (See Figure 4-10.)

- **100,000-m square identification**. The addition of two more letters locates a point within the 100,000-m grid square. The coordinates 16SGL (see Figure 4-13) locates the point within the 100,000-m square GL in the grid zone designation 16S. (Refer to the Defense Mapping Agency Technical Manual 8358.1 for more information.)
- **10,000-m square**. The breakdown of the U.S. Army military grid reference system continues as each side of the 100,000-m square is divided into 10 equal parts. This division produces lines that are 10,000 m apart. The coordinates 16SGL08 would locate a point as shown in Figure 4-20. The 10,000-m grid lines appear as index (heavier) grid lines on maps at 1:100,000 and larger.

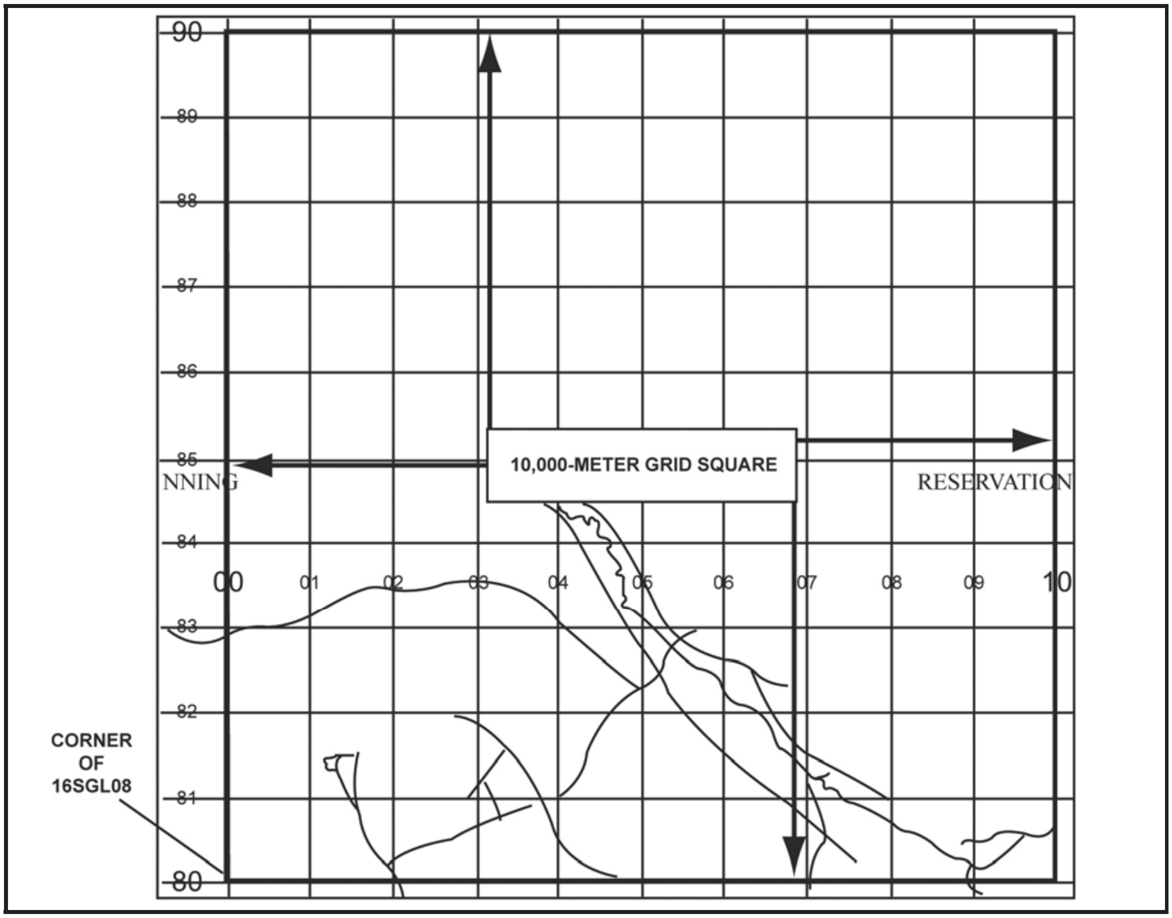


Figure 4-20. The 10,000-meter grid square

- **1000-meter grid square**. To obtain the 1000-m grid squares, each side of the 10000-m square is divided into 10 equal parts. This division appears on large-scale maps as the actual grid lines; they are 1000 meters apart (1 km). (See Figure 4-21.)

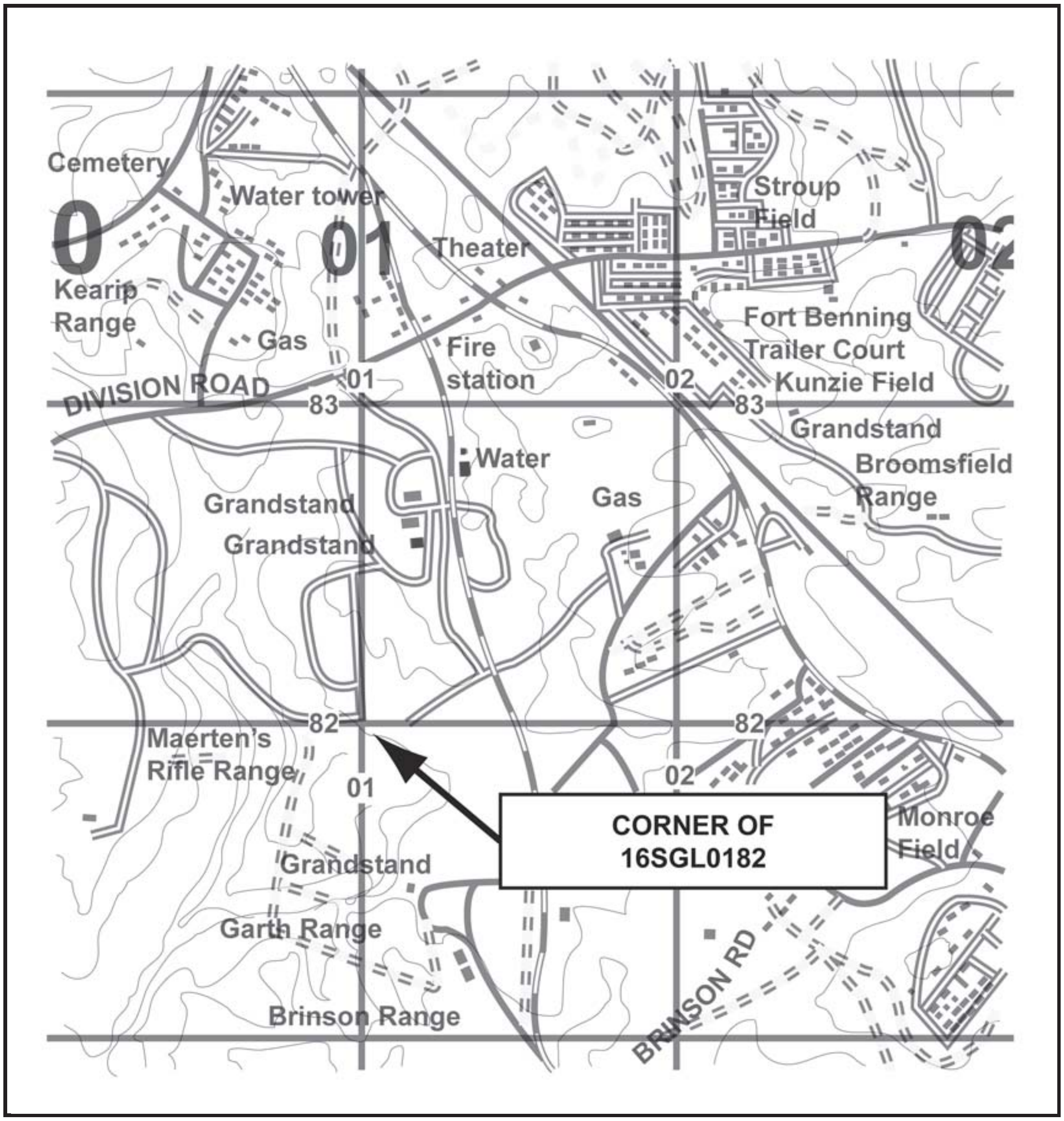


Figure 4-21. The 1000-meter grid square

- **100-meter identification**. To locate to the nearest 100 meters, the grid coordinate scale can be used to divide the 1000-m grid squares into 10 equal parts. (See Figure 4-22.)
- **10-meter identification**. The grid coordinate scale has divisions every 50 m on the 1:50,000-scale, and every 20 m on the 1:25,000-scale. These can be used to estimate to the nearest 10 m and give the location of one point on the earth's surface to the nearest 10 m**.** For example, 16SGL01948253 is a gas tank.

- **Precision.** The precision of a point's location is shown by the number of digits in the coordinates; the more digits, the more precise the location. (See Figure 4-22, insert.)

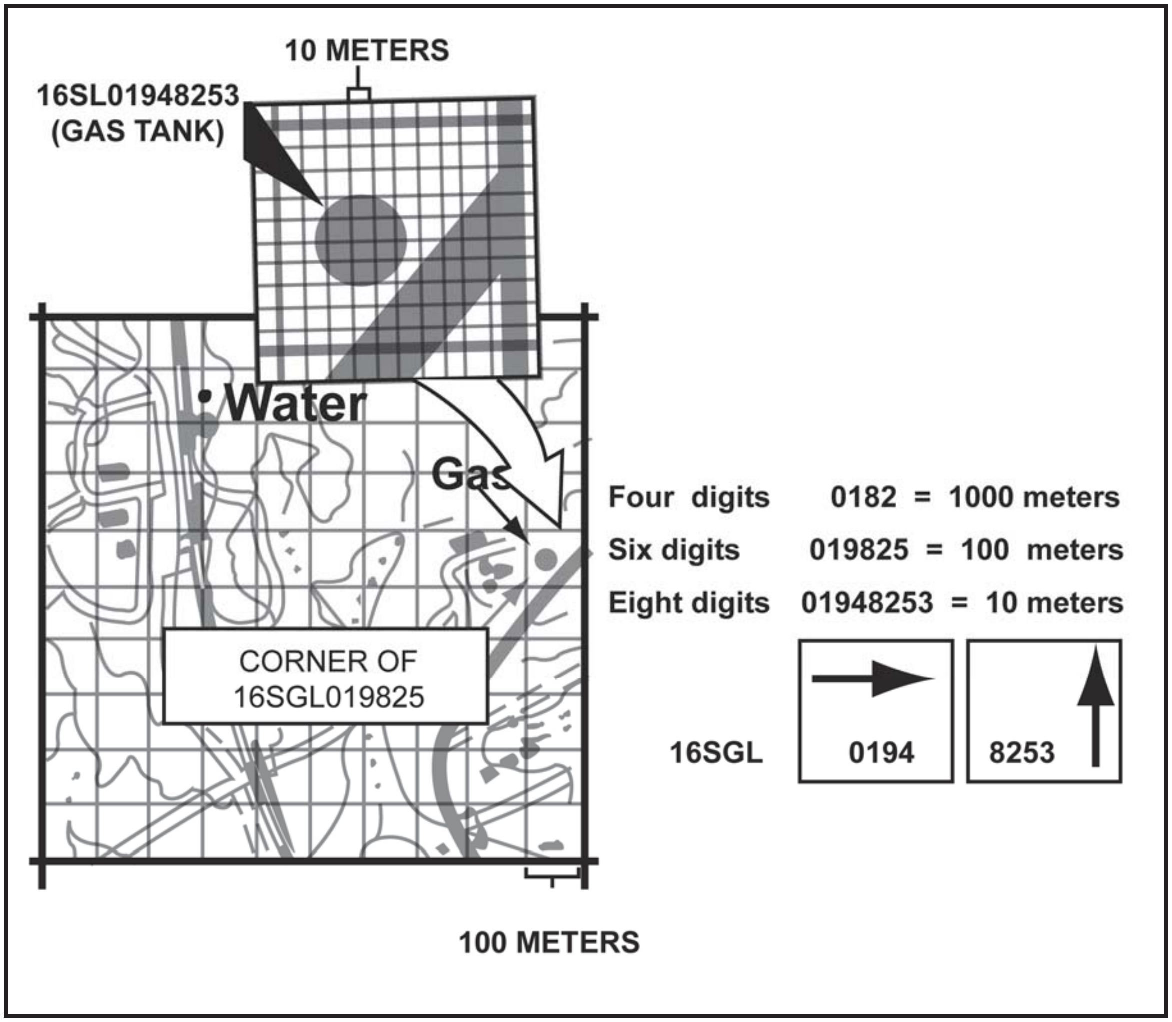


Figure 4-22. The 100-meter and 10-meter grid squares

Grid Reference Box

A grid reference box (see Figure 4-23) appears in the marginal information of each map sheet. It contains step-by-step instructions for using the grid and the U.S. Army military grid reference system. The grid reference box is divided into two parts. The left portion identifies the grid zone designation and the 100,000-m square. If the sheet falls in more than one 100,000-m square, the grid lines that separate the squares are shown in the diagram and the letters identifying the 100,000-m squares are given. For example, on the Columbus map sheet, the vertical line labeled 00 is the grid line that separates the two 100,000-m squares, FL and GL. The left portion also shows a sample for the 1000-m square with its respective labeled grid coordinate numbers and a sample point within the 1000-m square.

4-17. The right portion of the grid reference box explains how to use the grid and is keyed on the sample 1000-meter square of the left side. The following is an example of the military grid reference:

EXAMPLE: 16S locates the 6-degrees-by-8-degrees area (grid zone designation).

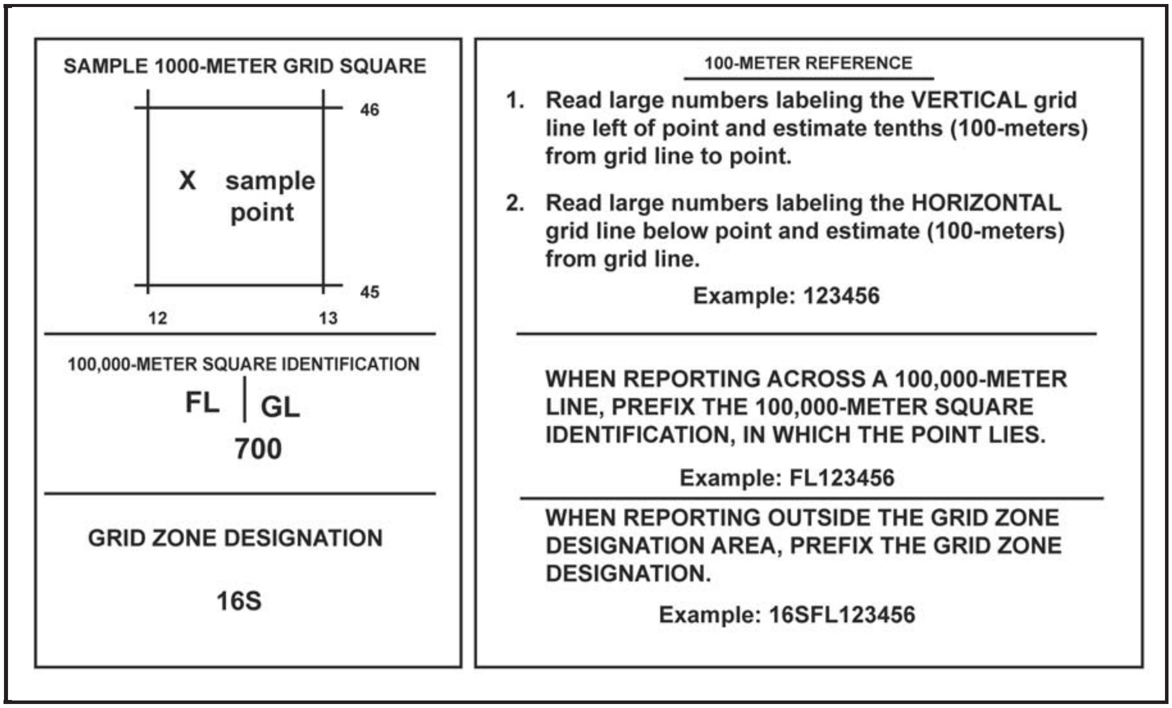


Figure 4-23. Grid reference box

OTHER GRID SYSTEMS

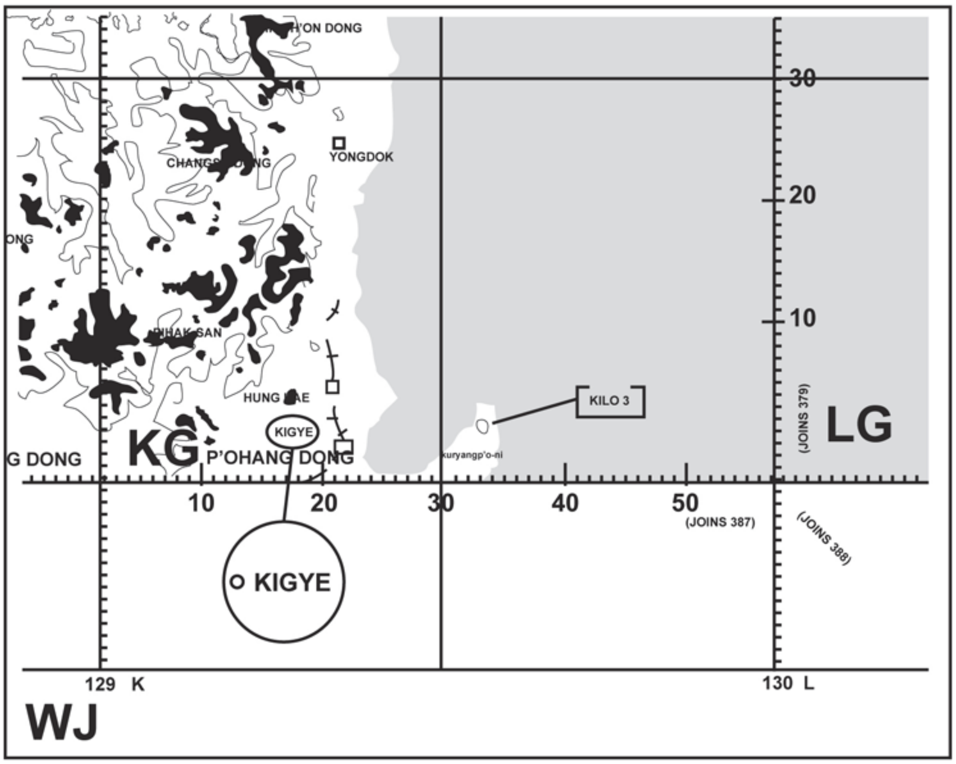
4-18. The military grid reference system is not universally used. Soldiers are prepared to interpret and use other grid systems, depending upon the area of operations or the personnel working together.

4-19. **British grids.** In a few areas of the world, British grids are still shown on military maps. However, the British grid systems are being phased out. Eventually all military mapping will be converted to the UTM grid.

4-20. **World Geographic Reference System (GEOREF).** This is a worldwide position reference system used primarily by the U.S. Air Force. It may be used with a map or chart that has latitude and longitude printed on it. Instructions for using GEOREF data are printed in blue and are found in the margin of aeronautical charts. This system is based upon a division of the earth's surface into quadrangles of latitude and longitude having a systematic identification code. It is a method of expressing latitude and longitude in a form suitable for rapid reporting and plotting. Figure 4-24 illustrates a sample grid reference box using GEOREF. The GEOREF System uses an identification code that has three main divisions:

- **First division.** There are 24 north-south (longitudinal) zones, each 15-degree wide. These zones, starting at 180 degrees and progressing eastward, are lettered A through Z (omitting I and O). The first letter of a GEOREF coordinate identifies the north-south zone in which the point is located. There are 12 east-west (latitudinal) bands, each 15-degrees wide. These bands are lettered A through M (omitting I) northward from the South Pole. The second letter of a GEOREF coordinate identifies the east-west band in which the point is located. The zones and bands divide the earth's surface into 288 quadrangles, each identified by two letters.
- **Second division.** Each 15° quadrangle is further divided into 225 quadrangles of 1 degree each (15-degrees-by-15-degrees). This division is effected by dividing a basic 15-degree quadrangle into 15 north-south zones and 15 east-west bands. The north-south zones are lettered A through Q (omitting I and O) from west to east. The third letter of a GEOREF coordinate identifies the 1-degree north-south zone within a 15-degree quadrangle. The east-west bands are lettered A through Q (I and O omitted) from south to north. The fourth letter of a GEOREF coordinate identifies the 1-degree east-west band within a 15-degree quadrangle. Four letters identify any 1-degree quadrangle in the world.

- **Third division.** Each of the 1-degree quadrangles is divided into 3,600 1” quadrangles. These 1” quadrangles are formed by dividing the 1-degree quadrangles into 60 1” north-south zones numbered 0 through 59 from west to east, and 60 east-west bands numbered 0 to 59 from south to north. To designate one of the 3,600 1” quadrangles requires four letters and four numbers. The rule READ RIGHT AND UP is always followed. Numbers 1 through 9 are written as 01, 02, and so forth. Each of the 1” quadrangles may be further divided into 10 smaller divisions both north-south and east-west, permitting the identification of 0.1” quadrangles. The GEOREF coordinate for a 0.1”quadrangle consists of four letters and six numbers. (See Figure 4-24.)



TO REFERENCE BY GEOREF(SHOWN IN BLUE) TO MINUTES

Select nearest intersection south and west of point.

Sample point: KIGYE

1. **WJ identifies basic 15° quadrangle.**
2. **KG identifies 1° quadrangle.**
3. **15 identifies GEOREF minute of longitude.**
4. **03 identifies GEOREF minute of latitude.**
5. **Sample reference: WJKG 1503.**

Figure 4-24. Sample reference using GEOREF

PROTECTION OF MAP COORDINATES AND LOCATIONS

4-21. A disadvantage of a standard system of location is that if the enemy intercepts a friendly message using the system, they can interpret the message and find our location. This possibility can be eliminated by using an authorized low-level numerical code to express locations. AR 380-40 outlines the procedures for obtaining authorized codes.

Chapter 5

Scale and Distance

A map is a scaled graphic representation of a portion of the earth's surface. The scale of the map permits the user to convert distance on the map to distance on the ground, or vice versa. The ability to determine distance on a map, as well as on the earth's surface, is an important factor in planning and executing military missions.

REPRESENTATIVE FRACTION

5-1. The numerical scale of a map indicates the relationship of distance measured on a map and the corresponding distance on the ground. This scale is usually written as a fraction and is called the representative fraction. The RF is always written with the map distance as 1, and is independent of a unit of measure. (It could be yards, meters, inches, or something else.) An RF of 1/50,000 or 1:50,000 means that one unit of measure on the map is equal to 50,000 units of the same measure on the ground.

5-2. The ground distance between two points is determined by measuring between the same two points on the map and then multiplying the map measurement by the denominator of the RF or scale. (See Figure 5-1.)

EXAMPLE: The map scale is 1:50,000 making RF = 1/50,000. The map distance from point A to point B is 5 units. 5 x 50,000 = 250,000 units of ground distance.

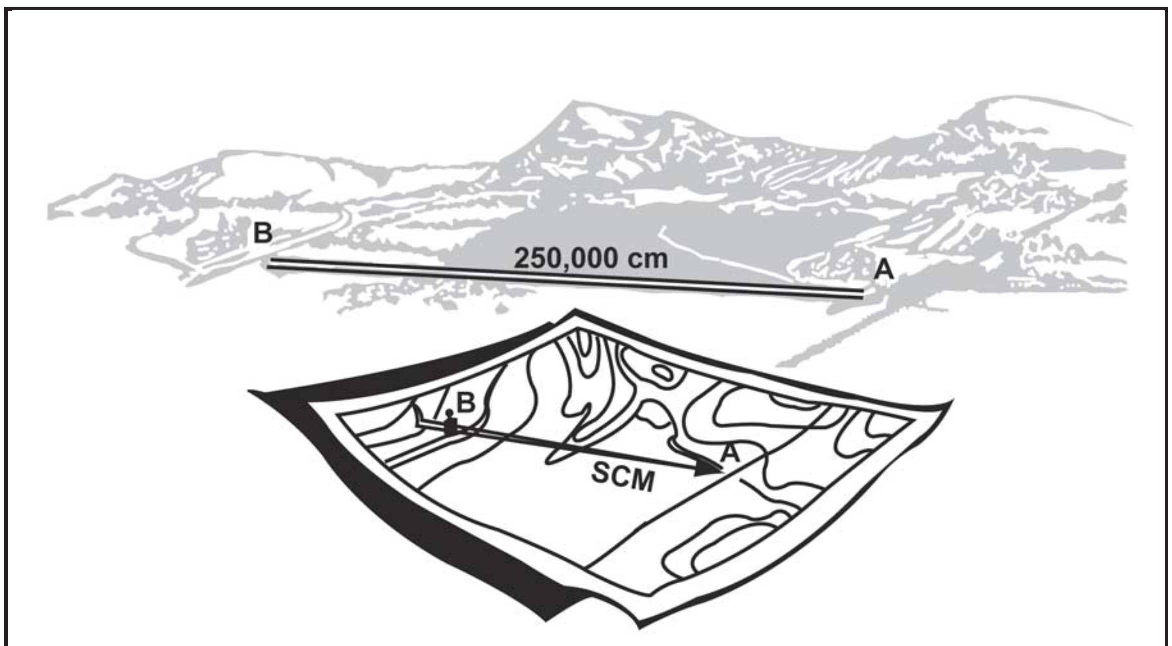


Figure 5-1. Converting map distance to ground distance

5-3. Since the distance on most maps is marked in meters and the RF is expressed in this unit of measurement, in most cases a brief description of the metric system is needed. In the metric system, the standard unit of measurement is the meter. It is multiplied this way:

- 1 m contains 100 centimeters (cm).
- 100 m is a regular football field plus 10 m.

- 1000 m is 1 km.
- 10,000 m is 10 km.

Note. Appendix E contains the units of measure conversion tables.

5-4. The situation may arise when a map or sketch has no RF or scale. To be able to determine ground distance on such a map, the RF is determined. There are two ways to do this:

- **Comparison with ground distance.** Measure the distance between two points on the map—map distance (MD). Determine the horizontal distance between these same two points on the ground—ground distance (GD). Use the RF formula and remember that RF is in the general form:

$$\mathbf{RF = \frac{1}{X} = \frac{MD}{GD}}$$

Both the MD and the GD is in the same unit of measure, and the MD is reduced to 1.

EXAMPLE: MD = 4.32 cm

GD = 2.16 km (216,000 cm)

$$\mathbf{RF = \frac{1}{X} = \frac{4.32}{216{,}000}} \;\; \textit{or} \;\; \mathbf{\frac{216{,}000}{4.32} = 50{,}000}$$

***therefore* RF = 1⁄50,000 *or* 1:50,000**

- **Comparison with another map of the same area that has an RF.** Select two points on the map with the unknown RF, and measure the MD between them. Locate those same two points on the map that has the known RF, and measure the MD between them. Using the RF for this map, determine GD, which is the same for both maps. Using the GD and the MD from the first map, determine the RF using the formula:

$$\mathbf{RF = \frac{1}{X} = \frac{MD}{GD}}$$

5-5. Occasionally, it may be necessary to determine map distance from a known ground distance and the RF:

$$\mathbf{MD = \frac{GD}{Denominator\ or\ RF}}$$

Ground distance = 2200 m
RF = 1:50,000

$$\mathbf{MD = \frac{2200\ m}{50{,}000} = 0.044\ m}$$

MD = 0.044 m X 100 (cm per meter)
MD = 4.4 cm

5-6. When determining ground distance from a map, the scale of the map affects the accuracy. As the scale becomes smaller, the accuracy of measurement decreases because some of the features on the map are exaggerated so that they may be readily identified.

GRAPHIC (BAR) SCALES

5-7. A graphic scale is a ruler printed on the map that is used to convert distances on the map to actual ground distances. 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 using a different unit of measure. (See Figure 5-2.) When using the graphic scale, be sure to use the correct scale for the unit of measure desired.

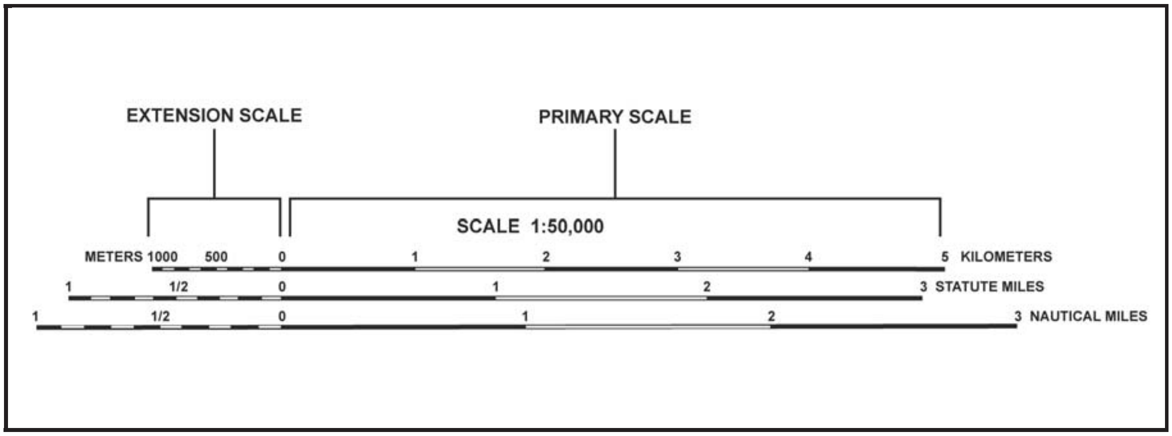


Figure 5-2. Using a graphic (bar) scale

5-8. To determine the straight-line distance between two points on a map, lay a straight-edged piece of paper on the map so that the edge of the paper touches both points and extends past them. Make a tick mark on the edge of the paper at each point. (See Figure 5-3.)

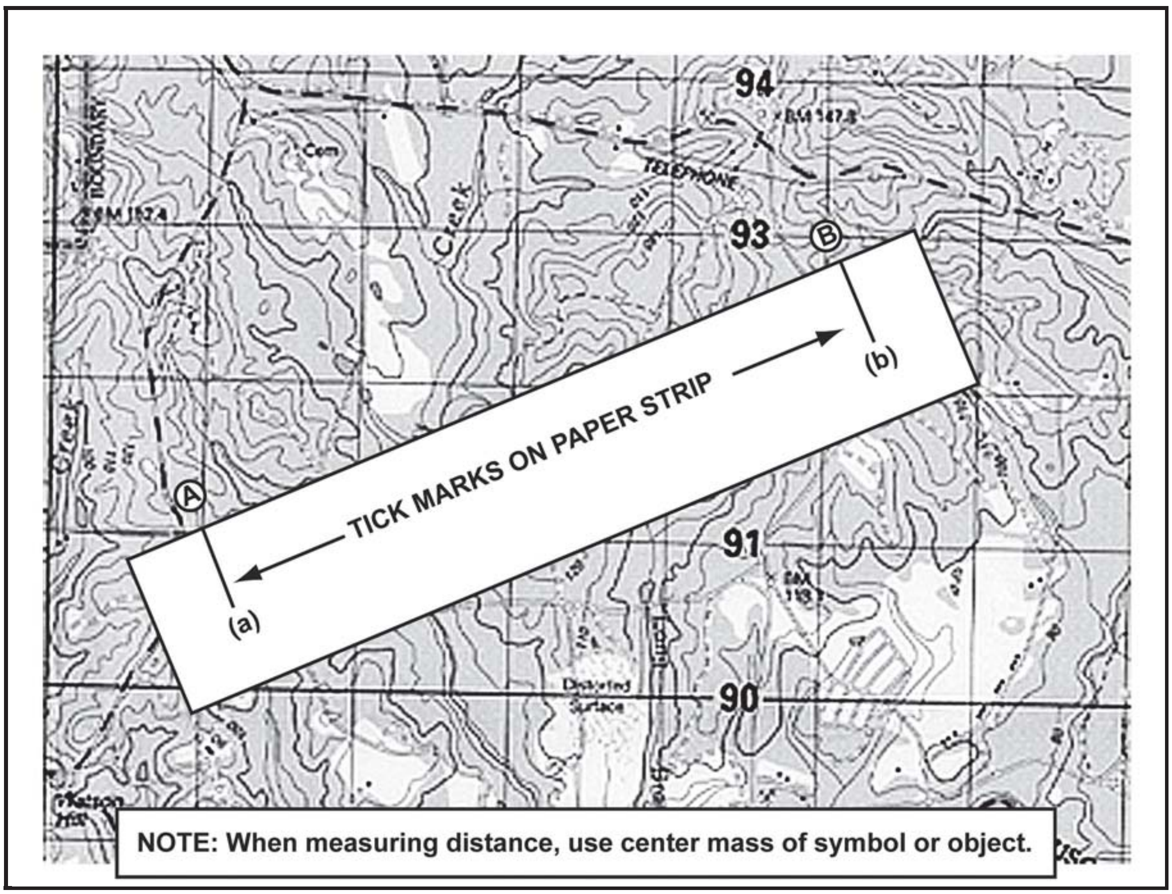


Figure 5-3. Transferring map distance to a paper strip

5-9. To convert the map distance to a measured ground distance, move the paper down to the graphic bar scale, and align the right tick mark (b) with a printed number in the primary scale so that the left tick mark (a) is in the extension scale. (See Figure 5-4.) The primary scale provides the whole unit distance, while the extension scale provides the divided scale used to determine smaller increments of measure.

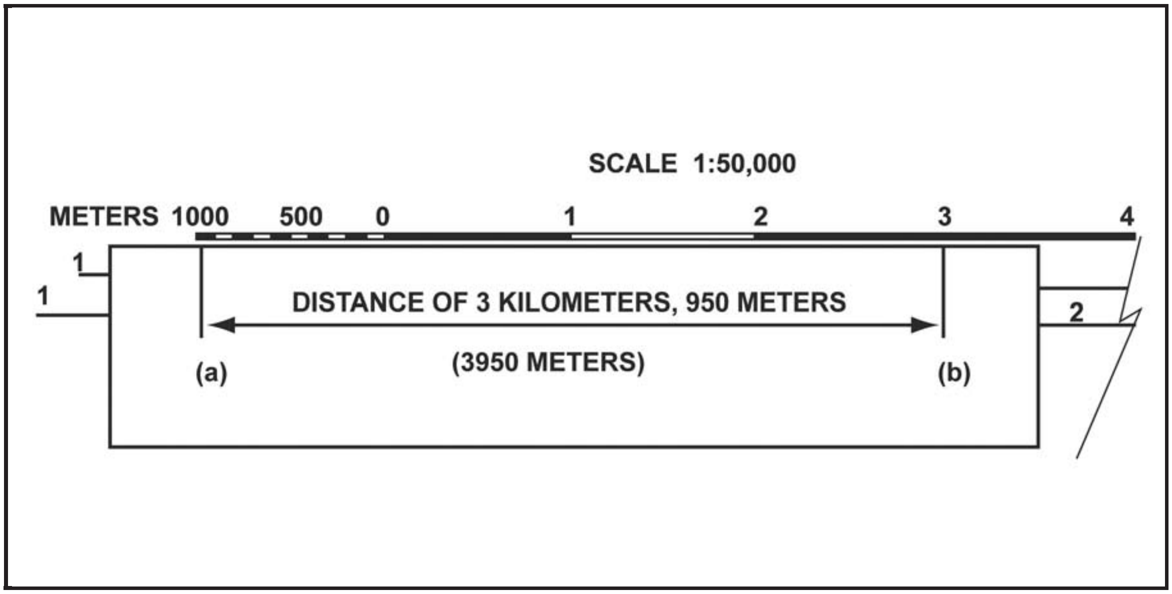


Figure 5-4. Measuring straight-line map distance

5-10. The primary scale is read from the zero mark to the right. Figure 5-4 shows the right tick mark (b) is aligned with the 3000-m mark in the primary scale with the left tick mark (a) in the extension scale, so the distance is at least 3000 m. To determine the distance between the two points to the nearest 100 m, look at the extension scale. The extension scale is numbered with zero at the right and increases to the left. (See Figure 5-4.) The first area on the extension scale represents 0 to 100 m. The second represents 100 to 200 m. Remember, the distance in the extension scale increases from right to left.

5-11. To determine the distance between the two points to the nearest 10 m, divide the distance inside the extension scale into tenths. In Figure 5-4, tick mark (a) falls within the 900 to 1000-m scale area. The location is approximate 5 tenths to the left of the 900 m start point. This is read as 950 m. Adding the distance of 3000 m determined in the primary scale to the 950 m determined by using the extension scale, the total distance between points (a) and (b) is 3950 m.

5-12. To measure distance along a road, stream, or other curved line, the straight edge of a piece of paper is used. In order to avoid confusion concerning the point to begin measuring from and the ending point, an eight-digit coordinate should be given for both the starting and ending points. Place a tick mark on the paper and map at the beginning point from which the curved line is to be measured. Align the edge of the paper along a straight portion and make a tick mark on both map and paper when the edge of the paper leaves the straight portion of the line being measured. (See A, Figure 5-5.)

5-13. Keeping both tick marks together (on paper and map), place the point of the pencil close to the edge of the paper on the tick mark to hold it in place. Then, pivot the paper until another straight portion of the curved line is aligned with the edge of the paper. Continue in this manner until the measurement is completed. (See B, Figure 5-5.)

5-14. When the distance is completely measured, move the paper to the graphic scale to determine the ground distance. The only tick marks being measured are (a) and (b). The tick marks in between are not used. (See C, Figure 5-5.)

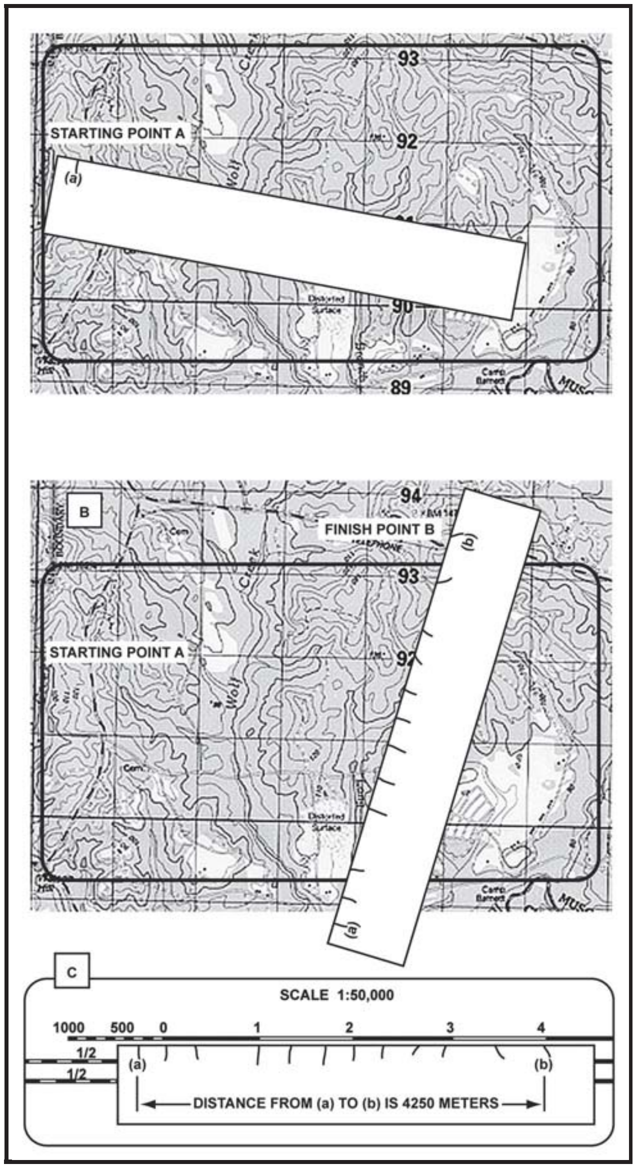


Figure 5-5. Measuring a curved line

5-15. There may be times when the distance being measured on the edge of the paper exceeds the graphic scale. In this case, there are different techniques that can be used to determine the distance:

- One technique is to align the right tick mark (b) with a printed number in the primary scale, in this case the 5. From point (a) to point (b) is more than 6000 m when the 1000 m in the extension scale is added. To determine the exact distance to the nearest 10 m, place a tick mark (c) on the edge of the paper at the end of the extension scale. (See A, Figure 5-6.) Point (b) to point (c) is 6000 m. With the tick mark (c) placed on the edge of the paper at the end of the extension scale, slide the paper to the right. (Remember the distance in the extension is always read from right to left.) Align tick mark (c) with zero and then measure the distance between tick marks (a) and (c). The distance between tick marks (a) and (c) is 420 m. The total ground distance between start and finish points is 6420 m. (See B, Figure 5-6.)

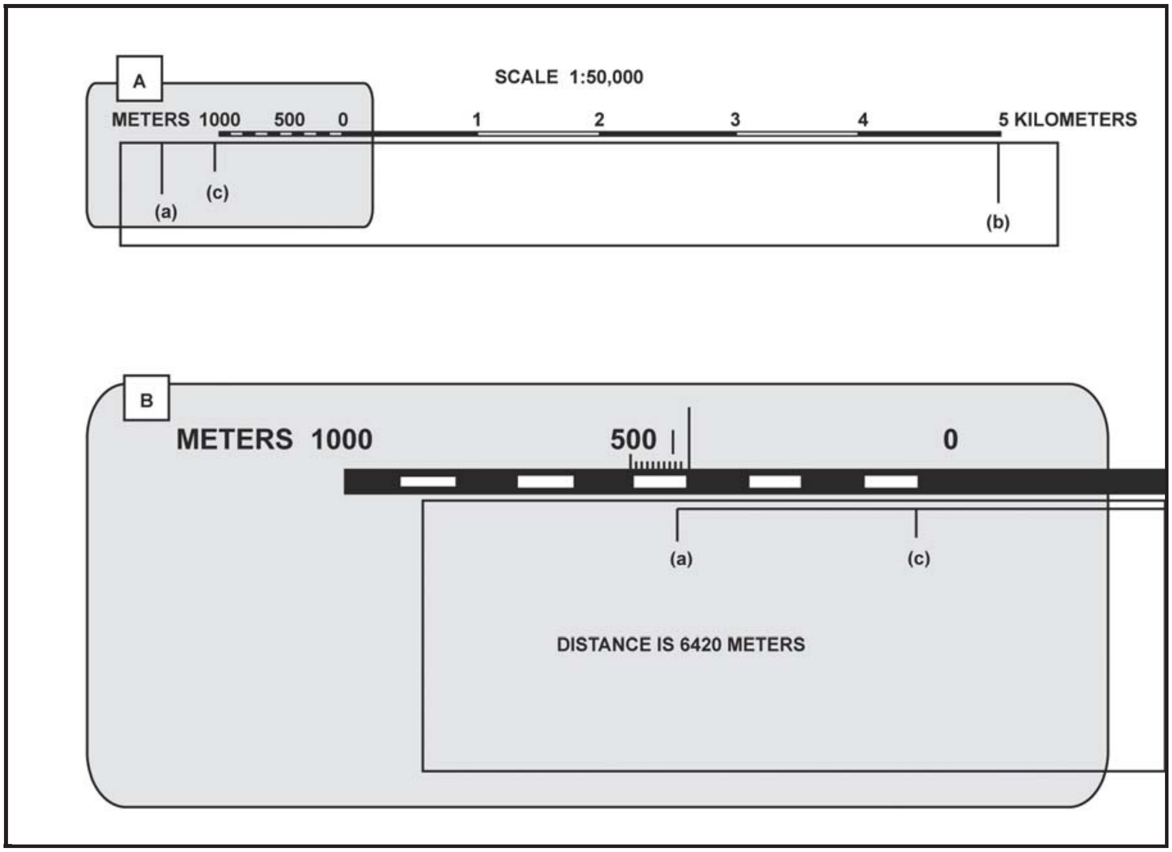


Figure 5-6. Determining the exact distance

- Another technique that may be used to determine exact distance between two points when the edge of the paper exceeds the bar scale is to slide the edge of the paper to the right until tick mark (a) is aligned with the edge of the extension scale. Make a tick mark on the paper, in line with the 2000-m mark (c). (See A, Figure 5-7.) Then slide the edge of the paper to the left until tick mark (b) is aligned with the zero. Estimate the 100-m increments into 10-m increments to determine how many meters tick mark (c) is from the zero line. (See B, Figure 5-7.) The total distance is 3030 m.
- At times it's necessary to know the distance from a point on the map to a point off the map. In order to do this, measure the distance from the start point to the edge of the map. The marginal notes give the road distance from the edge of the map to some towns, highways, or junctions off the map. To determine the total distance, add the distance measured on the map to the distance given in the marginal notes. Be sure the unit of measure is the same.
- When measuring distance in statute or nautical miles, round it off to the nearest one-tenth of a mile and make sure the appropriate bar scale is used.
- Distance measured on a map does not take into consideration the rise and fall of the land. All distances measured by using the map and graphic scales are flat distances. Therefore, the distance measured on a map increases when actually measured on the ground. This is taken into consideration when navigating across land.

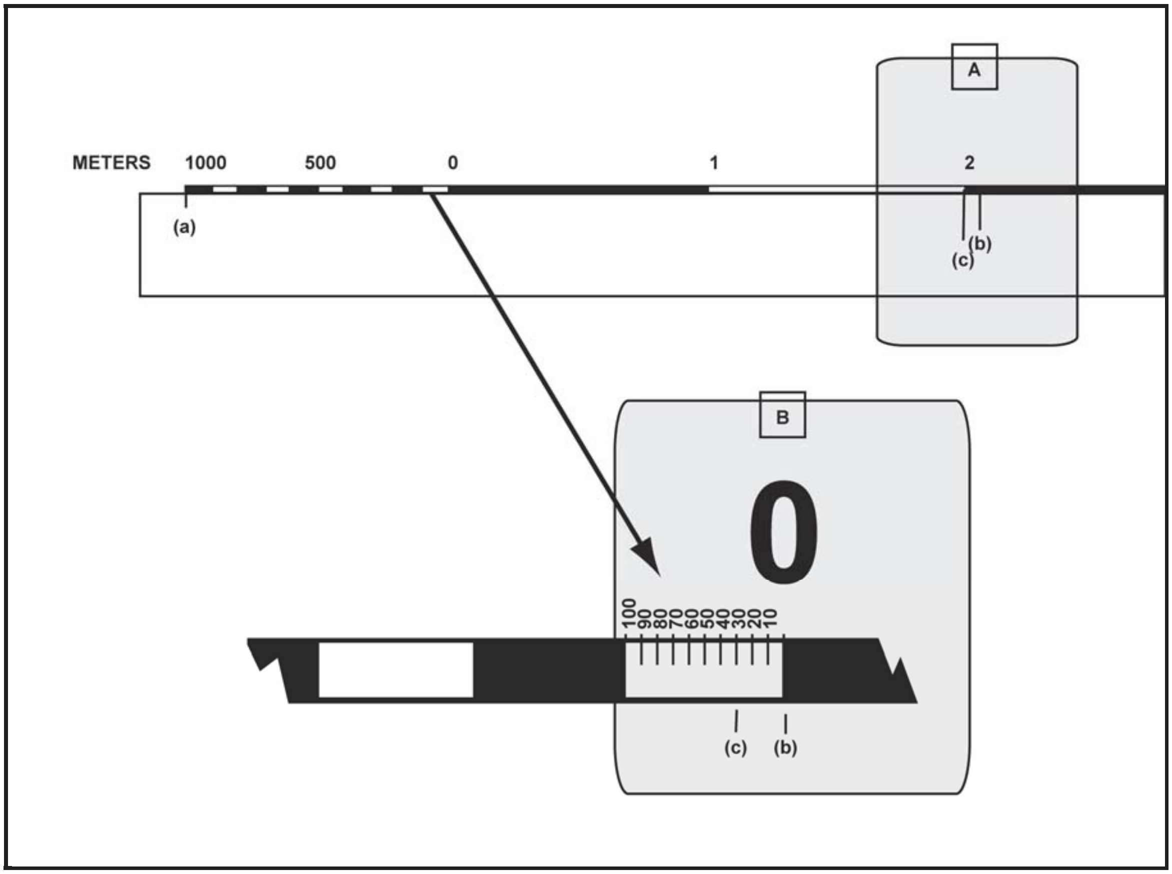


Figure 5-7. Reading the extension scale

5-16. The amount of time required to travel a certain distance on the ground is an important factor in most military operations. This can be determined if a map of the area is available and a graphic time-distance scale is constructed for use with the map as follows:

R = Rate of travel (speed)

T = Time

D = Distance (ground distance)

$$\mathbf{T = \frac{D}{R}}$$

5-17. For example, if an Infantry unit is marching at an average rate (R) of 4 kilometers per hour (kph), it takes about 3 hours of time (T) to travel the distance (D) of 12 km.

$$\mathbf{\frac{12\ (D)}{4\ (R)} = 3\ (T)}$$

5-18. To construct a time-distance scale (see A, Figure 5-8), knowing the length of march, rate of speed, and map scale (that is, 12 km at 3 km per hour on a 1:50,000-scale map), use the following process:

- Mark off the total distance on a line by referring to the graphic scale of the map or, if this is impracticable, compute the length of the line as follows:
  - Convert the ground distance to centimeters: 12 km X 100,000 (cm per km) = 1,200,000 cm.
  - Find the length of the line to represent the distance at map scale.

$$\mathbf{MD = \frac{1}{50} = \frac{1{,}200{,}000}{50{,}000} = 24\ cm}$$

- Construct a line 24 cm in length. (See A, Figure 5-8.)
  - Divide the line into equal increments of time corresponding to the rate of march. In this example, 1 hour increments representing the distance traveled in one hour (see B, Figure 5-8), and label.
  - Divide the scale extension (left portion) into the desired number of lesser time divisions.

1-minute divisions — 60
5-minute divisions — 12
10-minute divisions — 6

  - Section C, Figure 5-8, shows a 5-minute interval scale. Make these divisions in the same manner as for a graphic scale. The completed scale makes it possible to determine where the unit is located at any given time. However, it must be remembered that this scale is for one specific rate of march: only at 4 kph.

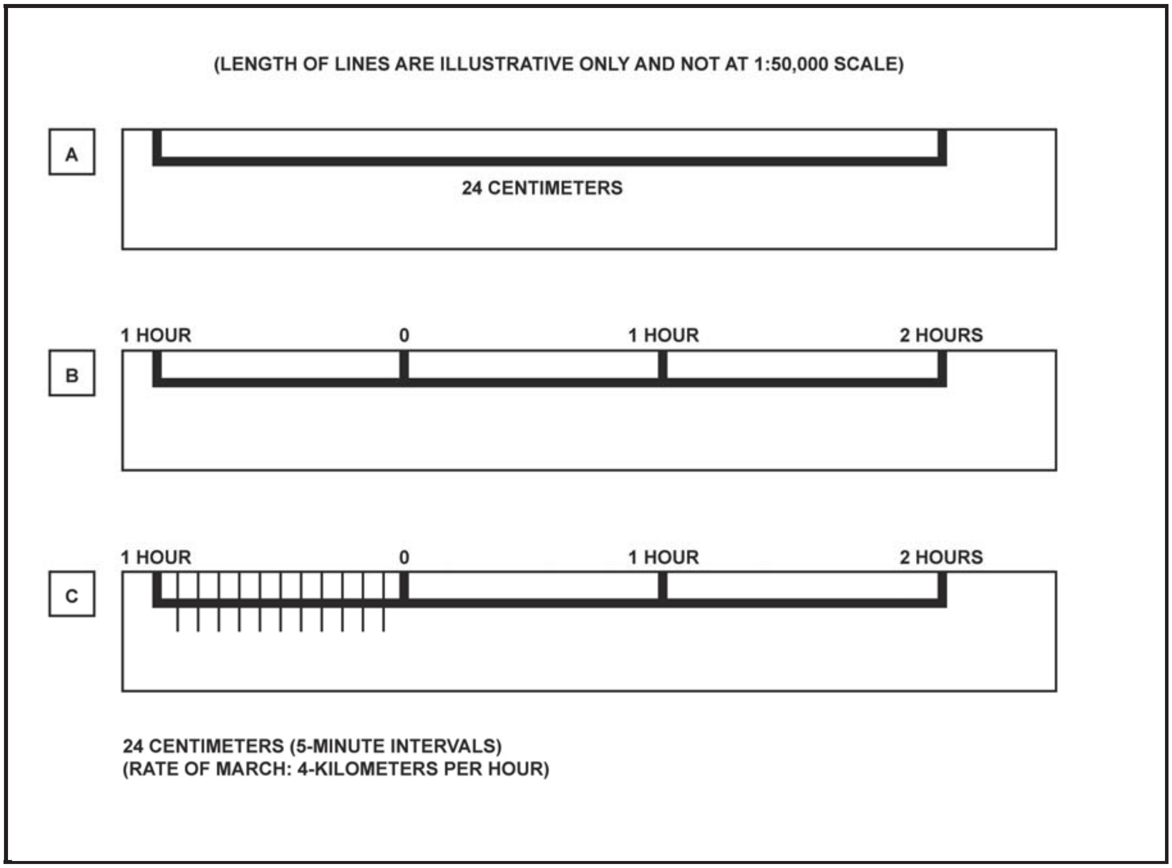


Figure 5-8. Constructing a time-distance scale

OTHER METHODS

5-19. Determining distance is a common source of error encountered while moving, either mounted or dismounted. There may be circumstances when it is not possible to determine distance using a map. It is essential to learn methods to accurately pace, measure, use subtense, or estimate distances on the ground.

PACE COUNT

5-20. A pace is equal to one natural step, about 30 inches long. To use the pace count method accurately, a Soldier knows how many paces it takes to walk 100 m. To determine this, walk an accurately-measured course and count the number of paces it takes to reach 100 m. (A pace course can be as short as 100 m or as long as 600 m.) The pace course, regardless of length, is on similar terrain as that to be walked over. It does no good to walk a course on flat terrain and then try to use that pace count on hilly terrain. To determine the pace count on a 600-m course, count the paces it takes to walk the 600 m, then divide the total paces by 6. The answer gives the average paces it takes to walk 100 m. It is important that each person who navigates while dismounted knows their pace count.

5-21. Many methods exist to keep track of the distance traveled when using the pace count. Some of these methods are to put a pebble in a pocket every time 100 m have been walked, tie knots in a string, or put marks in a notebook. Do not try to remember the count but always use one of these methods, or design another method.

5-22. Certain conditions affect the pace count in the field. Adjustments should be allowed for conditions such as—

- **Slopes.** A pace lengthens on a down slope and shortens on an upgrade. Keeping this in mind, if it normally takes an individual 120 paces to walk 100 m, the pace count may increase to 130 or more when walking up a slope.
- **Winds.** A head wind shortens the pace and a tail wind increases it.
- **Surfaces.** Sand, gravel, mud, snow, and similar surface materials tend to shorten the pace.
- **Elements.** Falling snow, rain, or ice causes the pace to be reduced in length.
- **Clothing.** Excess clothing and boots with poor traction affect the pace length.
- **Visibility.** Poor visibility such as in fog, rain, or darkness, shortens the pace.

ODOMETER

5-23. Distances can be measured by an odometer, which is standard equipment on most vehicles. Readings are recorded at the start and end of a course, and the difference is the length of the course.

To convert km to miles, multiply the number of km by 0.62.
EXAMPLE: 16 km = 16 x 0.62 = 9.92 miles

To convert miles to km, divide the number of miles by 0.62.
EXAMPLE: 10 miles = 10 divided by 0.62 = 16.12 km

SUBTENSE

5-24. Subtense is based upon a principle of visual perspective—the farther away an object is, the smaller it appears. The subtense method is a fast method for determining distance, and yields accuracy equivalent to that obtained by measuring distance with a premeasured piece of wire. An advantage is that a horizontal distance is obtained indirectly; the distance is computed rather than measured. This allows subtense to be used over terrain where obstacles such as streams, ravines, or steep slopes, may prohibit other methods for determining distance.

5-25. The principle used in determining distance by the subtense method is similar to that used in estimating distance by the mil relation formula. The mil relation formula is based upon the assumption that an angle of 1 mil subtends an arc of 1 m at a distance of 1000 m. The field artillery application of the mil relation formula involves only estimations. It is not accurate enough for survey purposes. However, the subtense method uses precise values with a trigonometric solution. The following two procedures are involved in subtense measurement:

- Establishing a base of known length.
- Measuring the angle of that base by use of the aiming circle.

5-26. The subtense base may be any desired length. However, if a 60-m base, a 2-m bar, or the length of an M16A1 or M16A2 rifle is used, precomputed subtense tables are available. The M16 or 2-m bar is held horizontal and perpendicular to the line of sight by a Soldier facing the aiming circle. The instrument operator sights on one end of the M16 or 2-m bar and measures the horizontal clockwise angle to the other end of the rifle or bar, doing this twice, and averaging the angles. Enter the appropriate subtense table with the mean angle and extract the distance. Accurate distances can be obtained with the M16 out to approximately 150 m, with the 2-m bar out to 250 m, and with the 60-m base out to 1000 m. If a base of another length is desired, a distance can be computed by using the following formula:

Distance = 1/2 (base in meters)/
Tan (1/2) (in mils)

ESTIMATION

5-27. At times, because of the tactical situation, it may be necessary to estimate range. The two ways to estimate range or distance are: the 100-m unit-of measure and the flash-to-bang methods.

100-Meter Unit-of-Measure Method

5-28. To use this method, the Soldier visualizes a distance of 100 m on the ground. For ranges up to 500 m, determine the number of 100-m increments between the two objects to measure. Beyond 500 m, the Soldier selects a point halfway to the object(s) and determines the number of 100-m increments to the halfway point, then doubles it to find the range to the object. (See Figure 5-9.)

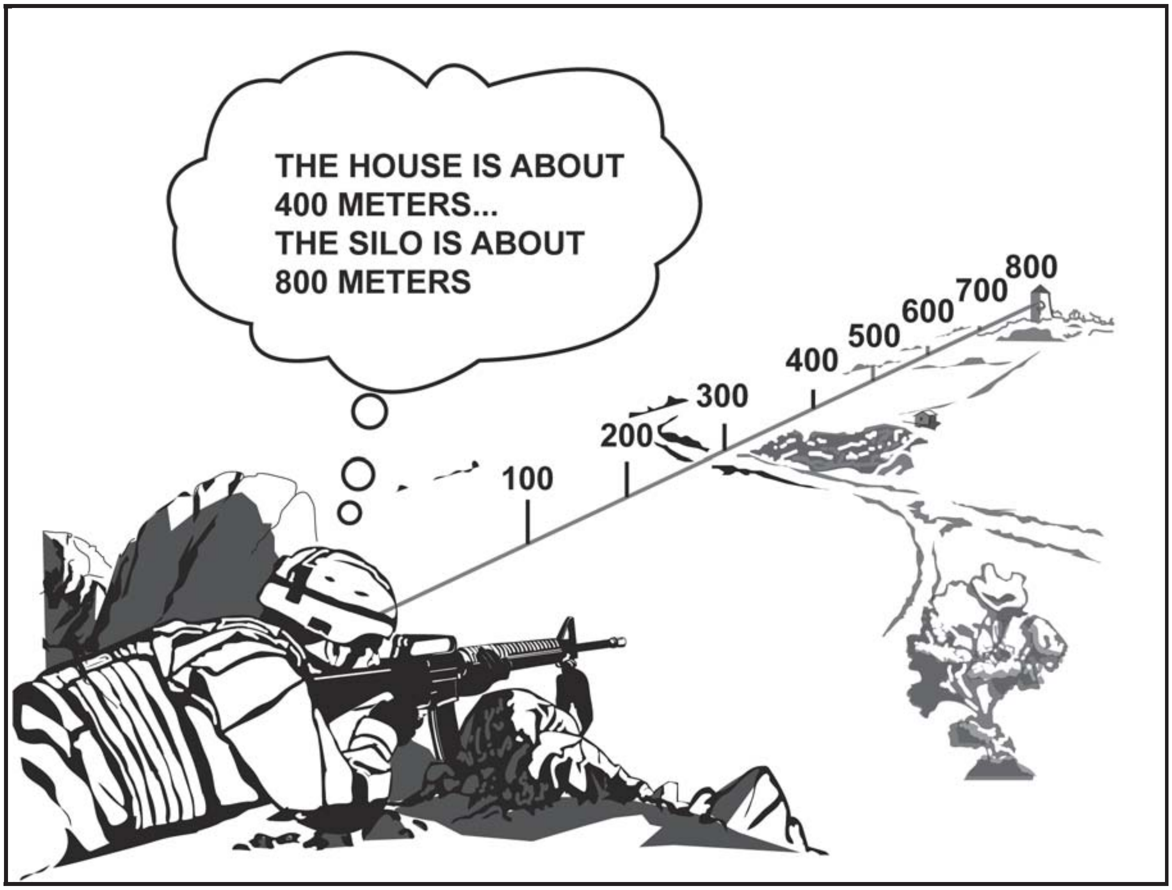


Figure 5-9. Using the 100-meter unit-of-measure method

Flash-to-Bang Method

5-29. To use this method for determining range to an explosion or enemy fire, begin to count when the flash is seen. Count the seconds until weapon fire is heard. This time interval may be measured with a stopwatch or by using a steady count, such as one-thousand-one, one-thousand-two, and so forth, for a three-second estimated count. If there is a count higher than 10 seconds, start over with one. Multiply the number of seconds by 330 m to get the approximate range.

Proficiency of Methods

5-30. The methods discussed above are used only to estimate range. (See Table 5-1.) Proficiency in both methods requires constant practice. The best training technique is requiring the Soldier to pace the range after estimating the distance. In this way, the Soldier personally discovers the actual range, which makes a greater impression than being told the answer.

Table 5-1. Factors of range estimation

Factors Affecting Range Estimation	*Factors Causing Underestimation of Range*	*Factors Causing Overestimation of Range*
Clearness of outline and details of the object.	Most of the object is visible and offers a clear outline.	When only a small part of the object can be seen or the object is small in relation to its surroundings.
Nature of terrain or position of the observer.	Looking across a depression that is mostly hidden from view or downward from high ground. Looking down a straight, open road or along a railroad. Looking over uniform surfaces like water, snow, desert, or grain fields. In bright light or when the sun is shining from behind the observer.	When looking across a depression that is totally visible. When vision is confined, as in streets, draws, or forest trails. When looking from low ground toward high ground. In poor light, such as at dawn or dusk; and in rain, snow, or fog. When the sun is in the observer's eyes.
Light and atmosphere.	When the object is in sharp contrast with the background or is silhouetted because of its size, shape, or color. When seen in the clear air of high altitudes.	When the object blends into the background or terrain.

This page intentionally left blank.

Chapter 6

Directions

Being in the right place at the prescribed time is necessary for successfully accomplishing military missions. Direction plays an important role in a Soldier's everyday life. It can be expressed as right, left, straight ahead, and so forth; but then the question arises, "To the right of what?" This chapter defines the word azimuth and the three different norths. It explains in detail how to determine the grid and the magnetic azimuths with the use of the protractor and the compass. It explains the use of some field-expedient methods to find directions, the declination diagram, and the conversion of azimuths from grid to magnetic, and vice versa. It also includes some advanced aspects of map reading such as intersection, resection, modified resection, and polar plots.

METHODS OF EXPRESSING DIRECTION

6-1. Military personnel need a way of expressing direction that is accurate, adaptable to any part of the world, and has a common unit of measure. Directions are expressed as units of angular measure, such as—

- **Degree.** The most common unit of measure is the degree (º) with its subdivisions of minutes (') and seconds ("). (See Chapter 4.)
- **Mil.** Another unit of measure, the mil (abbreviated m/ in graphics), is used mainly in artillery, tank, and mortar gunnery. The mil expresses the size of an angle formed when a circle is divided into 6400 angles, with the vertex of the angles at the center of the circle. A relationship can be established between degrees and mils. A circle equals 6400 mils divided by 360 degrees, or 17.78 mils per degree. To convert degrees to mils, multiply degrees by 17.78.
- **Grad.** The grad is a metric unit of measure found on some foreign maps. There are 400 grads in a circle (a 90-degree right angle equals 100 grads). The grad is divided into 100 centesimal minutes (centigrads) and the minute into 100 centesimal seconds (milligrads).

BASE LINES

6-2. To express direction as a unit of angular measure, there is a starting point or zero measure, and a point of reference. These two points designate the base, or reference line. The three base lines include true north, magnetic north, and grid north. (See Figure 6-1.) The most commonly used base lines are magnetic and grid. To explain further:

- **True north** is defined as a line from a point on the earth's surface to the North Pole. All lines of longitude are true north lines. True north is usually represented by a star.
- **Magnetic north** is the direction to the north magnetic pole, as indicated by the north-seeking needle of a magnetic instrument. The magnetic north is usually symbolized by a line ending with half of an arrowhead. Magnetic readings are obtained with instruments such as the lensatic and M2 compasses. It has been proven that the geomagnetic poles migrate over time. This means that the effect on the declination diagram varies depending on location. The declination diagram for Fort Richardson, Alaska in 1993 was 23° E, but by 2013 it was 18° E—a five degree change. The declination diagram for Fort Benning, Georgia in 1993 was 2° W, but by 2013 it was 4° W—a difference of two degrees. The National Oceanic and Atmospheric Administration (NOAA) provides a magnetic field calculator web site to calculate the declination using the current international geomagnetic reference field model. The website address is: http://www.ngdc.noaa.gov/geomag-web/?id=declinationFormId#declination.

- **Grid north** is established by using the vertical grid lines on the map. Grid north may be symbolized by the letters GN or the letter "y."

CAUTION

Check the map for the date; see Chapter 3 for location of map information. Declination diagrams older than 20 years may provide magnetic readings which are unreliable when converting True or Grid North with the Magnetic North, or the opposite.

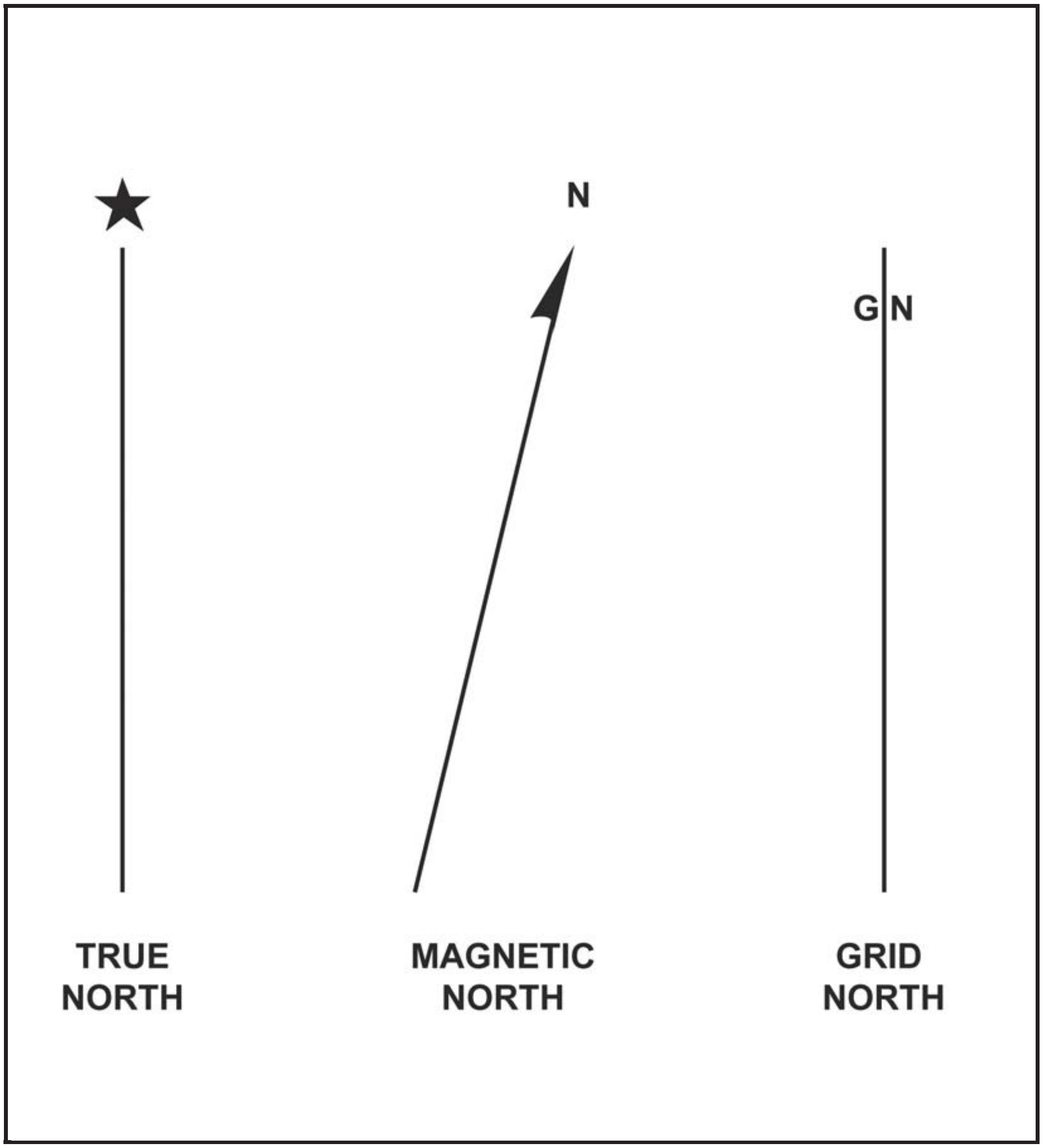


Figure 6-1. Three norths

AZIMUTHS

6-3. An azimuth is defined as a horizontal angle measured clockwise from a north base line. This north base line could be true north, magnetic north, or grid north. The azimuth is the most common military method to express direction. When using an azimuth, the point where the azimuth originates is the center of an imaginary circle. (See Figure 6-2.) This circle is divided into 360 degrees, or 6400 mils. Other azimuths are:

- **Back azimuth**. This is the opposite direction of an azimuth. It is comparable to doing an "about face." To obtain a back azimuth from an azimuth, add 180 degrees if the azimuth is 180 degrees or less; subtract 180 degrees if the azimuth is 180 degrees or more. (See Figure 6-3.) The back azimuth of 180 degrees may be stated as 0 degrees or 360 degrees. For mils, if the azimuth is less than 3200 mils, add 3200 mils; if the azimuth is more than 3200 mils, subtract 3200 mils.

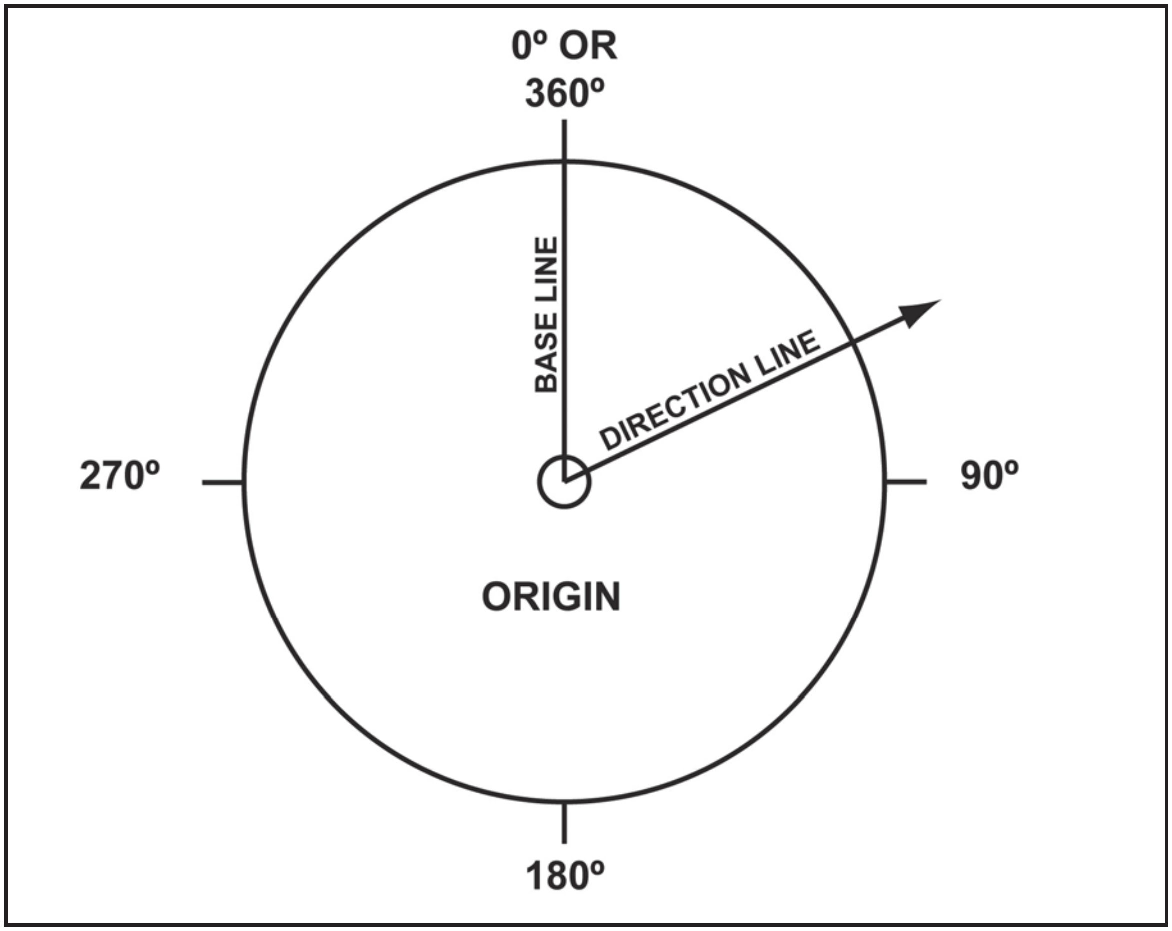


Figure 6-2. Origin of azimuth circle

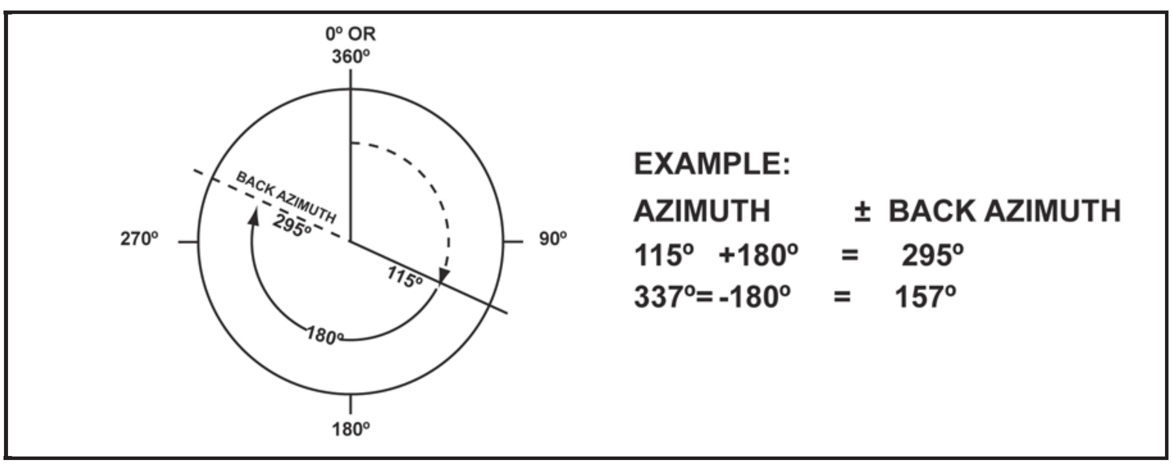


Figure 6-3. Back azimuth calculation with azimuth less than 180 degrees

WARNING

When converting azimuths into back azimuths, extreme care should be exercised when adding or subtracting the 180 degrees. A simple mathematical mistake could cause disastrous consequences.

- **Magnetic azimuth.** This is determined by using magnetic instruments such as lensatic and M2 compasses.
- **Field-expedient methods**. Several field-expedient methods to determine direction are discussed in Chapter 8.

GRID AZIMUTHS

6-4. When an azimuth is plotted on a map between point A (starting point) and point B (ending point), the points are joined by a straight line. A protractor is used to measure the angle between grid north and the drawn line, and this measured azimuth is the grid azimuth. (See Figure 6-4. The example given represents 99 degrees.)

WARNING

When measuring azimuths on a map, remember to measure from a starting point to an ending point. If a mistake is made and the reading is taken from the ending point, the grid azimuth is opposite, causing the user to go in the wrong direction.

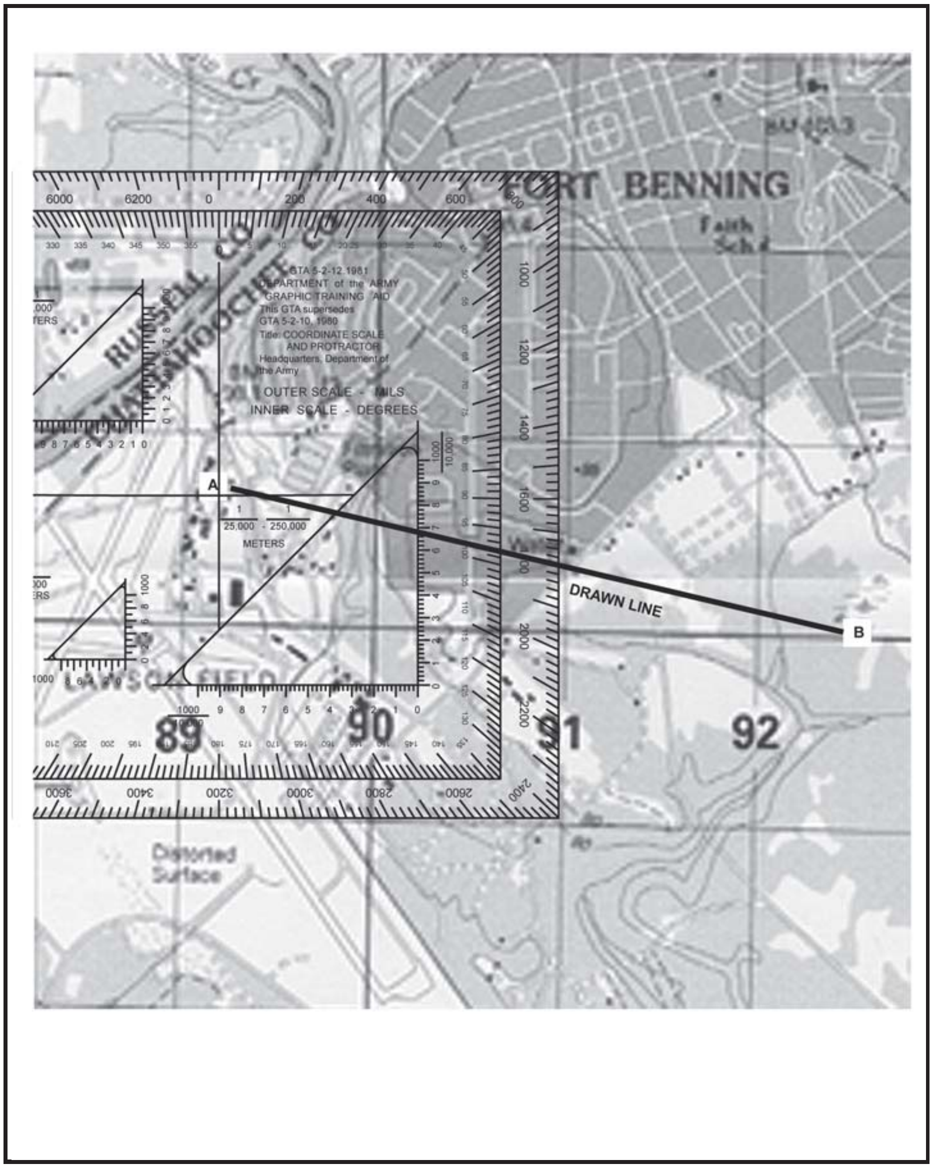


Figure 6-4. Measuring an azimuth

PROTRACTOR

6-5. The various types of protractors include: full circle, half circle, square, and rectangular. (See Figure 6-5.) All of them divide the circle into units of angular measure, and have a scale around the outer edge and an index mark. The index mark is the center of the protractor circle from which all directions are measured.

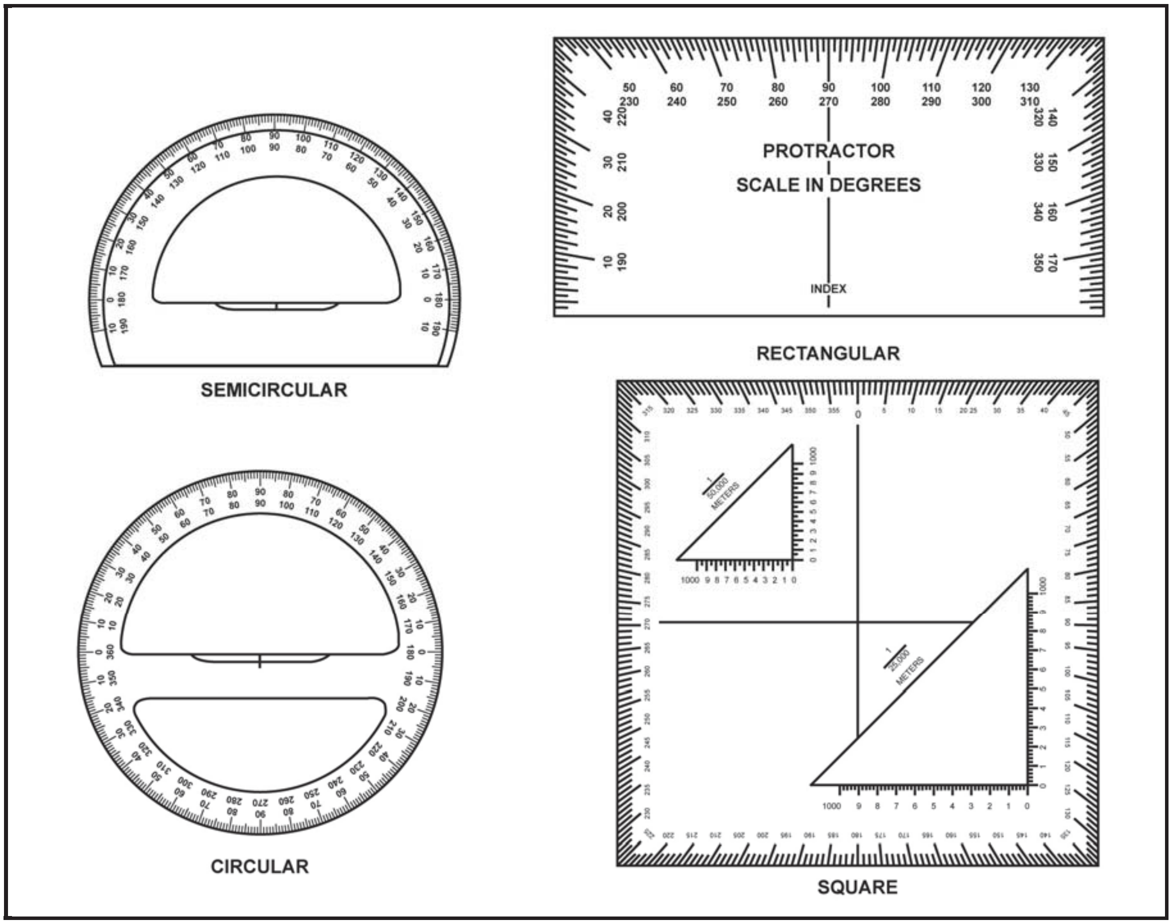


Figure 6-5. Types of protractors

6-6. The military protractor, GTA 5-2-12, contains two scales: one in degrees (inner scale) and one in mils (outer scale). This protractor represents the azimuth circle. The degree scale is graduated from 0 to 360 degrees, with each tick mark representing one degree. A line from 0 to 180 degrees is called the base line of the protractor. The index (or center) of the protractor is where the base line intersects the horizontal line, between 90 and 270 degrees. (See Figure 6-6.)

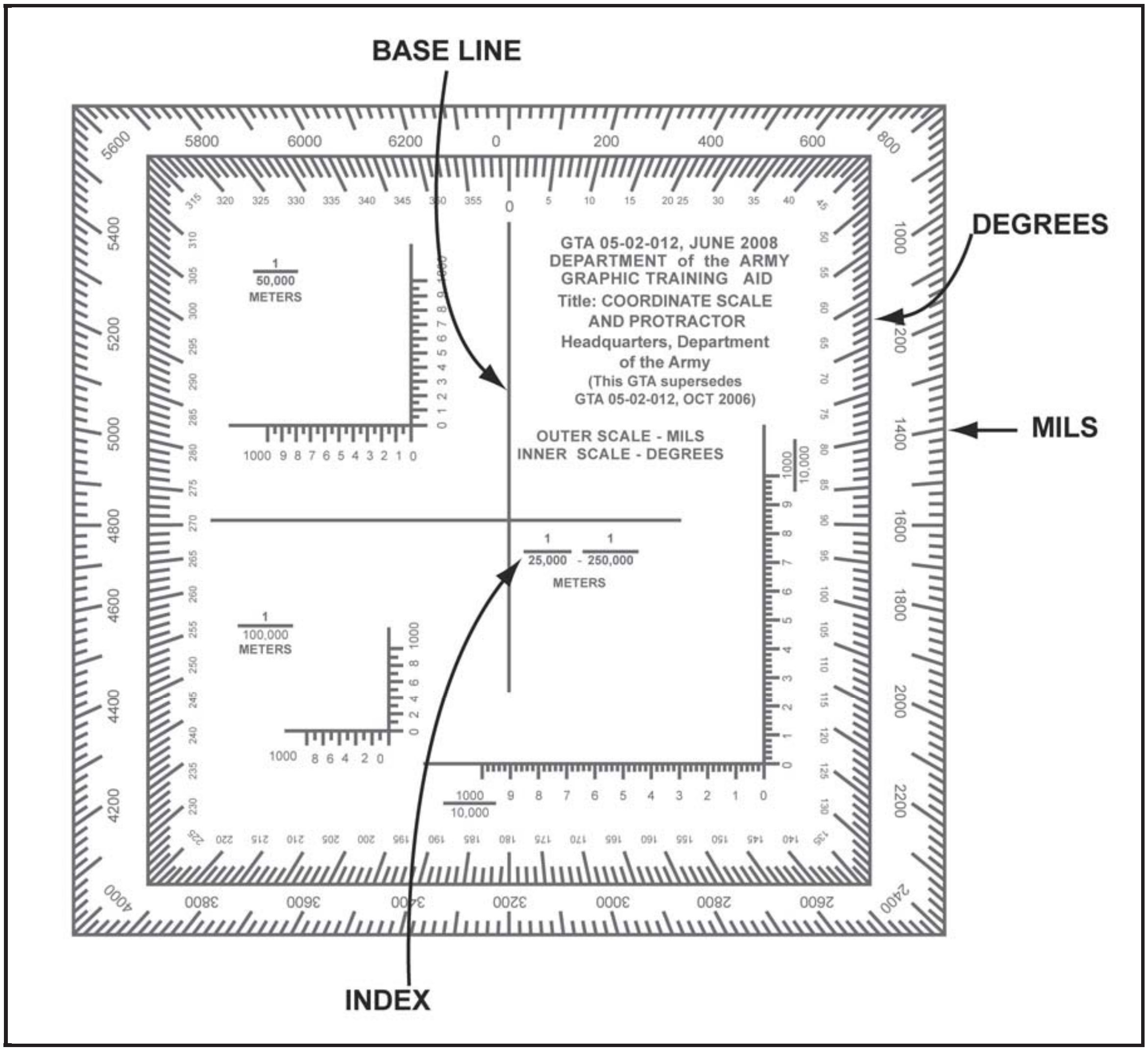


Figure 6-6. Military protractor

6-7. When using the protractor, the base line is always oriented parallel to a north-south grid line. The 0- or 360-degree mark is always toward the top or north on the map and the 90-degree mark is to the right. To determine the grid azimuth:

- Draw a line connecting the two points (A and B).
- Place the index of the protractor at the point where the drawn line crosses a vertical (north-south) grid line.
- Keeping the index at this point, align the 0- to 180-degree line of the protractor on the vertical grid line.
- Read the value of the angle from the scale; this is the grid azimuth from point A to point B. (See Figure 6-4.)

6-8. Figure 6-7 shows how to plot an azimuth from a known point on a map:

- Convert the azimuth from magnetic to grid, if necessary.

- Place the protractor on the map with the index mark at the center of mass of the known point, and the base line parallel to a north-south grid line.
- Make a mark on the map at the desired azimuth.
- Remove the protractor and draw a line connecting the known point and the mark on the map. This is the grid direction line (azimuth).

Note. When measuring an azimuth, the reading is always to the nearest degree or 10 mils. Distance does not change an accurately measured azimuth.

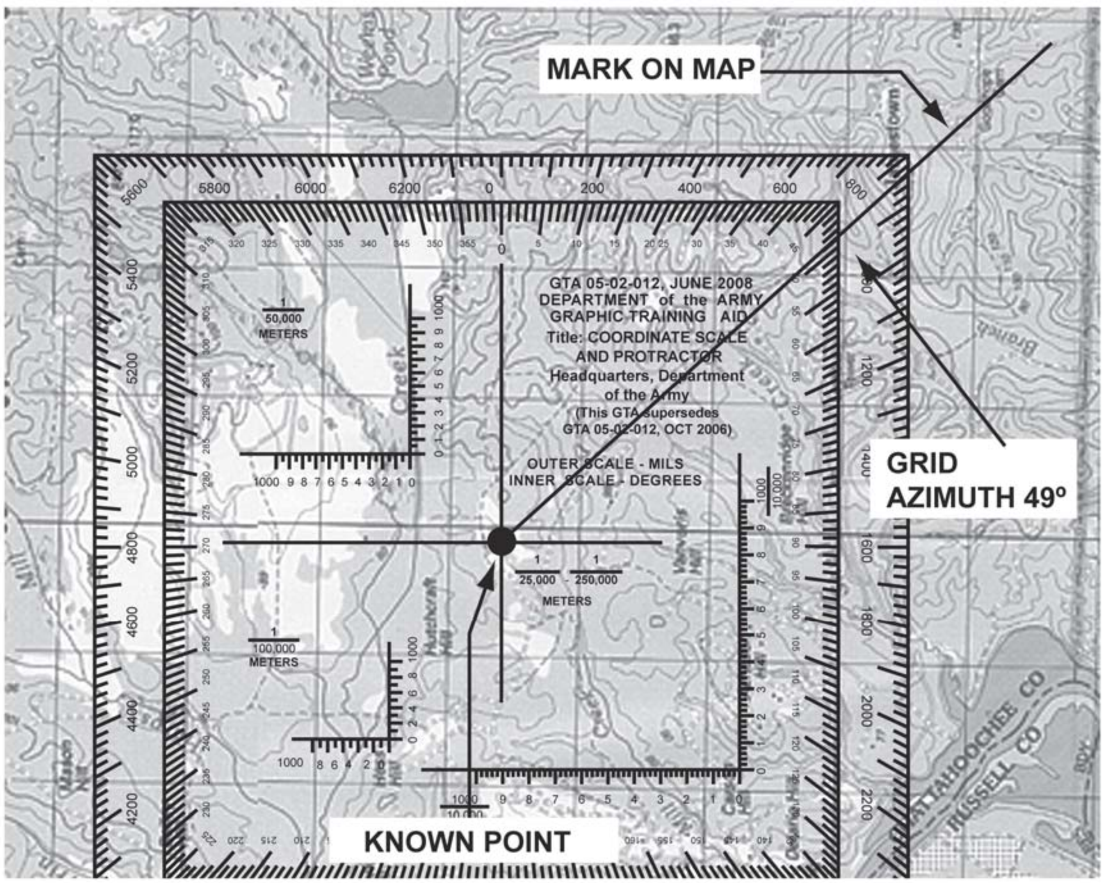


Figure 6-7. Plotting an azimuth on the map

6-9. To obtain an accurate reading with the protractor (to the nearest degree or 10 mils), there are two techniques to check that the base line of the protractor is parallel to a north-south grid line:

- Place the protractor index where the azimuth line cuts a north-south grid line, aligning the base line of the protractor directly over the intersection of the azimuth line with the north-south grid line. The user should be able to determine whether the initial azimuth reading was correct. The user should re-read the azimuth between the azimuth and north-south grid line to check the initial azimuth.
- Note that the protractor is cut at both the top and bottom by the same north-south grid line. Count the number of degrees from the 0-degree mark at the top of the protractor to this

north-south grid line and then count the number of degrees from the 180-degree mark at the bottom of the protractor to this same grid line. If the two counts are equal, the protractor is properly aligned.

DECLINATION DIAGRAM

6-10. Declination is the angular difference between two norths. Having a map and a compass, the declination of most interest is between magnetic and grid north. Soldiers primarily receive information based on a magnetic north or grid north azimuth. The declination diagram shows the angular relationship, represented by prongs among the grid, magnetic, and true norths. While the relative positions of the prongs are correct, they are seldom plotted to scale. Do not use the diagram to measure a numerical value. This value is written in the map margin (in degrees and mils) beside the diagram.

Note. Magnetic azimuths are generally used by Soldiers while navigating with a compass or dead reckoning (land navigation). The grid azimuth is generally used by planners and leaders when writing orders, controlling movement, or looking at graphic control measures.

6-11. A declination diagram is part of the information in the lower margin on most larger maps. On medium-scale maps, the declination information is shown by a note in the map margin. Other map information includes:

- **Grid-magnetic (G-M) angle.** The G-M angle value is the angular size that exists between grid north and magnetic north. It is an arc, indicated by a dashed line that connects the grid-north and magnetic-north prongs. This value is expressed to the nearest 1/2 degree, with mil equivalents shown to the nearest 10 mils. The G-M angle is important to the map reader/land navigator because azimuths translated between the map and ground are in error by the size of the declination angle, if not adjusted for it.
- **Grid convergence**. An arc indicated by a dashed line connects the prongs for true north and grid north. The value of the angle for the center of the sheet is given to the nearest full minute, with its equivalent to the nearest mil. These data are shown in the form of a grid-convergence note.
- **Conversion.** There is an angular difference between the grid north and the magnetic north. Since the location of magnetic north does not correspond exactly with the grid-north lines on the maps, a conversion from magnetic to grid or vice versa is needed.

CAUTION

Declination diagrams older than 20 years may provide magnetic readings which are unreliable when converting True or Grid North with a Magnetic North, or the opposite.

NOTES

6-12. When notes are furnished, simply refer to the conversion notes that appear in conjunction with the diagram explaining the use of the G-M angle. One note provides instructions for converting magnetic azimuth to grid azimuth; the other, for converting grid azimuth to magnetic azimuth. The conversion (add or subtract) is governed by the direction of the magnetic-north prong relative to that of the grid-north prong.

CONVERSION OF GRID AND MAGNETIC AZIMUTHS

6-13. A magnetic compass gives a magnetic azimuth, but in order to plot this line on a gridded map, the magnetic azimuth value is changed to grid azimuth. The opposite process is done for converting a grid azimuth to a magnetic azimuth. The declination diagram is used for these conversions.

6-14. Conversion of grid azimuths to magnetic azimuths and vice versa, depend on whether one is converting easterly or westerly G-M angles, the degree of declination change, and whether one is going from a magnetic azimuth to grid azimuth, or the opposite. (See Figure 6-8 and Table 6-1.) To do this—

- From an easterly magnetic azimuth to grid azimuth, one would add. To go from a grid azimuth to magnetic azimuth, one would subtract. (See Table 6-1.)
- From a westerly magnetic azimuth to a grid azimuth, one would subtract. To go from a grid azimuth to a magnetic azimuth, one would add. (See Table 6-1.)

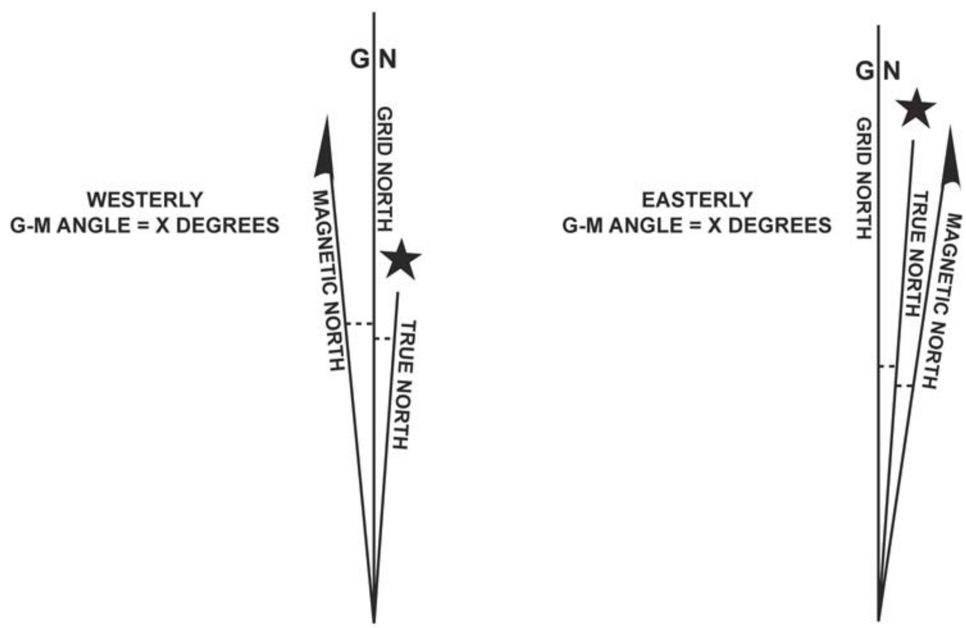


Figure 6-8. Declination diagrams

6-15. There are no negative azimuths on the azimuth circle. Since 0 degree is the same as 360 degrees, then 2 degrees is the same as 362 degrees. This is because 2 degrees and 362 degrees are located at the same point on the azimuth circle. The grid azimuth can now be converted into a magnetic azimuth because the grid azimuth is now larger than the G-M angle. (See Table 6-1.)

Table 6-1 Declination Conversion

	Westerly G-M Angle		Easterly G-M Angle	
Grid azimuth to magnetic azimuth	**ADD**		**SUBTRACT**	
Example	14° G-M Angle West		17° G-M Angle East	
	Grid azimuth G-M angle (add) Magnetic azimuth	93° +14° =107°	Grid azimuth G-M angle (subtract) Magnetic azimuth	303° -17° =286°
Magnetic azimuth to grid azimuth	**SUBTRACT**		**ADD**	
Example	5° G-M Angle West		12° G-M Angle East	
	Magnetic azimuth G-M angle (subtract) Grid azimuth	65° -5° =60°	Magnetic azimuth G-M angle (subtract) Grid azimuth	210° +12° =222°
Convert azimuths with angles greater than 360°	Given azimuth Angle of change Converted azimuth 360° subtraction Desired azimuth		357° +18° 375° -360° =15°	
Convert azimuths with angles less than 0°	Given azimuth Angle of change Converted azimuth 360° subtraction Desired azimuth		5° -12° -7° +360° =353°	

6-16. The G-M angle diagram should be used each time the conversion of azimuth is required. This procedure is important when working with a map for the first time

Note. When converting azimuths, exercise extreme care when adding and subtracting the G-M angle. A simple mistake of 1 degree could be significant in the field.

INTERSECTION

6-17. Intersection is the location of an unknown point by successively occupying at least two (preferably three) known positions on the ground, and then map sighting on the unknown location. It is used to locate distant or inaccessible points or objects such as enemy targets and danger areas. There are two methods of intersection—the map and compass method and the straightedge method (see Figures 6-9 and 6-10):

- When using the map and compass method—
  1. Orient the map using the compass.
  2. Locate and mark the position on the map,
  3. Determine the magnetic azimuth to the unknown position using the compass.
  4. Convert the magnetic azimuth to grid azimuth.
  5. Draw a line on the map from the position on this grid azimuth.
  6. Move to a second known point and repeat the steps 1 through 5 above.
  7. The location of the unknown position is where the lines cross on the map. Determine the grid coordinates to the desired accuracy.
- The straightedge method is used when a compass is not available. When using it—
  1. Orient the map on a flat surface by the terrain association method.
  2. From a known position (A). Locate and mark the position on the map.
  3. Lay a straightedge on the map with one end at the user's position (A) as a pivot point; then, rotate the straightedge until the unknown point is sighted along the edge.
  4. Draw a line along the straightedge
  5. Repeat the steps at a second known position (B) and check for accuracy.

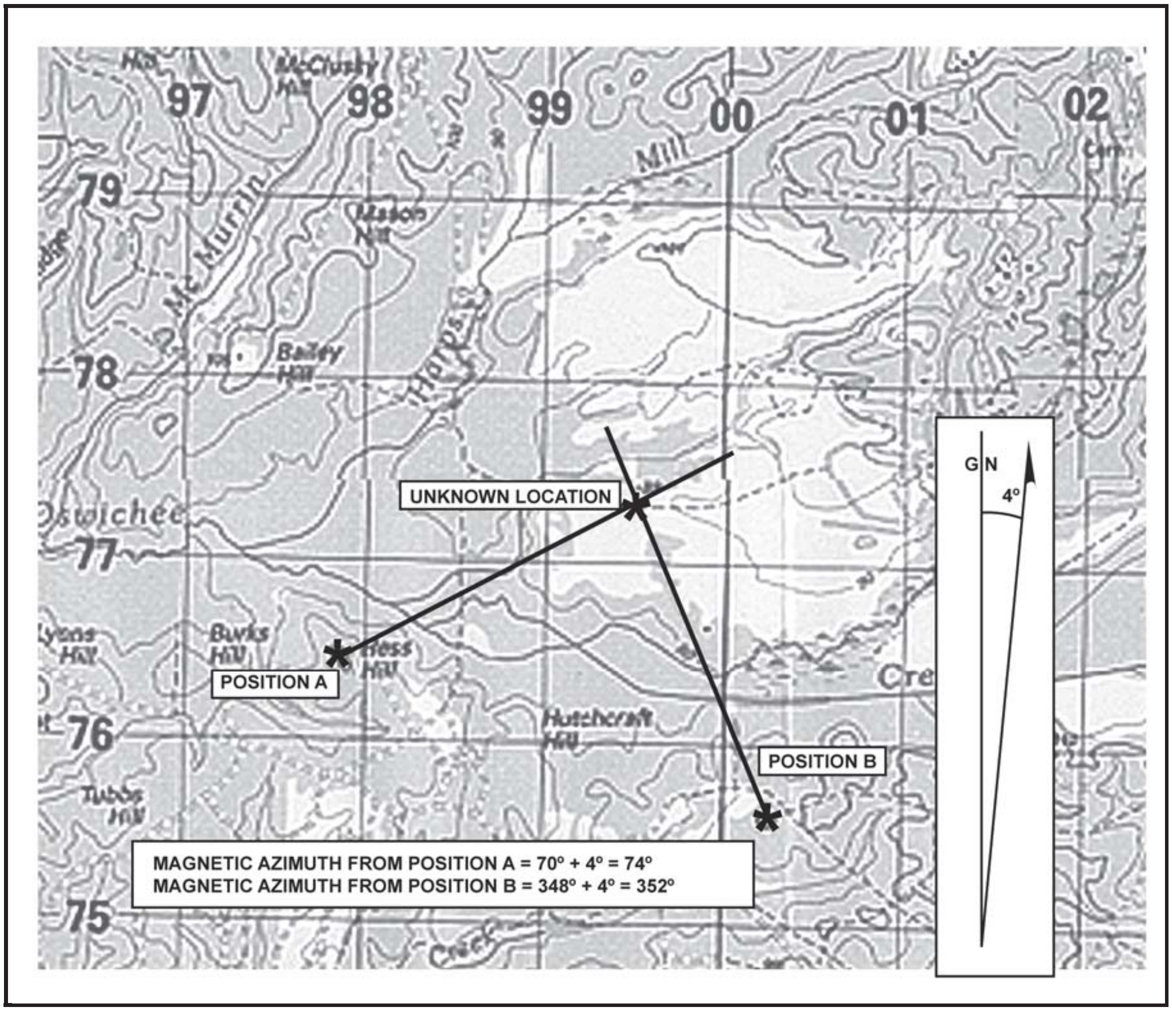


Figure 6-9. Intersection, using map and compass

- The intersection of the lines on the map is the location of the unknown point (C). Determine the grid coordinates to the desired accuracy. (See Figure 6-10.)

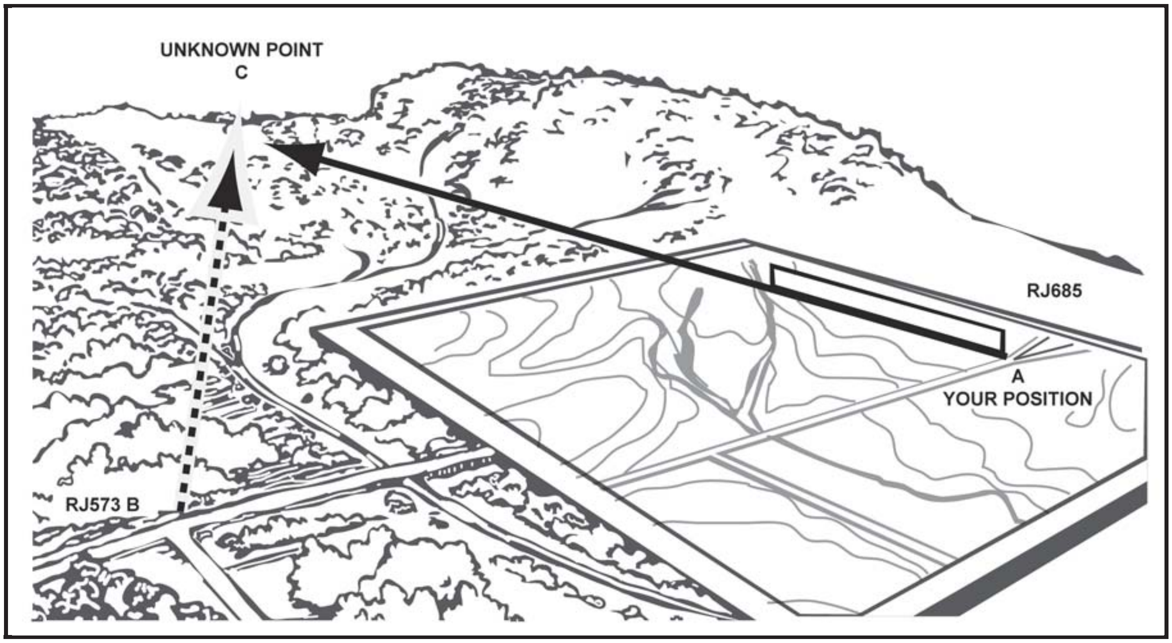


Figure 6-10. Intersection, using a straightedge

RESECTION

6-18. Resection is the method of locating one's position on a map by determining the grid azimuth to at least two well-defined locations that can be pinpointed on the map. For greater accuracy, the desired method of resection is to use three or more well-defined locations.

6-19. When using the map and compass method (see Figure 6-11)—

- Orient the map using the compass.
- Identify two or three known distant locations on the ground and mark them on the map.
- Measure the magnetic azimuth to one of the known positions from the location using a compass.
- Convert the magnetic azimuth to a grid azimuth.
- Convert the grid azimuth to a back azimuth. Using a protractor, draw a line for the back azimuth on the map from the known position back toward the unknown position.
- Measure and convert the magnetic azimuth to a grid azimuth, and convert the grid azimuth to a back azimuth for a second position (and a third position, if desired).
- The intersection of the lines is the location. Determine the grid coordinates to the desired accuracy.

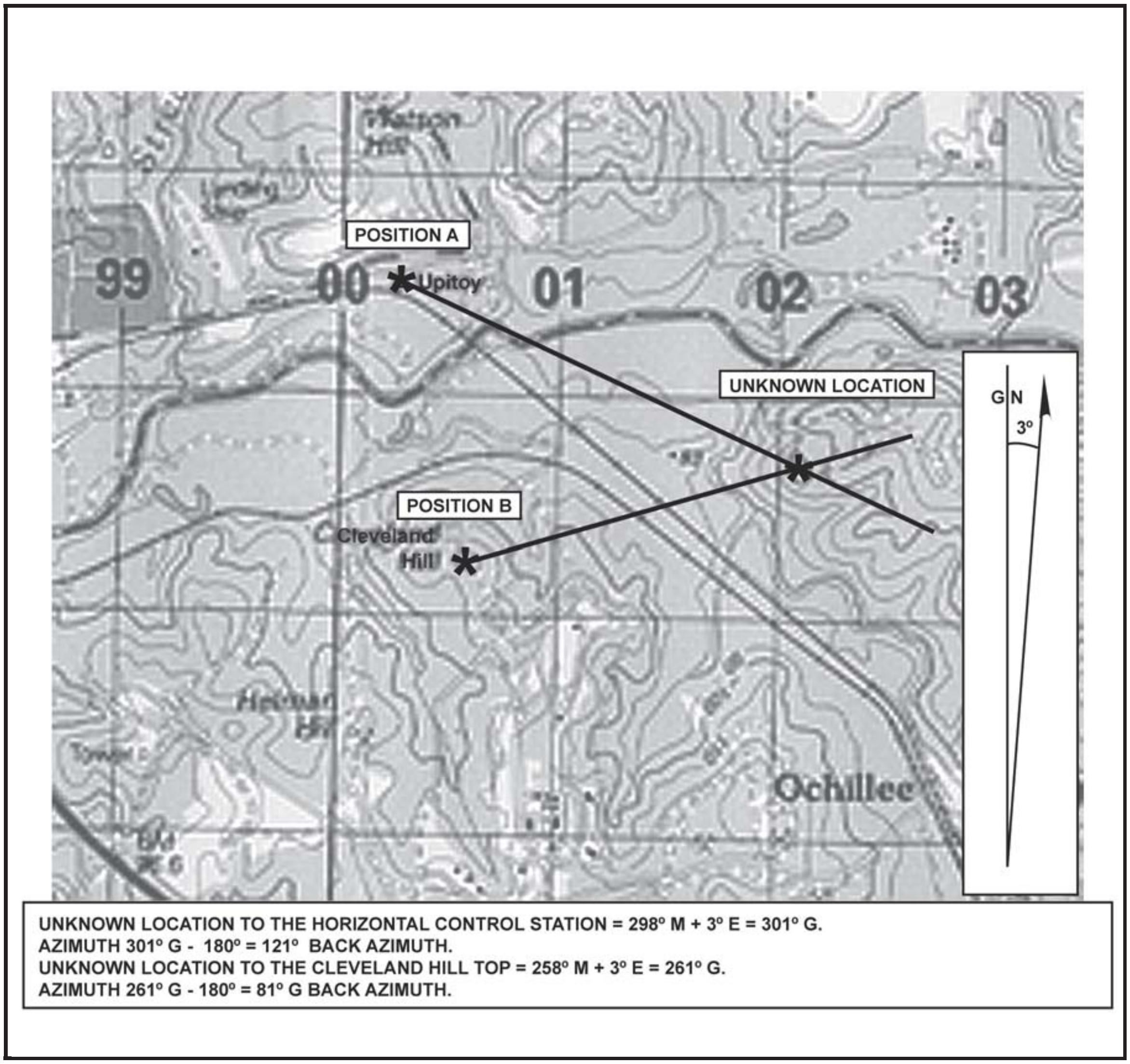


Figure 6-11. Resection with map and compass

6-20. When using the straightedge method (see Figure 6-12)—

- Orient the map on a flat surface by the terrain association method.
- Locate at least two known distant locations or prominent features on the ground and mark them on the map.
- Lay a straightedge on the map using a known position as a pivot point. Rotate the straightedge until the known position on the map is aligned with the known position on the ground.
- Draw a line along the straightedge away from the known position on the ground toward the position.
- Lay a straightedge on the map and draw a line using a second known position.
- The intersection of the lines on the map is the location. Determine the grid coordinates to the desired accuracy.

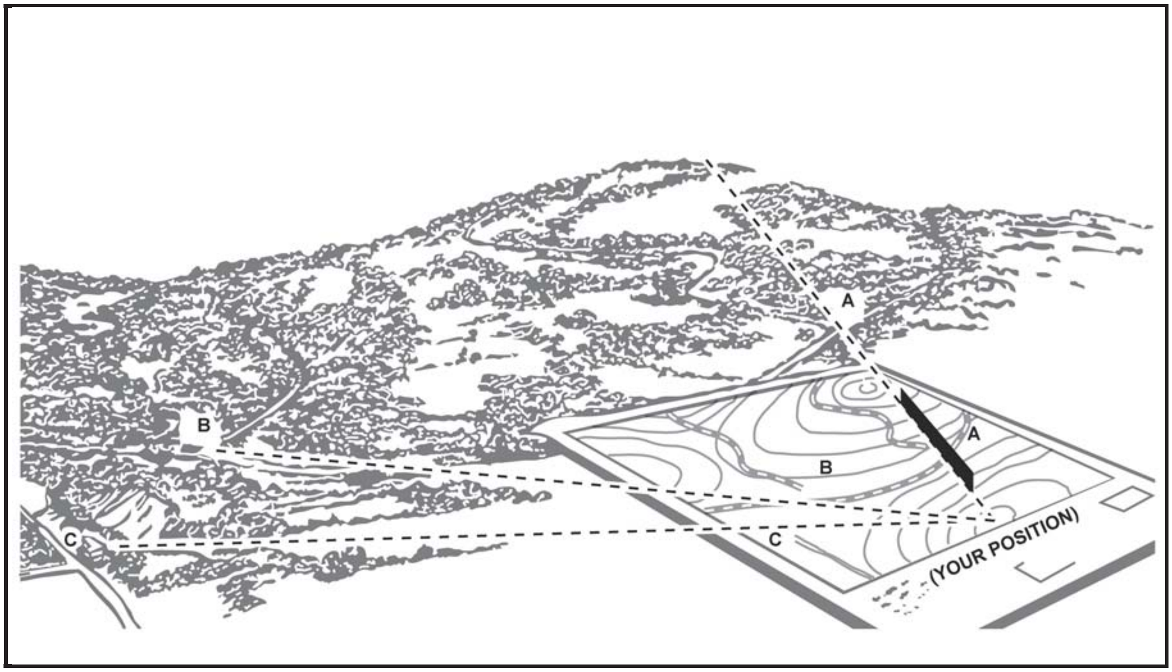


Figure 6-12. Resection with straightedge

MODIFIED RESECTION

6-21. Modified resection is the method of locating one's position on the map when the person is located on a linear feature on the ground, such as a road, canal, or stream. (See Figure 6-13.) Proceed as follows:

- Orient the map using a compass or by terrain association.
- Find a distant point that can be identified on the ground and on the map.
- Determine the magnetic azimuth from the location to the distant known point.
- Convert the magnetic azimuth to a grid azimuth.
- Convert the grid azimuth to a back azimuth. Using a protractor, draw a line for the back azimuth on the map from the known position back toward the unknown position.
- The location of the user is where the line crosses the linear feature. Determine the grid coordinates to the desired accuracy.

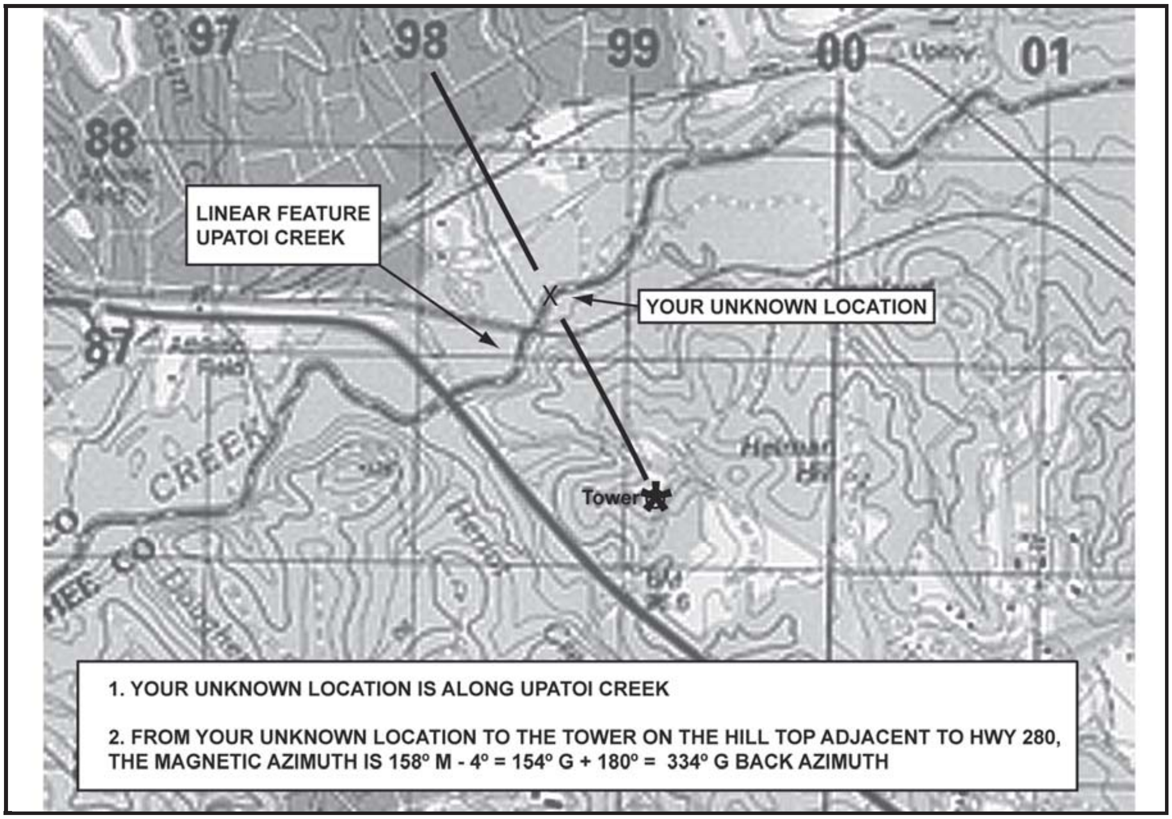


Figure 6-13. Modified resection

POLAR PLOT

6-22. A method of locating or plotting an unknown position from a known point by giving a direction and a distance along that direction line is called polar plot. The following elements are present when using polar plot (see Figure 6-14):

- Present known location on the map.
- Azimuth (grid or magnetic).
- Distance (in meters).

6-23. Using the laser range finder to determine the range enhances accuracy in determining the unknown position's location.

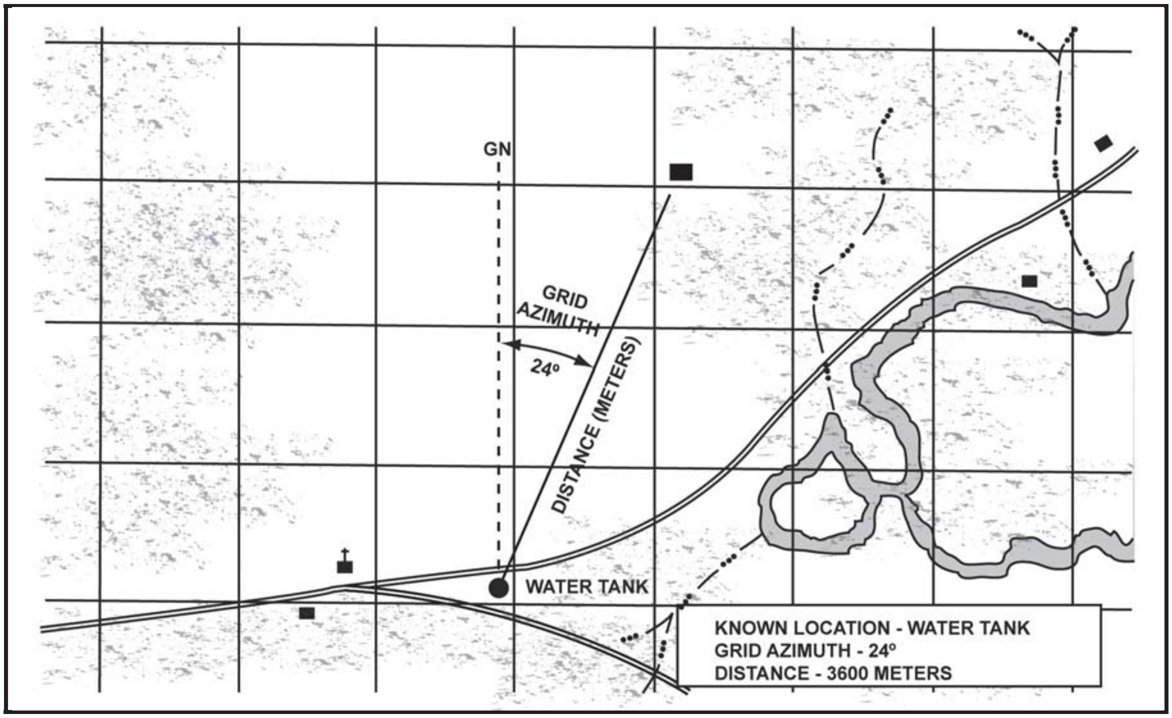


Figure 6-14. Polar plot

This page intentionally left blank.

Chapter 7

Overlays

An overlay is a clear sheet of plastic or semitransparent paper. It is used to display supplemental map and tactical information related to military operations. It is often used as a supplement to orders given in the field. Information is plotted on the overlay at the same scale as on the map, or any other graphic being used. When the overlay is placed over the graphic, the details plotted on the overlay are shown in their true position.

PURPOSE

7-1. Overlays are used to display military operations with enemy and friendly troop dispositions, and as supplements to orders sent to the field. They show detail that aid in understanding the orders, displays of communication networks, and other important information. Because overlays can clarify matters that are difficult to explain clearly in writing, they are also used as annexes to reports made in the field.

MAP OVERLAY

7-2. The three steps in making a map overlay are: orienting the overlay material, plotting and symbolizing the detail, and adding the required marginal information. (See Figure 7-1.)

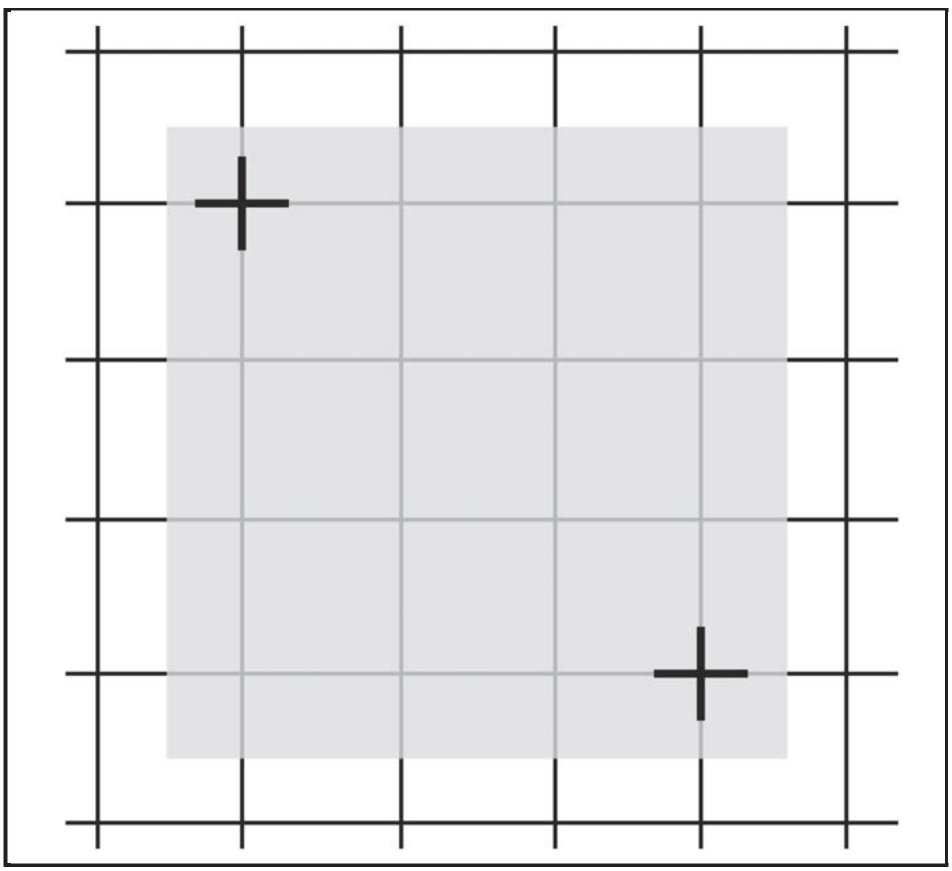


Figure 7-1. Orienting the overlay

7-3. Orient the overlay over the place on the map to be annotated. Then, if possible, attach it to the edges of the map with tape. Trace the grid intersections nearest the two opposite corners of the overlay using a straightedge, and label each with the proper grid coordinates. These register marks show exactly where the overlay fits on the map. Without them, the overlay is difficult to orient.

7-4. It is imperative that absolute accuracy be maintained in plotting the register marks, as the smallest mistake throws off the overlay. When creating an overlay, keep the following considerations in mind:

- To plot detail, use pencils or markers in standard colors that make a lasting mark without cutting the overlay. (Refer to FM 1-02 for more information.)
- Use standard topographic or military symbols where possible. Nonstandard symbols invented by the author are identified in a legend on the overlay. Depending on the conditions under which the overlay is made, it may be advisable to plot the positions first on the map, and then trace them onto the overlay. Since the overlay is to be used as a supplement to orders or reports and the recipient has an identical map, show only the detail that directly concerns the report.
- If observed topographic or cultural features are not shown on the map, such as a new road or a destroyed bridge, plot their positions as accurately as possible on the overlay and mark with the standard topographic symbol.
- If difficulty in seeing through the overlay material is encountered while plotting or tracing detail, lift the overlay from time to time to check the orientation of information being added in reference to the base.

7-5. When all required detail has been plotted or traced on the overlay, print information as close to the lower right-hand corner as detail permits. (See Figure 7-2.) This information includes the following data:

- **Title and objective.** This tells the reader why the overlay was made and may also give the actual location. For example, "Road reconnaissance" is not as specific as "Route 146 road reconnaissance."
- **Time and date**. Any overlay should contain the latest possible information. An overlay received in time is valuable to the planning staff and may affect the entire situation; an overlay that has been delayed may be of little use. Therefore, the exact time the information was obtained aids the recipients in determining its reliability and usefulness.
- **Map reference**. The sheet name, sheet number, map series number, and scale are included. If the reader does not have the same map that was used to construct the overlay, this information provides the information necessary to obtain the appropriate map.
- **Author**. The name, rank, and organization of the author, supplemented with a date and time of preparation of the overlay, lets the reader know if there is a time difference between when the information was obtained and when it was reported.
- **Legend**. If it is necessary to invent nonstandard symbols to show the required information, the legend shows what these symbols mean.
- **Security classification**. This corresponds to the highest classification of the map or the information placed on the overlay. This is also stated if the information and map are unclassified. The locations of the classification notes are shown in Figure 7-2, and the notes appear in both locations as shown.
- **Additional information**. Any other information that amplifies the overlay is also included. Make it as brief as possible.

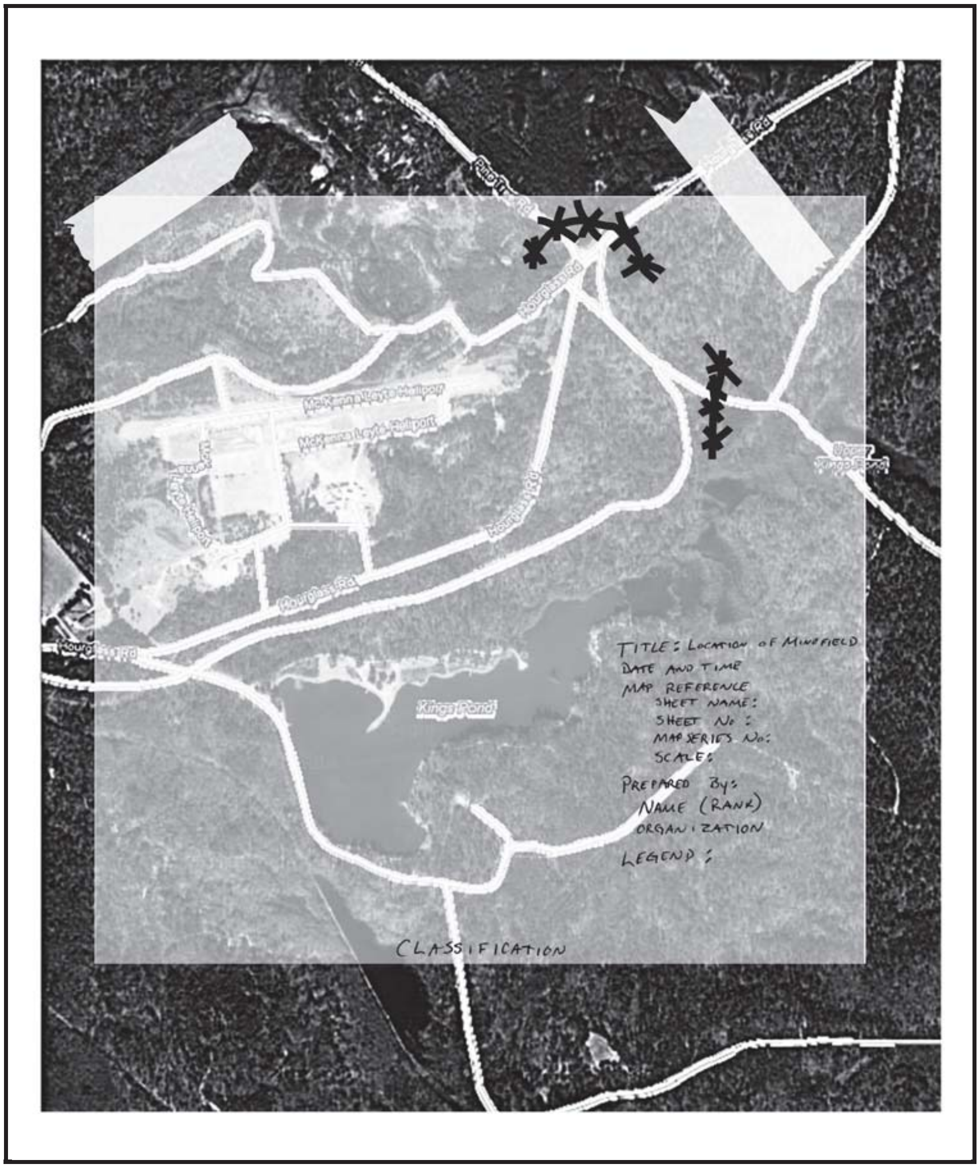


Figure 7-2. Map overlay with marginal information

This page intentionally left blank.

PART TWO

Land Navigation

Chapter 8

Navigation Equipment and Methods

Compasses and GPS devices are the primary navigational tools used when moving in an outdoor world. Soldiers should be thoroughly familiar with compasses, GPS devices, and their uses. Part One of this manual discussed the techniques of map reading. To complement these techniques, a mastery of field movement techniques is essential. This chapter describes the lensatic compass and its uses, and some of the field-expedient methods used to find directions.

TYPES OF COMPASSES

8-1. The lensatic compass is the most common and simplest instrument for measuring direction. The artillery M2 compass is a special-purpose instrument designed for accuracy and is discussed in Appendix F. The wrist/pocket compass is a small magnetic compass that can be attached to a wristwatch band. It contains a north-seeking arrow and a dial in degrees. A protractor can determine azimuths when a compass is not available. However, only grid azimuths can be obtained when using the protractor on a map.

LENSATIC COMPASS

8-2. The lensatic compass (see Figure 8-1) consists of three major parts: the cover, base, and lens. The compass cover protects the floating dial. The cover also contains the sighting wire (front sight) and two luminous sighting slots or dots, used for night navigation. The base of the compass contains the following movable parts:

- The floating dial is mounted on a pivot so it can rotate freely when the compass is held level. Printed on the dial in luminous figures are an arrow and the letters E and W. The arrow always points to magnetic north, and the letters fall at E 90 degrees and W 270 degrees on the dial. There are two scales; the outer scale denotes mils and the inner scale (normally in red) denotes degrees.
- Encasing the floating dial is a glass containing a fixed black index line.
- The bezel ring is a ratchet device that clicks when turned. It contains 120 clicks when rotated fully; each click is equal to 3 degrees. A short luminous line that is used in conjunction with the north-seeking arrow during navigation is contained in the glass face of the bezel ring.
- The thumb loop is attached to the base of the compass.
- The lens is used to read the dial and contains the rear-sight slot used in conjunction with the front for sighting on objects. The rear sight also serves as a lock and clamps the dial when closed for its protection. The rear sight is opened more than 45 degrees to allow the dial to float freely.

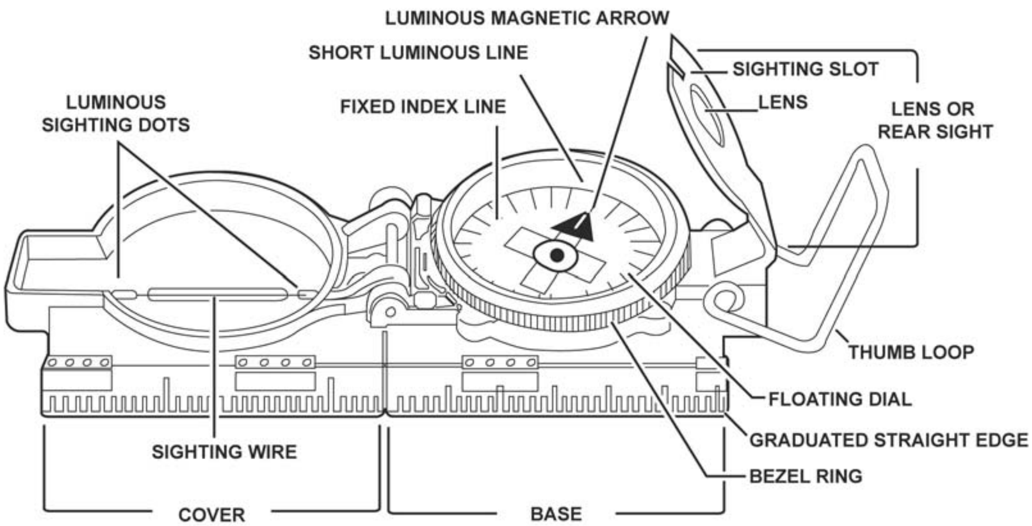


Figure 8-1. Lensatic compass

Note. When opened, the straight edge on the left side of the compass has a 1:50,000 coordinate scale.

WARNING

Some older compasses (pre-1990) have a 1:25,000-scale. This scale can be used with a 1:50,000-scale map, but the values read are divided in half. Check the scale.

COMPASS HANDLING

8-3. Compasses are delicate instruments and should be cared for accordingly. A detailed inspection is required when first obtaining and using a compass. One of the most important parts to check is the floating dial, which contains the magnetic needle. The user also makes sure the sighting wire is straight, the glass and crystal parts are not broken, the numbers on the dial are readable, and that the dial does not stick.

8-4. Metal objects and electrical sources can affect the performance of a compass. However, nonmagnetic metals and alloys do not affect compass readings. The following separation distances are suggested to ensure proper functioning of a compass:

- High-tension power lines..55 m.
- Field gun, truck, or tank...18 m.
- Telegraph or telephone wires and barbed wire........10 m.

8-5. A compass in good working condition is very accurate. However, a compass has to be checked periodically on a known line of direction, such as a surveyed azimuth, using a declination station. Compasses with more than 3 degrees variation should not be used.

8-6. If traveling with the compass unfolded, make sure the rear sight is fully folded down onto the bezel ring. This locks the floating dial, prevents vibration, and protects the crystal and rear sight from damage.

USING A COMPASS

8-7. Magnetic azimuths are determined using magnetic instruments such as lensatic and M2 compasses. Employ the following techniques when using the lensatic compass: centerhold technique and compass-to-cheek technique.

CENTERHOLD TECHNIQUE

8-8. First, open the compass to its fullest so that the cover forms a straightedge with the base. Move the lens (rear sight) to the rearmost position, allowing the dial to float freely. Next, 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. Place the thumb of the other hand between the lens (rear sight) and the bezel ring; extend the index finger along the remaining side of the compass, and the remaining fingers around the fingers of the other hand. Pull your elbows firmly into your sides; this places the compass between your chin and your belt.

8-9. To measure an azimuth, simply turn your entire body toward the object, pointing the compass cover directly at the object. Once you are pointing at the object, look down and read the azimuth from beneath the fixed black index line. (See Figure 8-2.) This preferred method offers the following advantages over the sighting technique:

- It is faster and easier to use.
- It can be used under all conditions of visibility.
- It can be used when navigating over all types of terrain.
- It can be used without putting down the rifle. However, the rifle is slung well back over either shoulder.
- It can be used without removing eyeglasses.

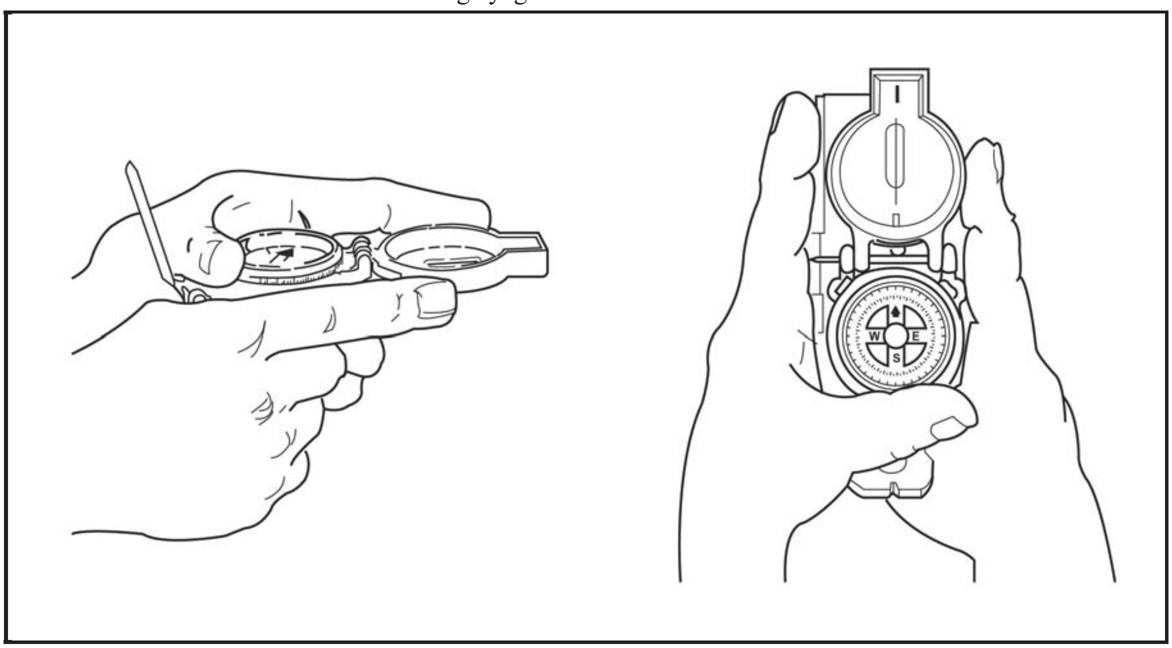


Figure 8-2. Centerhold technique

COMPASS-TO-CHEEK TECHNIQUE

8-10. Fold the cover of the compass containing the sighting wire to a vertical position; then fold the rear sight slightly forward. Look through the rear-sight slot and align the front-sight hairline with the desired object in the distance. Glance down at the dial through the eye lens to read the azimuth. (See Figure 8-3.)

> ***Note.*** The compass-to-cheek technique is used almost exclusively for sighting. It is the best technique for this purpose.

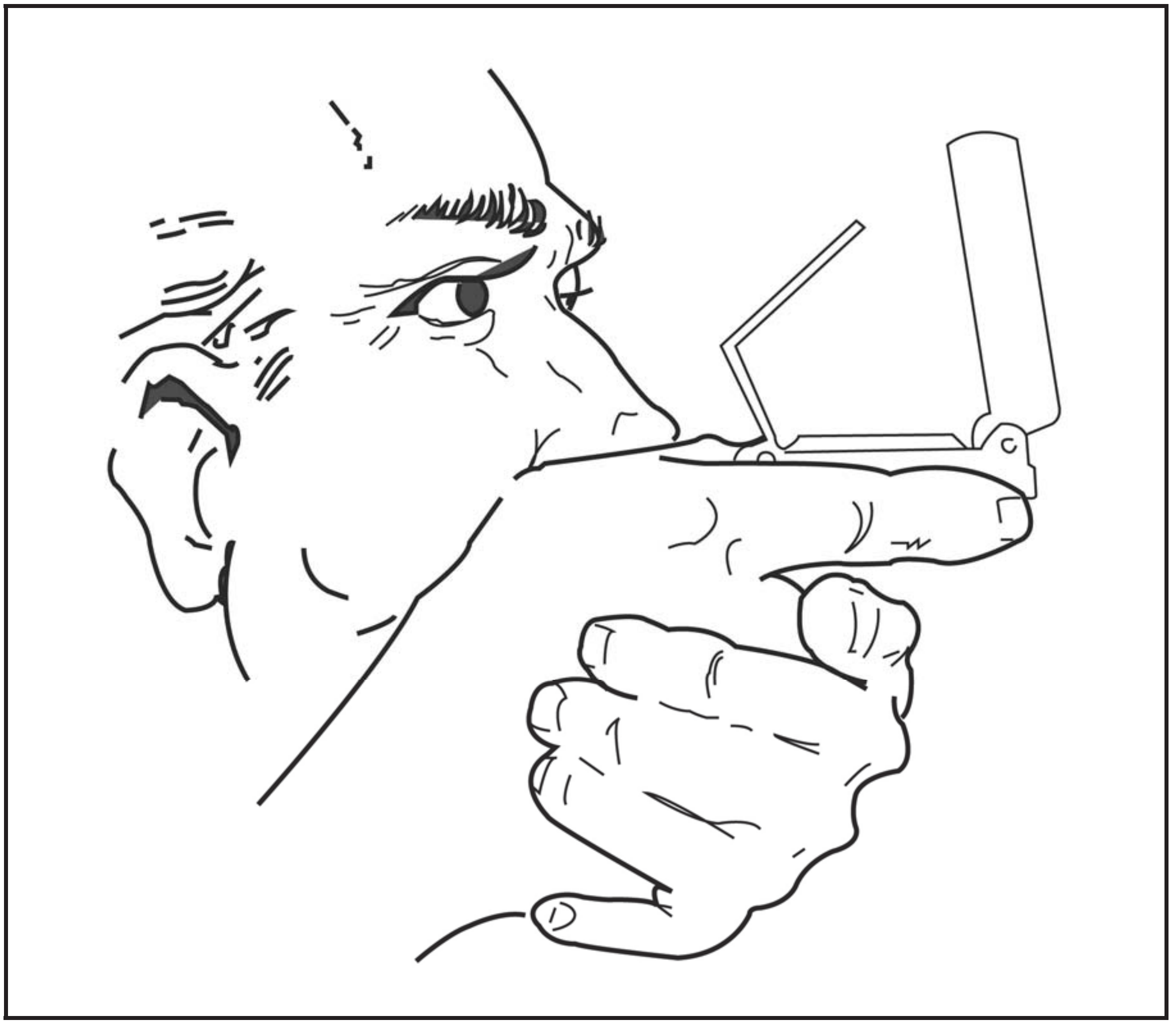


Figure 8-3. Compass-to-cheek technique

PRESETTING A COMPASS AND FOLLOWING AN AZIMUTH

8-11. Although different models of the lensatic compass vary somewhat in the details of their use, the principles are the same. During daylight hours or with a light source—

- Hold the compass level in the palm of the hand.
- Rotate it until the desired azimuth falls under the fixed black index line (for example, 320 degrees), maintaining the azimuth as prescribed. (See Figure 8-4.)
- Turn the bezel ring until the luminous line is aligned with the north-seeking arrow. Once the alignment is obtained, the compass is preset.
- To follow an azimuth, assume the centerhold technique, and turn your body until the north-seeking arrow is aligned with the luminous line. Proceed forward in the direction of the front cover's sighting wire, which is aligned with the fixed black index line that contains the desired azimuth.

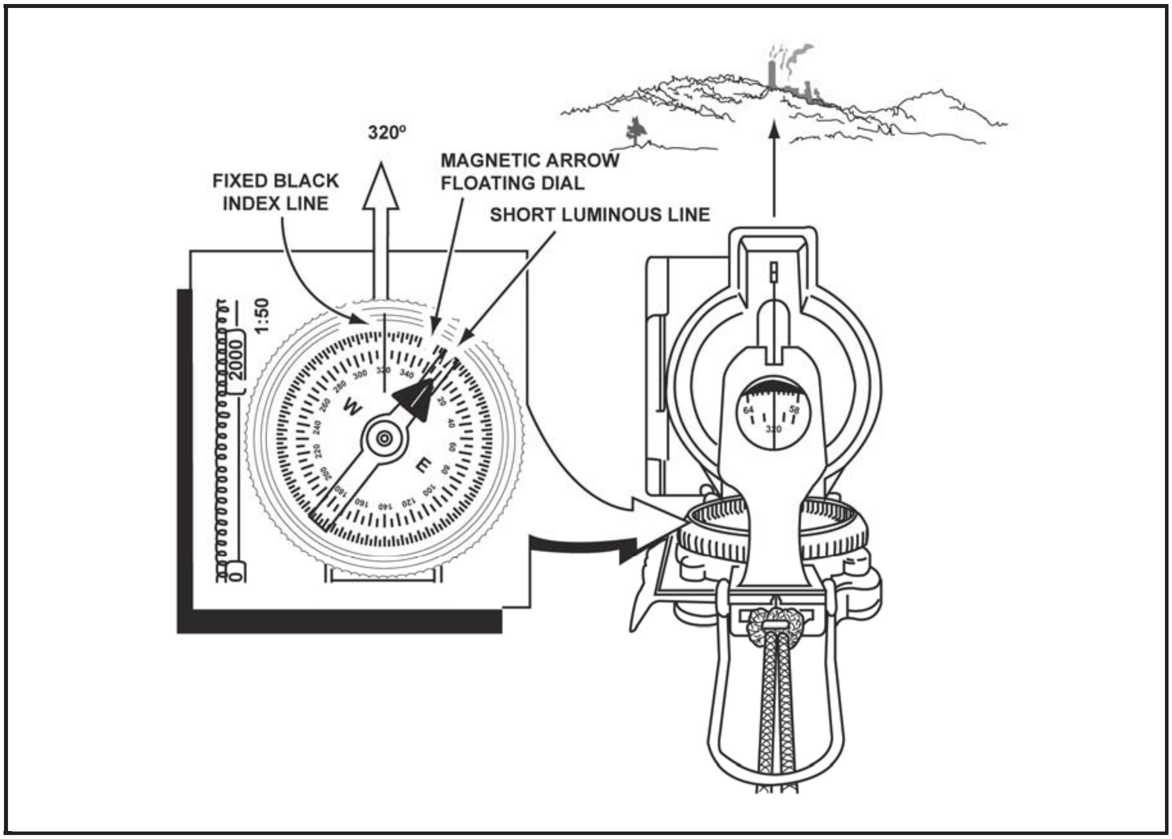


Figure 8-4. Compass preset at 320 degrees

8-12. During limited visibility, an azimuth may be set on the compass by the click method. Remember that the bezel ring contains 3-degree intervals (clicks). To employ the click method—

- Rotate the bezel ring until the luminous line is over the fixed black index line.
- Find the desired azimuth and divide it by three. The result is the number of clicks needed to rotate the bezel ring.
- Count the desired number of clicks. If the desired azimuth is smaller than 180 degrees, the number of clicks on the bezel ring should be counted in a counterclockwise direction. For example, the desired azimuth is 51 degrees; 51 degrees ÷ 3 = 17 clicks counterclockwise. If the desired azimuth is larger than 180 degrees, subtract the number of degrees from 360 degrees and divide by 3 to obtain the number of clicks. Count them in a clockwise direction. For example, the desired azimuth is 330 degrees; 360 degrees − 330 degrees = 30 ÷ 3 = 10 clicks clockwise.
- With the compass preset as described above, assume a centerhold technique and rotate your body until the north-seeking arrow is aligned with the luminous line on the bezel. Proceed forward in the direction of the front cover's luminous dots, which are aligned with the fixed black index line containing the azimuth.
- When the compass is to be used in darkness, an initial azimuth should be set while light is still available, if possible. With the initial azimuth as a base, another azimuth that is a multiple of three can be established using the clicking feature of the bezel ring.

Note. Sometimes the desired azimuth is not exactly divisible by three, causing an option of rounding up or rounding down. Rounding up causes an increase in the value of the azimuth, and the object is to be found on the left. Rounding down causes a decrease in the value of the azimuth, and the object is to be found on the right.

BYPASSING AN OBSTACLE

8-13. To bypass enemy positions or obstacles and still stay oriented, detour around the obstacle by moving at right angles for specified distances. For example, while moving on an azimuth of 90 degrees change the azimuth to 180 degrees and travel for 100 m. Change the azimuth to 90 degrees and travel for 150 m. Change the azimuth to 360 degrees and travel for 100 m. Then, change the azimuth to 90 degrees and return to the original azimuth line. (See Figure 8-5.)

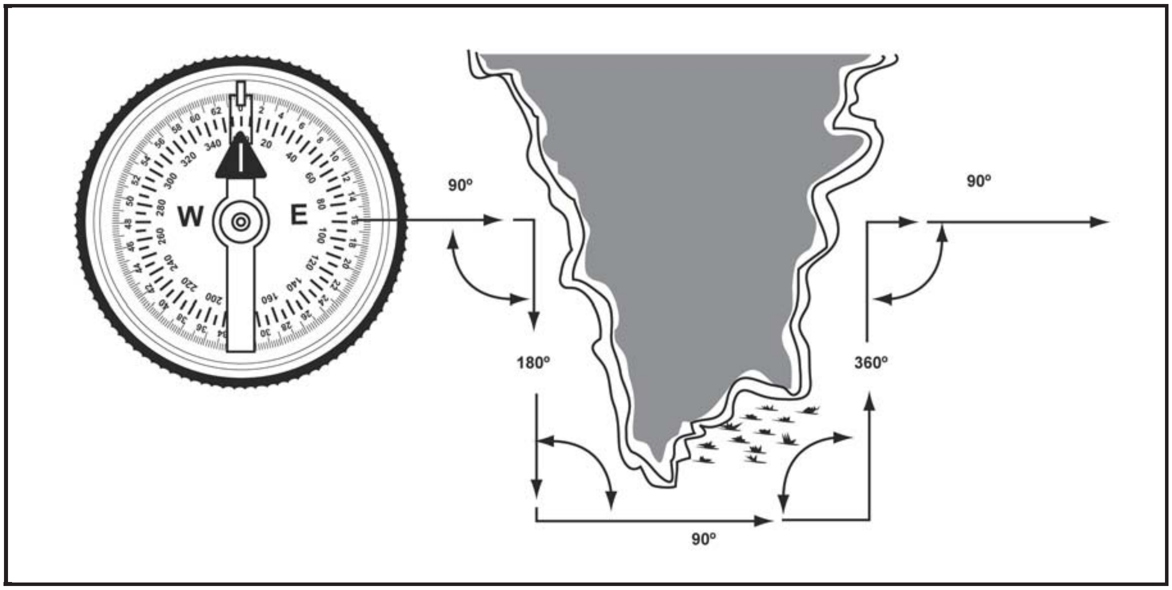


Figure 8-5. Bypassing an obstacle

8-14. Bypassing an unexpected obstacle at night is a fairly simple matter. To make a 90-degree turn to the right, hold the compass in the centerhold technique; turn until the center of the luminous letter E is under the luminous line (*do not* move the bezel ring). To make a 90-degree turn to the left, turn until the center of the luminous letter W is under the luminous line. This does not require changing the compass setting (bezel ring), and it ensures accurate 90-degree turns.

OFFSET

8-15. A deliberate offset is a planned magnetic deviation to the right or left of an azimuth to an objective. Use it when the objective is located along or in the vicinity of a linear feature such as a road or stream. Due to errors in compass or map reading, the linear feature may be reached without knowing whether the objective lies to the right or left. A deliberate offset by a known number of degrees in a known direction compensates for possible errors and ensures that upon reaching the linear feature, the user knows whether to go right or left to reach the objective. Ten degrees is an adequate offset for most tactical uses. Each degree offset moves the course about 18 m to the right or left for each 1000 m traveled. For example, in Figure 8-6, the number of degrees offset is 10 degrees. If the distance traveled to "X" is 1000 m, then "X" is located about 180 m to the right of the objective.

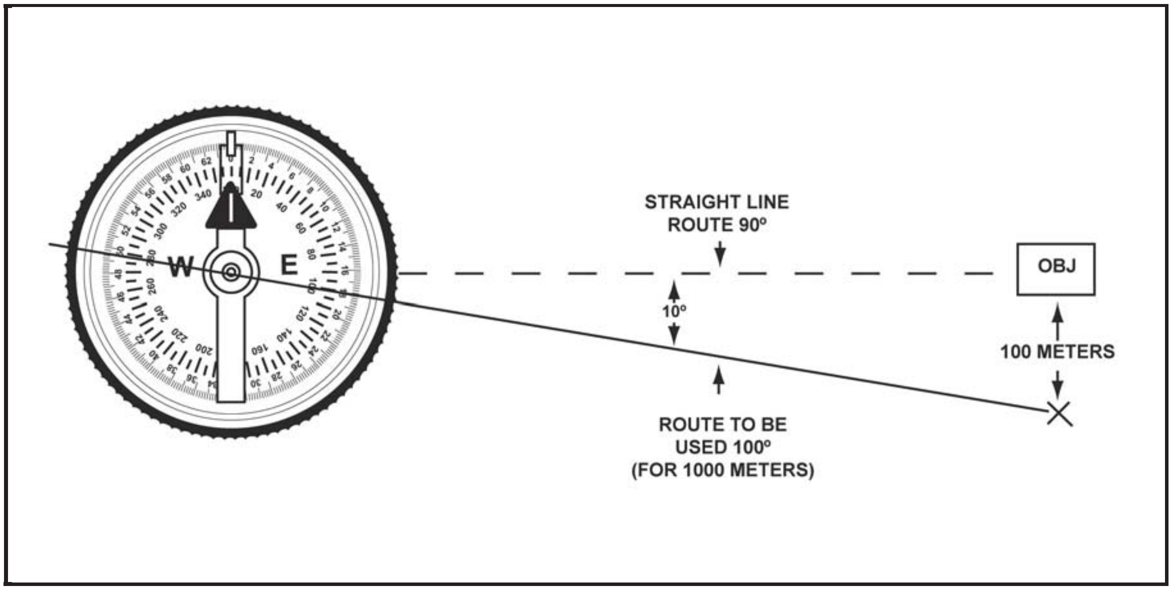


Figure 8-6. Deliberate offset to the objective

FIELD-EXPEDIENT METHODS

8-16. When a compass is not available, different techniques may be used to determine the four cardinal directions. The shadow-tip, watch, and star methods are outlined below.

Shadow-Tip Method

8-17. The shadow-tip method (see Figure 8-7) is a simple and accurate technique to find direction by the sun. It consists of four basic steps:

- **Step 1.** Place a stick or branch into the ground at a level spot where a distinctive shadow is cast. Mark the shadow tip with a stone, twig, or other means. This first shadow mark is always the west direction.
- **Step 2.** Wait 10 to 15 minutes until the shadow tip moves a few inches. Mark the new position of the shadow tip in the same way as the first.
- **Step 3.** Draw a straight line through the two marks to obtain an approximate east-west line.
- **Step 4**. Standing with the first mark (west) to your left, the other directions are simple; north is to the front, east is to the right, and south is to the rear.

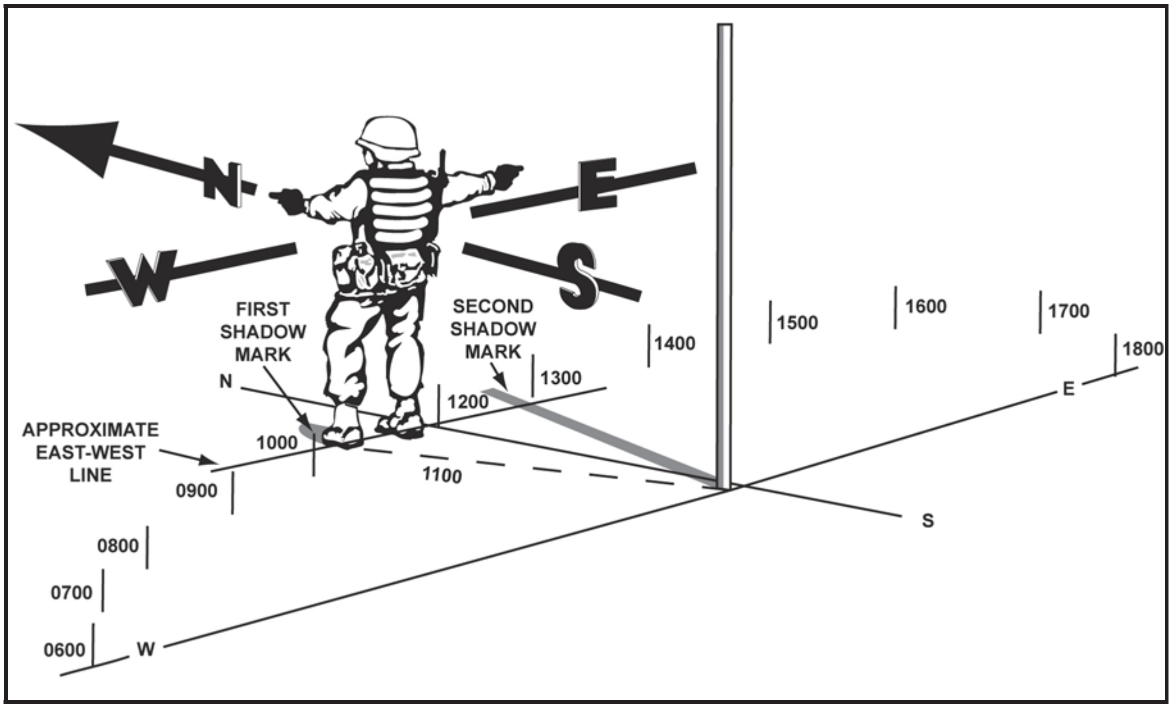


Figure 8-7. Determining directions shadow

8-18. A line drawn perpendicular to the east-west line at any point is the approximate north-south line. If you are uncertain which direction is east and which is west, observe this simple rule—the first shadow-tip mark is always in the west direction, everywhere on earth.

WATCH METHOD

8-19. A watch can be used to determine the approximate true north and true south. In the north temperate zone only, the hour hand is pointed toward the sun. A south line can be found midway between the hour hand and 1200 hours, standard time. If on daylight savings time, the north-south line is found between the hour hand and 1300 hours. If there is doubt as to which end of the line is north, remember that the sun is in the east before noon and in the west after noon.

8-20. The watch may also be used to determine direction in the south temperate zone; however, the method is different. The 1200-hour dial is pointed toward the sun, and halfway between 1200 hours and the hour hand is a north line. If on daylight savings time, the north line lies midway between the hour hand and 1300 hours. (See Figure 8-8.)

8-21. The watch method can be in error, especially in the lower latitudes, and may cause *circling*. To avoid this, make a shadow clock and set your watch to the time indicated. After traveling for an hour, take another shadow-clock reading. Reset your watch, if necessary.

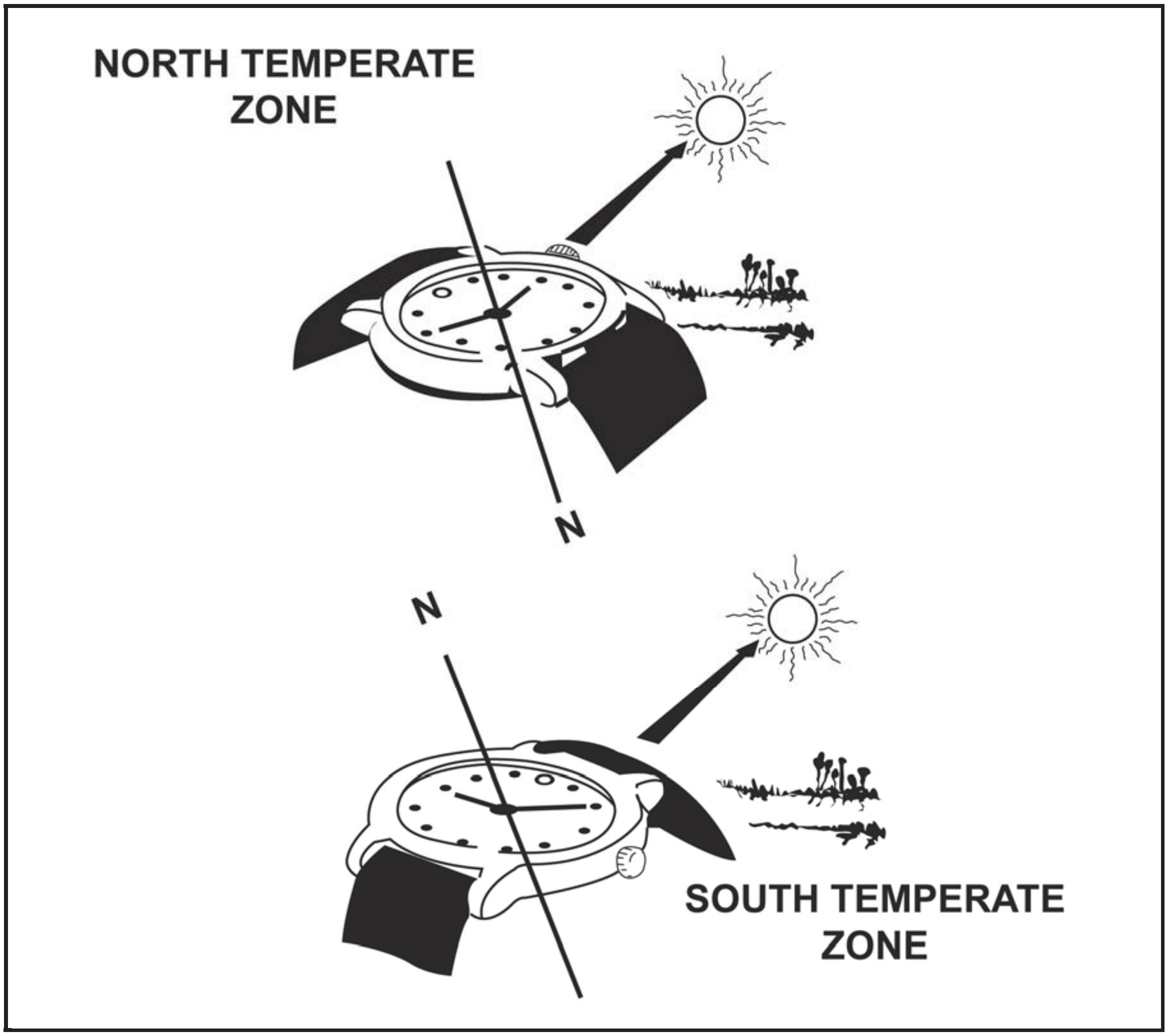


Figure 8-8. Determining direction using a watch

STAR METHOD

8-22. Less than 60 of about 5,000 stars visible to the eye are used by navigators. The stars seen as we look up at the sky at night are not evenly scattered across the whole sky. Instead they are in groups called constellations.

8-23. The constellations that are seen depend partly on where one is located on earth, the time of year, and time of night. The night changes with the seasons due to the journey of the earth around the sun. It also changes from hour to hour because the turning earth makes some constellations seem to travel in a circle, but there is one star that is in almost exactly the same place in the sky all night long every night. It is the North Star, also known as the Polar Star or Polaris.

8-24. The North Star is less than 1 degree off the true north and does not move from its place because the axis of the earth is pointed toward it. The North Star is in the group of stars called the Little Dipper. It is the last star in the handle of the dipper. The two stars in the Big Dipper help when trying to find the North Star. They are called the Pointers, and an imaginary line drawn through them multiplied five times their distance, points directly to the North Star.

8-25. Many stars are brighter than the North Star, but none is more important because of its location. However, the North Star can only be seen in the northern hemisphere so it does not serve as a guide south of the equator. The farther one goes north, the higher the North Star is in the sky, and above latitude 70 degrees it is too high in the sky to be useful. (See Figure 8-9.)

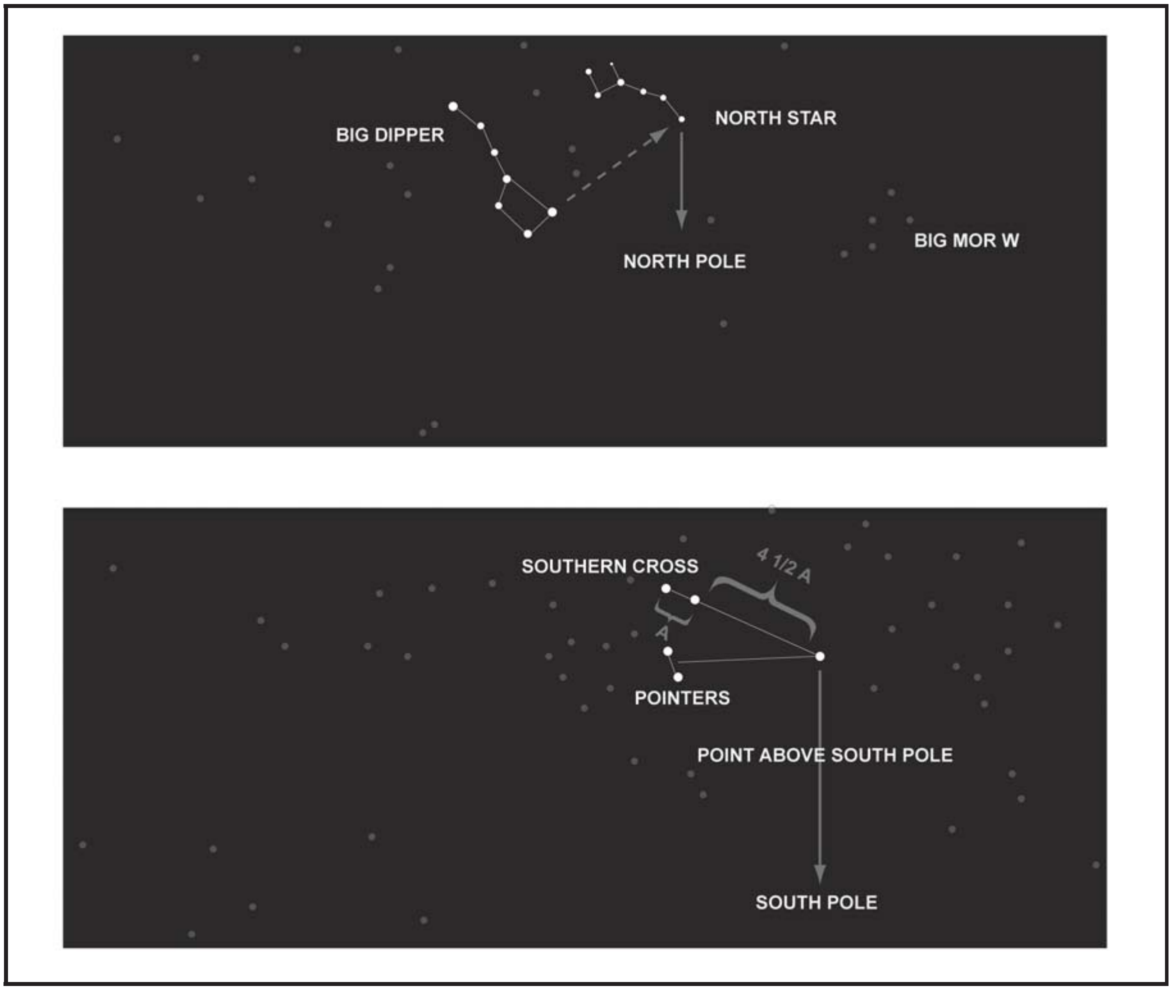


Figure 8-9. Determining direction by the North Star and Southern Cross

8-26. Depending on the star selected for navigation, azimuth checks are necessary. A star near the north horizon serves for about half an hour. When moving south, azimuth checks should be made every 15 minutes. When traveling east or west, the difficulty of staying on azimuth is caused more by the likelihood of the star climbing too high in the sky or losing itself behind the western horizon than it is by the star changing direction angle. When this happens, it is necessary to change to another guide star.

8-27. The Southern Cross is the main constellation used as a guide south of the equator, and the general directions for using north and south stars are reversed. When navigating using the stars as guides, the user knows the different constellation shapes and their locations throughout the world. (See Figures 8-10 and 8-11.)

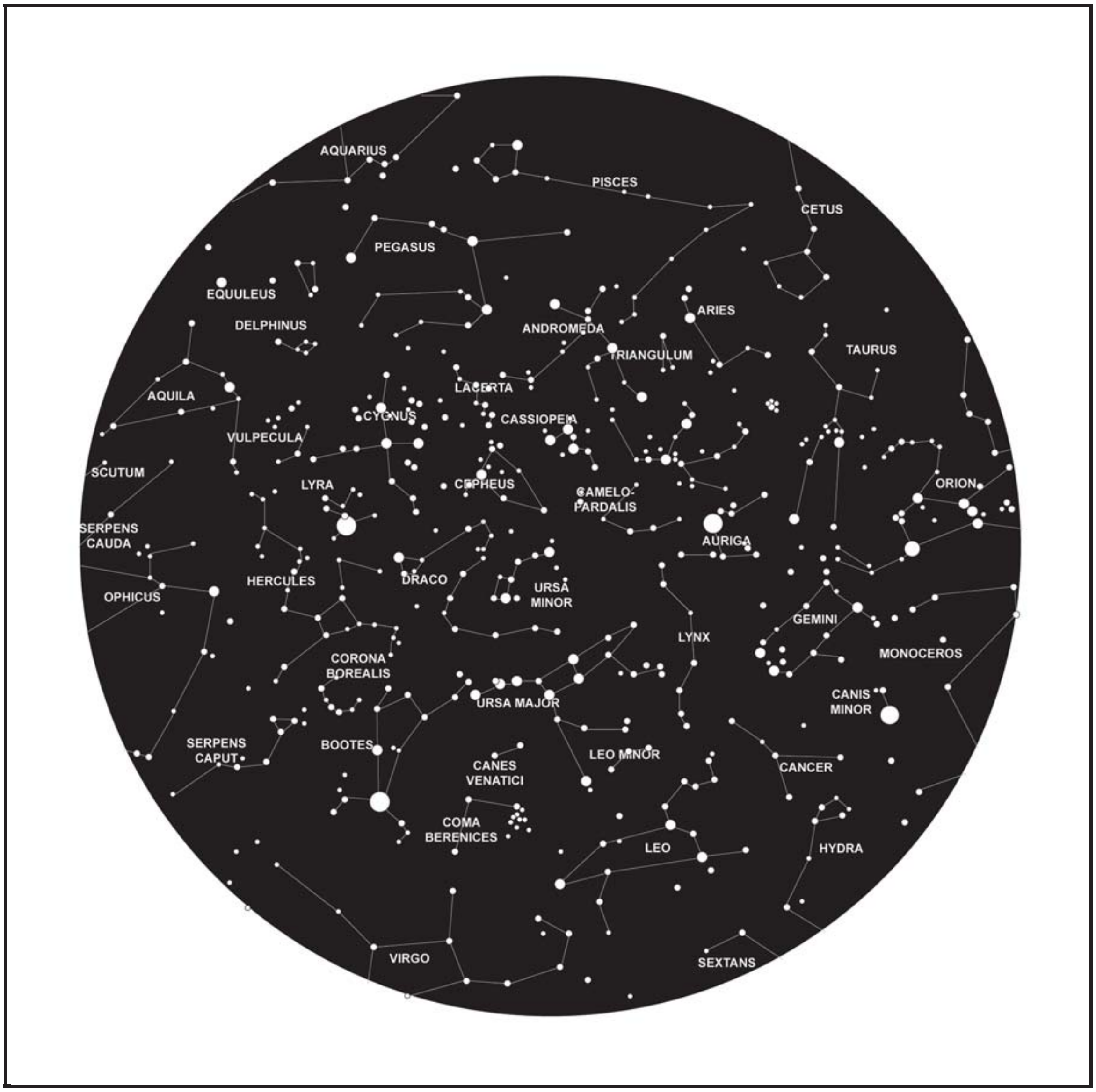


Figure 8-10. Constellations, northern hemisphere

Figure 8-11. Constellations, southern hemisphere

GLOBAL POSITIONG SYSTEM

8-28. The GPS is a space-based, global, all-weather, continuously available, radio positioning navigation system. It is highly accurate in determining position location derived from signal triangulation from a satellite constellation system. It is capable of determining latitude, longitude, and altitude of the individual user. It is fielded in handheld, man pack, vehicular, aircraft, and watercraft configurations. The GPS receives and processes data from satellites on a simultaneous or sequential basis. It measures the velocity and range with respect to each satellite, processes the data in terms of an earth-centered, earth-fixed coordinate system, and displays the information to the user in geographic or military grid coordinates. (See Appendix G, H, and I for more information on the GPS and GPS devices.)

8-29. The GPS can provide precise steering information and position location. The receiver can accept many checkpoints entered in the coordinate system by the user and convert them to the desired coordinate system. The user then calls up the desired checkpoint and the receiver displays direction and distance to the checkpoint. The GPS does not have inherent drift and the receiver automatically updates its position. The receiver can also compute time to the next checkpoint.

8-30. Specific uses for the GPS are position location; navigation; weapon location; target and sensor location; coordination of firepower; scout and screening operations; combat resupply; location of obstacles, barriers, and gaps; and communication support. The GPS also has the potential to allow units to train Soldiers and provide—

- Performance feedback.
- Knowledge of routes taken by the Soldier.
- Knowledge of errors committed by the Soldier.
- Comparison of planned versus executed routes.
- Safety and control of lost and injured Soldiers.

This page intentionally left blank.

Chapter 9

Elevation and Relief

The elevation of points on the ground and the relief of an area affect movement, positioning, and sometimes the effectiveness of military units. Soldiers know how to determine locations of points, measure distances and azimuths, and identify symbols on a map. They also determine the elevation and relief of areas on standard military maps. To do this, Soldier's first understand how the mapmaker indicated the elevation and relief on the map.

DEFINITIONS

9-1. The reference or start point for vertical measurement of elevation on a standard military map is the datum plane or mean sea level, the point halfway between high tide and low tide. Elevation of a point on the earth's surface is the vertical distance it is above or below mean sea level. Relief is the representation (as depicted by the mapmaker) of the shapes of hills, valleys, streams, or terrain features on the earth's surface.

9-2. Digital terrain is only accurate to the level of data input and display capabilities of the device, software, and the user display being accessed by the Soldier. These digital devices, systems, simulators, and simulations use digital terrain models and digital elevation models to express map data. Generally digital terrain models represent the sloped contour surface of the earth, without representation of man-made objects and vegetation. The digital elevation model represents the sloped contour surface of the earth, along with surface features such as man-made objects and vegetation. The depiction or exclusion of the map data including elevation, relief, terrain shapes, and terrain features is based on the system and software accessed.

METHODS OF DEPICTING RELIEF

9-3. Mapmakers use several methods to depict relief of the terrain: layer tinting, form lines, shaded relief, hachures, and contour lines.

9-4. Layer tinting is a method of showing relief by color. A different color is used for each band of elevation. Each shade of color, or band, represents a definite elevation range. A legend is printed on the map margin to indicate the elevation range represented by each color. However, this method does not allow the map user to determine the exact elevation of a specific point—only the range.

9-5. Form lines are not measured from a datum plane. Form lines have no standard elevation and give only a general idea of relief. Form lines are represented on a map as dashed lines and are never labeled with representative elevations.

9-6. Relief shading indicates relief by a shadow effect achieved with tone and color that result in the darkening of one side of terrain features such as hills and ridges. The darker the shading, the steeper the slope. Shaded relief is sometimes used in conjunction with contour lines to emphasize these features.

9-7. Hachures are short, broken lines used to show relief and are sometimes used with contour lines. They do not represent exact elevations, but are mainly used to show large, rocky outcrop areas. Hachures are used extensively on small-scale maps to show mountain ranges, plateaus, and mountain peaks.

9-8. Contour lines are the most common method of showing relief and elevation on a standard topographic map. A contour line represents an imaginary line on the ground, above or below sea level. All points on the contour line are at the same elevation. The elevation represented by contour lines is the vertical distance above or below sea level. The three types of contour lines (see Figure 9-1) include—

- **Index.** Starting at zero elevation or mean sea level, every fifth contour line is a heavier line. These are known as index contour lines. Normally, each index contour line is numbered at some point. This number is the elevation of that line.

- **Intermediate.** The contour lines falling between the index contour lines are called intermediate contour lines. These lines are finer and do not have their elevations given. There are normally four intermediate contour lines between index contour lines.
- **Supplementary**. These contour lines resemble dashes. They show changes in elevation of at least one-half the contour interval. Supplementary lines are normally found where there is very little change in elevation, such as on fairly level terrain.

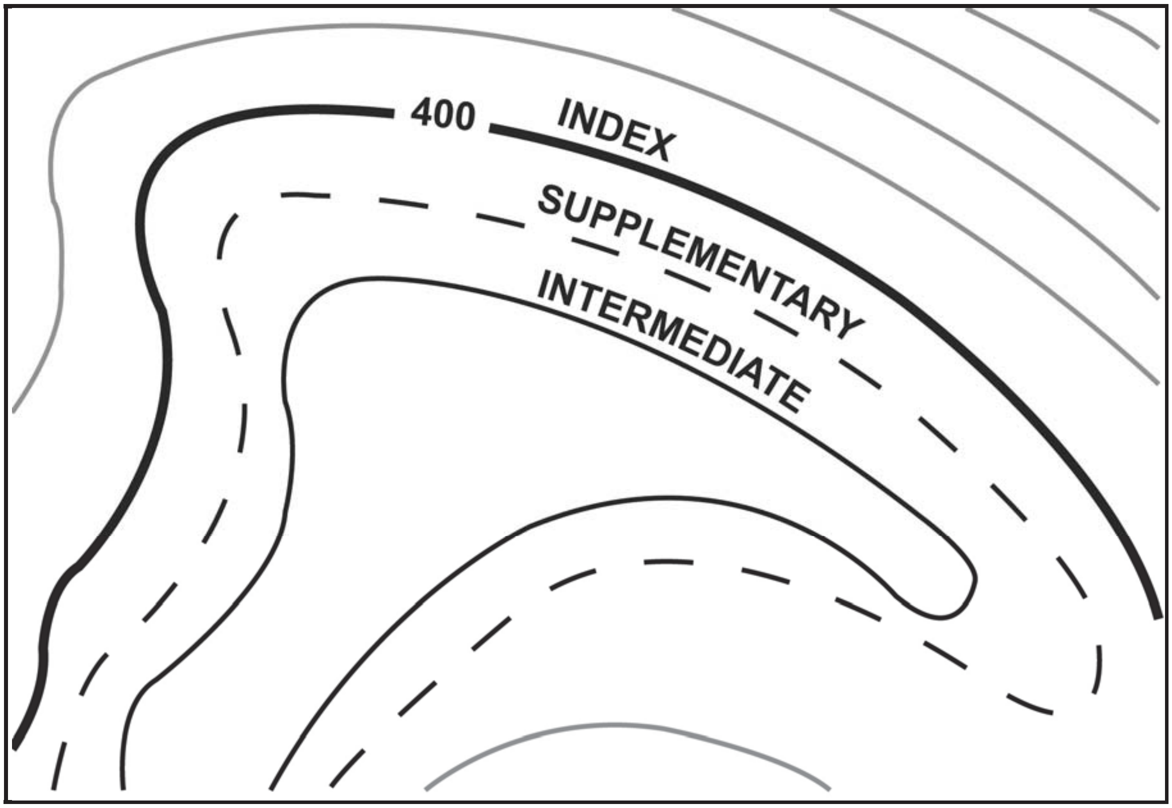


Figure 9-1. Contour lines

CONTOUR INTERVALS

9-9. Before the elevation of a point on the map can be determined, the user knows the contour interval for the map being used. The contour interval measurement given in the marginal information is the vertical distance between adjacent contour lines. Use the following procedures to determine the elevation of a point on the map:

- Determine the contour interval and the unit of measure used; for example, feet, meters, or yards. (See Figure 9-2.) Find the numbered index contour line nearest the point being determined for elevation.
- Determine if the elevation is going higher or lower. In Figure 9-2, point (a) is between the index contour lines. The lower index contour line is numbered 500, which means a point on that line is at an elevation of 500 m above mean sea level. The upper index contour line is numbered 600, or 600 m. Going from the lower to the upper index contour line shows an increase in elevation.
- To determine the exact elevation of point (a), start at the index contour line numbered 500 and count the number of intermediate contour lines to point (a). Point (a) is located on the second intermediate contour line above the 500-m index contour line. The contour interval is 20 m (see Figure 9-2), and each intermediate contour line crossed to get to point (a) adds 20 m to the 500-m index contour line. The elevation of point (a) is 540 m; the elevation has increased.
- To determine the elevation of point (b), go 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-m index contour line. Below means downhill or a lower elevation. Therefore, point (b) is located at an elevation of 580 m. If the elevation increases; add the contour

interval to the nearest index contour line. If it is decreasing, subtract the contour interval from the nearest index contour line.

- To determine the approximate elevation to a hilltop without a survey marker, add one-half the contour interval to the elevation of the last contour line. (See Figure 9-2, point c.) In this example, the last contour line before the hilltop is an index contour line numbered 600. Add one-half the contour interval, 10 m, to the index contour line. The elevation of the hilltop would be 610 m.

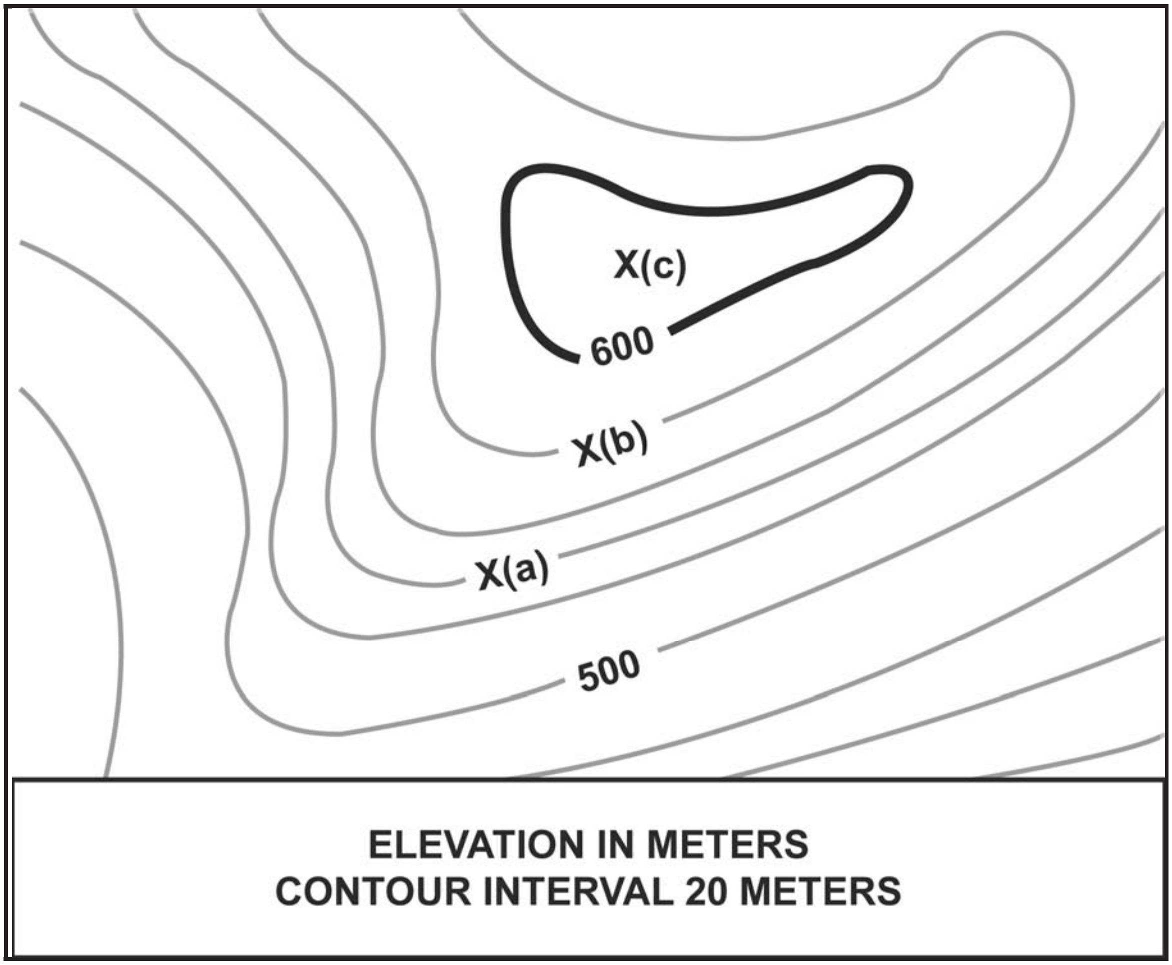


Figure 9-2. Points on contour lines and contour interval note

9-10. There may be times when elevation points need to be determined to a greater accuracy. To do this, determine how far between the two contour lines the point lays. However, most military needs are satisfied by estimating the elevation of points between contour lines. (See Figure 9-3.)

- If the point is less than one-fourth the distance between contour lines, the elevation is the same as the last contour line. In Figure 9-3, the elevation of point A is 100 m. To estimate the elevation of a point between one-fourth and three-fourths of the distance between contour lines, add one-half the contour interval to the last contour line.
- Point B is one-half the distance between contour lines. The contour line immediately below point b is at an elevation of 160 m. The contour interval is 20 m; one-half the contour interval is 10 m. In this case, add 10 m to the last contour line of 160 m. The elevation of point b is about 170 m.

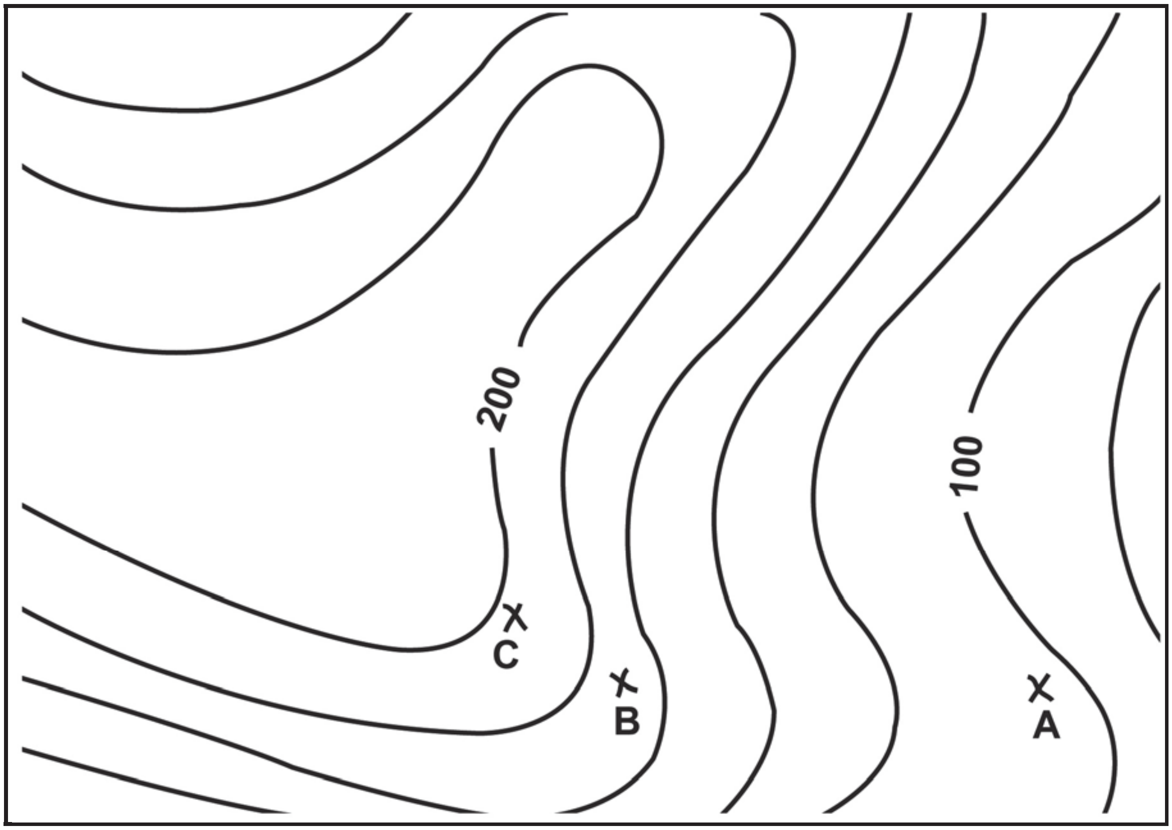


Figure 9-3. Points between contour lines

9-11. A point located more than three-fourths of the distance between contour lines is considered to be at the same elevation as the next contour line. Point C is located three-fourths of the distance between contour lines. In Figure 9-3, point c is considered to be at an elevation of 200 m.

9-12. To estimate the elevation to the bottom of a depression, subtract one-half the contour interval from the value of the lowest contour line before the depression. In Figure 9-4, the lowest contour line before the depression is 240 m in elevation, making the elevation at the edge of the depression 240 m. To determine the elevation at the bottom of the depression, subtract one-half the contour interval. The contour interval for this example is 20 m. Subtract 10 m from the lowest contour line immediately before the depression. The result is that the elevation at the bottom of the depression is 230 m. The tick marks on the contour line forming a depression always point to lower elevations.

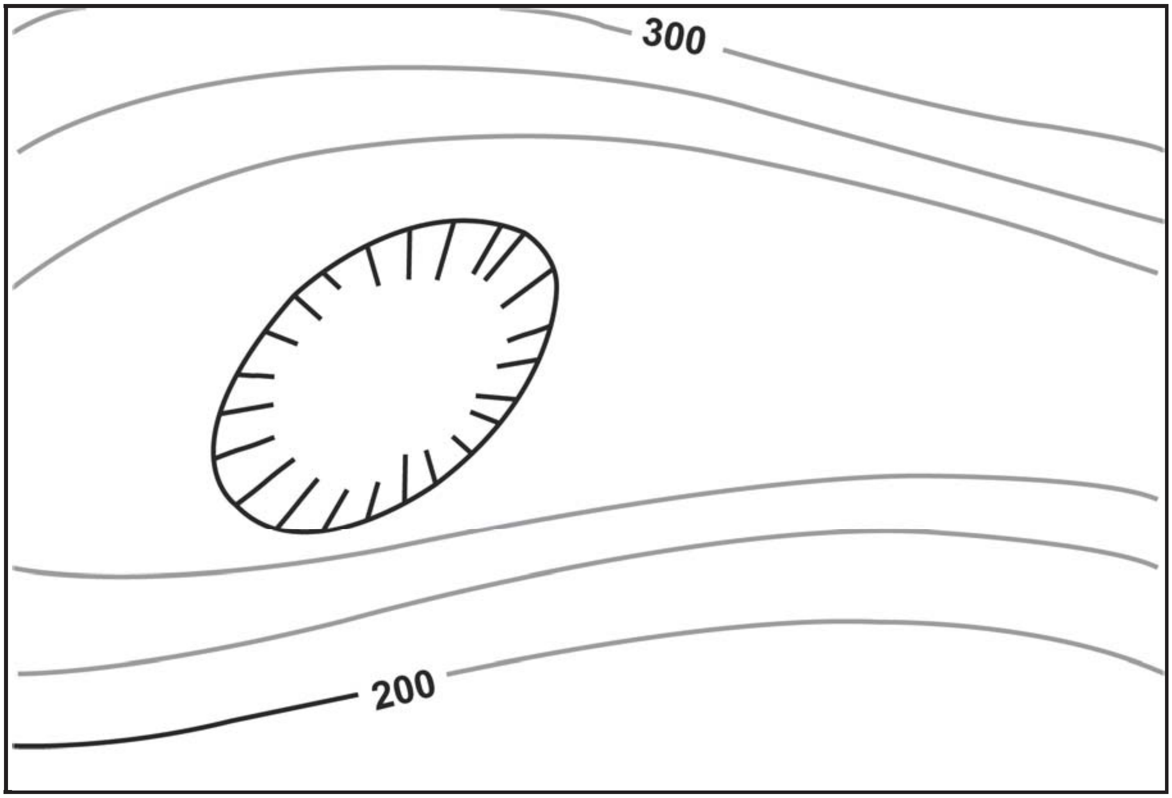


Figure 9-4. Depression

9-13. In addition to the contour lines, bench marks (BMs) and spot elevations are used to indicate points of known elevations on the map. Bench marks, the more accurate of the two, are symbolized by a black X; for example X BM 214. The 214 indicates that the center of the X is at an elevation of 214 units of measure (feet, meters, or yards) above mean sea level. To determine the units of measure, refer to the contour interval in the marginal information.

9-14. Spot elevations are shown by a brown X and are usually located at road junctions, hilltops, and other prominent terrain features. If the elevation is shown in black numerals, it has been checked for accuracy; if it is in brown, it has not been checked.

Note. New maps are printed using a dot instead of a brown X. Maps with a brown X and meter elevation marks continue to be issued.

TYPES OF SLOPES

9-15. The rate of rise or fall of a terrain feature is known as its slope. Depending upon the military mission, Soldiers may need to determine not only the height of a hill, but also the degree of the hill's slope. The speed at which equipment or personnel can move is affected by the slope of the ground or terrain feature. This slope can be determined from the map by studying the contour lines—the closer the contour lines, the steeper the slope; the farther apart the contour lines, the gentler the slope. Four types of slopes that concern the military are gentle, steep, concave, and convex.

9-16. Contour lines showing a uniform, gentle slope are evenly spaced and wide apart. (See Figure 9-5.) Considering relief only, a uniform, gentle slope allows the defender to use grazing fire. The attacking force has to climb a slight incline.

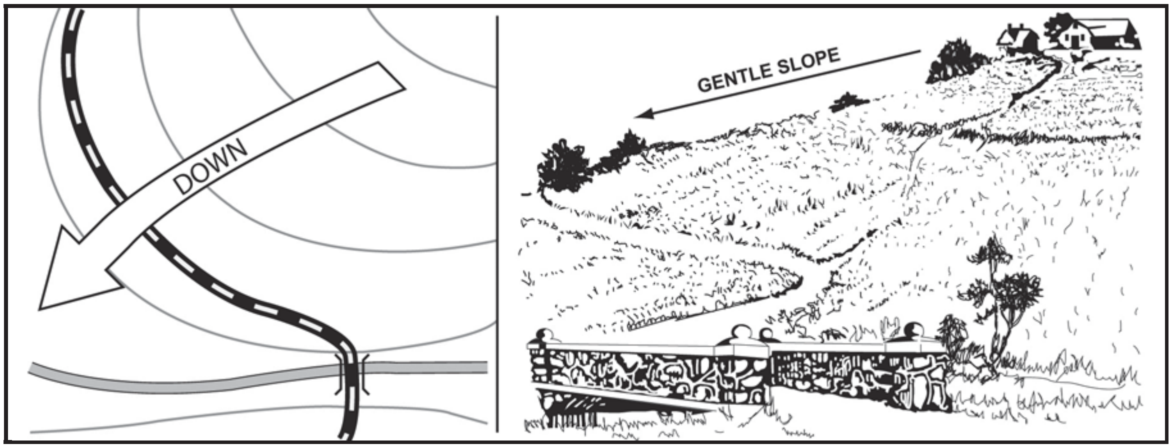


Figure 9-5. Uniform, gentle slope

9-17. Contour lines showing a uniform, steep slope on a map are evenly spaced but close together. The closer the contour lines, the steeper the slope. (See Figure 9-6.) Considering relief only, a uniform, steep slope allows the defender to use grazing fire, and the attacking force has to negotiate a steep incline.

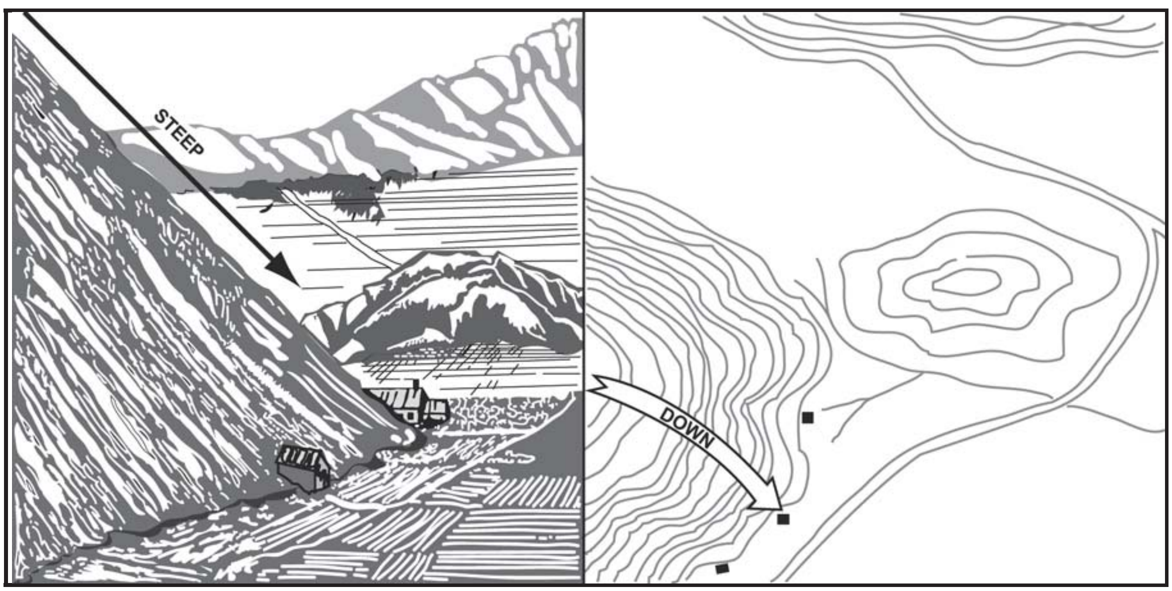


Figure 9-6. Uniform, steep slope

9-18. Contour lines showing a concave slope on a map are closely spaced at the top of the terrain feature and widely spaced at the bottom. (See Figure 9-7.) Considering relief only, the defender at the top of the slope can observe the entire slope and the terrain at the bottom, but cannot use grazing fire. The attacker would have no cover from the defender's observation of fire, and the climb would become more difficult going farther up the slope.

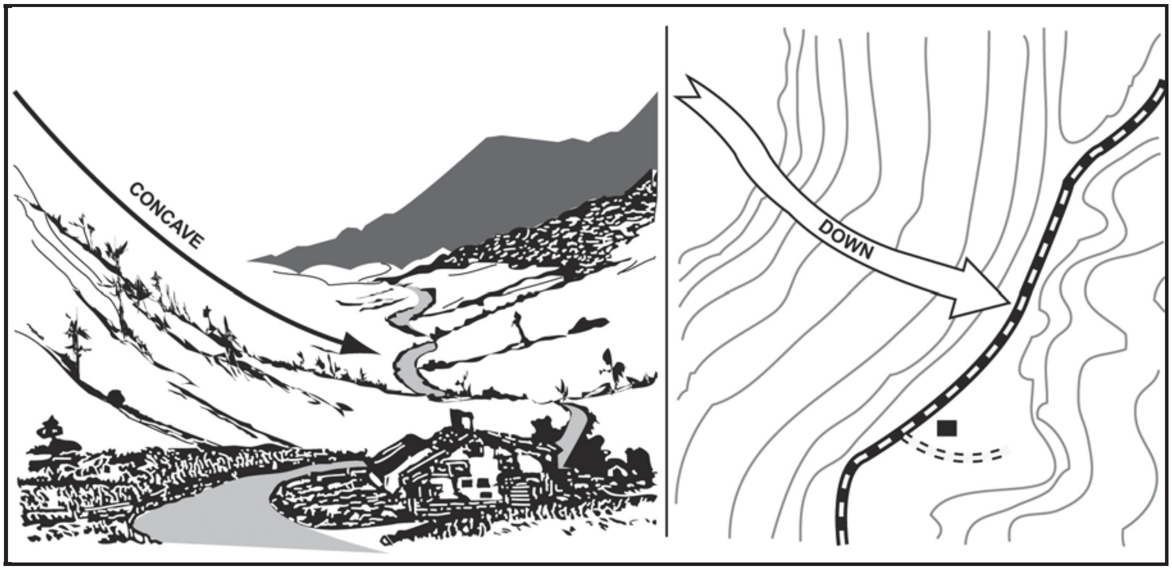


Figure 9-7. Concave slope

9-19. Contour lines showing a convex slope on a map are widely spaced at the top and closely spaced at the bottom. (See Figure 9-8.) Considering relief only, the defender at the top of the convex slope can obtain a small distance of grazing fire, but cannot observe most of the slope or the terrain at the bottom. The attacker has concealment on most of the slope and an easier climb nearing the top.

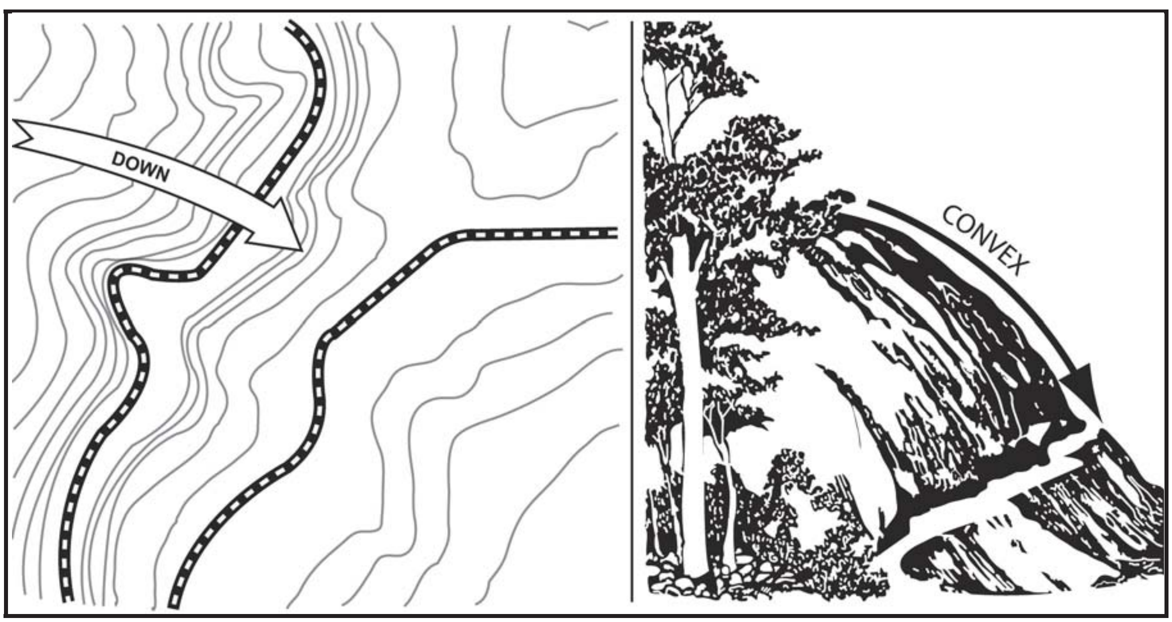


Figure 9-8. Convex slope

PERCENTAGE OF SLOPE

9-20. The speed at which personnel and equipment can move up or down a hill is affected by the slope of the ground and the limitations of the equipment. Because of this, a more exact way of describing a slope is necessary.

9-21. Slope may be expressed in several ways, but all depend upon the comparison of vertical distance (VD) to horizontal distance (HD). (See Figure 9-9.) Before determining the percentage of a slope, the VD of the slope is known. This is determined by subtracting the lowest point of the slope from the highest point. Use the contour lines to determine the highest and lowest point of the slope. (See Figure 9-10.)

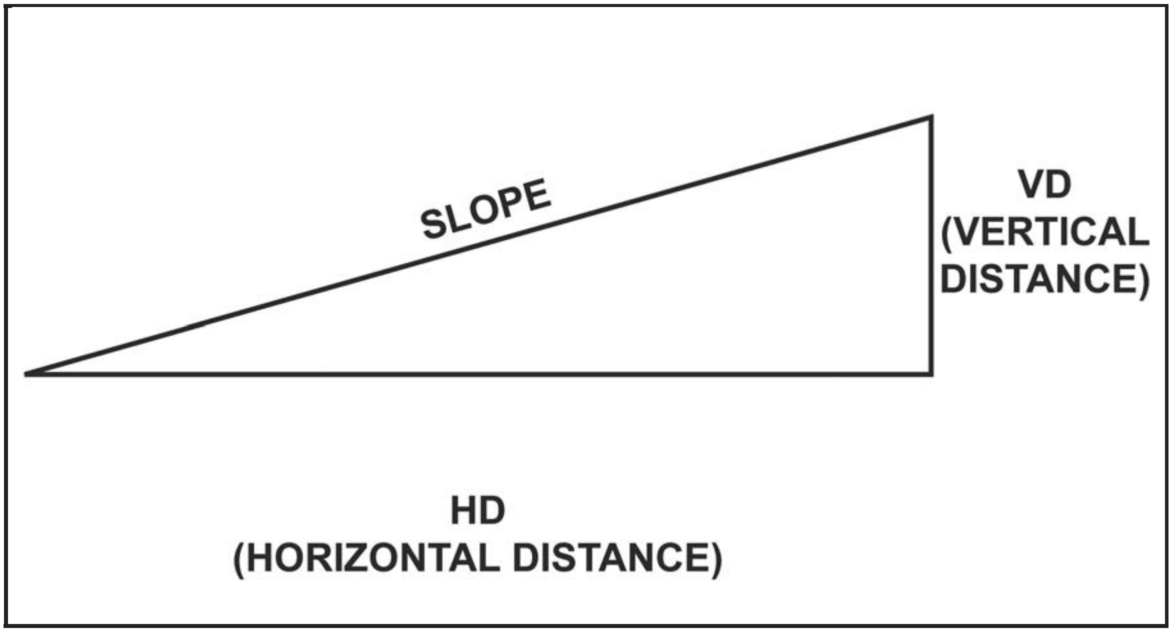


Figure 9-9. Slope diagram

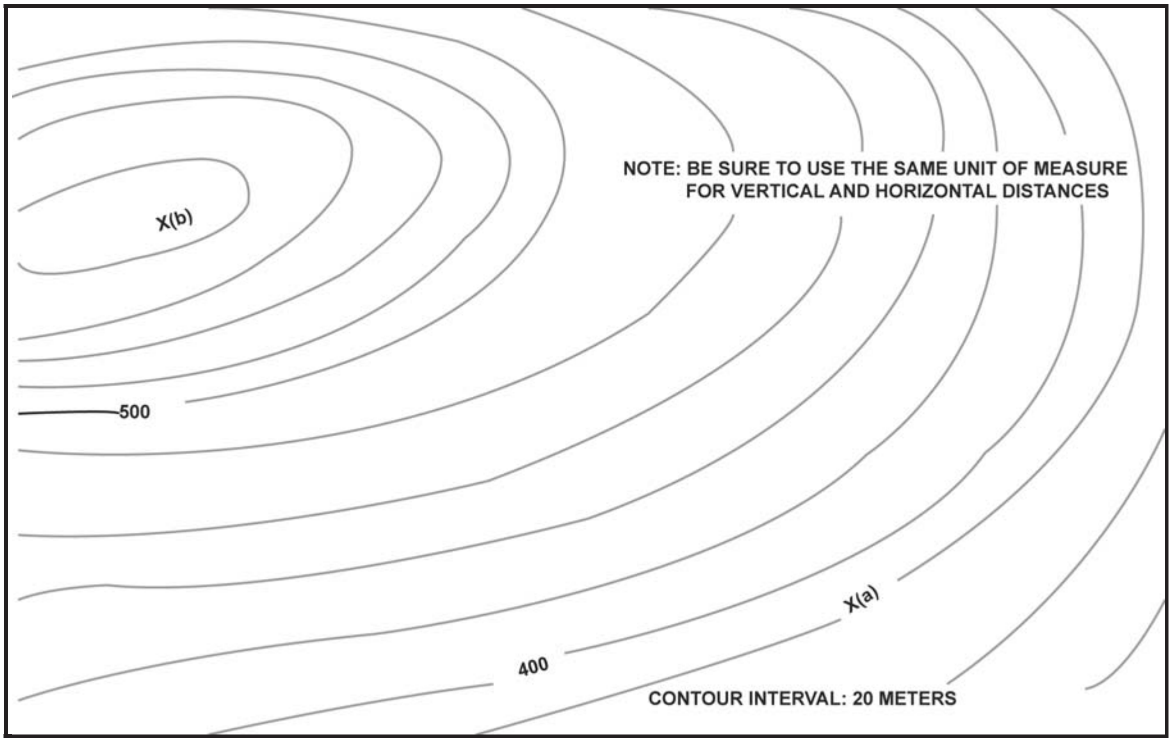


Figure 9-10. Contour lines around a slope

9-22. To determine the percentage of the slope between points (a) and (b) in Figure 9-10, determine the elevation of point (b) (590 m). Then determine the elevation of point (a) (380 m). Determine the vertical distance between the two points by subtracting the elevation of point (a) from the elevation of point (b).The difference (210 m) is the VD between points (a) and (b). Then measure the HD between the two points on the map. (See Figure 9-11.) After the horizontal distance has been determined, compute the percentage of the slope by using the formula shown in Figure 9-12.

Note. The references depicted in Figures 9-10 through 9-14 represent a uniform slope.

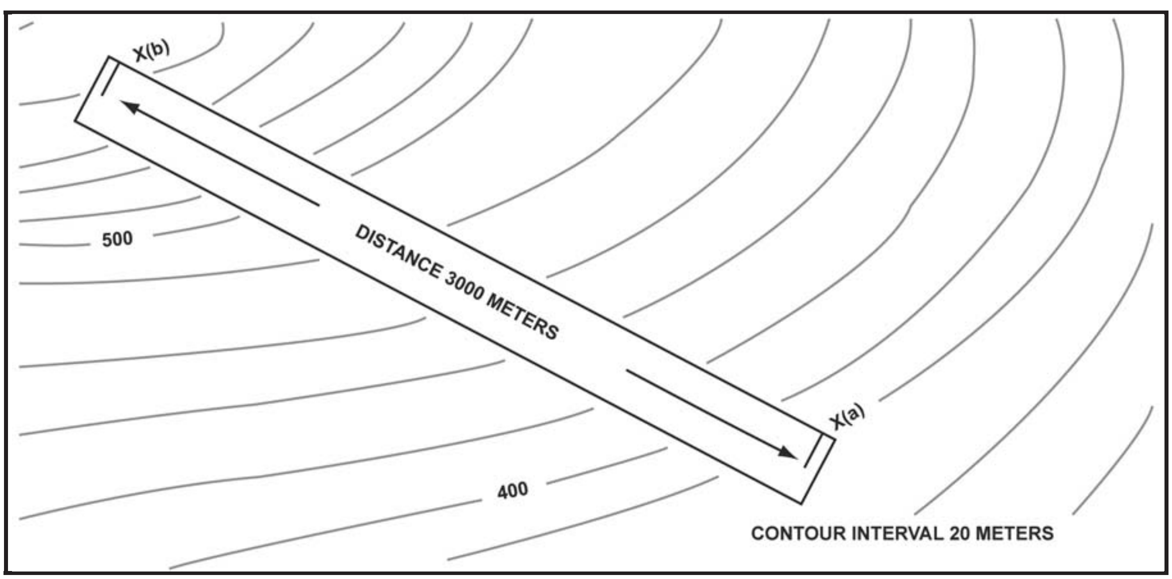


Figure 9-11. Measuring horizontal distance

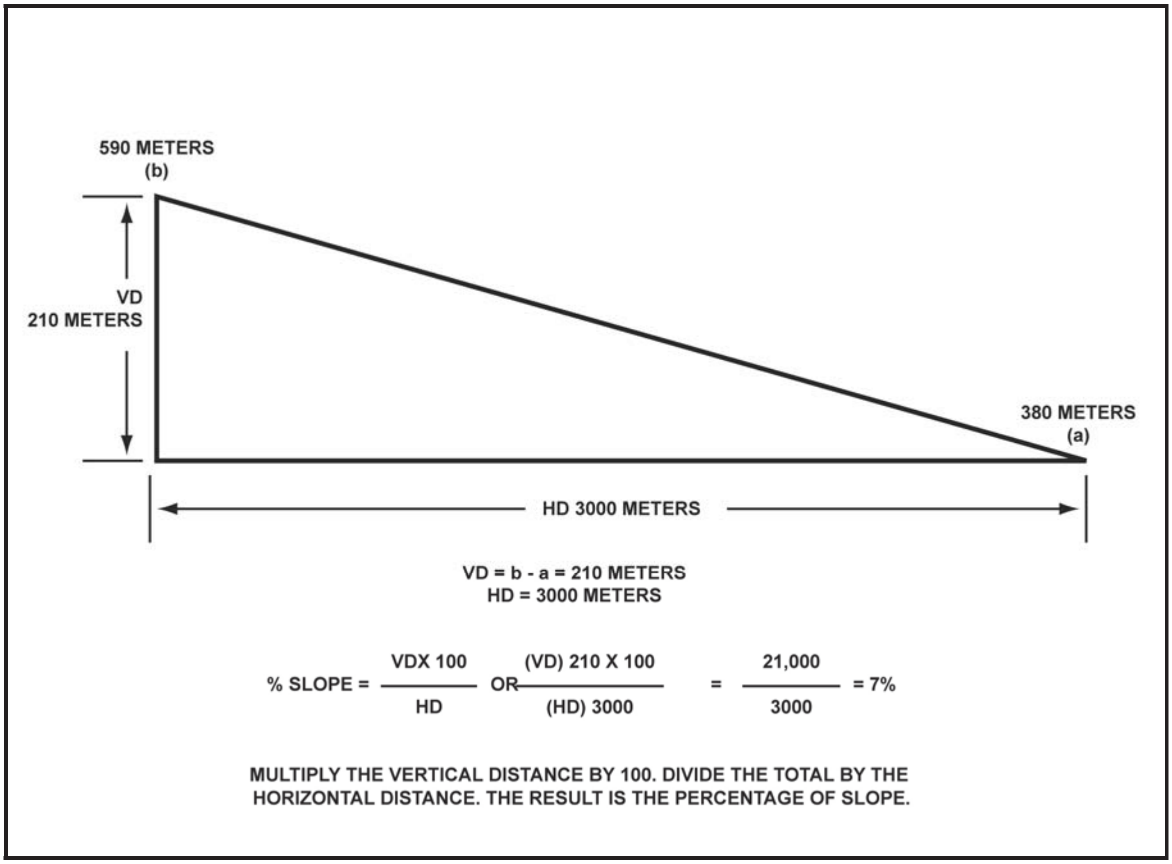


Figure 9-12. Percentage of slope in meters

9-23. The slope angle can also be expressed in degrees. To do this, determine the VD and HD of the slope. Multiply the VD by 57.3 and then divide the total by the HD. (See Figure 9-13.) This method determines the approximate degree of slope and is reasonably accurate for slope angles less than 20 degrees.

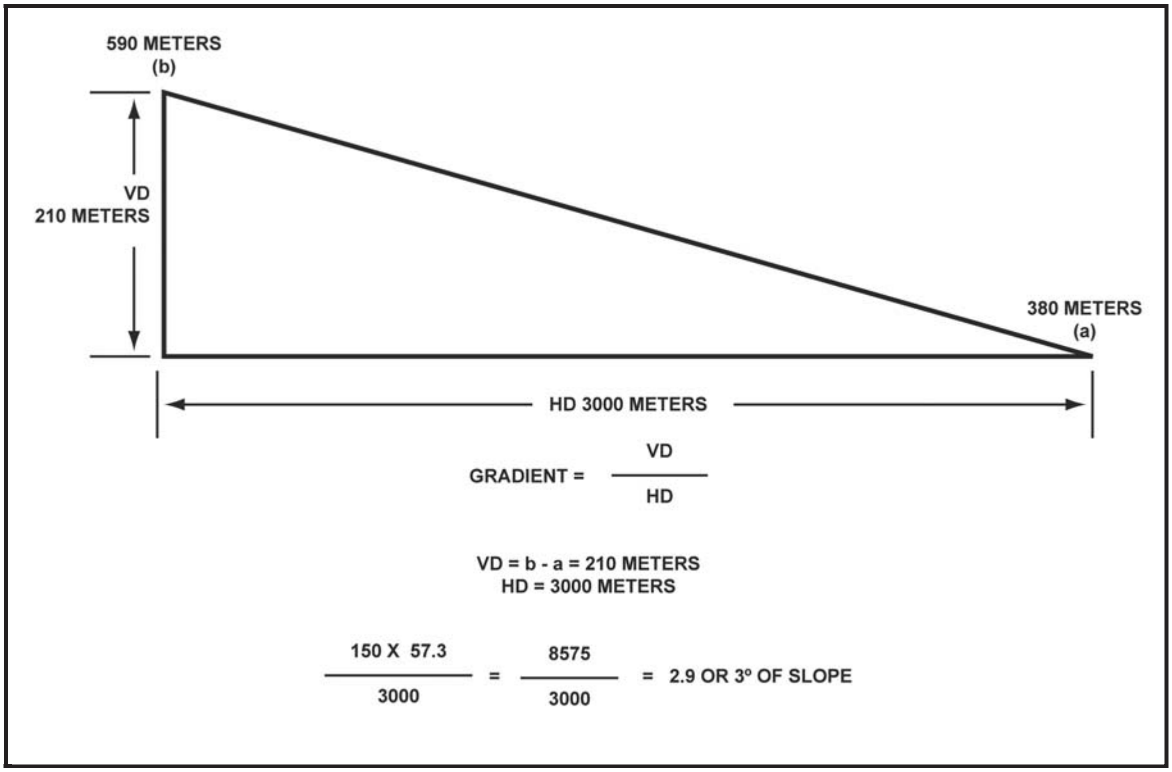


Figure 9-13. Degree of slope

9-24. The slope angle can also be expressed as a gradient. The relationship of horizontal and vertical distance is expressed as a fraction with a numerator of one. (See Figure 9-14.)

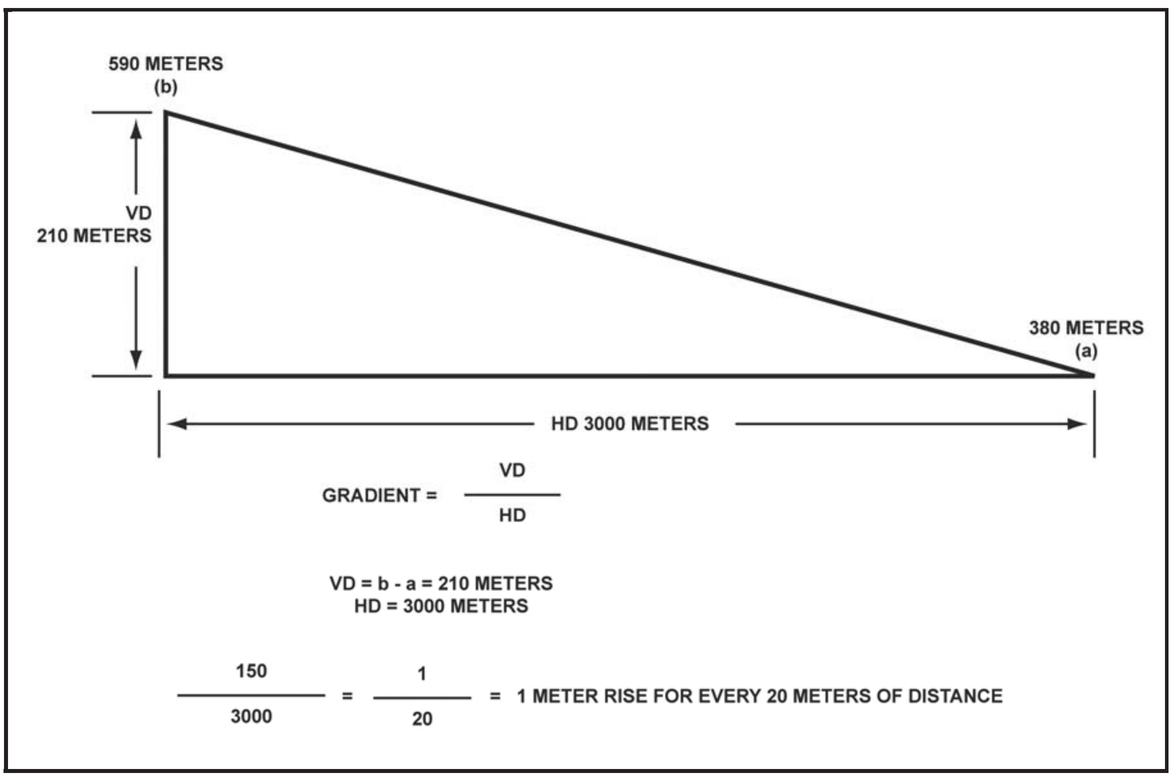


Figure 9-14. Gradient

TERRAIN FEATURES

9-25. All terrain features are derived from a complex landmass known as a mountain or ridgeline. (See Figure 9-15.) The term ridgeline is not interchangeable with the term ridge. A ridgeline is a line of high ground, usually with changes in elevation along its top and low ground on all sides, from which a total of 10 natural or man-made terrain features are classified.

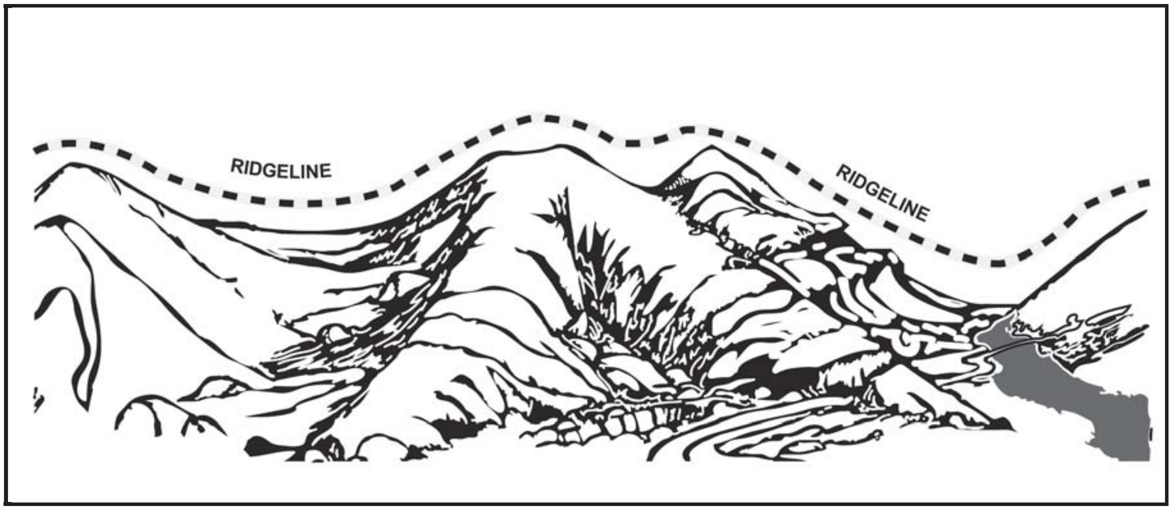


Figure 9-15. Ridgeline

MAJOR TERRAIN FEATURES

9-26. Major terrain features are hills, saddles, valleys, ridges, and depressions. They are uniquely represented on maps.

9-27. A hill is an area of high ground. From a hilltop, the ground slopes down in all directions. A hill is shown on a map by contour lines forming concentric circles. The inside of the smallest closed circle is the hilltop. (See Figure 9-16.)

Figure 9-16. Hill

9-28. A saddle is a dip or low point between two areas of higher ground. A saddle is not necessarily the lower ground between two hilltops; it may be simply a dip or break along a level ridge crest. If you are in a saddle, there is high ground in two opposite directions and lower ground in the other two directions. A saddle is normally represented as an hourglass. (See Figure 9-17.)

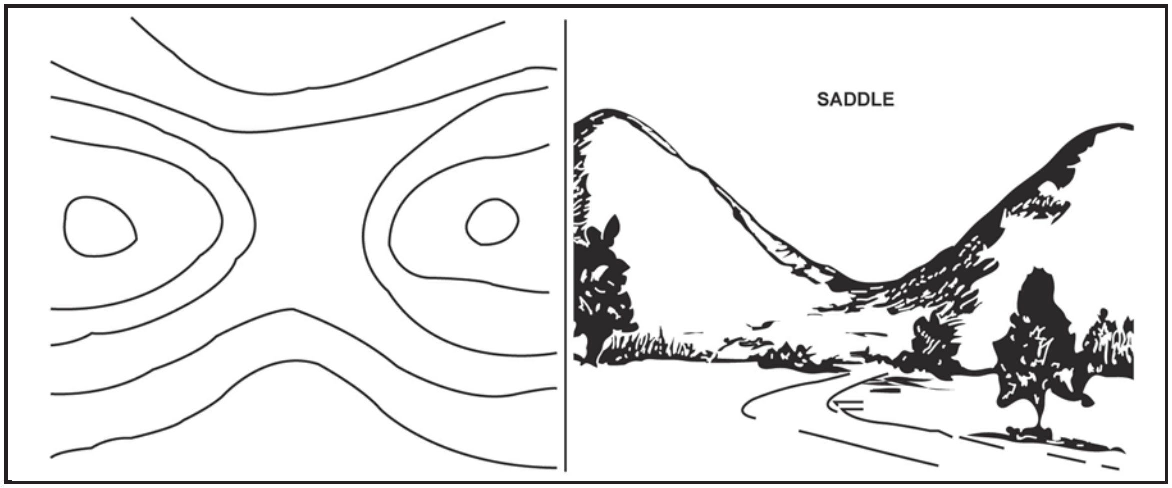


Figure 9-17. Saddle

9-29. A valley is a stretched-out groove in the land, usually formed by streams or rivers. It begins with high ground on three sides and usually has a course of running water through it. If standing in a valley, three directions offer high ground, while the fourth direction offers low ground. Depending upon its size and where a person is standing, it may not be obvious that there is high ground in the third direction, but water flows from higher to lower ground. Contour lines forming a valley are either U-shaped or V-shaped. To determine the direction water is flowing, look at the contour lines. The closed end of the contour line (U or V) always points upstream or toward high ground. (See Figure 9-18.)

Figure 9-18. Valley

9-30. A ridge is a sloping line of high ground. The centerline of a ridge normally has low ground in three directions and high ground in one direction, with varying degrees of slope. If a ridge is crossed at right angles, a Soldier climbs steeply to the crest and then descends steeply to the base. When moving along the path of the ridge, depending on the geographic location, there may be either an almost unnoticeable slope or a very obvious incline. Contour lines forming a ridge tend to be U-shaped or V-shaped. The closed end of the contour line points away from high ground. (See Figure 9-19.)

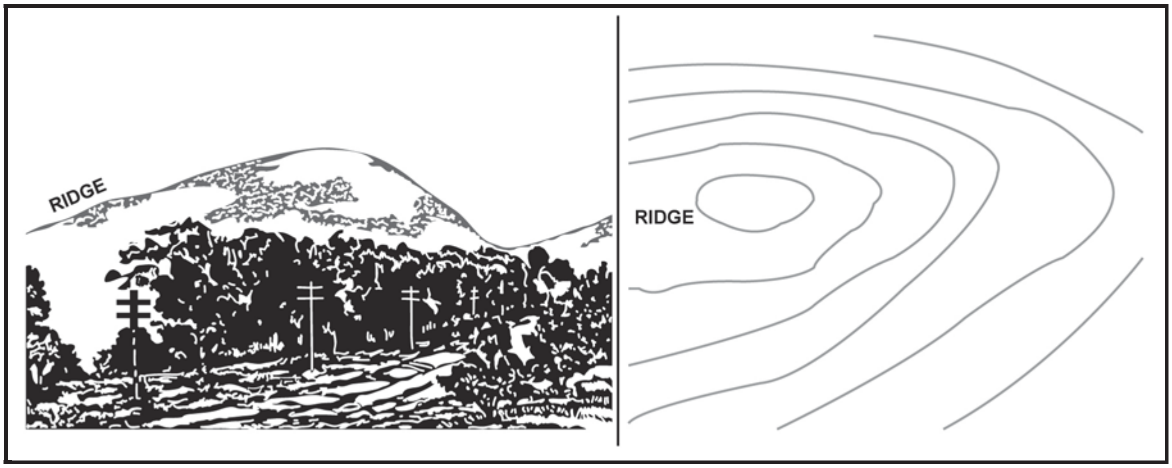


Figure 9-19. Ridge

9-31. A depression is a low point in the ground or a sinkhole. It could be described as an area of low ground surrounded by higher ground in all directions, or simply a hole in the ground. Usually, only depressions that are equal to or greater than the contour interval is shown. On maps, depressions are represented by closed contour lines that have tick marks pointing toward low ground. (See Figure 9-20.)

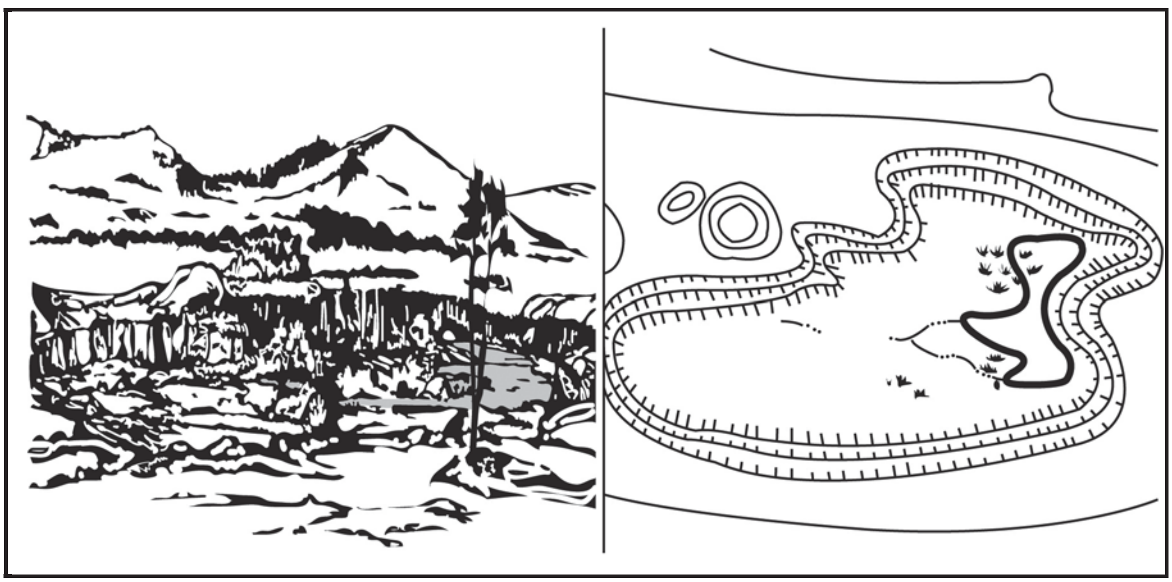


Figure 9-20. Depression

MINOR TERRAIN FEATURES

9-32. Minor terrain features include draws, spurs, and cliffs. They are represented on maps in unique ways.

9-33. A draw is a stream course that is less developed than a valley. In a draw, there is essentially no level ground and little or no maneuver room within its confines. In a draw, the ground slopes upward in three directions and downward in the other direction. A draw could be considered as the initial formation of a valley. The contour lines depicting a draw are U-shaped or V-shaped, pointing toward high ground. (See Figure 9-21.)

Figure 9-21. Draw

9-34. A spur is a short, continuous sloping line of higher ground normally jutting out from the side of a ridge. A spur is often formed by two roughly parallel streams cutting draws down the side of a ridge. The ground slopes down in three directions and up in one. Contour lines on a map depict a spur with the U or V pointing away from high ground. (See Figure 9-22.)

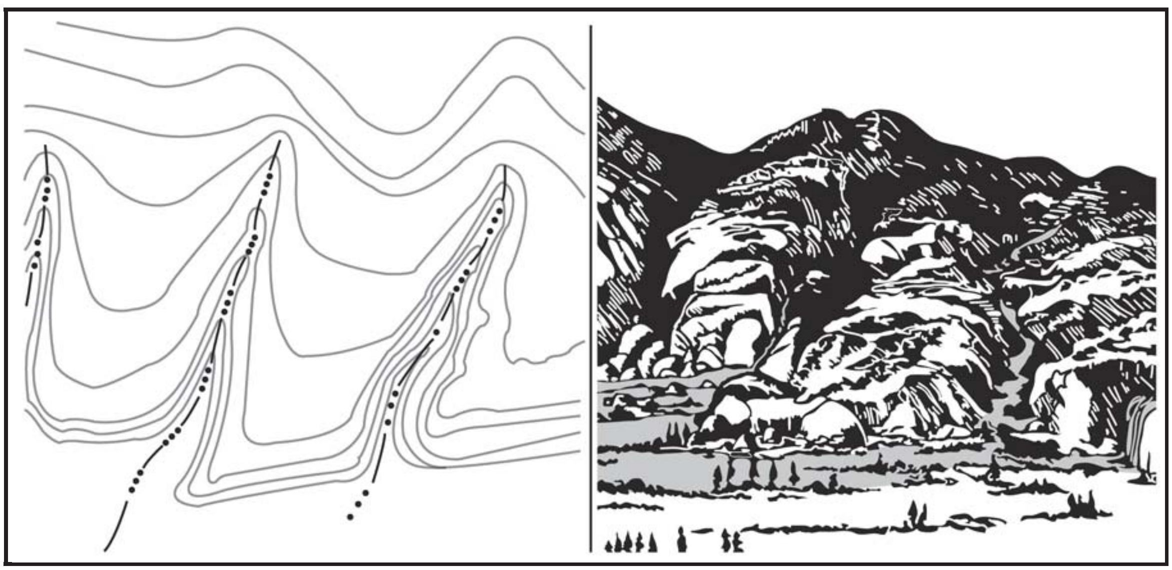


Figure 9-22. Spur

9-35. A cliff is a vertical or near-vertical feature that is an abrupt change of the land. When a slope is so steep that the contour lines converge into one "carrying" contour of contours, this last contour line has tick marks pointing toward low ground. (See Figure 9-23, A.) Cliffs are also shown by contour lines very close together and, in some instances, touching each other. (See Figure 9-23, B.)

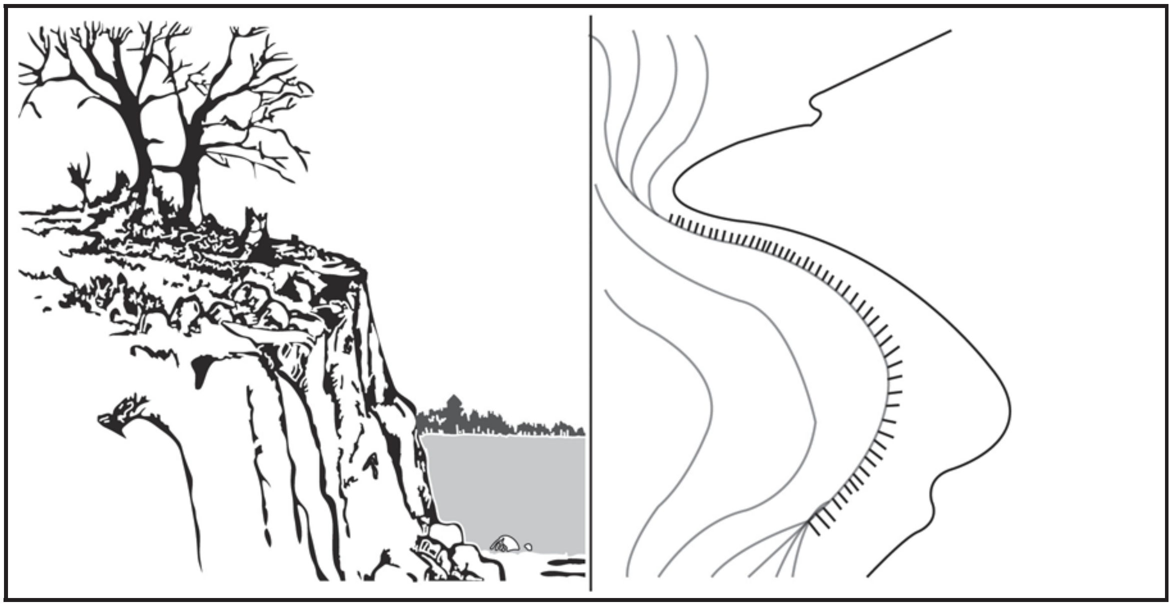


Figure 9-23, A. Cliff (with tick marks)

Figure 9-23, B. Cliff (without tick marks)

SUPPLEMENTARY TERRAIN FEATURES

9-36. Supplementary terrain features include cuts and fills. A cut is a man-made feature resulting from cutting through raised ground, usually to form a level bed for a road or railroad track. Cuts are shown on a map when they are at least 10 feet high, and they are drawn with a contour line along the cut line. This contour line extends the length of the cut and has tick marks that extend from the cut line to the roadbed, if the map scale permits this level of detail. (See Figure 9-24.)

9-37. A fill is a man-made feature resulting from filling a low area, usually to form a level bed for a road or railroad track. Fills are shown on a map when they are at least 10 feet high, and they are drawn with a contour line along the fill line. This contour line extends the length of the filled area and has tick marks that point toward lower ground. If the map scale permits, the length of the fill tick marks are drawn to scale and extend from the base line of the fill symbol. (See Figure 9-24.)

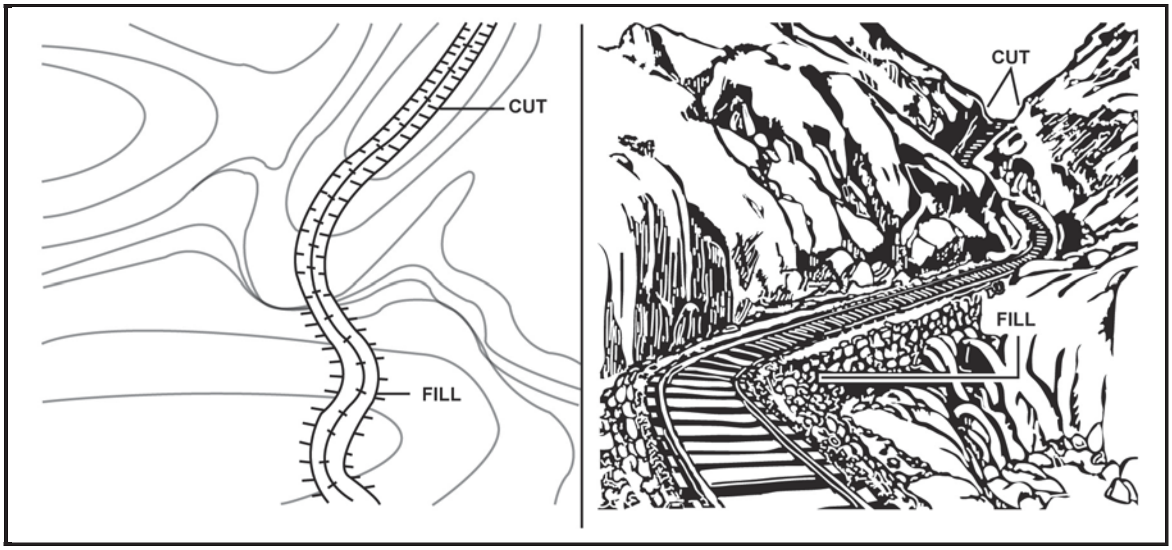


Figure 9-24. Cut and fill

INTERPRETATION OF TERRAIN FEATURES

9-38. Terrain features do not normally stand alone. To better understand these when they are depicted on a map, they need to be interpreted correctly. These terrain features (see Figure 9-25) are interpreted by using contour lines; the shape, orientation, size, elevation, and slope approach; ridgelining; or streamlining.

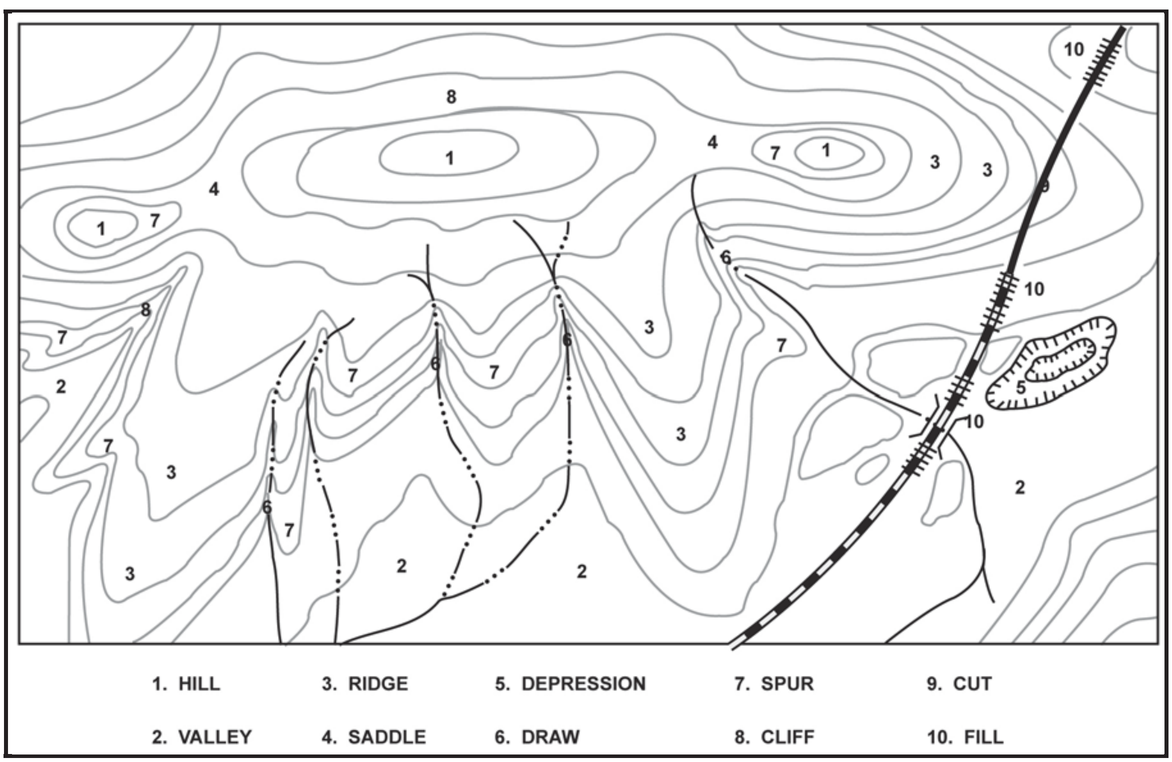


Figure 9-25. Terrain features

9-39. Emphasizing the main contour lines is a technique used to interpret the terrain of an area. By studying these contour lines, one can better understand the layout of the terrain and decide on the best route. The following description pertains to Figure 9-26:

- Running east to west across the complex landmass is a ridgeline. (See paragraph 9-25.) The changes in elevation are the three hilltops and two saddles along the ridgeline. From the top of each hill, there is lower ground in all directions. Because of the difference in size of the higher ground on the two opposite sides of a saddle, a full hourglass shape of a saddle may not be apparent. (See paragraph 9-28.)
- There are four prominent ridges. A ridge is on each end of the ridgeline and two ridges extend south from the ridgeline. The closed ends of the U's formed by the contour lines point away from higher ground. (See paragraph 9-30.)
- To the south lies a valley; the valley slopes downward from east to west. Note that the U of the contour line points to the east, indicating higher ground in that direction and lower ground to the west. Another look at the valley shows high ground to the north and south of the valley.
- Just east of the valley is a depression. Looking from the bottom of the depression, there is higher ground in all directions.
- There are several spurs extending generally south from the ridgeline. (See paragraph 9-34.) Their contour line U's point away from higher ground.
- Between the ridges and spurs are draws. They, like valleys, have higher ground in three directions and lower ground in one direction. Their contour line U's and V's point toward higher ground.
- Two contour lines on the north side of the center hill are touching or almost touching. They have ticks indicating a vertical or nearly vertical slope or a cliff.
- The road cutting through the eastern ridge depicts cuts and fills. The breaks in the contour lines indicate cuts, and the ticks pointing away from the road bed on each side of the road indicate fills.

9-40. Learning to identify several individual terrain features in the field and see how they vary in appearance takes practice. A recommended technique for identifying specific terrain features and then locating them on the map is to use five characteristics: shape, orientation, size, elevation, and slope. Terrain features can be examined, described, and compared with each other and with corresponding map contour patterns in terms of:

- **Shape** is the general form or outline of the feature at its base.
- **Orientation** is the general trend or direction of a feature from the current viewpoint. A feature can be in line, across, or at an angle to the viewpoint.
- **Size** is the length or width of a feature horizontally across its base. For example, one terrain feature might be larger or smaller than another.
- **Elevation** is the height of a terrain feature. This can be described in absolute or relative terms as compared to the other features in the area. One landform may be higher, lower, deeper, or shallower than another.
- **Slope** is the type (uniform, convex, or concave) and angle (steep or gentle) of the sides of a terrain feature.

9-41. The ridgelining technique helps with visualizing the overall lay of the ground within the area of interest on the map. (See Figure 9-26.) Use the following steps to implement this technique:

- Identify on the map the crests of the ridgelines in the area of operation by identifying the close-out contours that lie along the hilltop.
- Trace over the crests so each ridgeline stands out clearly as one identifiable line using solid or colored lines. The usual colors used for this tracing are red or brown; however, other colors may be used. Figure 9-26 depicts the ridgelining tracing using solid lines.
- Go back over each of the major ridgelines and trace over the prominent ridges and spurs that come out of the ridgelines.
- After completing the ridgelining process, the high ground on the map stands out and the relationship between the various ridgelines can be seen.

9-42. The streamlining procedure is similar to that of ridgelining. (See Figure 9-26.) Follow these steps:

- Identify all the mapped streams in the area of operations.

- Trace over them to make them stand out more prominently using dashed or colored lines. The color used for this is usually blue; but again, if blue is not available; another color may be used so long as the distinction between the ridgelines and the streamlines is clear. Figure 9-26 depicts the streamlining tracing as dashed lines.
- Identify other low ground, such as smaller valleys or draws that feed into the major streams, and trace over them. This brings out the drainage pattern and low ground in the area of operation on the map.

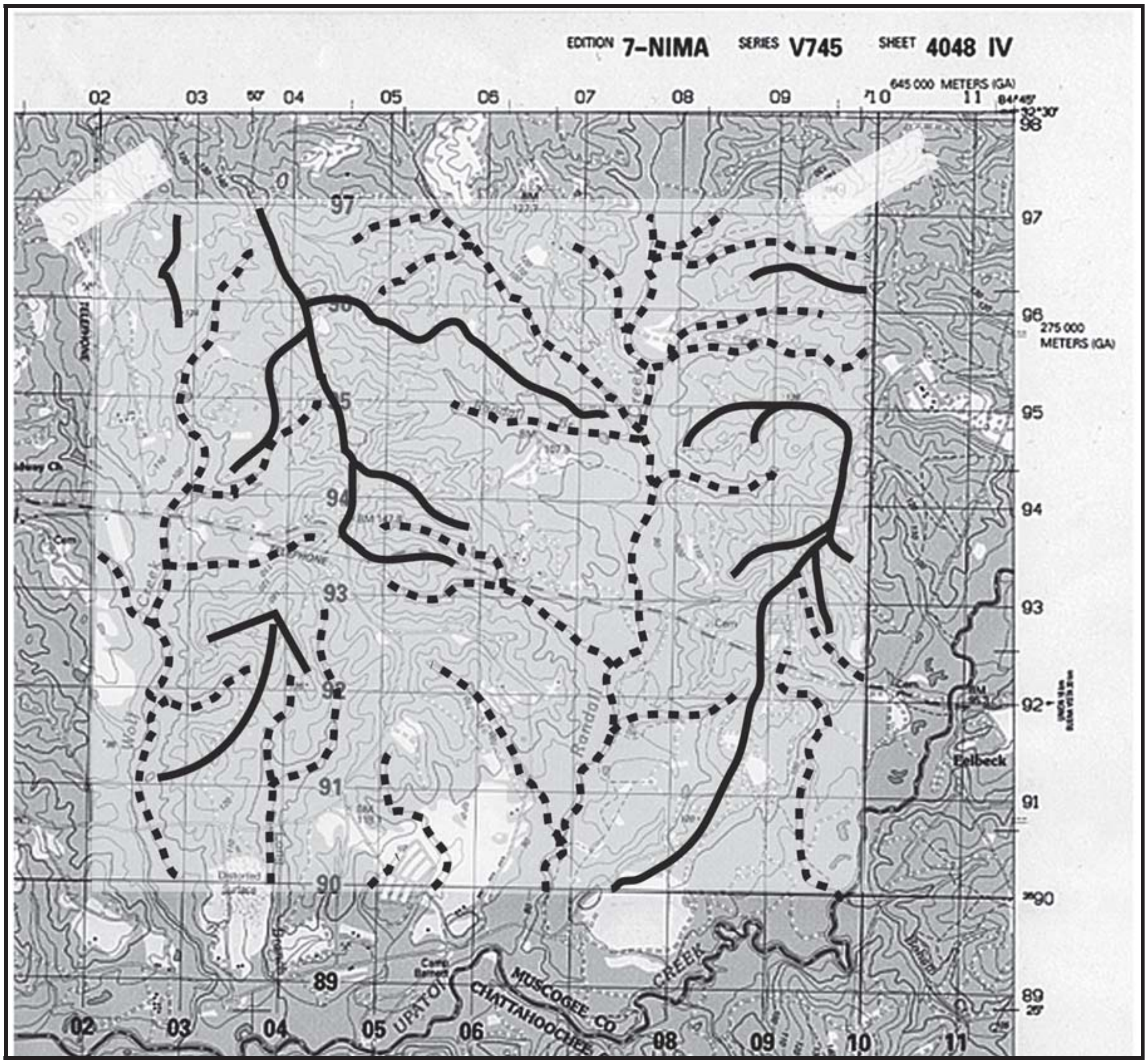


Figure 9-26. Ridgelining and streamlining

PROFILES

9-43. The study of contour lines to determine high and low points of elevation is usually adequate for military operations. However, there may be times when a quick and precise reference to determine exact elevations of specific points is needed. When exactness is demanded, a profile is required. A profile, within the scope and purpose of this manual, is an exaggerated side view of a portion of the earth's surface along a line between two or more points.

9-44. A profile can be used for many purposes. The primary purpose is to determine if line of sight is available. Line of sight is used to—

- Determine defilade positions.

- Plot hidden areas or dead space.
- Determine potential direct fire weapon positions.
- Determine potential locations for defensive positions.
- Conduct preliminary planning in locating roads, pipelines, railroads, or other construction projects.

9-45. A profile can be constructed from a contoured map using the following steps:

- Draw a line on the map from where the profile is to begin to where it is to end. (See Figure 9-27.)
- Find the value of the highest and lowest contour lines that cross or touch the profile line. Add one contour value above the highest and one below the lowest to take care of hills and valleys.
- Select a piece of lined notebook paper with as many lines as was determined above. The standard Army green pocket notebook or other paper with 1/4-inch lines is ideal. Wider lines, up to 5/8-inch, may be used. If lined paper is not available, draw equally spaced horizontal lines on a blank sheet of paper.
- Number the top line with the highest value and the bottom line with the lowest value as determined above.

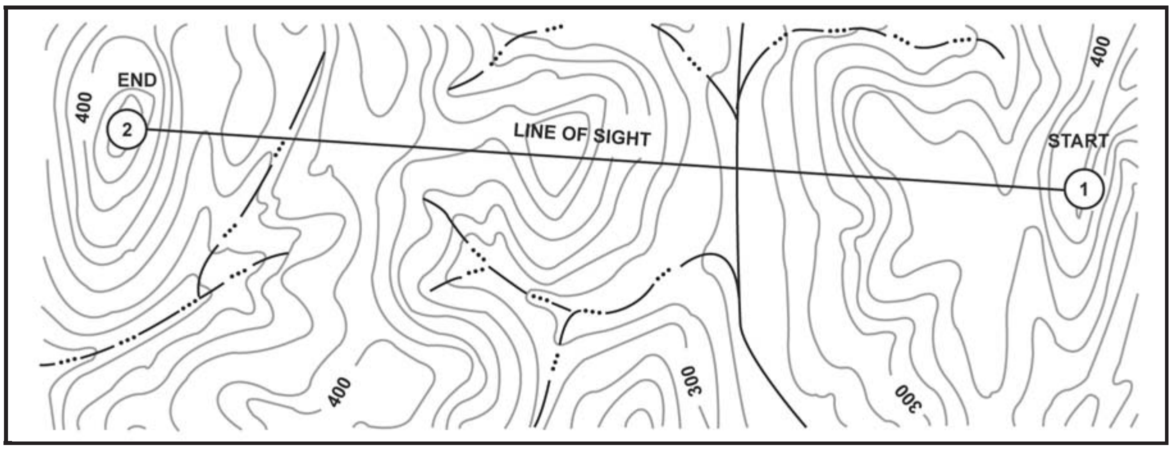


Figure 9-27. Connecting points

- Number the rest of the lines in sequence, starting with the second line from the top. The lines are numbered according to the contour interval. (See Figure 9-28.)
- Place the paper on the map with the lines next to and parallel to the profile line.
- From every point on the profile line where a contour line, stream, intermittent stream, or other body of water crosses or touches, drop a perpendicular line to the line having the same value. Place a tick mark where the perpendicular line crosses the number line. Where trees are present, add the height of the trees to the contour line, and place a tick mark there. Assume the height of the trees to be 50 feet or 15 m where dark green tint is shown on the map. Vegetation height may be adjusted up or down when operations in the area provide known tree heights.
- After all perpendicular lines have been drawn and tick marks placed where the lines cross, connect all tick marks with a smooth, natural curve to form a horizontal view of the terrain along the profile line. (See Figure 9-28.)
- The profile drawn may be exaggerated. The spacing between the lines drawn on the sheet of paper determines the amount of exaggeration and may be varied to suit the purpose.

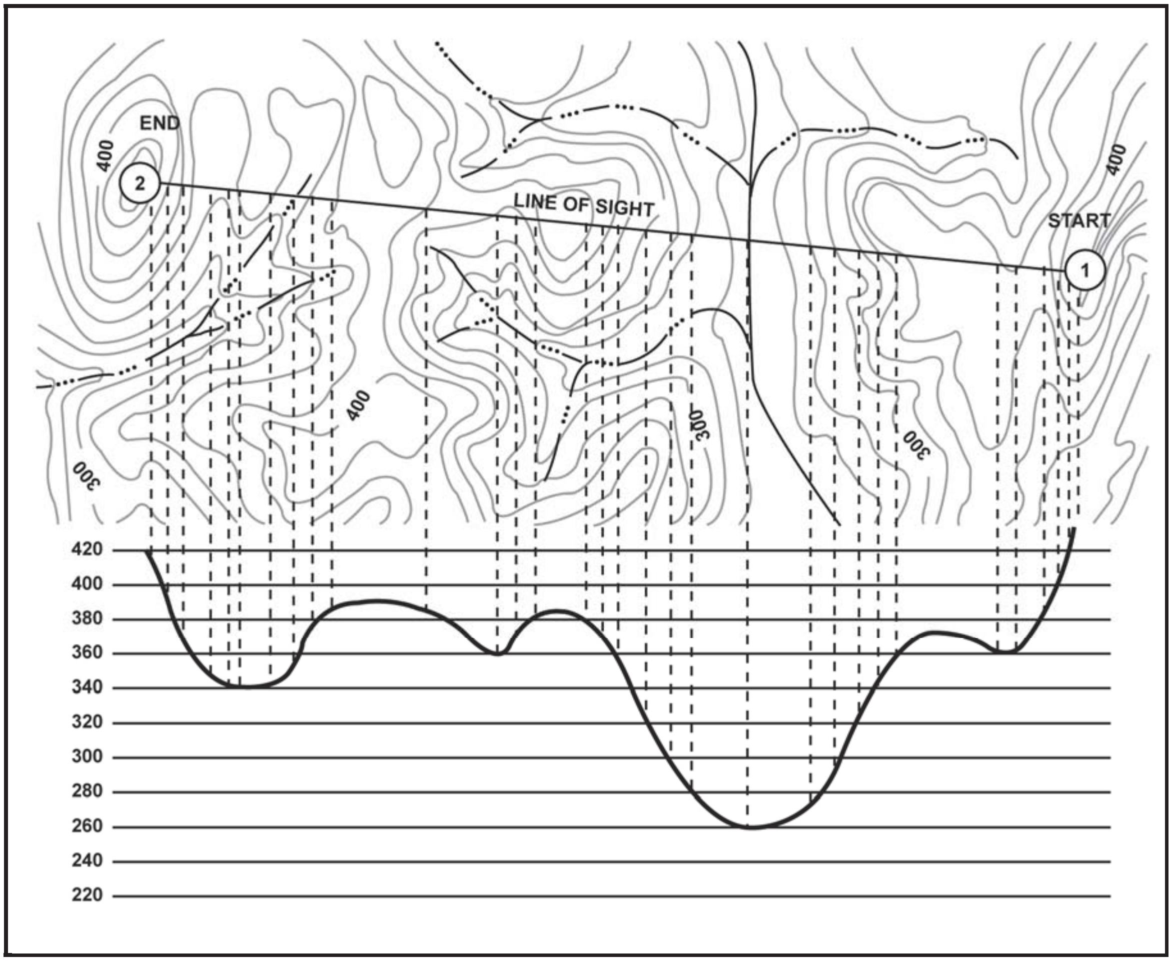


Figure 9-28. Dropping perpendiculars

- Draw a straight line from the start point to the end point on the profile. If the straight line intersects the curved profile, line of sight to the end point is not available. (See Figure 9-29.)

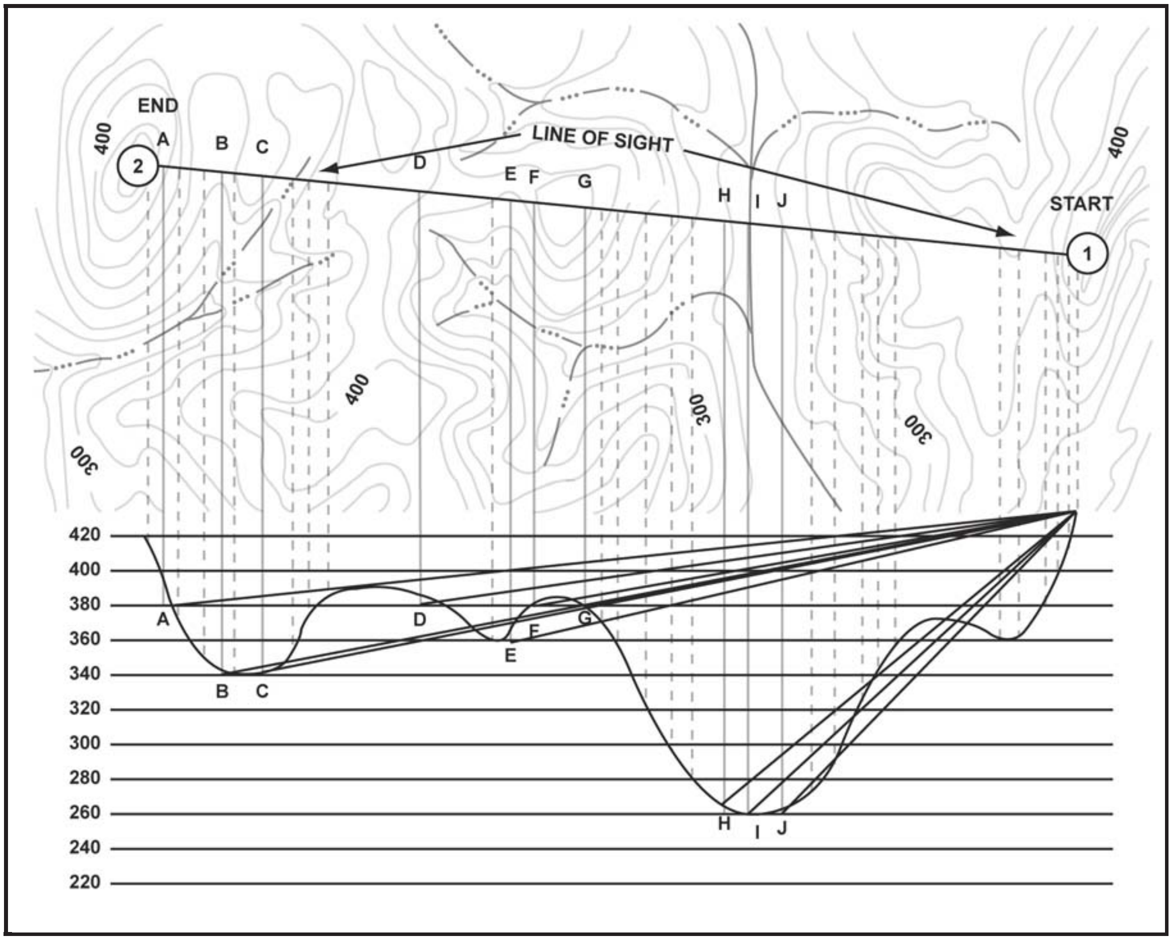


Figure 9-29. Drawing lines to additional points

- Line of sight to other points along the profile line can be determined by drawing a line from the start point to additional points. In Figure 9-30, line of sight is available to:

A – YES	**C – NO**	**E – NO**	**G – YES**	**I - NO**
B – NO	**D – YES**	**F – NO**	**H – NO**	**J - NO**

- The vertical distance between navigable ground up to the line of sight line is the depth of defilade.