Map and Survey Drafting

Learning Objectives

After studying this chapter, you will be able to:

- List and explain common terms associated with map drafting.
- Identify and describe the common types of drawings used in map drafting.
- Explain common methods used for data collection in mapmaking.
- Describe the special kinds of drafting required in the preparation of map drawings.

Technical Terms

Azimuth
Back azimuth
Backsight
Bearing
Cadastral map
Cartography
Closed traverse
Contour lines
Deflection angle
Engineering map
Foresight
Geographic information system (GIS)
Geographic map
Geological map
Geology
Grid survey
Horizontal curve
Interpolation
Magnetic north
Mosaic
North
Open traverse
Photogrammetry
Plat
Stations
Survey
Surveying
Topographic map
Traverse
True north
Vertical curve

Cartography is the science of mapmaking. Special kinds of drafting are required in the preparation of maps. Drafting techniques used for some of the more common types of maps are presented in this chapter.

Mapping and Surveying Terms

A number of terms are basic to an understanding of surveying and map drafting. Some of the most common terms are discussed here.

- ***Azimuth***. The angle that a line makes with a north-south line, measured clockwise from the north. The terms *azimuth, back azimuth,* and *bearing* are illustrated in **Figure 25-1**.
- ***Back azimuth***. The angle measured clockwise from the north to a line running in the opposite direction from the azimuth measurement. The back azimuth is always equal to the azimuth plus or minus 180°.
- ***Backsight***. A sighting line indicating a measurement taken with a surveying instrument back to the last station occupied. The terms *backsight, foresight, deflection angle,* and *station* are illustrated with respect to a *traverse* in **Figure 25-2**.

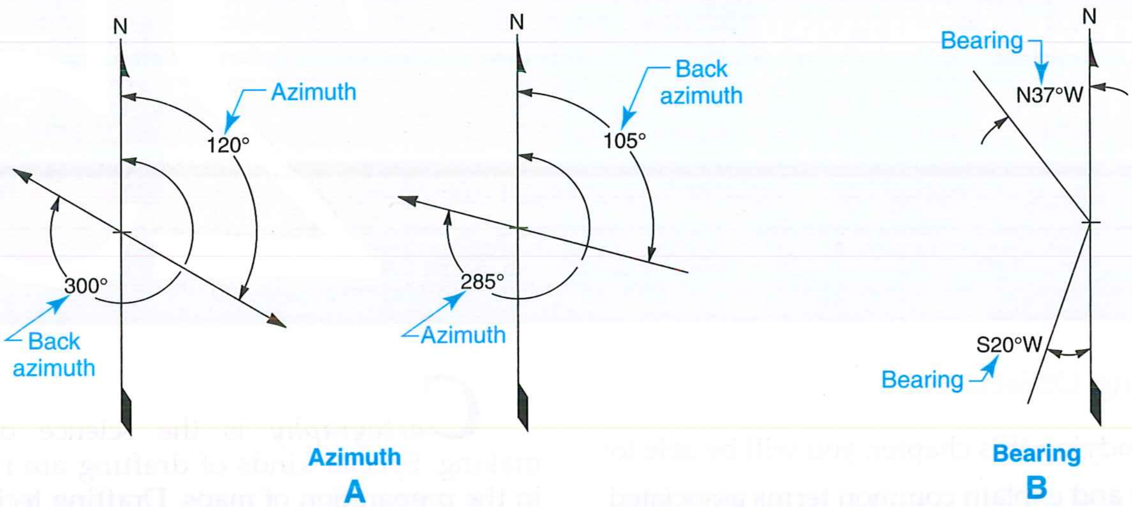


Figure 25-1. Azimuth and bearing describe the angular directions of lines with respect to north-south lines. A—The azimuth of a line describes the angle of a line in degrees from north. B—The bearing of a line describes the angle of a line in degrees measured from either the north or south.

- ***Bearing***. The angle of a line measured from either the north or south. Refer to **Figure 25-1B**. The bearing of a line is measured from 0° to 90° in relation to one of the 90° quadrants of a compass. For example, a line with a bearing of 20° to the west of south would be stated as South 20° West.
- ***Contour lines***. The irregularly shaped lines used on topographic maps and other map drawings to indicate changes in terrain elevation. On any single contour line, every point is at the same elevation.
- ***Deflection angle***. The angle of a line measured to the foresight from the current station point in relation to the backsight. A left deflection angle is laid out to the left. A right deflection angle is laid out to the right.
- ***Foresight***. A sighting line indicating a measurement taken with a surveying instrument from a previous station to a new station.
- ***Horizontal curve***. A change of direction in the horizontal or plan view that is achieved by means of a curve.
- ***Interpolation***. A technique used to locate, by proportion, intermediate points between given data in contour plotting problems.
- ***Mosaic***. A series of aerial photographs of adjacent land areas, taken with intentional overlaps and fitted together to produce a larger picture.
- ***North***. The direction normally indicated on the top of a map. ***Magnetic north***, as indicated by a magnetic compass, is satisfactory for most maps, but is subject to local deflection errors affecting the magnetic compass. ***True north***, as determined by the direction of the North Pole, is considered to be the most accurate.
- ***Plat***. A plan that shows land ownership, boundaries, and subdivisions.

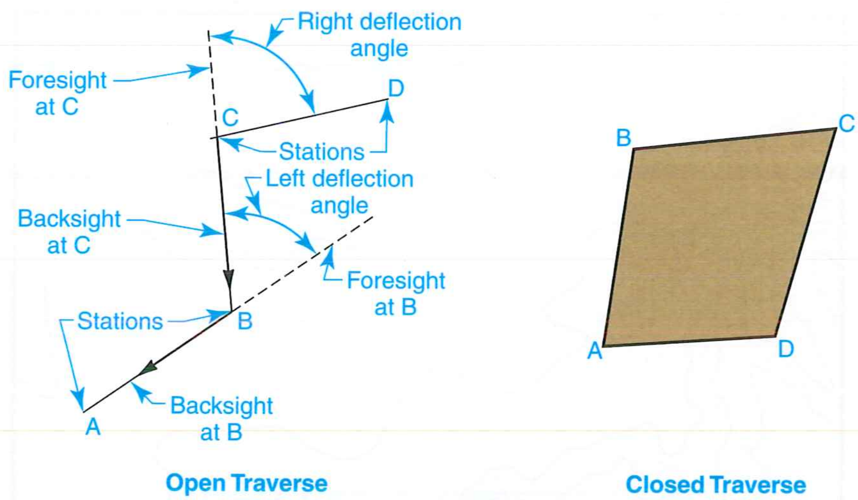


Figure 25-2. Terms used in laying out open and closed map traverses.

- ***Stations.*** Established points on a map traverse or map drawing. In highway construction surveys, points at 100′ intervals on the centerline in the plan view are also called stations. They are located by stakes with station numbers on them.
- ***Survey.*** An analysis of data using linear and angular measurements and calculations to determine the boundaries, position, elevation, or profile of a part of the earth's surface or another planet's surface.
- ***Traverse.*** A series of lines laid out by means of angular and linear measurements to represent accurate distances, such as the lengths of a property boundary. Refer to **Figure 25-2**. A ***closed traverse*** is one that returns to its point of origin at a previously identified point. An ***open traverse*** neither returns nor ends at a previously identified point.
- ***Vertical curve.*** A change of direction in the grade, shown in a profile view, that is achieved by means of a curve (usually a parabolic curve).

Types of Maps

All maps are representations, on flat surfaces, of a part of the surface of the earth (or any other planet). Although all types of maps have common features, they may be classified into specific types based on their intended use.

Geographic Maps

The ***geographic map*** is familiar to most students as the type found in social studies textbooks. It illustrates, by color variation or other technique, the locations of rivers, cities, and countries, as well as such elements as climate, soil, vegetation, land use, and population. The geographic map normally represents a large area and must be drawn to a very small scale.

Geological Maps

Geology is the study of the earth's surface, its outer crust and interior structure, and the changes that have taken and are

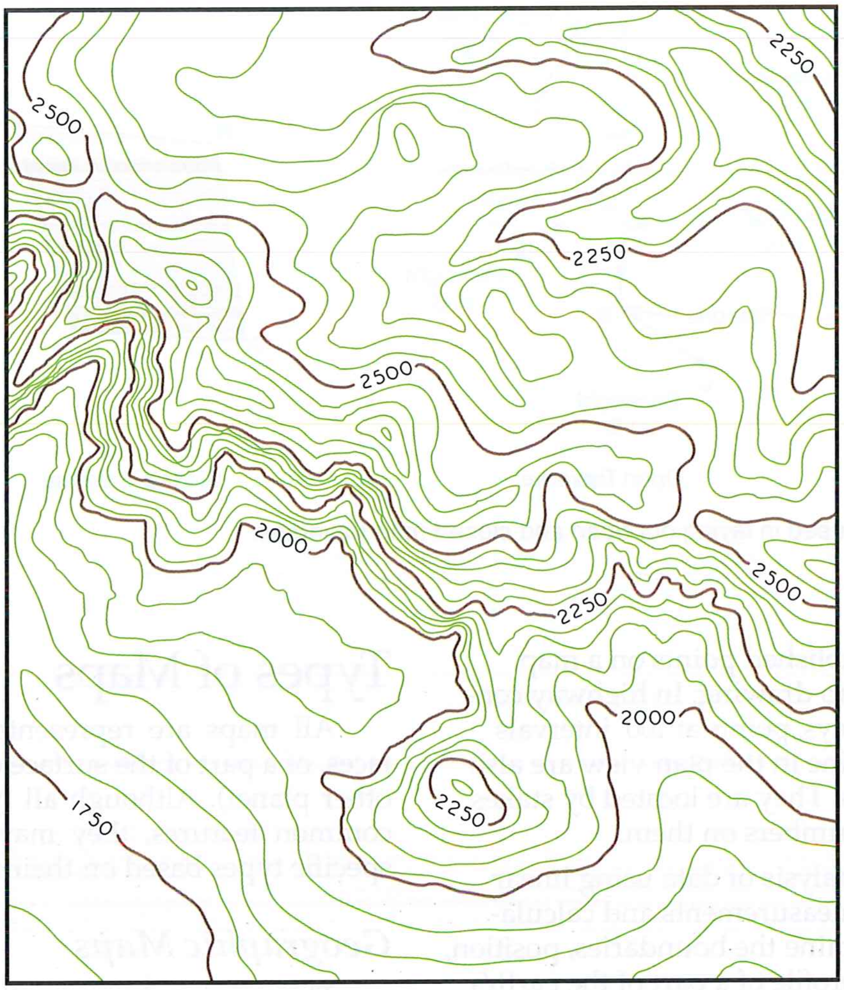


Figure 25-3. A geological surface map.

taking place. A ***geological map*** reports this information pictorially. A geological surface map is shown in **Figure 25-3**. Maps that show geological sections of the subsurface are also used, **Figure 25-4**.

Topographic Maps

In contrast to a geographic map, a ***topographic map*** gives a detailed description of a relatively small area. Depending on their intended use, topographic maps may include natural features, boundaries, roads, pipelines, electric lines, houses,

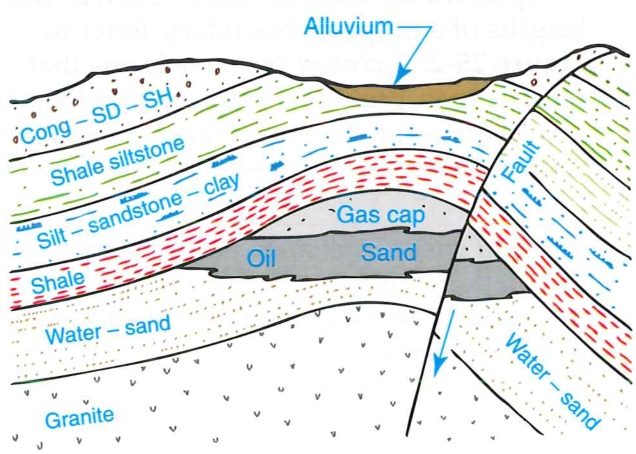


Figure 25-4. A geological section map shows a section of the earth's interior structure.

and vegetation, **Figure 25-5**. Contour lines are normally used to show elevation. Standard map symbols may be employed to show natural or constructed features.

Cadastral Maps

A ***cadastral map*** is drawn to a scale large enough to accurately show the locations of streets, property lines, buildings, and other features of a town or city. See **Figure 25-6**. Cadastral maps are also used in the control and transfer of property. They are used to show plats of additions to a city and to identify property owners along roadways.

Engineering Maps

An ***engineering map*** shows construction details for a given project. Engineering maps range

Figure 25-5. A topographic map shows contour elevations, natural features, and constructed features. Shown is a portion of a CAD-generated topographic map. (Autodesk, Inc.)

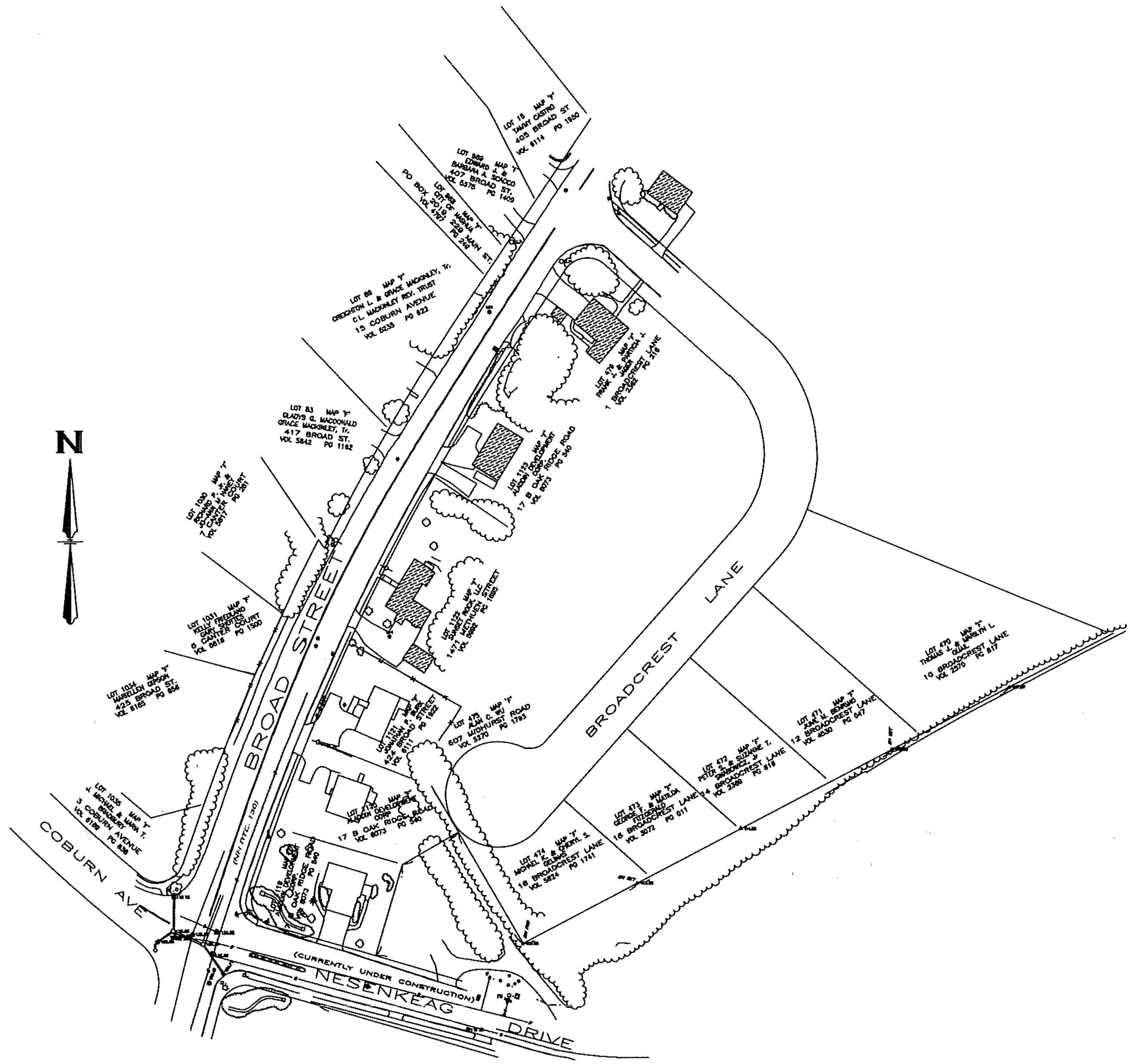


Figure 25-6. A cadastral map aids in locating property lines. It is drawn to a scale large enough to show individual buildings. (Autodesk, Inc.)

from a simple plot plan for a residence to such major engineering projects as commercial buildings, industrial plants, electrical transmission lines, bridges, and hydroelectric dams. An engineering map for a highway construction project is shown in **Figure 25-7**. The horizontal curve details are drawn in the aerial or plan view. The vertical curves indicating elevation are shown on the same sheet in the profile view. The two are referenced by common grid points.

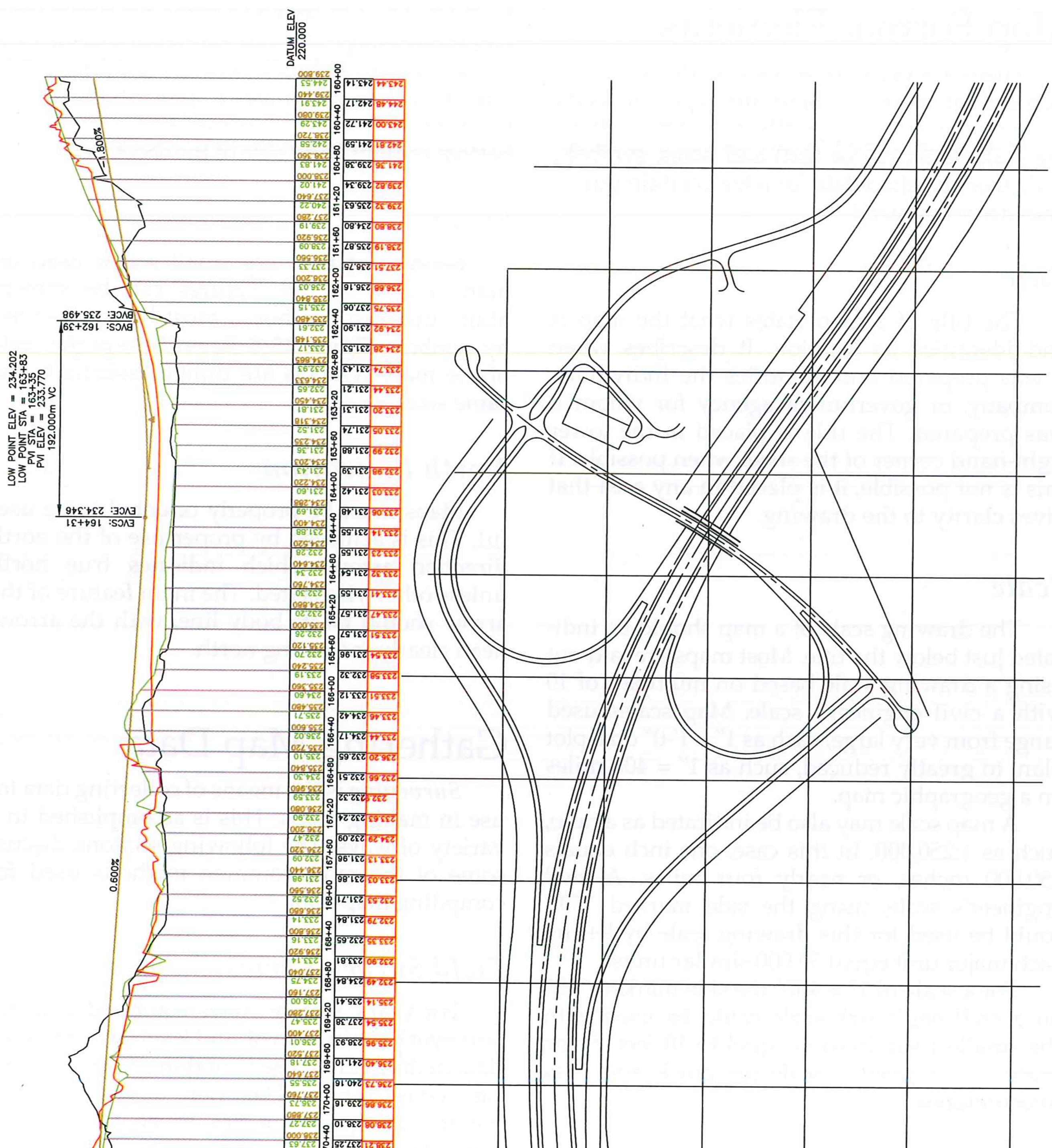


Figure 25-7. A CAD-generated civil engineering map showing the horizontal and vertical curves of a section of highway construction. This type of map drawing requires careful study and detailing. (Autodesk, Inc.)

Map Format Elements

There are perhaps as many different layout formats for maps as there are types of maps. However, each map typically has a title, a drawing scale, lettering (or text) and notes, symbols, and other standard data for which certain guidelines are recognized.

Title

The title of a map states what the map is and identifies its location. It describes when it was prepared and identifies the individual, company, or government agency for whom it was prepared. The title is placed in the lower right-hand corner of the sheet when possible. If this is not possible, it is placed in any area that gives clarity to the drawing.

Scale

The drawing scale of a map should be indicated just below the title. Most maps are laid out using a drawing scale based on multiples of 10 with a civil engineer's scale. Map scales used range from very large, such as 1″ = 1′-0″ on a plot plan, to greatly reduced, such as 1″ = 400 miles on a geographic map.

A map scale may also be indicated as a ratio, such as 1:250,000. In this case, one inch equals 250,000 inches, or nearly four miles. A civil engineer's scale, using the side marked "50," could be used for this drawing scale by letting each major unit equal 50,000 similar units.

For a scale of 1″ = 400′, the side marked "40" on a civil engineer's scale could be used with the smallest subdivision equal to 10 feet. Some maps use a graphic scale for quick and easy interpretation.

Lettering, Text, and Notes

On engineering maps, lettering (on manual drawings) or text (on CAD drawings) is drawn with single-stroke capital letters, either vertical or inclined. The two lettering types are never used on the same map. Map titles are sometimes drawn using a Roman style of lettering, providing a little more flair than the single-stroke Gothic style. All lettering and notes are placed to read from the bottom or right-hand side of the sheet.

Symbols

Because of the very small scales used on many maps, not all features can be shown. Many that can be shown must be represented by symbols, **Figure 25-8**. Regardless of the scale of the map, symbols are drawn essentially the same size.

North Indication

Maps must be properly oriented to be useful. This is achieved by proper use of the north direction arrow, which indicates true north unless otherwise stated. The main feature of the arrow should be its body line, with the arrowhead clearly indicating north.

Gathering Map Data

Surveying is the means of collecting data for use in making maps. This is accomplished in a variety of ways. The following sections discuss some of the most common methods used for compiling map data.

Field Survey Crews

For years, survey crews equipped with the surveyor's chain, transit, and level have gathered data in the field for use in making maps. This is a time-consuming and laborious task, particularly where the equipment has to be carried over rough terrain.

Today, many of these surveying devices have been replaced, particularly on large-scale projects, with faster and more accurate instruments. However, survey crews are still used to

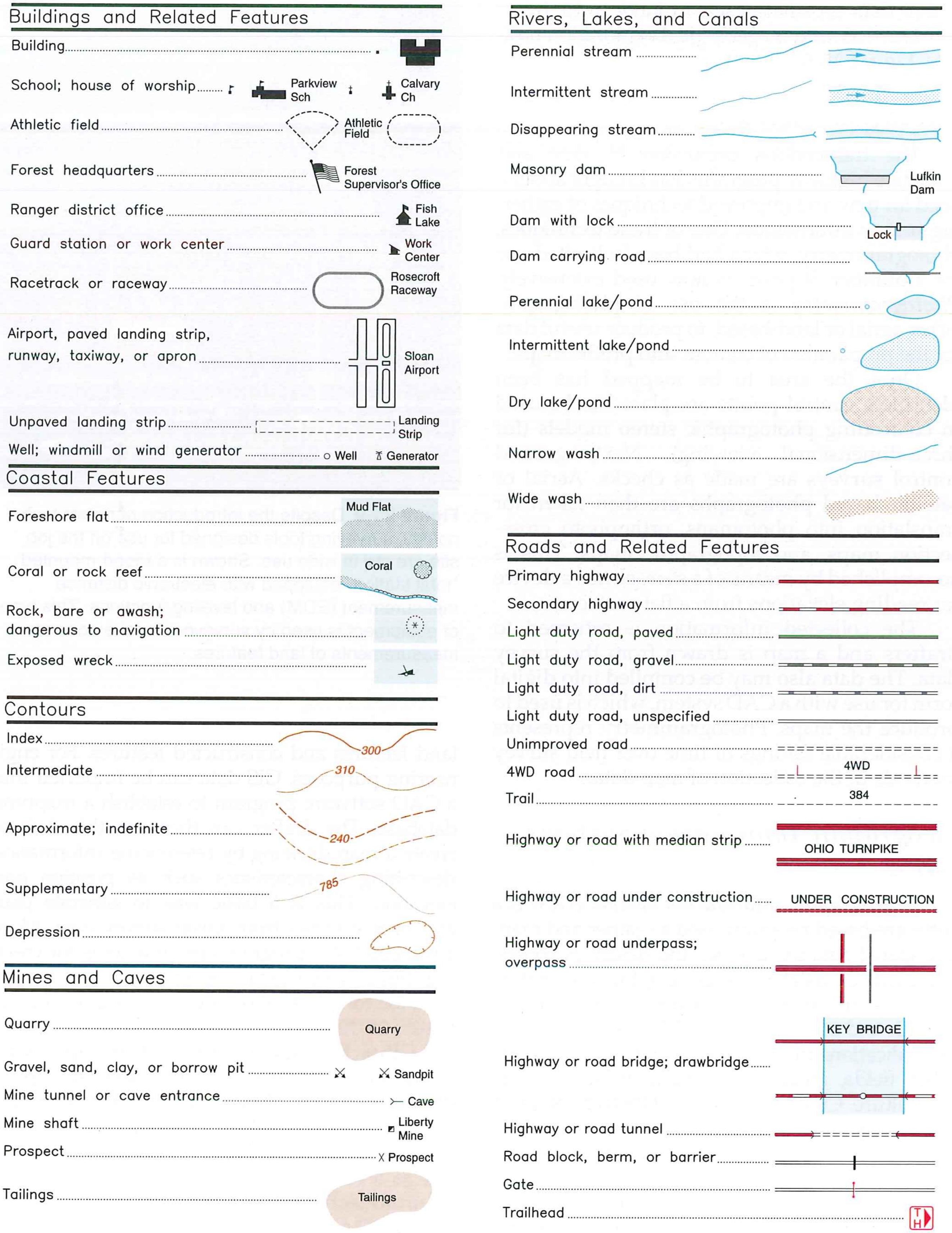


Figure 25-8. Symbols are used on maps to conserve space and make the information easier to understand. Shown are examples of standard topographic map symbols. (US Geological Survey)

gather data on small tracts of land, in highway construction, and on geological exploration projects, **Figure 25-9**.

Photogrammetry

The tremendous expansion in state and interstate highway programs has brought about a need for new and improved techniques of gathering survey information. One of these techniques, photogrammetry, which had been in limited use for a number of years, is now used extensively. ***Photogrammetry*** is the use of photography, either aerial or land-based, to produce useful data for the preparation of contour and profile maps.

Once the area to be mapped has been identified, control points are placed to be used in controlling photographic stereo models (for three-dimensional viewing). Next, ground control surveys are made as checks. Aerial or satellite-based photographs are then taken for translation into photomaps, orthophoto cross-section maps, and topographic maps. This is accomplished by means of a *stereoplotter,* a device for reading elevations from a flat surface.

The collected information is returned to drafters and a map is drawn from the survey data. The data also may be compiled into digital form for use with a CAD system, which is used to produce the maps. Photogrammetry represents a considerable savings of time over field survey methods in the collection of map data.

Figure 25-9. Despite the introduction of newer technology, surveying tools designed for use on the job site are still in wide use. Shown is a tripod-mounted "total station" equipped with electronic distance measurement (EDM) and leveling functions. This type of equipment is used by surveyors to take accurate measurements of land features.

Geographic Information Systems (GIS)

A ***geographic information system (GIS)*** is a software-based program used to gather and manage spatial data for analysis and design purposes. It provides a database of geographic information for use with other types of data, such as demographic and economic data. GIS has a wide variety of applications in mapmaking as well as in many other fields, including geology, hydrology, and agriculture. Civil engineers use GIS technology in planning projects that require the analysis of geographical data for proposed developments, such as improvements to urban infrastructure.

A GIS system provides a record of spatial and attribute data by defining the point locations, contours, and other geographic characteristics of land features and constructed features. For engineering purposes, GIS data can be imported into a CAD software program to establish a mapping database. The drafter can then use this data to create a map drawing by referencing information describing characteristics such as position and elevation. This is a basic way to generate plan and profile views from given survey data. More advanced CAD programs provide tools for creating three-dimensional topographic models that describe the physical contours of a region of land, **Figure 25-10**.

GIS technology is very useful for mapmaking applications because it provides accurate, up-to-date information about land features. The data can be used to analyze relationships between features as well as conditions that may change due to a variety of factors, such as climate and environmental changes. When used together with CAD software, a GIS system provides powerful tools for map drafters and engineers.

Map Drafting Techniques

Once map data has been gathered, there are different methods used to create the actual map drawing. These methods vary based on the type of map being created and whether manual or CAD drawing techniques are used. In manual drafting, contour maps and profile views are typically plotted from survey data using manual construction methods. In 2D-based CAD drafting, map drawings are generated using special software tools that simplify the creation of plan views and profile views. In 3D-based CAD drawing applications, map drawings are typically created as three-dimensional surface models from spatial data.

While the same fundamentals are used in drawing maps in both manual and CAD drafting, there are several manual-based methods that are special to map drafting in comparison to other types of drafting. These methods should be understood by the map drafter and are discussed here.

Plotting Contour Lines

As previously discussed, contour lines are irregular lines used to show equal points of elevation. A contour line may be thought of as the line produced when an imaginary horizontal plane meets the earth's surface. Every point on a single contour line is at the same elevation, and every contour line closes when extended far enough (this point may be off the particular map being drawn). A contour map with a corresponding profile view is shown in **Figure 25-11**.

The contour interval (vertical distance) of spacing between contour lines may be chosen to represent any distance, depending somewhat on the scale of the map and the nature of the terrain. The contour interval is usually 5′, 10′, or 20′ on maps where the terrain is reasonably flat. However, contour lines may be spaced at 100′, 200′, or more, in mountainous terrain. The contour interval in **Figure 25-11** is 10′.

The elevation is given for each contour interval or for alternate intervals. The elevation figures should appear parallel to the contour lines and oriented to read from the bottom of the map where possible. The elevation of a peak or depression is represented by a point, and the elevation figure is given. The usual practice is to show every fifth contour with a heavier line to assist the reader in following contours. This is the convention used in **Figure 25-11**.

Contour lines are plotted from data gathered in the field. One way to locate the elevation points on a contour map is to use *interpolation*. This is

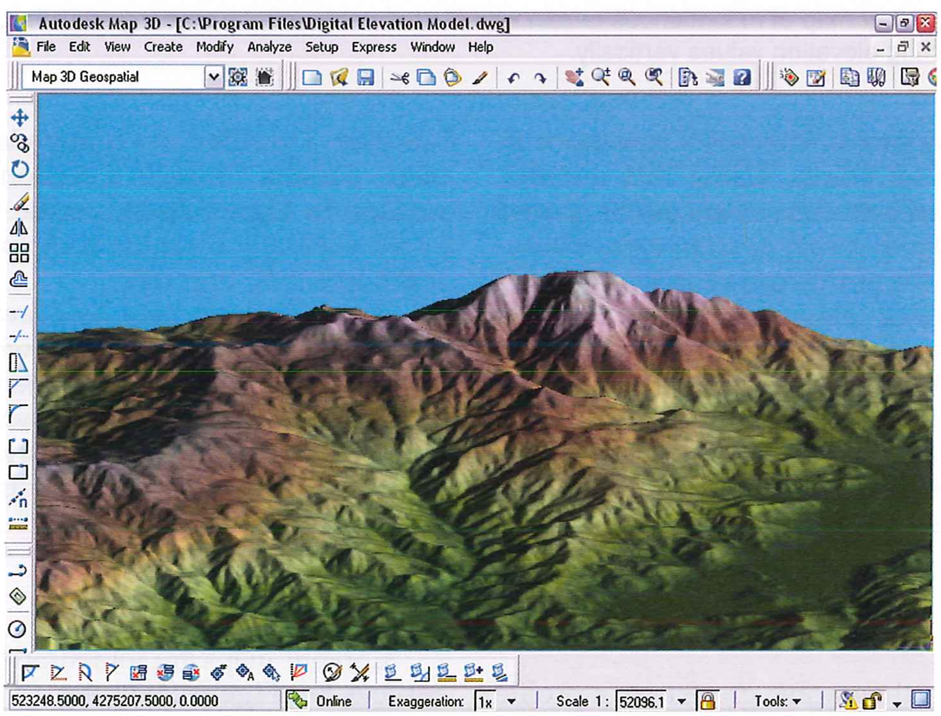


Figure 25-10. A rendering of a terrain model created from spatial data with CAD mapping software. (Autodesk, Inc.)

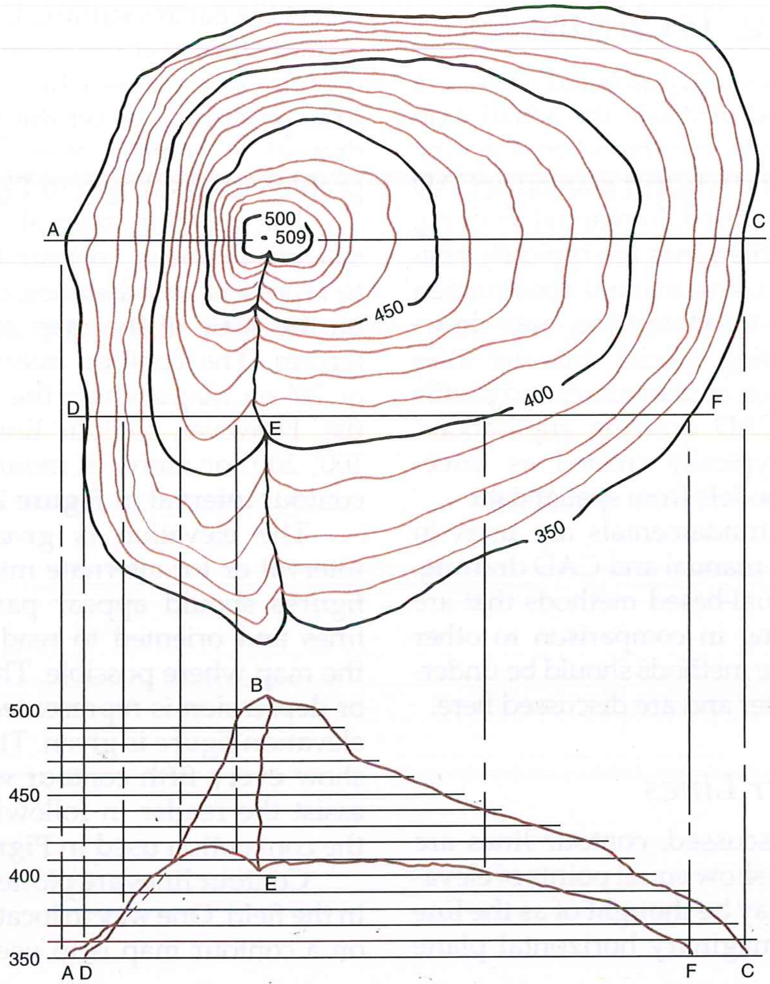


Figure 25-11. A contour map of mountainous terrain with plotted contour lines showing elevation. The profile view is drawn by projecting elevation values vertically.

a method that approximates point elevations in relation to control points. Using this method, points are located between control points spaced close enough together so that accurate measurements between the points can be made. The differences in elevation between the control points are calculated and used to set off approximate elevations at proportional linear distances.

Where the terrain takes a decided change in elevation, such as a steep bank or cliff, measurements may be taken at the point of change and recorded for use in plotting. This adds to the accuracy in plotting particular features of an area.

Drawing Profile Views

In regular orthographic projection, a profile view is one of the side views. In map drafting, however, a profile view is any view of a vertical plane passing through a section of the earth's surface. In **Figure 25-11**, profile views are projected vertically from the contour map to represent Lines ABC and DEF.

A profile view may be drawn to the same scale as the contour map from which it is taken. Or, the scale may be exaggerated to emphasize changes in elevation. Profile views are used to detail vertical curves and elevations of cuts and fills for highways, canals, and similar construction projects.

Drawing Grid Surveys

Contour maps are sometimes laid out as grid surveys. See **Figure 25-12**. A ***grid survey*** employs a rectangular grid with identified elevation points

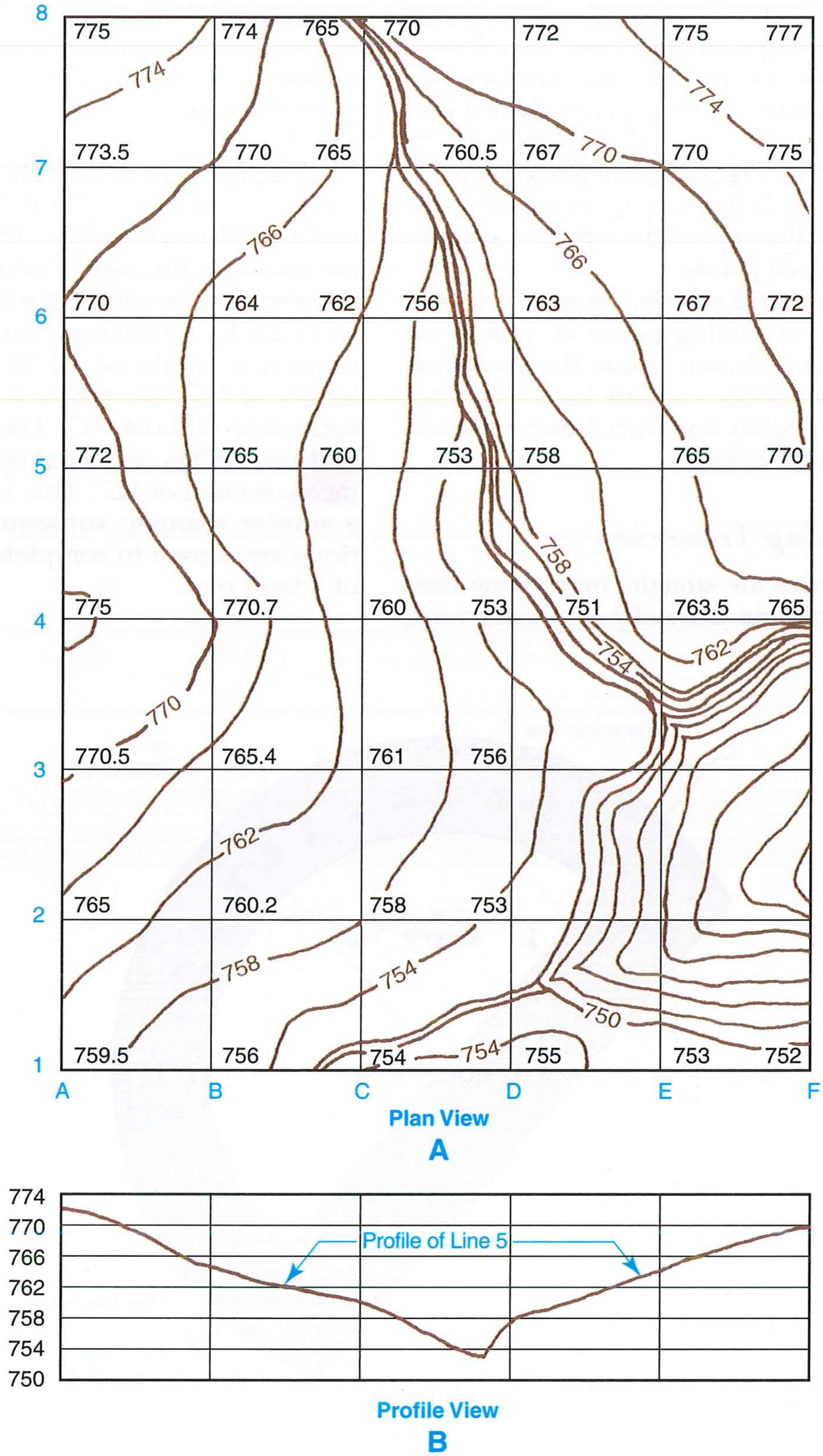


Figure 25-12. A grid survey uses a rectangular grid system for plotting contour lines. Points are projected vertically to draw the profile view.

at the grid intersections. To plot the contour lines for the map, interpolation is used to calculate elevation points. Horizontal distances between the measured points on the grid are divided proportionally to establish elevation points between grid intersections. The points are plotted at regular contour intervals. In making interpolations, it is assumed that the slope of the terrain is uniform between measured points.

To lay out a grid survey, the grid is placed below a sheet of tracing paper or vellum on which the map is drawn. Then, the points are plotted for the various contour lines. The lines are sketched in lightly and then drawn freehand to the correct line weight.

Drawing Map Traverses

Map traverses are straight, intersecting lines that may be laid out manually in several ways, depending on the time available and accuracy required. For most maps, a protractor and scale are satisfactory for laying out traverses, **Figure 25-13**. For maps requiring greater accuracy, trigonometric calculations are used.

The layout procedure shown in **Figure 25-13** starts at Station 1 (Point B) from a known backsight line (Line BA). The line is extended far enough through Point C to allow the protractor to be aligned with the center point at Point B. Assuming Station 3 has a right deflection angle of 82°30′ and a foresight length of 127′, the protractor is located to the right side of Line AC. The angle is laid off, and Line BD is extended by laying off a scale measurement of 127′. This locates Station 3. In a similar manner, subsequent lines and stations are drawn to complete a closed traverse of a land plot.

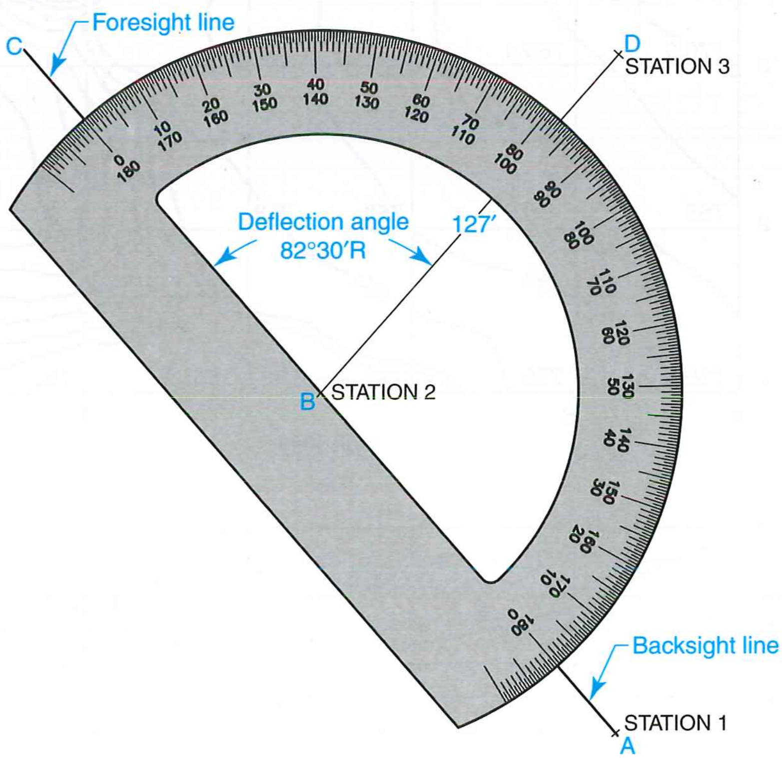


Figure 25-13. Laying out a map traverse with a protractor.

Chapter Summary

Special kinds of drafting are required in the preparation of maps. The drafter must be familiar with a number of mapping and surveying terms to be able to prepare maps from surveying data.

Maps can typically be classified as geographic maps, geological maps, topographic maps, cadastral maps, and engineering maps. Map layout elements vary, but most maps include a title, drawing scale, lettering (or text) and notes, symbols, and other standard data.

Surveying is the means of collecting data for use in making maps. This is accomplished in a variety of ways. The most traditional method is data collection by field survey crews. Map data is also collected through photogrammetry. This is the use of photography to produce useful map data. Maps are also created from information provided by geographic information systems (GIS). A GIS system provides a database of information (including spatial and attribute data) for use with other types of data. GIS technology is commonly used in conjunction with CAD software to develop map drawings and three-dimensional models.

Special drawing methods are used to create maps in manual drafting. Contour maps and grid surveys are laid out using special construction techniques that differ from methods used in other types of drafting.

Additional Resources

Publications

CaGIS Journal
Cartography and Geographic Information Society
www.cartogis.org

USGS Library
US Geological Survey
www.usgs.org

Manual of Instructions for the Survey of the Public Lands of the United States
US Department of the Interior (Bureau of Land Management)
www.blm.gov

Computers and CAD Software

Autodesk, Inc.
Developer of Civil 3D and Land Desktop
www.autodesk.com

Eagle Point Software
Developer of land development software
www.eaglepoint.com

Review Questions

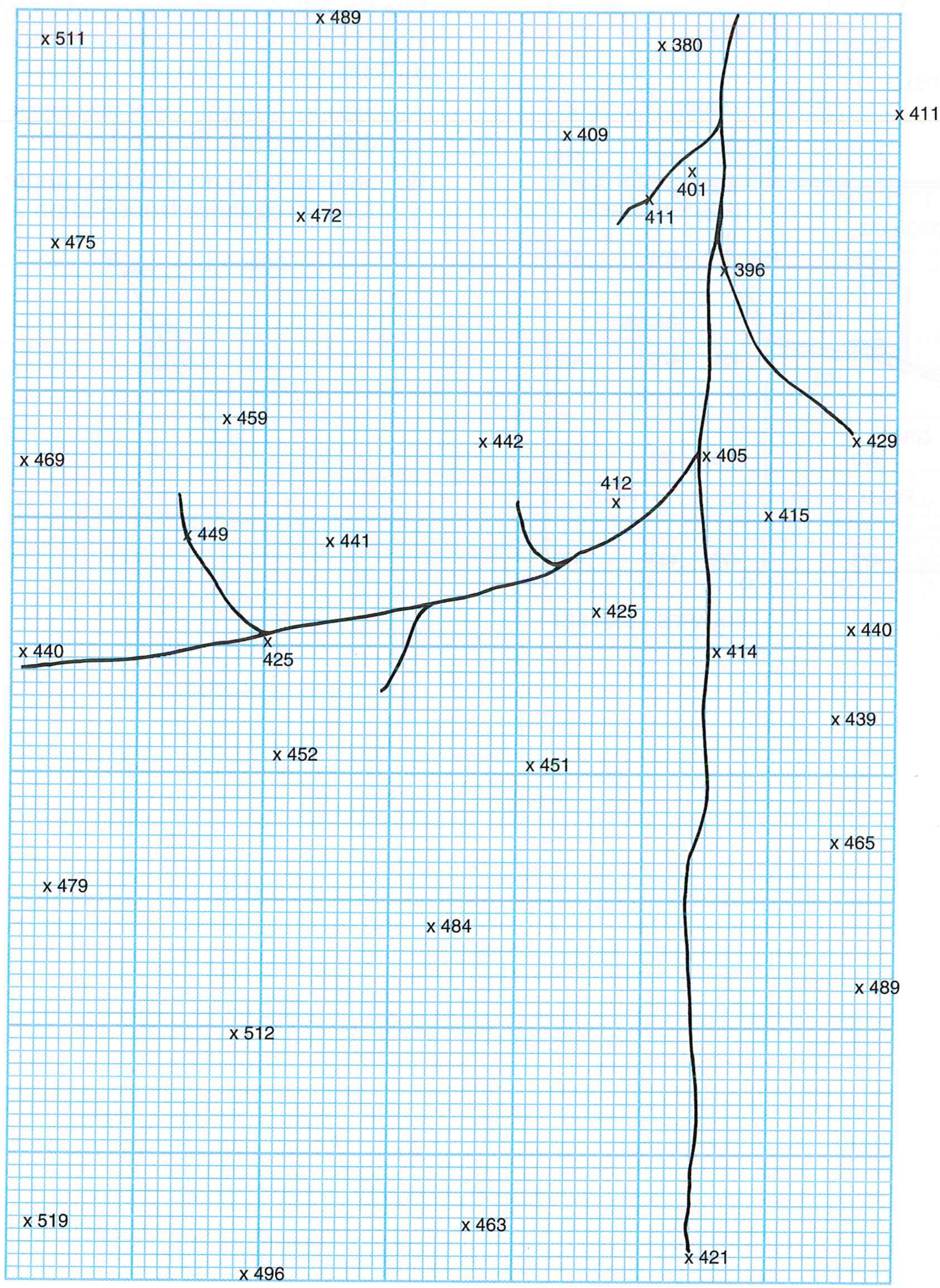
1. The science of mapmaking is called _____.
2. Define the term *bearing.*
3. The irregularly shaped lines used on topographic maps and other map drawings to indicate changes in terrain elevation are _____ lines.
4. What is *interpolation*?
5. A plan that shows land ownership, boundaries, and subdivisions is called a _____.
6. A(n) _____ map normally represents a large area and must be drawn to a very small scale.
   A. cadastral
   B. engineering
   C. geographic
   D. topographic

7. _____ is the study of the earth's surface, its outer crust and interior structure, and the changes that have taken and are taking place.
8. A(n) _____ map gives a detailed description of a relatively small area and may show natural features, boundaries, roads, pipelines, electric lines, houses, and vegetation.
9. A _____ map is drawn to a scale large enough to accurately show the locations of streets, property lines, buildings, and other features of a town or city.
10. What type of map shows construction details for a given project?
11. Most maps are laid out using a drawing scale based on multiples of _____ with a civil engineer's scale.
12. All lettering and notes on a map are placed to read from the _____ or _____ side of the sheet.
13. The north direction arrow on a map indicates _____ north unless otherwise stated.
14. Define the term *surveying.*
15. _____ is the use of photography, either aerial or land-based, to produce useful data for the preparation of contour and profile maps.
16. What is a *geographic information system*?
17. On map drawings, the elevation of a peak or depression is represented by a _____, and the elevation figure is given.
18. In map drafting, a _____ view is any view of a vertical plane passing through a section of the earth's surface.
19. What is a *grid survey*?

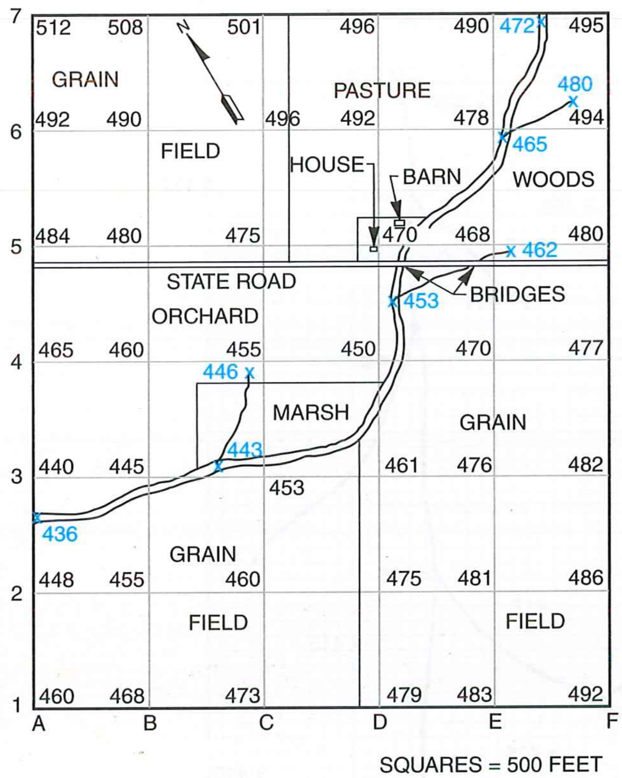
Problems and Activities

The following problems are designed to provide you with an opportunity to apply knowledge gained in your study of map drafting and to help you become familiar with the procedures used. The problems can be drawn manually or with a CAD system. Complete each problem as assigned by your instructor.

1. Select an appropriate scale and contour interval and plot the contours for the map shown. Use the given elevation data and interpolation to locate plotting points.



2. Select an appropriate scale and contour interval and plot the contours, as well as the natural and constructed features, for the grid survey shown. Use the given elevation data and interpolation to locate plotting points.



3. Draw a profile map showing the shape of the terrain at Lines 1 and 4 through the map section shown in Problem 2. Use the same scale as that used for the contour map.

4. Lay out the map traverse shown using the given line and station data. Indicate the north direction on the map, and then orient the first station and backsight line with it. Use the following station points. Lay out a closed traverse after locating Station 3 and indicate the direction and distance.

   A. Station 2: Right deflection angle = 75°; distance from Station 1 = 129′

   B. Station 3: Right deflection angle = 138°30′; distance from Station 2 = 162.5′