CHAPTER 12

Navigation

"No, I can't say as I was ever lost, but I was bewildered once for three days."

—Daniel Boone (1734–1820), frontiersman

Nature has provided many of its creatures with keen senses of direction. Species of birds migrate thousands of miles between warm southern climes and northern breeding grounds. Some butterflies also are migratory, and animals as diverse as honeybees, bats, whales, and reindeer seem to move with great certainty about where they are and where they wish to go.

Humans do not have the gift of strong directional instinct. What we do possess, however, is the ability to think clearly. By supplementing our reasoning with a few navigational instruments, we can make our way through even the most complicated wilderness terrain.

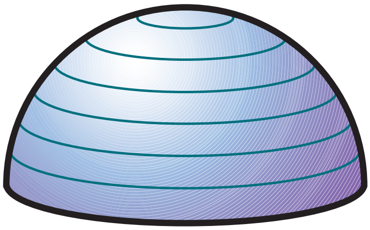
Navigation is problem solving of the highest order. It demands that you pay attention to details and make sense out of many bits of information. As with most outdoor skills, navigational competence can be developed only with practice. Increase your awareness of topography by observing your surroundings on outdoor trips and noting the lay of the land. Imagine the most likely locations for trails, campsites, portages, and summit routes, and then see if your guesses are right. Hone your ability to use maps and compasses by referring to them from the time you leave the trailhead. Before long you will seldom find yourself confused.

The mastery of map-and-compass skills is essential for anyone wishing to become self-reliant in the out-of-doors. Electronic navigational aids, especially those referencing global positioning systems, can augment travelers' ability to find their way but are no substitute for the importance and the pleasure of learning to use compasses and maps.

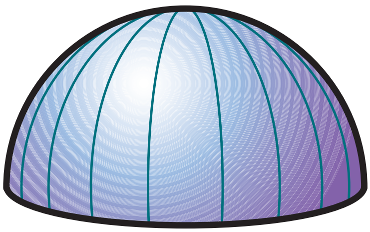
Maps

Maps are written records of places. Featuring both natural and constructed features, *planometric maps* offer an artistic representation of an area. *Topographic maps* go a step further by including three-dimensional representations of the shape of the terrain. The most useful maps for trek adventures are those based upon data prepared by the U.S. Geological Survey (USGS) of the Department of the Interior. Sporting goods stores often carry maps of nearby recreational areas. Maps for many parts of the country can be downloaded from Internet sites or ordered directly from the USGS.

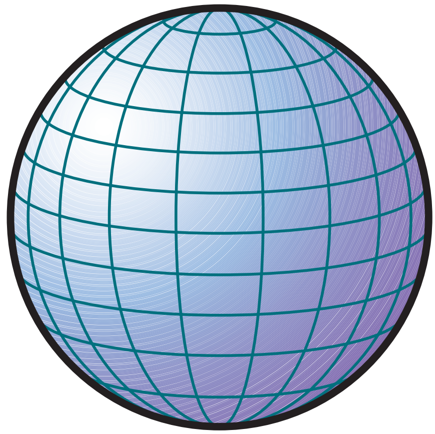
For more on the U.S. Geological Survey and on downloading maps, see the *Fieldbook* Web site.



Latitude



Longitude



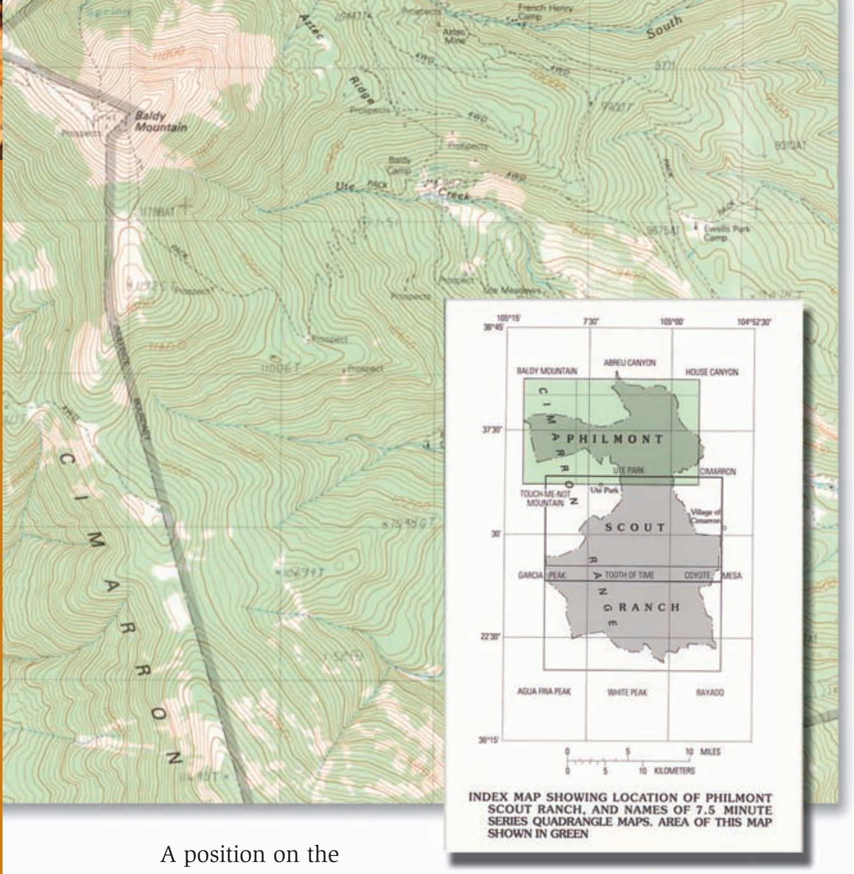
Latitude and longitude

Latitude and Longitude

As a means of pinpointing geographic locations, *cartographers* (those who make maps) have overlaid the globe of Earth with a grid of numbered, intersecting lines. The north-south lines—*meridians of longitude*—are drawn from the North Pole to the South Pole. Just as there are 360 degrees in a circle, there are 360 lines of longitude. The *prime meridian*—the line passing through the Royal Observatory at Greenwich, England—is *zero degrees longitude*. The numbering of meridians proceeds both westward and eastward from the prime meridian, meeting in the Pacific Ocean at 180 degrees longitude. (This 180th meridian also serves as the *international date line*.)

The east-west lines of the grid are *parallels of latitude*. The equator serves as *zero degrees latitude*. Lines running parallel with it are numbered sequentially to the poles. The North Pole is 90 degrees of latitude north of the equator; the South Pole is 90 degrees south. In a manner similar to that by which an hour of time is divided into smaller units, each degree of longitude and latitude is divided into 60 *minutes*, and each minute of longitude and latitude is divided into 60 *seconds*.

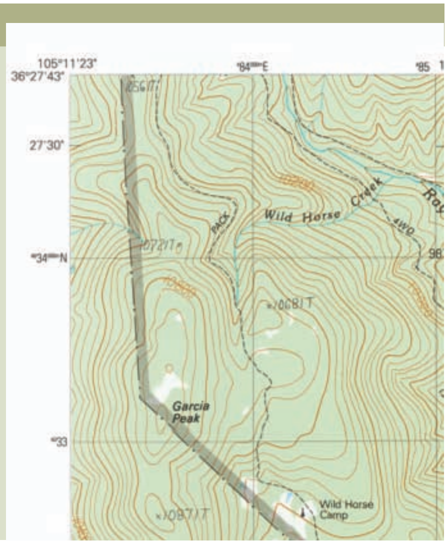
A downloaded map that you print out at home might not stand up very well to moisture. Ink can run when exposed to rain or snow, and the paper might disintegrate when wet. Fold a map so that the critical information shows, then keep the map in a self-sealing plastic bag.

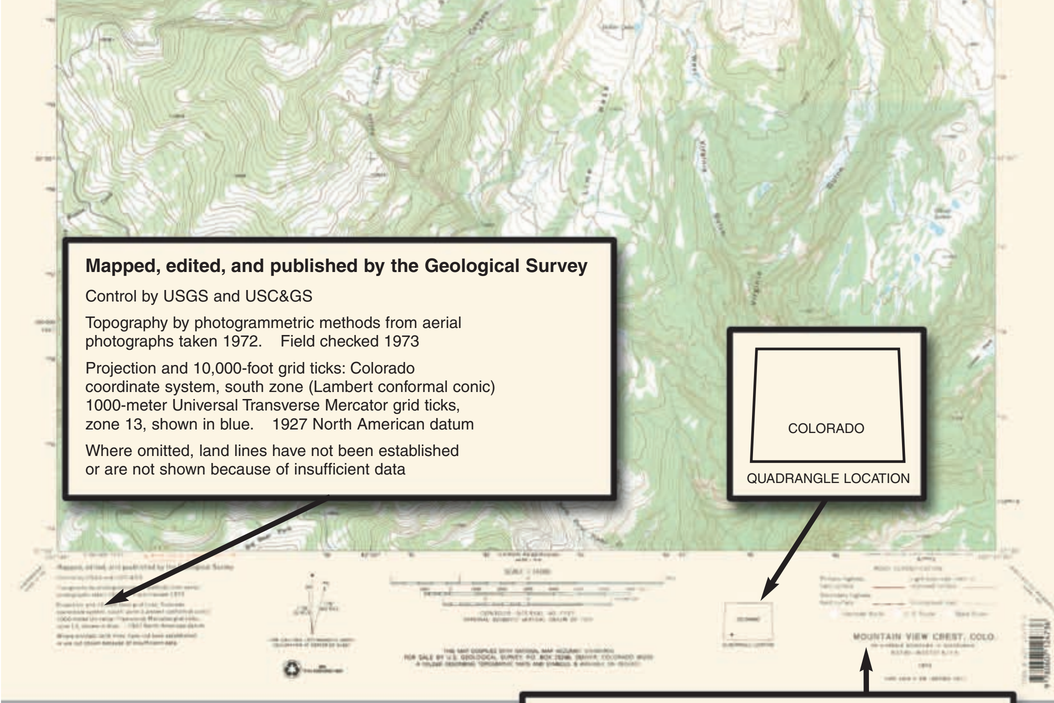


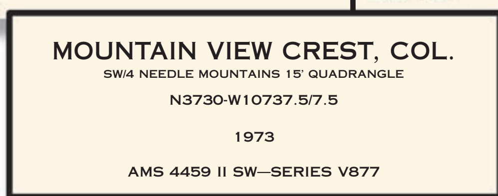
A position on the globe is stated latitude first, followed by longitude. For example, the coordinates of latitude and longitude for the summit of Baldy Mountain, the highest point on Philmont Scout Ranch in New Mexico, are *36°37′45″ N* and *105°12′48″ W.* That means that hikers standing atop Baldy are 36 degrees, 37 minutes, 45 seconds north of the equator, and 105 degrees, 12 minutes, 48 seconds west of the prime meridian.

The UTM Grid

Often used by search-and-rescue teams, the *universal transverse macerator (UTM)* grid is a metric coordinate system designed to pinpoint any location on Earth, with the exceptions of north and south polar regions. UTM grid lines are always 1 kilometer apart (about six-tenths of a mile) and are aligned with true north (discussed later in this chapter). Numerical notations for the UTM grid appear in the margins of many topographic maps.







Map Margins

The margins of a USGS map contain a wealth of useful information:

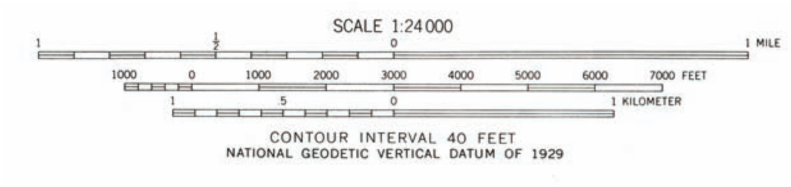
Date

Time is the enemy of map accuracy. The newer a map, the more precisely it can portray the current appearance of an area and the more exactly it will note the declination of magnetic north (discussed later in this chapter). The date printed in a map's margin indicates the year the map was created or most recently revised.

Location and Size

The geographical area covered by a topographic map is indicated by the coordinates of latitude and longitude printed in the map's corners. (Each map also will bear the name of a prominent geographic feature appearing somewhere within its boundaries—Knox Bluffs, for instance, or Waubonsie Peak.) The size of that area can be cited in the margin in terms of minutes. The maps most useful for backcountry travelers are *7.5-minute* maps and *15-minute maps:*

- *7.5-minute maps* encompass an area that is 7.5 minutes of latitude south to north, and 7.5 minutes of longitude east to west. (Since 1 minute of latitude on the ground is 6,200 feet, a 7.5-minute map will cover about 9 miles, north to south. The area covered by a 7.5-minute map ranges from 49 to 71 square miles, depending upon its latitude. The width of a minute of longitude, and thus the width of the map, will vary depending on the map's distance from the equator.)
- *15-minute maps* enclose an area that is 15 minutes of latitude south to north, and 15 minutes of longitude east to west.



Scale

The *scale* of a map compares the size of the map itself to the dimensions of the land it represents. A 7.5-minute map has a scale of 1:24,000 (1 inch on the map representing 24,000 inches on the land; thus, a mile is about $2^1/_2$ inches on a map). A 15-minute map features a scale of 1:62,500. (Maps downloaded from the Internet might print out in formats sized differently from the original maps. To ensure accuracy, always use the *distance rulers* printed near the scale indicator in the bottom margin to translate the scale into map distances of feet, miles, and kilometers.)

Map Colors

Cartographers rely on different colors of ink to indicate the various landscape features of a topographic map:

BLUE ***is used for aquatic features—streams, lakes, oceans, wetlands, etc. Contour lines of glaciers and permanent snowfields are also blue. Aquatic landmarks such as rivers and lakes are further denoted by having their names written in*** *italics.*

GREEN ***indicates vegetation, usually forests sufficiently dense to hide a group of travelers.***

WHITE ***signifies land such as meadows and boulder fields with little or no tall vegetation. A group of travelers would be visible from the air.***

BLACK ***ink is used for anything that is the work of humans—buildings, railroads, trails, etc. Names of geographical features are always written in black.***

RED ***ink can be applied to certain survey lines (township and range, for instance) and to highlight primary highways and other significant constructed features.***

PURPLE ***overlays revisions to a map that are based on aerial photos but have not yet been fully verified in the field.***

BROWN ***is reserved for contour lines and elevations.***

Contour Lines

A topographic map is a two-dimensional model of the three-dimensional world. The sense of three dimensions is portrayed through the use of *contour lines,* which are drawn with brown ink. Each contour line represents a specific elevation above sea level. The vertical difference between adjacent lines is indicated in the margin of a map as that map's *contour interval*—anywhere from 10 feet to 200 feet, depending on the scale of the map and the ruggedness of the terrain.

Each contour line forms a loop. Hike a line and, because you will stay at exactly the same elevation, you eventually will return to your starting point. Lines close together indicate steeper areas than regions with contour lines far apart. Maps with few contour lines signify relatively flat territory such as that forming a prairie or wetland.

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Map Symbols

For more information on map symbols, see the *Fieldbook* Web site.

TOPOGRAPHIC MAP SYMBOLS

Roads, Railroads, and Other Features

Primary highway	Railroad: single track
Secondary highway	Railroad: multiple track
Light-duty road	Overpass; underpass
Unimproved road	Power transmission line
Trail	Landmark line (Telephone)

Land Surface Features

U.S. mineral prospect	Distorted surface
Quarry; gravel pit	Gravel beach
Mine shaft	Glacier
Mine dump	Woodland
Tailings	Orchard
Tailings pond	Vineyard
Dune area	Mangrove
Sand area	Scrub
Levee	

Buildings and Related Features

Buildings	Airport, paved landing strip, runway, taxiway, or apron
School	
House of worship	Campground; campsite
Cemetery (Cem)	Winter recreation area
Tanks (Water Tank)	Ranger district office
Wells (Oil, Gas)	Guard station or work center
Picnic area	
Landmark	

Water Features

Dam with lock	Rapids
Canal with lock	Falls
Exposed wreck	Intermittent lake
Rock or coral reef	Dry lake bed
Rock: bare or awash	Marsh (swamp)
Wide wash	Submerged marsh
Narrow wash	Wooded marsh
Perennial streams	Aqueduct tunnel
Intermittent streams	Channel
Water well; spring	Sounding; depth curve 10

Elevation

Horizontal control station		Index contour	
Vertical control station	BM × 671 × 672	Supplementary contour	
Checked spot elevation	× 5970	Intermediate contour	
Unchecked spot elevation	× 5970	Depression contours	

Boundary

Federally administered park, reservation, or monument (internal)

Meaning of Map Colors

Green	Major vegetation (forest, brush, orchard)
Blue	Water (lake, stream, spring, marsh, water tank)
Red	Highways or boundaries
Black	Human-made structures and place names (buildings, roads, trails, bridges, railroads)
White	Absence of major vegetation, (prairie, meadow, tundra—above timberline)
Brown	Contour lines and standard elevations

Determining Distance

A compass bearing can point you in the direction you wish to travel, but it can't tell you how far along that route you will need to go in order to reach your destination. For that, you can refer to the distance rulers in the map's margin.

1. Place one end of a piece of string on the map at your starting point.
2. Lay out the string on top of the route you plan to use, bending the string to conform with any twists and turns of the route.
3. Pinch the string where it touches the map symbol for your destination.
4. Stretch the string on the bar scale in the bottom margin of the map and measure it to the point where you are pinching it. That's the approximate length of your route.

Compasses

The sextant is a navigational device used since Columbus' time.

For directional guidance, early explorers relied on the North Star, the prevailing winds, the movements of ocean currents, the migrations of birds, and other observations of the natural world. When they could, they followed sketchy maps and the reports of fellow wanderers. Then came the compass, appearing a thousand years ago in Asia and a century later in Europe. At first it was nothing more than a magnetized bit of metal floating on a piece of wood in a bowl of water. By Columbus's time it had evolved into an instrument sufficiently reliable to guide the explorer's three ships across the Atlantic. Today, the liquid-filled compass is an indispensable navigational tool.

Celestial Navigation

Before compasses, people who needed to move from one place to another often guided their travels by looking to the stars. Perhaps you can already identify the North Star and prominent northern constellations, such as Ursa Major and Cassiopeia. Maybe you know how to find Orion and Scorpius in the southern sky. Whenever they are visible, these and other skymarks can serve as reliable references of direction.

For more on stars and constellations, see the chapter titled "Watching the Night Sky."

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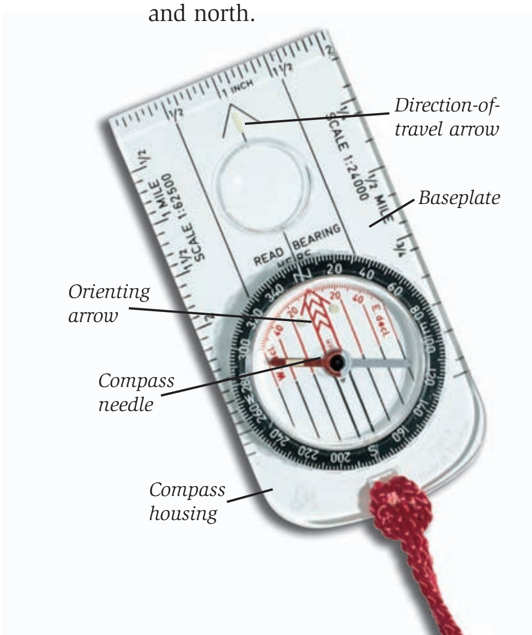
The compass most useful for adventure-trek navigation consists of a magnetized needle balanced inside a circular, rotating housing mounted atop a baseplate. The plate is etched with a *direction-of-travel arrow.* The floor of the compass housing is engraved with an *orienting arrow* and, parallel with it, several north-south *orienting lines.*

The circumference of the housing is divided into directions—north, south, east, and west—and further divided into 360 degrees, just as in any circle: *0°* coincides with north, *90°* with east, *180°* with south, *270°* with west, and *360°* is again north (*0°* and *360°* overlap as they close the circle). Any direction can be expressed in degrees. For example, *95°* is a little south of straight east, while *315°* is midway between west and north.



> *"There has always been a romantic fascination to persons who could find their way through the wilderness and over hidden trails—the Indian, the pioneer scout, the guide, the tracker, the explorer."*
>
> —Bjorn Kjellström, orienteering enthusiast and founder of the Silva compass company

Because magnetic north continually drifts westward across the United States, declination for a particular area is always changing. The National Geographic Data Center's Web site (http://www.ngdc.noaa.gov/seg/potfld/geomag.shtml) *provides up-to-date declination information to help you determine your true bearing.*

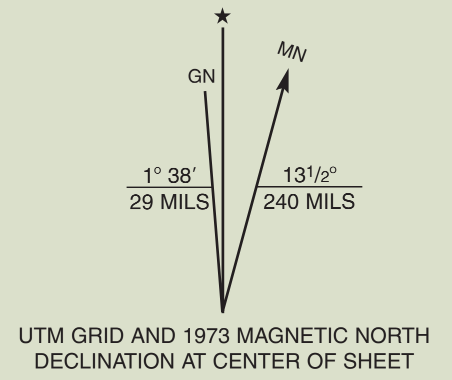
Declination

Somewhere north of Canada's Hudson Bay lies the center of a natural magnetic field strong enough to pull the tip of a compass needle toward itself. This area is called *magnetic north,* and it is toward magnetic north that all compass needles point. Magnetic north is more than a thousand miles away from the North Pole, or *true north.* (You can find the approximate location of magnetic north on a globe or other map of the world at latitude 78° N, longitude 104° W.)

Draw an imaginary line from the North Pole to the point where you are standing. Draw a second line from magnetic north to your position. The difference between those two lines, expressed as the degrees of the angle they form, is the *declination* for a particular location.

In the American Midwest, the lines drawn from the two norths will be close to one another and the declination small. In fact, a line drawn northward through Mississippi and Wisconsin will intersect both the magnetic and geographic North Poles. Along that *agonic line,* a compass needle pointing at magnetic north will also be pointing at true north.

However, if you move west of the agonic line, the angle between a line drawn from your location to the geographic North Pole and a line from your location to magnetic north will gradually increase. At Philmont Scout Ranch in New Mexico, the magnetized compass needle will point about 10 degrees to the right of true north, while in Seattle it will point about 18 degrees to the right. Take the compass east of the agonic line to New York City, and the needle will swing about 14 degrees to the left of true north. On the coast of Maine, the declination will have increased to 18 degrees or more.



Citations in the margins of many USGS maps indicate the declination of an area.

On older USGS maps, a margin diagram of two arrows indicates the declination for that map's area. The arrow representing true north may be labeled *True North,* or topped by a representation of the North Star. The arrow indicating magnetic north will probably be labeled *Magnetic North* or *MN.* The angle formed by the two arrows is the declination for that map. (Newer maps might include degrees of declination, but not the arrows, in their margins.)

Dealing With Declination

Where declination is greater than a few degrees—that is, anywhere except in a narrow corridor near the agonic line through the center of North America—failing to account for declination can lead to errors in navigation that could render a compass and a map almost useless. Over the course of a mile's travel, an error of just a few degrees can pull you off your intended route by hundreds of yards.

Most maps are drawn with true north as their reference and can be said to "speak the language of true north." (Remember those lines of longitude extending to the North Pole? They form the left and right borders of the majority of maps.) Compasses, however, rely on a magnetized needle and thus have magnetic north as their native language. To use a map and compass together, you must resolve this difference, either by changing the compass or by changing the map.

Magnetic north is drifting westward at a rate that changes declination in much of the United States by about one degree each decade. Note the date of a map; the older the map, the less accurate its stated declination.

Marking a Compass for Declination

A basic baseplate compass can be marked to help travelers adjust for declination. On the compass housing, place a tiny *declination dot* of indelible ink, brightly colored enamel paint, or fingernail polish at the degree reading that matches the declination of the area where you intend to travel. For example, if the declination is 15 degrees to the east of true north, place the dot at 15 degrees on the circumference of the compass housing. If the declination is 15 degrees to the west of true north, place the dot at 345 degrees—that is, 360 degrees (true north) minus 15 degrees. A careful look at the declination information in the map margin should make it clear whether magnetic north is to the left or to the right of true north.

Marking a compass for declination

When your adventures take you to a region with a different declination, remove the original declination dot of ink, paint, or polish with a cotton swab dipped in denatured alcohol. Replace the dot with a fresh one correctly positioned on the compass housing.

Turn the compass housing so that *N* (true north) touches the direction-of-travel arrow. Then, holding the compass in the palm of your hand, turn your body until the red tip of the magnetic needle points at the declination dot. The needle is pointing to magnetic north, but the rest of the compass is speaking the language of true north.

Adjusting a Compass for Declination

For a few dollars more than the price of a basic compass, you can purchase a compass that can be corrected for declination. Follow the manufacturer's instructions to make the adjustment, usually by turning a small screw or gently twisting an inner portion of the compass housing to change the position of the orienting arrow etched on the housing floor.

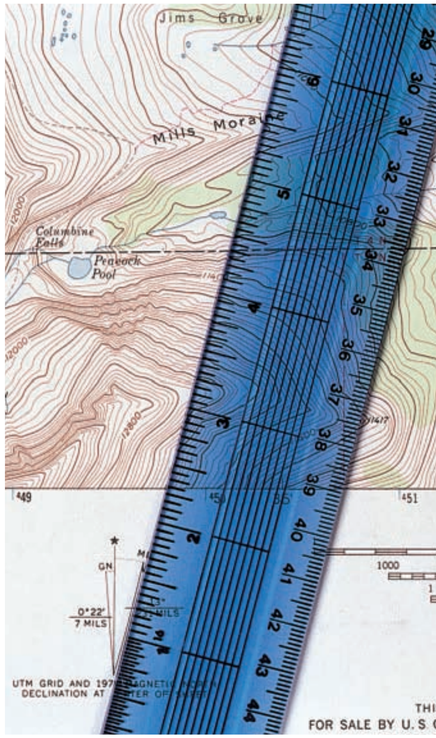
Adjusting a compass for declination

After you have adjusted it, turn the entire housing of the compass so that north on the circumference of the housing (indicated by *0°* or the letter *N*) is aligned with the direction-of-travel arrow on the baseplate. For the moment, think of that as the line drawn to true north. The angle the true-north line forms with the newly adjusted orienting arrow should be the same as the angle formed in the map margin by the true-north and magnetic-north lines.

Changing the Map for Declination

Another way to deal with declination is by teaching a map to understand the language of magnetic north. Use a protractor (and the skills you learned in geometry class) to transfer the angle of declination to the map, then use a straightedge ruler to extend a magnetic-north line across the map. Draw additional lines parallel with the first line, a ruler's width apart. Use these *magnetic-north lines* as your references when using an unadjusted compass (that is, one that is also speaking the language of magnetic north) to orient the map and find your way.

(*Note:* The margin arrows indicating the angle of declination of older maps might not be drawn to scale. Though good for suggesting the general aspect of declination, they are not a reliable guide for extending magnetic-north lines across a map.)



Draw magnetic-north lines on a map with the help of a protractor and a straightedge.

> *"A good navigator is never lost, but having learned humility, always carries enough food and clothing to survive hours or even days of temporary confusion."*
>
> —From *Mountaineering: The Freedom of the Hills,* 4th edition, 1982

Using Maps and Compasses Together

Maps and compasses used together serve as a much more powerful navigational aid than either a map or a compass alone.

Orienting a Map

A map that is *oriented* is aligned with the topography it represents. North on the map points toward the North Pole. Landscape features in the real world have the same directional relationships to one another as are indicated on the map.

To orient a map, first rotate the compass housing until *N* lines up with the direction-of-travel arrow on the baseplate. The *compass bearing* is north.

Next, place the long edge of the compass baseplate alongside any true-north line on the map—the left or right border, any line of longitude, township boundaries, etc. Turn the compass and the map as a unit until the red tip of the compass needle points toward the declination dot (for declination-marked compasses) or the compass needle settles inside the orienting arrow on the floor of the compass housing (for declination-adjusted compasses). When that happens, the map is oriented. (If you have adjusted the *map* for declination but not the compass, line up the baseplate with any magnetic-north lines you have extended across the map and allow the compass needle to settle inside the orienting arrow.)

True-North Lines

True-north lines on a map are any lines that parallel meridians of longitude—most notably the map's vertical boundaries. Based on longitude meridians, north-south township lines and UTM grid lines also can be used as true-north lines. In the field, a map without many true-north lines can prove difficult to use with a compass. Prepare the map ahead of time by using a straightedge and a pencil to scribe lines on the map running parallel with the map's north-south borders.

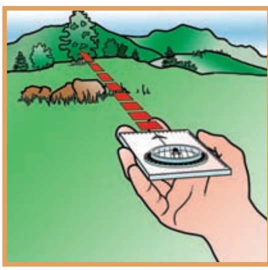
Identifying Landmarks

Have you ever seen a mountain range and wondered what each summit was called? With a compass and a sharp eye, you can identify any landmark prominent enough to appear on your map. Here's how:

Hold the compass in the palm of your hand, and point the direction-of-travel arrow on the baseplate at the landmark in question. Turn the compass housing until the red end of the needle points at the declination dot (for declination-marked compasses) or until the needle is aligned with the orienting arrow (for declination-adjusted compasses). That will give you the *bearing* from your position to the landmark.

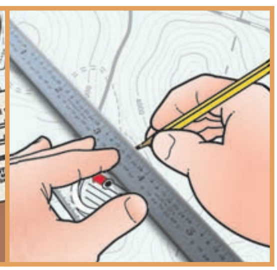
Next, place the compass on your map with the long edge of the baseplate touching the spot that represents your present location. (The map does not need to be oriented.) Ignoring the needle, rotate the compass baseplate around that point on the map until the orienting arrow and orienting lines are parallel with any true-north lines on the map. Beginning from the map symbol for your location, draw an actual or imaginary line *away from yourself* along the edge of the baseplate. The line should intersect the point on the map representing the landmark.

To identify landmarks with a compass that has not been adjusted for declination, use the *magnetic-north lines* you have drawn across the map instead of the *true-north lines.* The same is true of other map-and-compass procedures, including pinpointing your location and finding your way.



Take a bearing on the landmark.

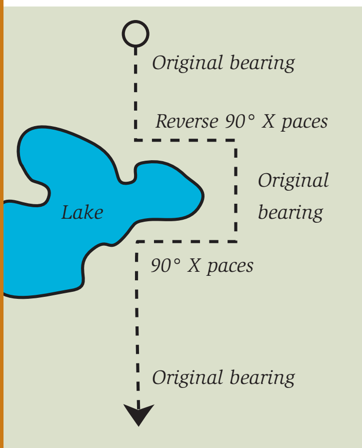
Orient the map.



Identify the landmark.

Avoiding Obstacles

To avoid an obstacle such as a lake or rock outcropping, take a 90-degree reading to both sides of your course of travel and count your paces as you go. When you have cleared the obstacle, continue on your original bearing until you completely bypass the obstacle. Then take a reverse 90-degree reading and take the same number of paces as you did previously. At that point, continue on your original course of travel.

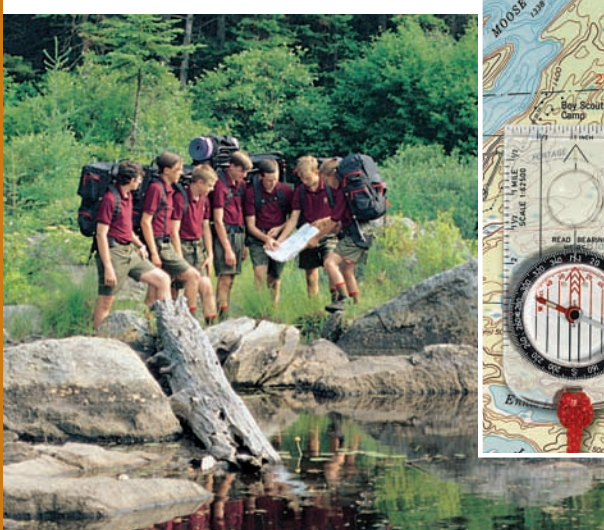


Pinpointing Your Location

If you're not sure where you are but you can see a couple of features on the land that are also indicated on your map, it's easy to determine your location. First, point the baseplate direction-of-travel arrow on your compass at one of the landmarks—a mountaintop, the outlet of a lake, a building, etc. Then, holding the baseplate still, turn the compass housing until the red tip of the needle points at the declination dot (for declination-marked compasses) or until the needle lines up in the outline of the orienting arrow (for declination-adjusted compasses). You've just taken a bearing on the landmark.

Now place the compass on your map with the edge of the baseplate touching the symbol representing the landmark. (The map does not need to be oriented.) Ignoring the needle, rotate the entire compass around that point on the map until the orienting lines on the floor of the compass housing are parallel with any true-north lines on the map. Lightly pencil a line *toward yourself* along the baseplate edge from the landmark symbol.

Find a second landmark and repeat the process of taking a bearing, placing the compass on the map, and drawing a line toward yourself. The spot on the map at which the two lines intersect indicates where you are. To confirm your readings, repeat the procedure with another landmark.

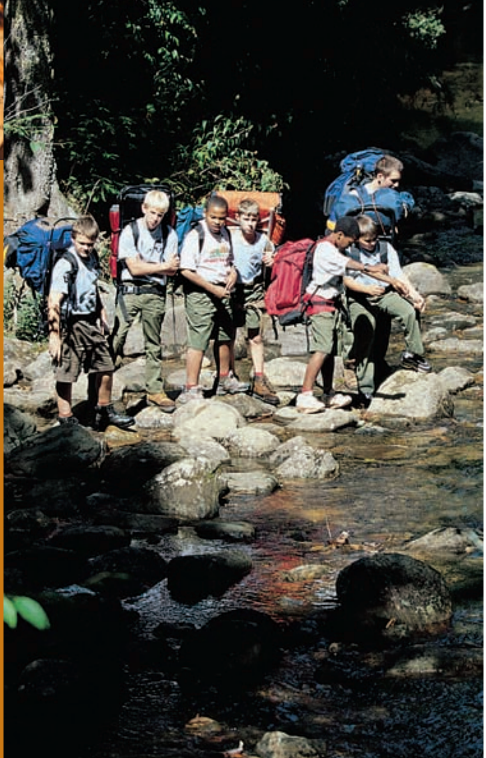


Finding Your Way

Assume you know where you are. On the map you see a lake you would like to reach by the most direct route. Place the long edge of your compass baseplate on a real or imaginary line connecting the map points representing your present location and that of the lake. Turn the compass housing until the orienting lines in the compass housing parallel any true-north lines on the map.

Hold the compass at waist level with the direction-of-travel arrow on the baseplate pointing *away from you.* Without changing the compass setting, turn your body until the compass needle aligns itself with the orienting arrow (for declination-adjusted compasses) or the red tip of the needle points to the declination dot (for declination-marked compasses). When that happens, the direction-of-travel arrow will be aimed at the lake. You have just taken a bearing for the route to your destination.

Look up along the direction of travel. If you can see the lake, you need make no further use of the compass. If the lake is out of sight, though, locate an intermediate landmark toward which the direction-of-travel arrow is pointing—a tree, boulder, or other feature—and walk to it. Take another bearing, identify the next landmark in line with the direction-of-travel arrow, and go to it. Continue until you reach your destination.



Offset Technique

Hiking uphill, crossing streams, ducking under brush, and scratching bug bites as you navigate your way through the backcountry can cause *lateral drift,* an accumulation of small errors in taking and following compass bearings that can throw you off your intended course. Compensate for lateral drift by using *offset technique*—deliberately aiming a little to the left or right of your destination.

For instance, assume the lake you want to reach is very small. You notice on the map that a creek flows from it to the left, perpendicular to your line of travel. Rather than take a bearing on the lake itself and risk missing it by passing too far to the right, set a course for a point on the creek a few hundred yards below the lake. When you reach the creek anywhere along its length, all you need to do is follow it upstream until you arrive at the lake. (Streams, power lines, fences, drainage ditches, trails, roads, and ridges all make good *backstops* or *handrails* for offset technique.)

Measuring Distances in the Field

Counting your steps is a good way to estimate distances as you travel. Learn the length of your step this way:

1. Using a tape measure, mark a 100-foot course on the ground.
2. Walk at a normal speed from one end of the course to the other, counting your steps as you go.
3. Divide the total number of steps into 100 and you'll know the length of one step.

For example, if you used 50 steps to go 100 feet, your step length is 2 feet. If it took you 40 steps, figure $2\frac{1}{2}$ feet per step. In the field, you can measure distances by counting every step along the way, or by counting each time your right foot touches the ground. (A $2\frac{1}{2}$-foot *step* becomes an easier-to-count 5-foot *pace.)*

Global Positioning Systems (GPS)

Modern technology has provided travelers with a powerful electronic means of navigation—the global positioning system. A GPS receiver accurately calculates the latitude and longitude of any spot on the globe by taking bearings on satellites orbiting 12,000 miles above Earth. Small enough to carry in the pocket of a pack, a GPS receiver can be used to

- Identify precise locations.
- Note elevations above sea level.
- Chart routes by inputting coordinates of latitude and longitude, or by downloading entire maps.
- Plot the record of a trek, creating a history that can guide a group retracing its steps.

Electronic navigational instruments surely will continue to improve in accuracy, versatility, and ease of use. But just as having a calculator does not eliminate the need to know how to add and subtract, a GPS receiver (especially one with dead batteries) is no substitute for being able to navigate with traditional tools. Develop confidence in your ability to use maps and compasses and then, if you wish, augment them with a GPS receiver.

For more on augmenting navigational skills with the global positioning system, see the *Fieldbook* Web site.