TRIP PREPARATION • MAP • ALTIMETER • COMPASS • CLINOMETER • GPS • ORIENTATION BY INSTRUMENT • ORIENTING A MAP • ORIENTATION USING GPS • NAVIGATION BY INSTRUMENT • COMMUNICATION DEVICES • LOST • FINDING THE FREEDOM OF THE HILLS

CHAPTER 5

NAVIGATION

“Where am I now, and how can I find my way to the summit —and back? What if I need help in an emergency?” These are the most frequently asked questions in mountaineering. This chapter shows how to find the answers with the first of the Ten Essentials: navigation.

Modern mountaineers have a broad set of tools to accomplish the two key objectives of navigation: First, they need to know where they are and how to get to their objective and back safely. Second, they need to be able to communicate with emergency responders should the need arise. The modern tools of navigation allow the mountaineer to accomplish both objectives with far more confidence than in the past. Today there are five essential tools for navigating the backcountry: map, altimeter, compass, GPS device, and a personal locator beacon (PLB) or other device to contact emergency first responders. Using multiple tools increases mountaineers’ confidence in their location and route, provides backup when tools fail, and increases situational awareness (see “Mountaineering with a GPS Device” later in this chapter).

TRIP PREPARATION

First, a few definitions concerning navigation are in order. *Orientation* is determining your exact position on the earth. *Navigation* is guiding yourself to a destination. *Routefinding* is selecting and following the best path to that destination. Routefinding is covered in more detail in Chapter 6, Wilderness Travel, but understanding it requires a solid foundation in the tools and skills described in this chapter.

Routefinding begins at home. Consult guidebooks and internet sources for critical information. Seek out other climbers who have done the climb who can perhaps provide a GPS track or critical waypoints (see "GPS" later in this chapter). Useful details are also packed into various types of maps and satellite images. Maps must be downloaded or installed onto GPS devices at home prior to the climb. See "Gather Route Information" in Chapter 6, Wilderness Travel, for suggestions on researching a route.

Before starting any trip into the wilderness, be sure to have a mental image of the route to the planned climb. Using the information gained from guidebooks or other climbers, plot the route on the topographic map. Based upon your experience, and from all the sources of information about the climb, make the terrain work in your favor.

To avoid brush, keep the route out of watercourses and drainages; select ridges rather than hillsides and gullies. Clear-cuts are also often full of logging slash or second-growth trees. A rock slide area can be a feasible route—providing the party avoids generating new rockfall. One problem in planning the route is that a rock slide area may look the same on a map as an avalanche gully, which can be an avalanche hazard in winter and spring and choked with brush in summer and fall. If sources are not helpful, only a firsthand look can clear up this question.

The most straightforward return route is usually the same as the route going in. If the plan is to come back a different way, careful advance preparation for that route is also necessary. And before leaving on the trip, give the trip itinerary—members of the party, trailhead, vehicle description and license plate number, and expected return date—to a responsible person (see "Organizing and Leading a Climb" in Chapter 22, Leadership, for more details).

MAP

Every mountaineer should travel with a map. There are several types.

Relief maps. Terrain is shown in three dimensions with various hues of green, gray, and brown, plus terrain shading, on relief maps. These maps help in visualizing the ups and downs of the landscape and have some value in trip planning.

Land management and recreation maps. Because recreation maps are updated frequently, they are useful for current details on roads, trails, ranger stations, and other human constructions. They usually show only a two-dimensional (flat) relationship of natural features, without contour lines that indicate the shape of the land (see "Topographic maps" below). These recreation maps, published by the US Forest Service and other government agencies, are suitable for trip planning.

Climbers' sketch maps. Often called climbers' topos, climbers' sketch maps are not topographic maps but are generally crudely drawn, two-dimensional sketches that usually make up in specialized route detail what they lack in draftsmanship. Such drawings can be effective supplements to other map and guidebook information.

Guidebook maps. Some guidebook maps are merely sketches, whereas others are accurate interpretations of topographic maps. They vary greatly in quality but generally contain useful details on roads, trails, and climbing routes.

Topographic maps. Essential to off-trail travel, topographic maps (or *topos*) are the best of all for climbers. They depict topography—the shape of the earth's surface—by showing contour lines that represent constant elevations above sea level. These maps are produced in many countries. Some are produced by government agencies; others are printed by private companies, with special emphasis on trails and other recreational features.

The most familiar topographic maps in the United States are those produced by the US Geological Survey (USGS). Up to about the year 2006, the USGS produced a series of topographic maps using aerial photographs, with trails and structures added manually based on field observations; these maps are now referred to as "Historical." Since then, the USGS has produced a new series referred to as "US Topo," dated 2011 and beyond. These maps contain more "layers" of data (such as aerial and satellite photos and terrain features), which users can select online. All of the older "Historical" topographic maps have been digitized and are still available from the USGS digital map database.

In some areas of the United States, private companies produce maps based on USGS topographic maps, but that are updated with more recent trail and road details, and sometimes these commercially produced maps combine sections of USGS maps. These maps are often useful supplements to standard topographic maps.

Digital maps. A variety of sources exist from which digital maps can be created, installed, and used with home computers, phones, some watches, and dedicated GPS receivers. GPS manufacturers (such as Garmin) sell or provide free a variety of map packages to install onto their devices, and some devices come with topographic maps already installed. Some GPS devices also allow users to install maps obtained from third parties (see Resources for examples). A variety of phone apps (such as Gaia GPS and BackCountry Navigator) allow users to seamlessly download a wide variety of map types, typically free, for viewing on phones and tablets. These sources include all of the USGS maps ("Historical" and "US Topo"); US National Park Service and Forest Service maps; Canadian topographic maps from Natural Resources Canada (NRCan); road, nautical, and cycling maps; overlays for shaded relief, slope, and contours; satellite photographs; and OpenStreetMap (OSM) maps. OpenStreetMap, a collaborative project inspired by Wikipedia to create a free map of the world, often has the most up-to-date information on trails and roads worldwide. (For map sources, see Resources.)

Digital maps, when displayed on GPS devices, hold one overwhelmingly compelling advantage over their paper progenitors: they show a "you are here" arrow that renders orientation trivial. Other advantages include the ability to record a GPS track of the exact route traveled, to mark waypoints of critical locations, and to follow a planned route or track of previous climbers. With so many freely available map sources, climbers can afford to download multiple map types for a single trip, as well as a much larger seamless map area than will likely be needed to allow for unexpected changes in plans.

Though these digital maps are valuable when loaded onto GPS devices, they disappear when the device's batteries die. For this reason, physical (paper or plastic) maps should also be printed and carried along with the digital maps, to ensure that climbers always have a map of the climbing area. When printing maps, it is preferable to use a laser jet printer if possible, since maps printed on cheaper inkjet printers can smear if they get wet.

Satellite photographs. Though not maps, satellite photographs can be of significant help in researching wilderness routes. With some GPS devices, satellite photographs can be downloaded like any other map type.

HANDLING AND CARRYING MAPS

Sometimes a trip travels through an area covered by portions of two or more maps. Either fold adjoining maps at the edges and bring them together, or create a customized map by cutting out the pertinent areas and splicing them with tape. Include plenty of territory so that there is an overview of the trip area, including the surrounding terrain. Computer programs can create customized maps, though these maps are limited by printer quality and paper size.

Maps—precious objects that they are—deserve tender care in the wild. Some custom maps can be obtained or printed on waterproof paper that makes it easier to care for them under wet conditions that can destroy ordinary paper maps. A physical map can also be kept in a protective map case or resealable plastic bag. Some maps are printed on plastic rather than paper, which makes them easier to protect. On the climb, carry the map in a pocket or other easily accessible place where you can keep it relatively flat and you do not have to take off your pack to reach it.

READING A TOPOGRAPHIC MAP

Topographic maps are essential to wilderness travel, and mountaineers must be able to glean as much information from them as possible. Understanding topographic features such as coordinate systems, datums, scale, and contour lines is a crucial navigation skill.

All topographic maps are prepared according to a legend of symbols and colors used for the map's features. For example, in a "Historical" USGS map (see "Topographic maps" above), contour lines are brown except on permanent snowfields or glaciers, where they are blue. Blue is also used for water features such as lakes and rivers. Multiple methods and colors are used to show roads, trails, vegetation, and other features. Be sure that digital maps have legends, too, in order to know what the mapmaker intends you to learn from the map.

Coordinate Systems

Maps use three principal coordinate systems to describe a location on the earth: latitude and longitude, UTM, and MGRS (see below for more on these last two).

Latitude and longitude coordinates divide the earth into the 360 degrees of a circle. A measurement east or west around the globe is called *longitude*; a measurement north or south is called *latitude*. Longitude is measured 180 degrees east and 180 degrees west, starting at the north-south line (*meridian*) that goes through the Royal Observatory, Greenwich, near London, England. Latitude is measured 0 to 90 degrees north and 0 to 90 degrees south, starting from the equator. This system allows each place on the planet to have a unique set of coordinates. For example, New York City is situated near 74 degrees west longitude and 41 degrees north latitude.

Each degree of latitude or longitude is divided into 60 minutes, and each minute is further subdivided into 60 seconds—just as for units of time. On a map, a latitude of 47 degrees, 41 minutes, 7 seconds north is written like this: 47°41'7"N. Search and rescue organizations, as well as cell phones, tend to use decimal degrees; the latitude in the previous example would be written in decimal degrees as 47.6853°, with the positive number indicating north (a negative number would indicate south). Longitudes east of Greenwich to 180 degrees east are written as positive numbers, while those west of Greenwich to 180 degrees west and throughout the western hemisphere are written as negative numbers.

The most common type of USGS topographic map used by mountaineers in the United States covers an area of 7.5 minutes (that is, 1/8 degree) of latitude by 7.5 minutes of longitude. These maps are known as the "7.5-minute series." An older type of USGS map covers an area of 15 minutes (that is, ¼ degree) of latitude by 15 minutes of longitude. These maps are part of what is called the "15-minute series."

The Universal Transverse Mercator (UTM) coordinate system is another method for identifying a point on a map. Because the UTM system is metric-based, it allows easy computation of distances between points and is often used with GPS (see "Orientation Using GPS" near the end of this chapter).

The UTM system evolved into the Military Grid Reference System (MGRS), used today by the United States Department of Defense and the militaries of other nations in the North Atlantic Treaty Organization (NATO).

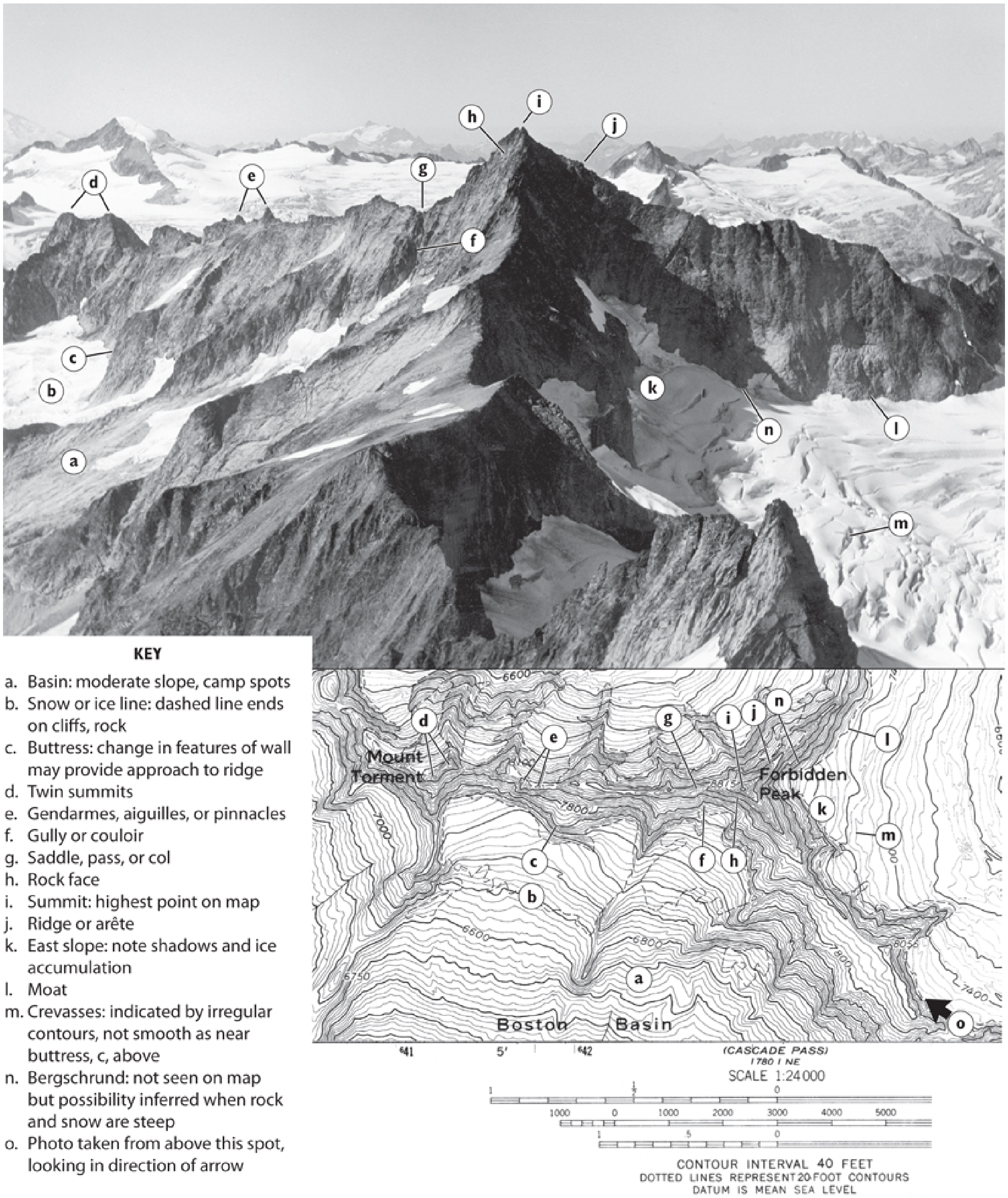

Fig. 5-1. Photograph of a mountainous area; keyed features are also represented on the accompanying topographic map.

Datums

The coordinate systems described in the preceding section must be anchored to actual points on the earth, similar to surveyors' benchmarks. These anchoring points are referred to as a *datum*, and maps are made using many datums. Datums are important because a single set of coordinates (for instance, a latitude and longitude or UTM coordinates) will yield different points on the earth depending on the datum used.

The two datums currently used on USGS topos are North American Datum 1927 (NAD27) and World Geodetic System 1984 (WGS84). The difference in position between these two datums can be as much as about 500 feet (160 meters), which is important to know when using topographical maps in conjunction with GPS devices (see "GPS" later in this chapter). NAD27 is used on "Historical" USGS topos, whereas WGS84 is used on the new "US Topo" series, and is the default system for most GPS devices.

Scale

The scale of a map is a ratio between measurements on the map and measurements in the real world. A common way to state the scale is to compare a map measurement with a ground measurement—for example, 1 inch equals 1 mile—or to give a specific mathematical ratio of map inches to real-world inches: for example, 1:63,360, which means that 1 map inch is equal to 63,360 real-world inches—exactly 1 mile. The scale is usually shown graphically at the bottom of a map (fig. 5-1).

Metric maps are used in Canada and most other countries of the world outside of the United States. The scales of such maps are often 1:25,000 (1 centimeter on the map equals 250 meters or 0.25 kilometer in the field) or 1:50,000.

In the USGS 7.5-minute series, the scale is 1:24,000, which means that 1 map inch is equal to 24,000 real-world inches—about 0.38 mile—or, inversely, roughly 2.5 inches to 1 mile (4.2 centimeters to 1 kilometer). The map's north-south extent is about 9 miles (14 kilometers), while its east-west extent varies from about 6 miles (10 kilometers) in the north to about 8 miles (13 kilometers) in the south. (The east-west span of maps decreases as one moves north, due to the fact that the lines of longitude converge as they get closer to the North and South poles.) In the older 15-minute series, the scale is usually 1:62,500, or about 1 inch to 1 mile (1.6 centimeters to 1 kilometer), and each map covers four times the area of the 7.5-minute maps. Mountaineers prefer the 7.5-minute maps because of their greater detail. The scale of 1:24,000 is used for all US states except Alaska, where the scale is 1:63,360.

The 7.5-minute map is now the standard for the United States, except for Alaska. The 15-minute maps have been phased out by the USGS for the other 49 states, though some private companies still produce them (such as Green Trails Maps for selected regions of Washington, Oregon, California, Nevada, Arizona, and British Columbia).

Each topographic map is referred to as a quadrangle (or *quad*) and covers an area bounded on the north and south by latitude lines that differ by an amount equal to the map series (such as 7.5 minutes or 15 minutes) and on the east and west by longitude lines that differ by the same amount. Each quadrangle is given the name of a prominent topographic or human feature of the area: for example, USGS Mount Rainier West.

Contour Lines

The distinctive feature of a topographic map that provides the heart of its useful information is its overlay of contour lines, each line indicating a constant elevation as it follows the shape of the actual landscape. A map's contour interval is the difference in elevation between two adjacent contour lines. In mountainous areas, this interval is often 40 or 50 feet (12 or 15 meters) on 7.5-minute maps, and 80 or 100 feet (24 or 30 meters) on 15-minute maps. To make contour lines easier to use, every fifth contour line is printed darker than the other lines and is labeled periodically with the elevation. On metric maps, a contour interval of 5, 10, or 20 meters (16, 33, or 66 feet) is usually used.

A topographic map shows whether a route travels uphill or downhill. If the route crosses contour lines of increasingly higher elevation, it is going uphill; if it crosses contour lines of increasingly lower elevation, it is going downhill. Flat or sidehill travel is indicated by a route that crosses no contour lines. The direction perpendicular to contour lines is the *fall line*, that is, the direction of the slope. Contours also indicate cliffs, summits, passes, and other terrain features (see Figure 5-2). Climbers can improve their interpretation of these lines by comparing actual terrain with the map (see Figure 5-1). The goal is to be able to glance at a topographic map and have a clear mental image of the actual lay of the land. Following are the main features depicted by contour lines:

Flat areas have no contour lines at all, or contour lines very far apart (fig. 5-2a).

Gentle slopes have widely spaced contour lines (fig. 5-2b; see also Figure 5-1a).

Steep slopes have closely spaced contour lines (fig. 5-2c; see also Figure 5-1k).

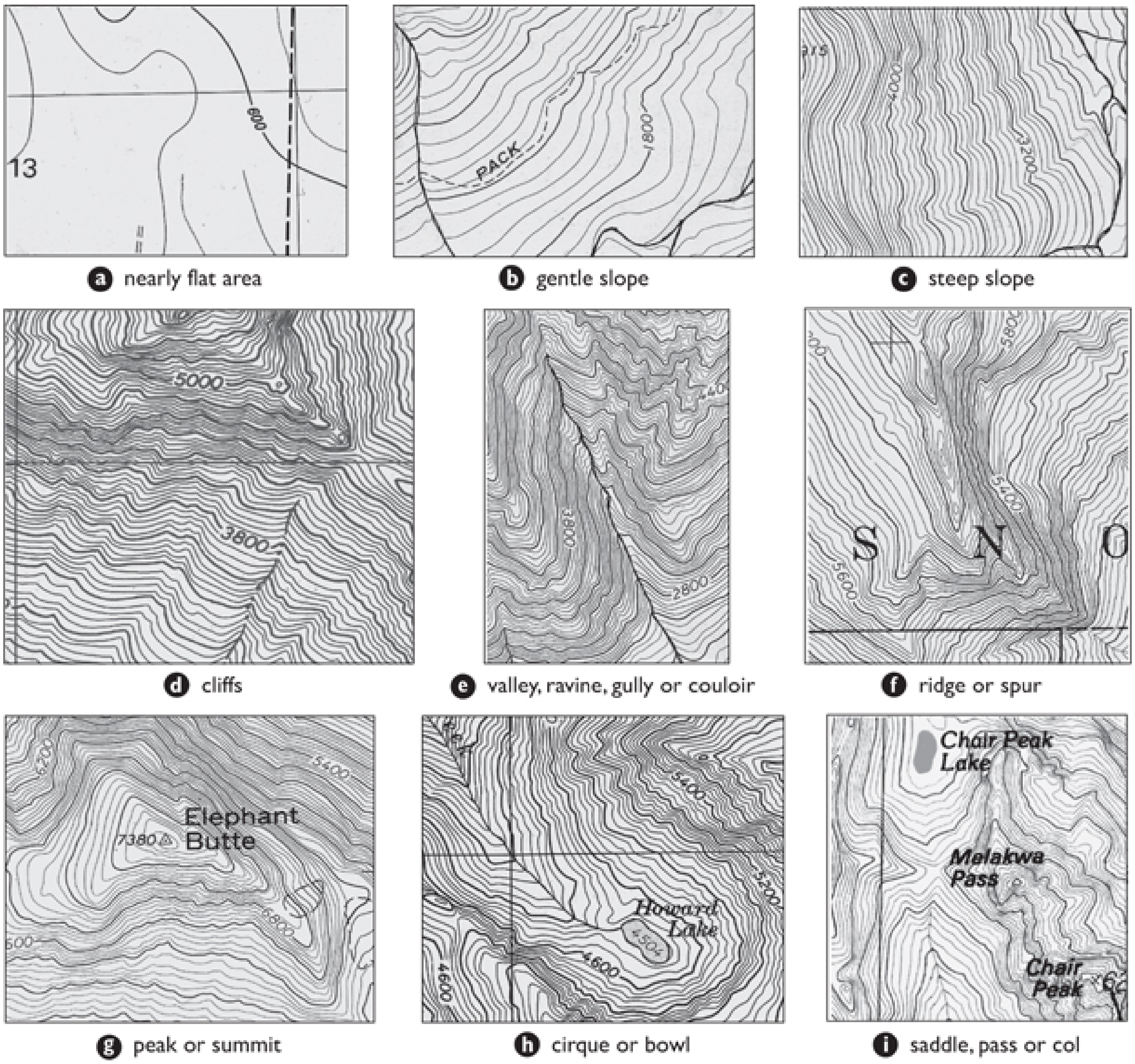

Fig. 5-2. Contour lines showing basic topographic features.

Cliffs have contour lines extremely close together or touching (fig. 5-2d; see also Figure 5-1h).

Valleys, ravines, gullies, and couloirs have contour lines in a U or V pattern pointing uphill. An uphill-pointing U pattern shows a gentle, rounded valley or gully; an uphill-pointing V pattern shows a sharp valley or gully (fig.

5-2e; see also Figure 5-1f). The U and V patterns point in the direction of higher elevation.

Ridges or spurs have contour lines in a U or V pattern pointing downhill. A downhill-pointing U pattern shows a gentle, rounded ridge; a downhill-pointing V shows a sharp ridge (fig. 5-2f; see also Figure 5-1j). The U and V patterns point in the direction of lower elevation.

Peaks or summits have concentric patterns of contour lines, with the summit the innermost and highest ring (fig. 5-2g; see also Figure 5-1d and i). A peak may also be indicated by an "x," an elevation number, a benchmark (BM), or a triangle symbol.

Cirques or bowls have patterns of contour lines forming a semicircle, rising from a low spot in the center of the partial circle, showing a natural amphitheater at the head of a valley (fig. 5-2h).

Saddles, passes, or cols have an hourglass shape, with higher contour lines on each side, indicating a low point on a ridge (fig. 5-2i; see also Figure 5-1g). The closer the contour lines, the steeper the terrain.

Other Information on Topographic Maps

The margin of a USGS topographic map holds important information, such as date of publication and revision, names of maps of adjacent areas, the contour interval, and the map scale. The margin also gives the area's magnetic declination (discussed later in this chapter), which is the difference between true north and magnetic north.

Topographic maps have certain limitations. They do not show all the terrain features that can actually be seen on a route because there is a limit to what can be jammed onto a map without reducing it to an unreadable clutter. If a feature is not at least as high as the contour interval, it may not be shown, so if climbers are navigating with a map that has a 40-foot contour interval, a 30-foot cliff may come as a surprise to them.

All USGS topos have their dates printed upon them. Be sure to check the date of the map, because topographic maps are not revised very often—so information on forests, magnetic declination, roads, streams and rivers, and other changeable features could be out of date. A forest may have been logged or a road either extended or closed since the last map revision. Although topographic maps are essential to wilderness travel, climbers may need to supplement them with information from visitors to the area, Forest Service or

Park Service rangers, guidebooks, and other maps. Note changes on the map as they are encountered.

Choosing a Topographic Map

The new “US Topo” series maps are, at present, a work in progress. They are totally digital, with clear, sharp, and accurate representations of topography, and can be viewed and downloaded free on the USGS.gov website. However, they currently do not contain certain features commonly found on the “Historical” topographic maps: trails, printed elevations (other than for index contours), structures such as buildings and shelters, and edges of glaciers and permanent snowfields. The USGS plans to add some of these features over time. Accordingly, these maps are, at least for now, less useful to the mountaineer than the “Historical” map series.

When using the “Historical” topo maps, it is important to recognize their temporal nature, especially for older maps. For example, glaciers are shrinking around the world, so an older “Historical” map may show a glacier covering an area where it does not exist today. Some other features of the “US Topo” series maps also differ from those of the “Historical” maps, such as the representation of contour lines on glaciers as solid blue lines on “Historical” maps but as brown contour lines on the “US Topo” maps.

Table 5-1 provides a summary of different types of topographic maps for mountaineering use. Printed topo maps are available from a variety of sources, including brick-and-mortar stores such as Recreational Equipment, Inc. and Canadian Map Distribution Centres, as well as by mail order from the USGS and from online retailers (see Resources).

ROUTEFINDING WITH A MAP

Most routefinding with a map is done by simply looking at the surroundings and comparing them with the map before, during, and after a trip.

Before the Trip

Before the trip, make some navigational preparations with the map, such as identifying handrails and baselines (see below), as well as possible routefinding problems. Prepare a route plan: a well-thought-out description of how the party plans on navigating to its objective and getting back.

Identify handrails and baselines. Any linear feature on a map that parallels the direction of travel is called a *handrail*: a feature that helps a party to stay on route. The handrail should be within frequent sight of the route, so it can serve as an aid to navigation. Roads, trails, powerlines, railroad tracks, fences, borders of meadows, valleys, streams, cliff bands, ridges, and lakeshores could all serve as useful handrails.

A long, unmistakable line that always lies in the same direction from the party, no matter where the party is during a trip, is called a *baseline*; it provides another map technique that can help the party find its way home if they have gone offtrack. A baseline (or *catch line*) can be a road, the shore of a large lake, a river, a trail, a powerline, or any other feature that is at least as long as the area the party will be traveling in. During trip planning, pick out a baseline. If the party knows the shore of a large lake always lies west of the trip area, heading west at any time will get the party to this identifiable landmark and may save the group from being truly lost.

Anticipate routefinding problems. Before the trip, anticipate specific routefinding problems. For example, if the route traverses a glacier or any large, featureless area such as a snowfield, consider carrying route-marking wands (see Chapter 16, Snow Travel and Climbing). Identify any escape routes that can be used in case of sudden bad weather, loss of visibility, or other setbacks.

TABLE 5-1. COMPARISON OF TOPOGRAPHIC MAPS					
MAP TYPE	SOURCES	SIZE IN INCHES (CM)	COST AND AVAILABILITY	ADVANTAGES	DISADVANTAGES
USGS "Historical" topos (standard scale is 1:24,000)	USGS.gov or via mail order, plus other sources	26 in. (66 cm) long by variable width	$8 USD; Up to 2 weeks by mail	All features shown, including trails and elevations; professional print quality	May not be up to date: some created 40 years ago, others as recently as 10 years ago
USGS "US Topo" maps (standard scale is 1:24,000)	USGS.gov or via mail order, plus other sources	26 in. (66 cm) long by variable width	$15 USD; Up to 1 week by mail	Custom features, such as grids; professional print quality; more current than "Historical" topos	Do not contain trails or some other features, such as printed elevations of some locations shown on USGS "Historical" topos
Canadian topo maps (standard scale is 1:50,000)	Canadian Map Distribution Centres and online sources	Typically 24 in. x 36 in. (61 x 91 cm); varies with location	$15 USD, typically	More area shown than USGS 1:24,000 maps	Less detail than USGS 1:24,000 maps
Digital topo maps printed on paper	Phone apps, USGS.gov, CalTopo, Gmap4	Limited by printer	Cost of paper and ink	Instant availability; customized map location and format; can share and customize	Print quality depends on size and resolution of map image and type of printer and paper
Digital topo maps used on a GPS device	Phone apps, dedicated GPS unit, watch device manufacturers, and other sources	Equal to screen size	Free for phone apps and bundled with some dedicated GPS units	Instant availability; most current; can typically share and customize; multiple types can be easily downloaded for field use	Small screen size; device is battery dependent

Obtain maps and route descriptions. Obtain a topographical map or maps of the area covering the entire route. Allow up to two weeks for postal delivery of physical topographic maps from the USGS (see Resources at the back of the book). If the party is doing a spur-of-the-moment trip, go to the USGS website or a number of others to view, download, and print portions of the USGS map. Using a color printer provides the most descriptive maps. Once you have the physical topographic map, read a route description of the trip in a guidebook or online, if available, then trace the route description onto the map.

Prepare GPS. See Table 5-5, "Navigation Workflow with GPS Devices," later in this chapter.

Set the compass. Always confirm that your compass is set for the amount and direction of magnetic declination at the site of the trip (see "Compass," below). If the trip is to a location far from home, remember to reset declination.

During the Trip

Get off on the right foot by making sure that everyone in the party understands the route and the route plan. At the trailhead, gather the party around the map, taking time to discuss the route and make contingency plans in case the party gets separated. On the map, point out where the party is and correlate the surroundings with what is shown on the physical map in front of everyone.

Monitor the rate of travel. Part of navigation is having a sense of the party's speed; estimating the rate of travel along with elapsed time helps to maintain orientation. Given all the variables, will it take the party one hour to travel 2 miles (3.2 kilometers), or will it take two hours to travel 1 mile (1.6 kilometers)? The answer is rather important if it is 3:00 p.m. and base camp is still 5 miles (8 kilometers) away. After enough trips into the wilds, climbers are good at estimating their speed (see the "Typical Speeds for Average Party" sidebar). There will be much variation; for example, in heavy brush the rate of travel can drop to a third or even a quarter of what it would be on a good trail. At high altitudes, the rate of travel will also greatly decrease, perhaps down to as little as 100 feet (30 meters) of elevation gain per hour.

With a watch and a notebook (or a good memory), monitor the rate of progress on any outing. Always make sure to note the time of starting from the trailhead. Also note the times at which important identifiable streams, ridges, trail junctions, and other points along the route are reached; this helps you for the return trip.

Experienced climbers regularly assess their party's progress and compare it with trip plans. Make estimates—and reestimates—of what time the party will reach the summit or other destination, as well as what time the party will get back to base camp or the trailhead. If it begins to look as though the party could become trapped in tricky terrain after dark, the group may decide to change its plans and bivouac in a safe place or call it a day and return home.

TYPICAL SPEEDS FOR AVERAGE PARTY

- **Hiking on a gentle trail, with a light day pack:** 2 to 3 miles per hour (3 to 5 kilometers per hour)
- **Hiking up a steep trail, with a heavy full-size pack:** 1 to 2 miles per hour (2 to 3 kilometers per hour)
- **Traveling cross-country up a moderate slope, with a light day pack:** 1,000 feet (300 meters) of elevation gain per hour
- **Traveling cross-country up a moderate slope, with a heavy full-size pack:** 500 feet (150 meters) of elevation gain per hour

Relate surroundings to the map. Along the way, everyone should keep relating the terrain to the map. Ignorance is definitely not bliss for any daydreaming climber who does not pay attention to the territory and then gets separated from the party. Whenever a new landmark appears, connect it with the map. At every chance—at a pass, a clearing, or a break in the clouds—update your fix on the group's exact position. Keeping track of your position this way makes it easy to plan each succeeding leg of the trip, and it will help to prevent climbers from getting lost. It also may turn them into expert map interpreters, because they will know what a specific valley or ridge looks like compared with its representation on the map.

Look ahead to the return trip. The route always looks amazingly different on the way back. Avoid surprises and confusion by glancing back over your shoulder from time to time on the way in to see what the route should look like on the return. If you cannot keep track of it all, jot down times, elevations, landmarks, and so on in a notebook. A few cryptic words—"7,600, intersect ridge"—can save a lot of grief on the descent. It will remind you that when the party has dropped to 7,600 feet, it is time to leave the ridge and start down the slope. If using a GPS device, you should mark waypoints at crucial points along the way; also see Table 5-5, "Navigation Workflow with GPS Devices," later in this chapter.

Think about the route. Your brain is your most valuable navigational tool; be sure to use it. As the party heads upward, ask questions: "How will we recognize this important spot on our return?" "What will we do if the climb leader is injured?" "Would we be able to find our way out in a whiteout or if snow covered our tracks?" "Should we be using wands or other route-marking methods right now?" "Should I mark and save a waypoint here?" Ask the questions as you go, and act on the answers. Each person in the party should know the route, the route plan, and how to get back.

Mark the route if necessary. At times, it may be best to mark the route going in so that it can be found again on the way out. This situation can arise when the route is over snowfields or glaciers during changeable weather, when the route is in heavy forest, or when fog or nightfall threatens to hide landmarks. On snow, climbers sometimes use wands to mark the path. In the forest, plastic surveyors' tape is sometimes tied to branches to show the route, but its use is discouraged due to its blight and permanence. From an ecological standpoint, a short length of unbleached toilet paper is the best marker, because it will usually disintegrate during the next rainfall. Use toilet paper if you are certain of dry weather. If not, use white crepe paper in thin rolls. It will survive an approaching storm but will disintegrate over the winter.

One commandment is needed here: Remove route markers. Markers are litter, and mountaineers never, ever litter. If there is any chance the party will not come back the same way and will not be able to remove the markers, be especially sure to use degradable paper markers.

Piles of rocks used as markers—*cairns*—appear here and there, sometimes dotting an entire route and at other times signaling the point where a route changes direction. These heaps of rock are another imposition on the landscape, and they can create confusion for any traveler but the one who put them together—so do not build them. If there comes a time when a cairn must be built, then do so, but tear it down on the way out. The rule is different for existing cairns: let them be, on the assumption that someone, perhaps even land managers, may depend on them.

Keep oriented. As the trip goes on, it may be helpful to mark the party's progress on the map. Keep oriented so that at any time you can point out your actual position to within roughly a half mile (about a kilometer) on the map.

On Technical Portions of a Climb

When the going gets tough, it is easy to forget about navigation and start worrying about the next foothold—but climbers should keep the map and other route information handy for use during occasional rests. On rock climbs, do not let the mechanics of technical climbing overwhelm the need to stay on route.

On a Summit

The summit provides a golden opportunity to rest, relax, and enjoy—and to learn more about the area and about map reading by comparing the actual view with the way it looks on the map. The summit is also the place to make final plans for the descent, which often leads to many more routefinding errors than on the ascent. Remind one another that once the party has reached the summit, the climb is only half complete, so avoid letting your guard down with regard to safety and care in navigation. Repeat the trailhead get-together by discussing the route plan and emergency strategies with everyone. Stress the importance of keeping the party together on the descent, when some climbers will want to race ahead while others lag behind. Give yourselves enough time to return to camp or car in daylight on the way down.

During a Descent

The descent of a climb is a time for extra caution while mountaineers fight to keep fatigue and inattention at bay. As on the ascent, everyone should maintain a good sense of the route and how it relates to the map. Stay together, do not rush, and be even more careful if the party is taking a descent route that is different from the ascent route.

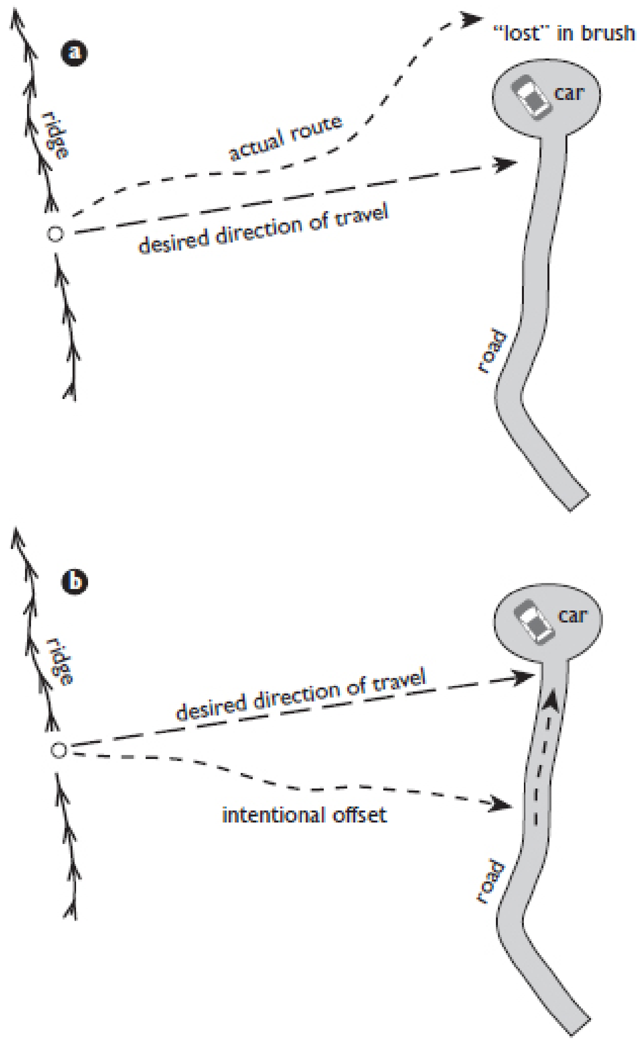

Fig. 5-3. Navigating to a specific point on a line: a, inevitable minor errors can sometimes have disastrous consequences; b, to avoid such problems, follow a course with an intentional offset.

Imagine that the climbing team is almost back to the car after a tough 12-hour climb. The party follows a compass bearing directly back to the logging road but cannot see the car, because the group has gotten off route by a few degrees. The car is on the road to either the left or the right, perhaps around a bend, so the party may have to guess which way to go. It will be a bad ending to a good day if the car is to the right of the route and the party goes left. It will be even worse if the car is parked at the end of the road and a routefinding error takes the party beyond that point and on and on through the forest (fig. 5-3a).

Intentional offset. This situation gave rise to the concept of intentional offset, also called *aiming off* (fig. 5-3b). If the party fears it might get into this kind of trouble, just travel in a direction that is intentionally offset some amount (say, 20 to 30 degrees) to the right or the left of where it really wants to be. When the group intersects the road (or river, ridge, or whatever), there will be less doubt about which way to turn. The correct location can sometimes be confirmed using an altimeter (see below).

After the Trip

Back home, write a description of the route and of any problems, mistakes, or unusual features; do it while the details are fresh in mind. Imagine what you would like to know if you were about to take this trip for the first time, so you will be ready with the right answers when another hiker or climber asks about it. If a guidebook or a map was confusing or wrong, take time to write to the publisher.

ALTIMETER

Mountaineers have long understood the importance of knowing elevation for navigation. An altimeter provides a simple elevation point. With a topographic map and just one more scrap of data—a trail, a stream, a ridge, or a bearing to a known peak—location can often be determined. By monitoring elevation and checking it against the topographic map, mountaineers can keep track of their progress, pinpoint their location, and find the way to critical junctions in the route. Every climber in the party should carry some type of altimeter.

Barometric altimeters. Sometimes called pressure altimeters, these are basically modified barometers. Both instruments measure air pressure (the weight of air), but whereas the barometer is calibrated in inches of mercury, hectopascals, or millibars, the altimeter is calibrated in feet or meters above sea level based on the predictable decrease in air pressure with increasing altitude. Barometric altimeters are available in digital wristwatches and on some GPS devices. They are affected by weather changes and so must be set at a known elevation.

Digital altimeters. Today's digital altimeter is based on a sliver of silicon that can measure air pressure (barometrically) or use GPS satellite signals—or a combination of the two. The most popular digital altimeter is the unit worn on the wrist. Most climbers wear a watch anyway, so this type of altimeter is helpful because it combines two functions in one piece of equipment. The altimeter worn on the wrist is also more convenient to use than one kept in a pocket or pack. Some digital altimeters display additional information, such as the temperature and the rate of change in altitude gain or loss.

Though a digital altimeter requires a battery, these batteries are usually good for years, and climbing parties typically carry more than one altimeter, so if one altimeter's battery dies, another climber's altimeter can be used. Another drawback to digital altimeters is that their liquid-crystal display (LCD) screens usually go blank at temperatures near about 0 degrees Fahrenheit (minus 18 degrees Celsius), though this is usually not a problem if they are worn on the wrist and under a parka. (To keep an altimeter watch from getting banged up on the rock or ice when a climber is starting a technical pitch, it is a good idea to remove it from the wrist and attach it to a pack strap or put it in a pocket or pack.) Inexpensive wristwatch altimeters costing less than $40 are perfectly adequate for mountaineering use. Wristwatch altimeters are instantly available for a quick check of altitude, whereas GPS devices (see below) are frequently turned off to conserve battery power, and after they are turned back on, require a minute or more to acquire satellite signals and display a position and altitude.

Altimeter as a function of GPS devices. GPS devices determine position in three dimensions—horizontal position (from east to west and from north to south) as well as elevation above sea level—and can therefore display a climber's altitude as determined by GPS satellites, rather than by barometric pressure. Some phones, as well as dedicated GPS units, also have an internal altimeter using a barometric pressure sensor and can display altitude derived from multiple sources based on the two types of sensors, or one altitude that uses both sensors. Some GPS apps for phones (see "GPS" later in this chapter) include altitude readouts as well as horizontal position; other apps are available that display altitude only.

TABLE 5-2. COMPARISON OF ALTIMETERS

ALTIMETER TYPE	COST	ADVANTAGES	DISADVANTAGES
Digital wristwatch	$40 to $600	Convenient to carry; altitude always displayed	Needs recalibration for changes in weather; LCD screen

		at a glance; inexpensive unit is adequate; long battery life	can go blank at subfreezing temperatures; battery occasionally needs replacement (one year or more battery life)
Dedicated GPS unit	Internal barometer adds $50 or more to cost of GPS device	GPS (satellite-derived) altitude reading unaffected by weather; altitude plus position displayed together; may display altitude from GPS or internal barometric altimeter	Needs time to access satellites before displaying altitude; shorter battery life than wrist or pocket units; LCD screen can go blank at subfreezing temperatures
Smartphone with app	Free app	Same as above	Same disadvantages as above; also may need a case to make it rugged enough for mountaineering use

Analog altimeters. Early altimeters were expensive analog devices with Swiss-made gears. They have been almost totally replaced by today's ubiquitous digital wristwatch altimeters.

Altimeter accuracy. The accuracy of a barometric altimeter depends on the weather because a change in weather is generally accompanied by a change in air pressure, which changes the altimeter reading. During periods of unstable weather, the indicated elevation may change by as much as 500 feet (150 meters) in one day even though the actual elevation has remained the same. Even during apparently stable conditions, an erroneously indicated change in elevation of 100 feet (30 meters) per day is not uncommon. Because of the strong influence of weather on a barometric altimeter's accuracy, *do not trust the instrument until it is first set at a location of known elevation*, such as a trailhead or using a GPS device. Then, while traveling, check the reading whenever another point of known elevation is reached (or occasionally using GPS) and reset the altimeter if necessary, or at least be aware of the error. A combined GPS-barometric altimeter can usually do better. Table 5-2 provides a summary of the features of altimeters used for mountaineering.

HOW ALTIMETERS AID MOUNTAINEERS

Altimeters can help mountaineers in several key ways: calculating the party's rate of ascent, determining its position (orientation) and navigating, and predicting the weather.

Calculating Rate of Ascent

The altimeter helps mountaineers decide whether to continue a climb or to turn back, by letting them calculate their rate of ascent. For example, during a climb, a party that checks time and elevation hourly, by taking altimeter readings, sees that they have gained only 500 feet (150 meters) in the past hour. The summit is at an elevation of 8,400 feet (2,560 meters), and an altimeter reading shows the party is now at 6,400 feet (1,950 meters), so they still have 2,000 feet (610 meters) to gain. The climbers can predict that if they maintain their present ascent rate, it will take roughly four more hours to reach the summit. That information, courtesy of the altimeter, combined with a look at the weather, the time of day, and the condition of the party members, gives the group the data on which to base a sound decision about whether to proceed with the climb or turn back.

Determining Position and Navigating

An altimeter also can help determine exactly where a party is (orientation). If they are climbing a ridge or hiking up a trail shown on the map but they do not know their exact position along the ridge or trail, they can check the altimeter for elevation. The likely location is where the ridge or trail reaches the contour line closest to that elevation on the map.

Another way to use an altimeter to determine where a climbing party is located is to start with a compass bearing to a summit or some other known feature (see "Compass" below). Find that peak on the map, and plot the bearing line from the mountain back toward the climbing party. The group now knows it must be somewhere along that line—but where? Take an altimeter reading and find out the elevation. The party's likely location is where the compass bearing line crosses a contour line at that elevation on the map.

The altimeter, map, and compass can be used together to help confirm or reject your assumed location by using the fall line: the direction a falling object travels downhill. Since the direction perpendicular to the contour lines indicates the direction uphill or downhill, a climber can take a bearing in the direction of the fall line and note the elevation using the altimeter. Then a glance at the map for your assumed location should show that the direction perpendicular to the contour lines at that elevation is the same as that measured with your compass. If they match, your assumed position may be correct, though not with absolute certainty. If they do not match, then your assumed position is definitely wrong.

Navigation gets easier with the aid of an altimeter. If climbers find a convenient couloir that gains the summit ridge, they can note the elevation of the top of the couloir. On the way back, they can descend the ridge to that same elevation to easily find the couloir again, to ensure that they descend the correct couloir. Some guidebook descriptions direct climbers to change course at particular elevations; doing so is much easier if an altimeter is used.

Last but not least, an altimeter may reveal whether the party is on the true summit, not a false one, for example, when the visibility is too poor to allow climbers to tell by looking around.

Predicting Weather

The barometric altimeter can help in predicting weather. The readings on a barometric altimeter and on a barometer operate inversely to each other: when one goes up, the other goes down. A barometric altimeter reading showing an increase in elevation when no actual elevation change has taken place (such as at camp overnight) means a falling barometric pressure, which often predicts deteriorating weather. A decreasing barometric altimeter reading, on the other hand, means increasing barometric pressure and improving weather. This is an oversimplification, of course, because weather forecasting is complicated by the wind, local weather peculiarities, and the rate of barometric pressure change. (See "Field Forecasting in the Mountains" in Chapter 28, Mountain Weather, for more information on interpreting barometric changes.)

Some digital wristwatch altimeters can be adjusted to read barometric pressure instead of altitude, but keep in mind that changes in barometric pressure are caused not only by changes in the weather but also by changes in elevation while climbing. This will lead to erroneous conclusions regarding barometric pressure.

GPS devices whose altitude display is derived from GPS satellites only (devices that do not use internal barometric sensors) are not useful by themselves for weather forecasting. To differentiate between changes in air pressure readings caused by changes in elevation while climbing or descending and those caused by changing weather conditions, first calibrate the barometric altimeter to the GPS elevation and then watch to see if they diverge significantly over the next few hours. If the barometric altimeter diverges from the GPS altitude, the cause is likely due to changing weather conditions. See Table 28-2 to determine what action to take.

CAUTIONS REGARDING ALTIMETER USE

Because barometric altimeters are strongly affected by the weather, do not be misled into trusting them to an accuracy greater than is possible. Though a typical high-quality barometric altimeter may have a resolution of 3 feet (1 meter), this does not mean that the altimeter will be that accurate. Changes in weather could easily throw the reading off by hundreds of feet or meters.

An altimeter sensor expands and contracts due to variations in temperature, causing changes in the indicated elevation. All altimeters compensate for temperature changes, but the compensation is not perfect. Try to keep the temperature of an altimeter as constant as possible. Body heat is usually enough to warm a wristwatch altimeter, particularly if it is worn under a parka when the outside temperature is low.

Get to know your own altimeter, use it often, check it at every opportunity, and note differences of information between it and the map. Recalibrate barometric altimeters at known elevations (for instance, saddles or summits). You will soon know just what accuracy to expect, and your altimeter will then be a dependable aid.

COMPASS

A compass is essentially a freely rotating magnetized needle that responds to the earth's magnetic field and is marked on one end to indicate north. Available compasses include the traditional baseplate compass, compass apps for smartphones, and features in some dedicated GPS units and some watches. The baseplate compass is an essential tool for navigation, not only to determine direction but also to measure and plot bearings on a map. The baseplate compass doesn't require batteries or calibration, and it operates in subzero temperatures. The essential features of a baseplate compass (fig. 5-4a) are as follows:

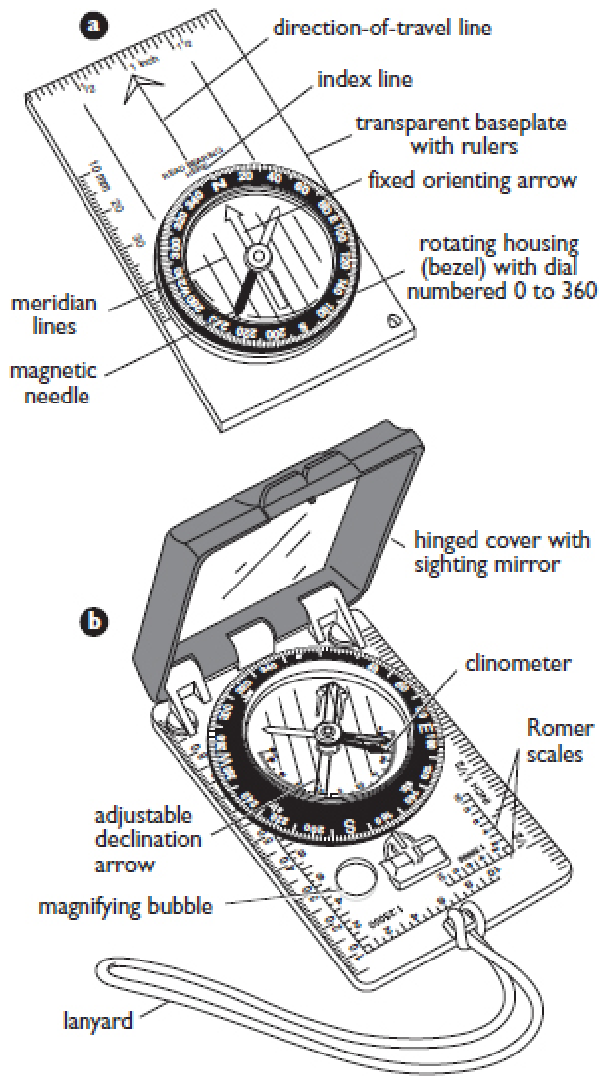

Fig. 5-4. Features of mountaineering compasses: a, essential features; b, useful optional features.

- **Rotating housing (bezel).** This is sometimes filled with a fluid to dampen (reduce) vibrations of the needle.

- **Dial around the circumference of the housing.** This dial is graduated clockwise in degrees from 0 to 360.
- **Orienting arrow and a set of parallel meridian lines.** These are used for aligning with a map.
- **Transparent baseplate.** This includes a **direction-of-travel line.**
- **Rulers.** These are used for measuring distances on a map.
- **Index line.** Bearings are read and set at the index line, which may be one end of the direction-of-travel line.

Optional features on some compasses (fig. 5-4b) include the following:

- **Adjustable declination arrow.** The adjustable declination arrow is an easy way to correct for magnetic declination. “Gear-driven” adjustability, made with a tiny screwdriver, is easier and more dependable than “tool-free” adjustability.
- **Sighting mirror.** This mirror, with a sighting notch at the top of the housing, improves accuracy (and also permits emergency signaling). The direction-of-travel line may be a line extending from the notch across the center of the mirror.
- **Clinometer.** This is used to measure the angle of a slope and the upward or downward angle to another object (see “Clinometer” later in this chapter).
- **Romer scale.** A Romer (interpolation) scale is used to measure UTM position.
- **Lanyard.** This cord attaches the compass to a belt, jacket, or pack. Putting it around your neck is unsafe, particularly when doing any technical climbing.
- **Magnifying glass.** Use the magnifier to help read closely spaced contour lines.

Some compasses that have an adjustable declination arrow but no mirror offer a good cost compromise. Table 5-3 provides a summary of compass characteristics for mountaineering use.

BEARINGS

A bearing (also known as an *azimuth*) is the direction from one place to another, measured in degrees of angle from true north. The round dial of a compass is divided into 360 degrees (fig. 5-5). The cardinal directions are: north at 0 degrees (the same as 360 degrees), east at 90 degrees, south at 180 degrees, and west at 270 degrees. The *intercardinal* directions are halfway between the cardinal directions: northeast is at 45 degrees; southeast, 135 degrees; southwest, 225 degrees; and northwest, 315 degrees.

The compass is used for two tasks regarding bearings:

1. **Taking bearings,** also known as *measuring bearings.* Taking a bearing means measuring the direction from one point to another, either on a map or on the ground.

TABLE 5-3. COMPARISON OF COMPASS TYPES

COMPASS TYPE	COST	ADVANTAGES	DISADVANTAGES
Full-featured with gear-driven adjustable declination arrow and sighting mirror	\$50 to \$90	No need to correct for magnetic declination mentally or by modifying compass	Most expensive
Full-featured with tool-free adjustable declination arrow and sighting mirror	\$20 to \$50	Same as above	Some have difficult-to-use declination adjustment.
Full-featured with gear-driven adjustable declination arrow; no sighting mirror	\$20 to \$50	Same as above	Slightly less accurate without mirror
Full-featured	\$20 to \$30	Same as above	Same as above;

with tool-free adjustable declination arrow; no sighting mirror			some have difficult-to-use declination adjustment.
Basic baseplate compass without adjustable declination arrow; no sighting mirror	$10 to $40	Lowest cost	Must correct declination mentally or by modifying compass (see “Adjusting Bearings for Magnetic Declination” later in this chapter)
Electronic compass on dedicated GPS unit, smartphone, or watch	Often included in these digital items	Convenience of one instrument for several functions	Cannot use to measure or plot bearings on map; may require recalibrations; battery-dependent; may not display at subfreezing temperatures

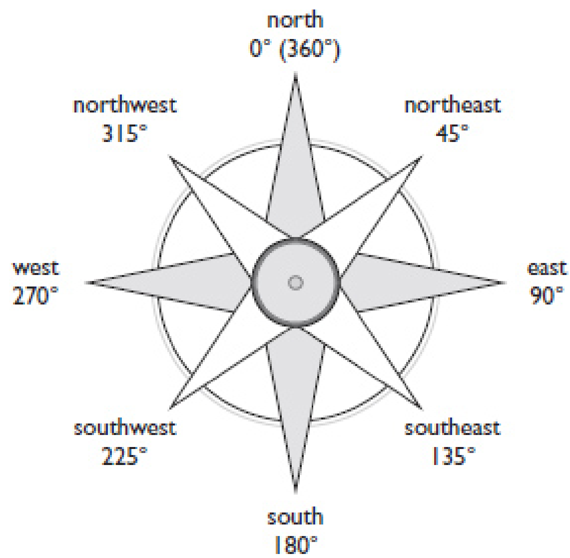

Fig. 5-5. Cardinal and intercardinal directions and corresponding bearings in degrees on the compass.

2. **Plotting bearings,** also known as *following bearings.* Plotting a bearing means setting a specified bearing on the compass and then plotting out, or following, the direction where that bearing points, either on a map or on the ground.

Bearings on a Map

The compass is used as a protractor to both measure and plot bearings on a map. Magnetic north and magnetic declination have nothing to do with these operations. Therefore, never make any use of the magnetic needle when taking or plotting bearings on a map. The only time the magnetic needle is used on the map is whenever you orient the map to true north (see "Orientation by Instrument" later in this chapter), but there is no need to orient the map to measure or plot bearings.

Taking (measuring) a bearing on the map. Place the compass on the map, with one long edge of the baseplate running directly between two points of interest (fig. 5-6). While measuring the bearing from point A to point B, make sure that the compass's direction-of-travel line always points in the direction from point A to point B, as shown—don't reverse the compass 180 degrees so the direction-of-travel line points from B to A.

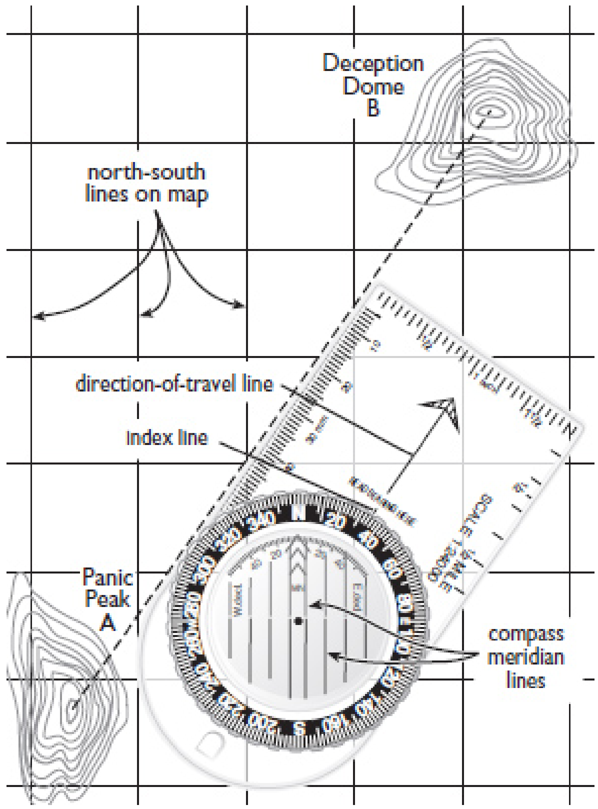

Fig. 5-6. Taking a bearing on a map with the compass as a protractor (magnetic needle omitted for clarity).

Then turn the rotating housing, or bezel, until its meridian lines are parallel to the north-south lines on the map. If the map does not have north-south lines, draw some in, parallel to the edge of the map and at intervals of 1 to 2 inches (3 to 5 centimeters). Be sure the orienting arrow (not the magnetic needle) that turns with the meridian lines is pointing to the top of the map, to the north. If the orienting arrow is pointed toward the bottom of the map, to the south, the reading will be 180 degrees off. (In Figure 5-6, the magnetic needle has been omitted to provide a better view of the meridian lines and orienting arrow.)

Now read the number on the dial that intersects with the index line. This is the bearing from point A to point B. In the example shown in Figure 5-6, the bearing from point A, Panic Peak, to point B, Deception Dome, is 34 degrees.

Plotting (following) a bearing on the map. To follow a bearing, you must start with a known bearing. Where does that bearing come from? It comes from an actual landscape compass reading. In a hypothetical example, a friend returns from a climb, remorseful for having left his camera somewhere along the trail. During a rest stop, he had taken some pictures of Mount Magnificent, and at the same time, he had taken a compass bearing on Mount Magnificent and found it to be 130 degrees. That is all you need to know. You happen to be heading into that same area next week, so get out the Mount Magnificent quadrangle, and prepare to figure out where your friend left his camera.

First, turn the rotating housing to set the bearing of 130 degrees at the compass index line (fig. 5-7). Next, place the compass on the map, with one long edge of the baseplate touching the summit of Mount Magnificent. Now rotate the entire compass (without further turning the rotating housing) until the compass meridian lines are parallel with the map's north-south lines (again, draw some lines on the map if necessary; see the preceding section), and make sure the edge of the baseplate is still touching the mountain's summit. Ensure that the orienting arrow points to the top of the map, toward north.

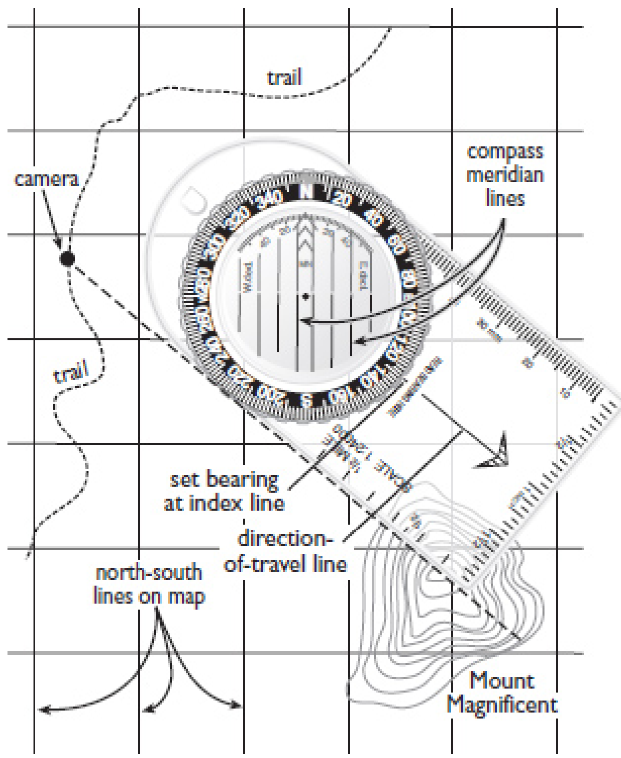

Fig. 5-7. Plotting a bearing on a map with the compass as a protractor (magnetic needle omitted for clarity).

Now follow the edge of the baseplate, heading in the opposite direction from the direction-of-travel line, because the original bearing was measured toward the mountain. Where an imaginary line extending from the edge of the baseplate crosses the trail is where your friend's camera is (or was last week).

Bearings in the Field

All bearings in the field are based on where the magnetic needle points, so now that needle must do its job. The first two examples below, for the sake of simplicity, ignore the effects of magnetic declination (covered in the next section): imagine taking bearings in central Arkansas, where declination is negligible in 2017.

Taking (measuring) a bearing in the field. Holding the compass in front of you, first, point the direction-of-travel line at the object whose bearing you want to find (fig. 5-8). Second, rotate the compass housing until the pointed end of the orienting arrow is aligned with the north-seeking end of the magnetic needle. Last, read the bearing on the dial where it intersects the index line; for example, in Figure 5-8 the bearing is 270 degrees.

If the compass has no sighting mirror, hold the compass at or near arm's length and at or near waist level (fig. 5-9). If the compass has a sighting mirror, fold the mirror back at about a 45-degree angle and hold the compass at eye level, with the sighting notch at the top of the mirror pointing at the object (fig. 5-10). Observe the magnetic needle and the orienting arrow in the mirror while rotating the housing to align the needle and the arrow.

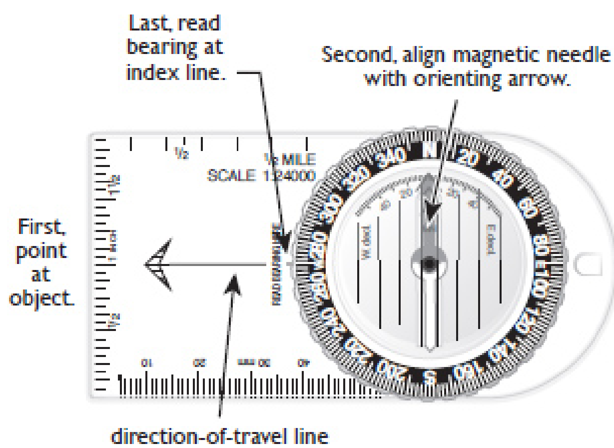

Fig. 5-8. Taking a compass bearing in the field in an area with zero declination.

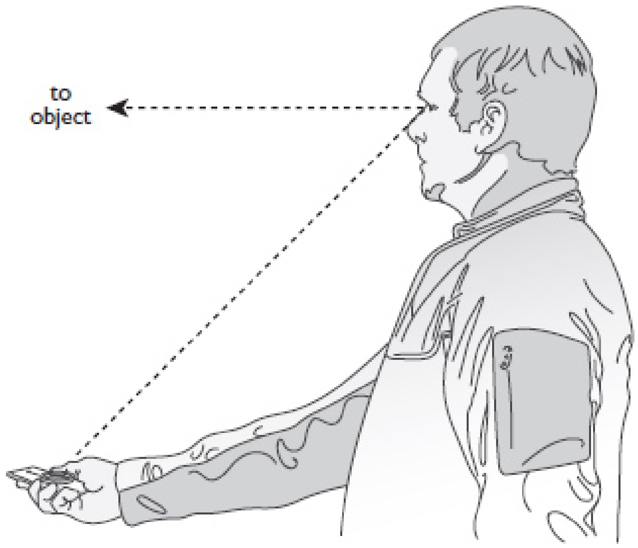

Fig. 5-9. Holding compass with no sighting mirror at arm’s length and waist height.

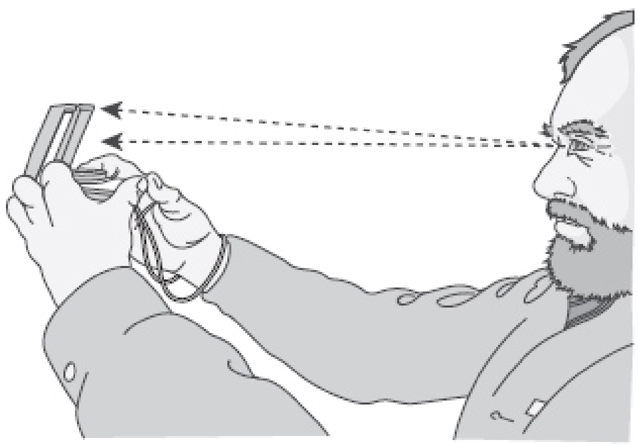

Fig. 5-10. Using a sighting mirror.

In either case, hold the compass level. Keep it away from ferrous metal objects, which can easily deflect the magnetic needle (see “Cautions in Using a Compass” below).

Plotting (following) a bearing in the field. Simply reverse the process used to take a bearing in the field. Start by rotating the compass housing until the desired bearing, say 270 degrees (due west), is set at the index line (see Figure 5-8). Hold the compass level in front of you, and then turn your entire body (including your feet) until the north-seeking end of the magnetic needle is aligned with the pointed end of the orienting arrow. The direction-of-travel line is now pointing due west.

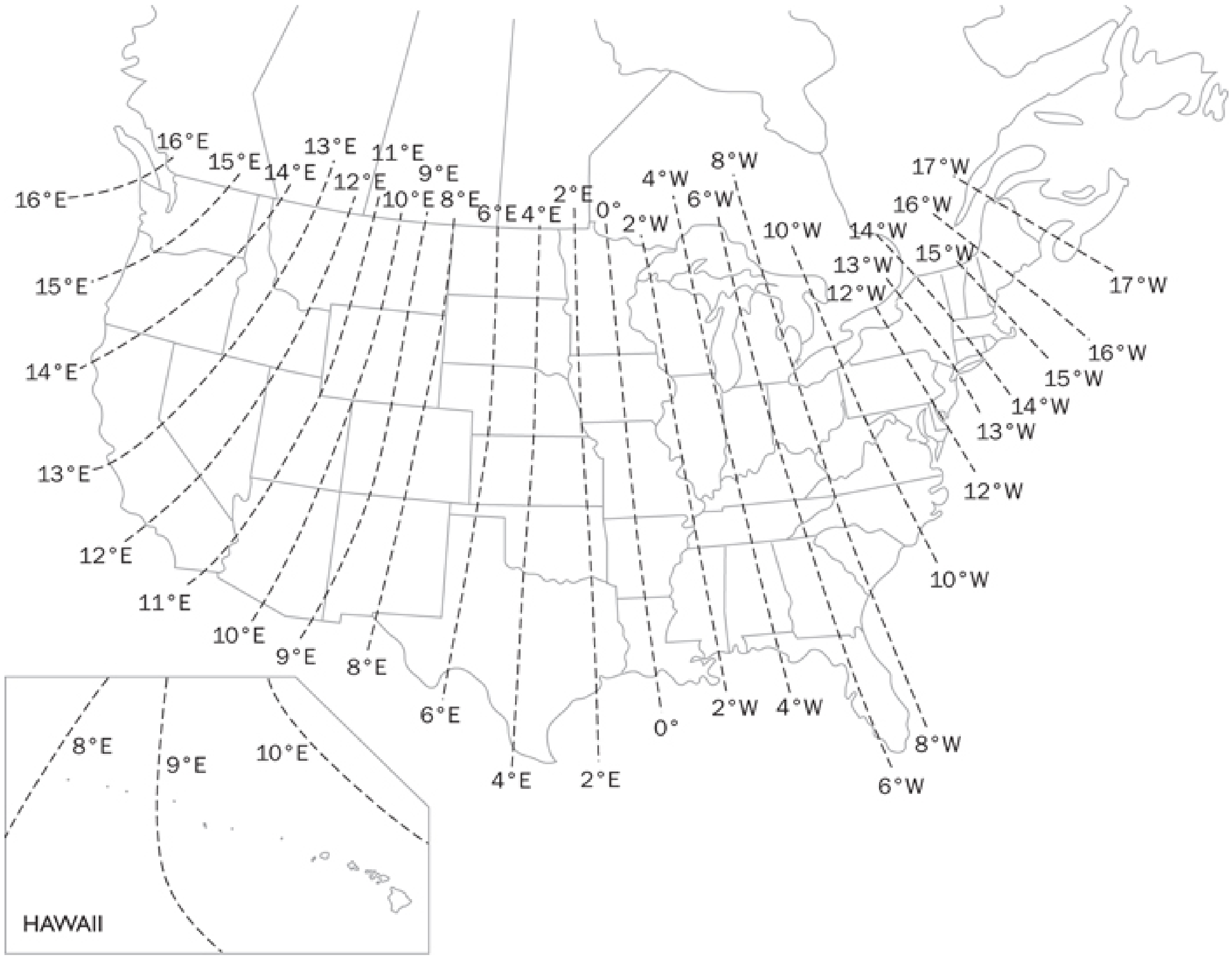

Fig. 5-11. Projected magnetic declination in the United States (excepting Alaska) in 2020.

MAGNETIC DECLINATION

A compass needle is attracted to *magnetic north*, whereas most maps are oriented to a different point on the earth: the geographic North Pole, called *true north*. This difference between the direction to true north and the direction to magnetic north is called *magnetic declination*. It is usually expressed in degrees east or west of true north. A simple compass adjustment or modification is necessary to correct for magnetic declination.

The line connecting all points where true north aligns with magnetic north is called the *line of zero declination*. In the United States, this line now runs from Minnesota to Louisiana (fig. 5-11). In areas west of the line of zero declination, the magnetic needle points somewhere to the east of true north, so these areas are said to have east declination. It works just the opposite east of the line of zero declination, where the magnetic needle points somewhere to the west of true north: these areas have west declination.

Changes in Magnetic Declination

Declination changes with time (hence, figures show projected declination), because the molten magnetic material in the earth's core is continually moving. Declination is shown on all USGS topographic maps, but since these are not updated very frequently, the declination shown on maps may be somewhat out of date. The map in Figure 5-11 shows the declination for the year 2020 for the contiguous 48 states and Hawaii, and it will be accurate to within about half a degree for most such locations from 2017 to about 2023.

The map in Figure 5-12 shows the declination for the year 2018 for the state of Alaska, and it should be accurate to within about 1 degree for the period from 2016 to 2020. Some websites can be used to find the current magnetic declination for any location on the earth (fig. 5-13): the Geological Survey of Canada calculator at the National Resources Canada (NRCan) site, for example, as well as the US National Oceanic and Atmospheric Administration's (NOAA) National Geophysical Data Center site (see Resources).

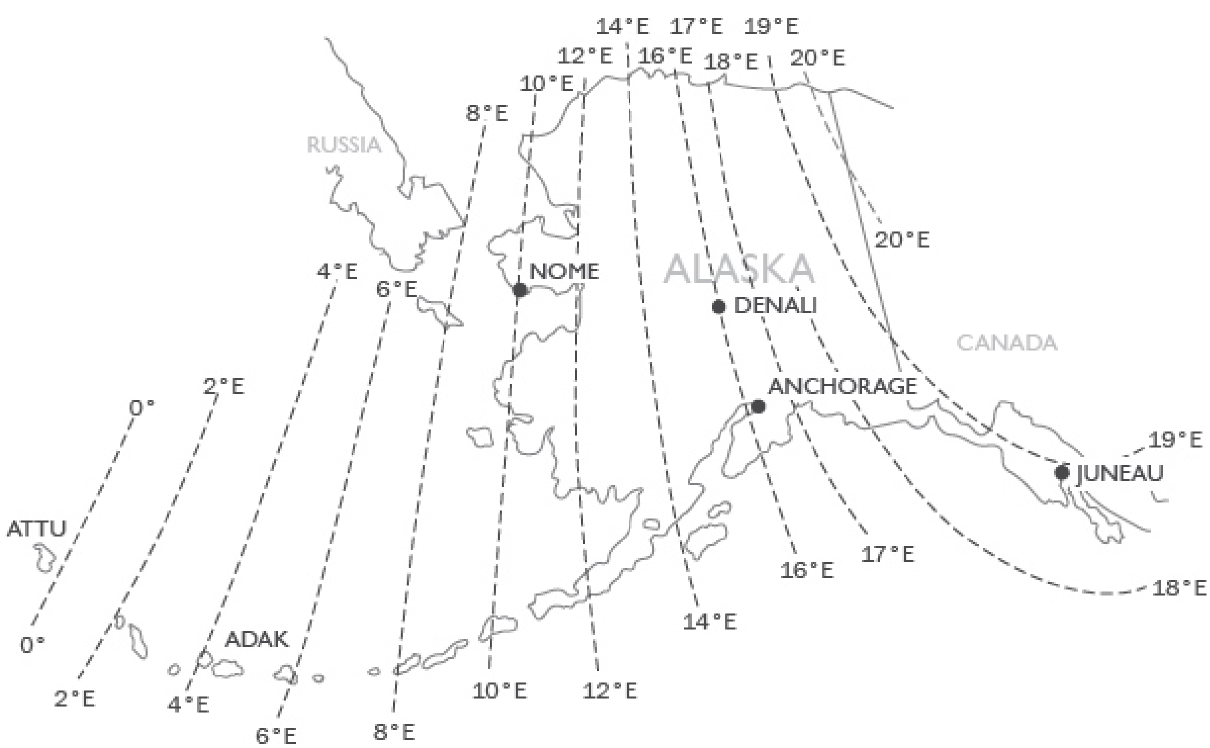

Fig. 5-12. Projected magnetic declination in Alaska in 2018.

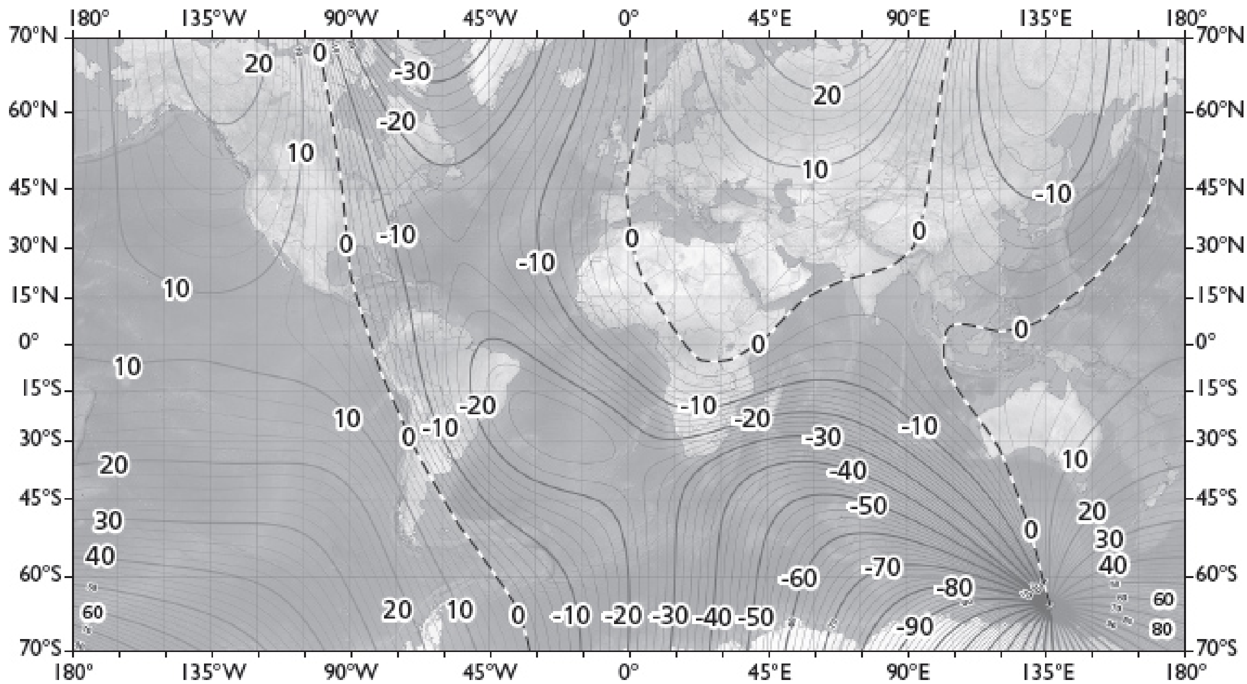

Fig. 5-13. World declination map for the year 2015: lines of constant declination are at 2-degree intervals. Positive numbers indicate east declinations, and negative numbers indicate west declinations.

As an example of declination change, a USGS map of the Snoqualmie Pass area of Washington State dated 1989 stated a declination of 19°30’E (19.5 degrees). Another map of the same area dated 2003 gave a declination of 18°10’E (18.2 degrees).

Declination change varies widely throughout the world. In Washington, DC, declination is barely changing as of 2017. In northeast Alaska, it is changing by as much as 1 degree every three years. In Washington State, the change is about 1 degree every six years. In Colorado, it is about 1 degree every eight years. (These values can be found for any location in the world using either the NOAA or NRCan website; see Resources.) From these examples, it should be clear that the declination on maps more than a few years old should not be trusted; it is important to find the latest declination information to prevent errors in navigation by compass.

Adjusting Bearings for Magnetic Declination

Consider a traveler in eastern Idaho, where the declination is 12 degrees east (fig. 5-14a). The *true bearing* is a measurement of the angle between the line to true north and the line to the objective. The compass’s magnetic needle, however, is pulled toward magnetic north, not true north. So instead it measures the angle between the line to magnetic north and the line to the objective. This *magnetic bearing* is 12 degrees less than the true bearing in eastern Idaho. To get the true bearing, it is possible to add 12 degrees to the magnetic bearing, though easier ways are described in the “Adjustable declination arrow” paragraph below.

Travelers in all areas west of the zero declination line, as in the Idaho example above, could add the declination to the magnetic bearing. In the Rocky Mountains of Colorado, for example, about 8 degrees would be added. In central Washington State, it is about 15 degrees.

East of the zero declination line, the declination can be subtracted from the magnetic bearing to get the true bearing. In northern New Hampshire, for example, the magnetic bearing is 15 degrees greater than the true bearing (fig. 5-14b). Subtracting the declination of 15 degrees gives a climber in New Hampshire the true bearing.

Adjustable declination arrow. Adjusting for magnetic declination is very simple in theory but can be confusing in practice, and in the wilderness, errors in mental arithmetic can have potentially serious consequences. A more practical way to handle the minor complication of declination is to pay somewhat more for a compass with an adjustable declination arrow (as shown in Figure 5-4b) instead of buying one with a fixed orienting arrow (as shown in Figure 5-4a). The declination arrow can quickly be set for any declination by following the instructions supplied with the compass. Then the bearing at the index line will automatically be the true bearing, and there will be no need for concern about a declination error. If climbers travel to a location with a different declination, they can make a simple adjustment to set the new declination value.

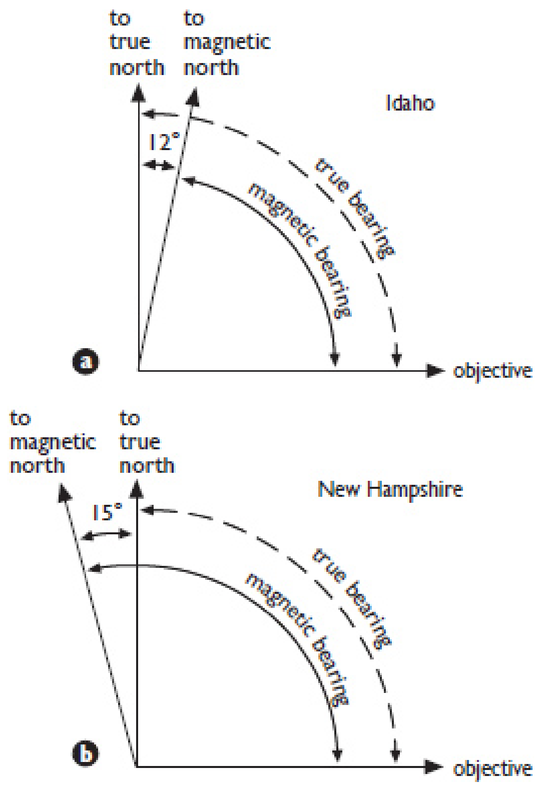

Fig. 5-14. Magnetic and true bearings: a, in Idaho, east declination; b, in New Hampshire, west declination.

Customized declination arrow. On compasses with fixed, nonadjustable orienting arrows, a similar effect can be achieved by sticking a thin strip of adhesive or masking tape to the bottom of the rotating housing to serve as a customized declination arrow, as shown in Figure 5-15. Trim the tape to a point, with the point aimed directly at the specific declination for the intended climbing area, and use this homemade arrow, not the prepainted original.

In the eastern Idaho example, the taped declination arrow must point at 12 degrees east (clockwise) from the 360-degree point (marked "N" for north) on the rotating compass dial (fig. 5-15a). In the northern New Hampshire example, it must point at 15 degrees west (counterclockwise) from the 360-degree point on the dial, that is, at 345 degrees (fig. 5-15b). In central Washington State, it must point at 15 degrees east (clockwise) from 360 degrees. If you travel to a place with a different declination, peel the tape off and apply a new customized tape arrow for the new declination.

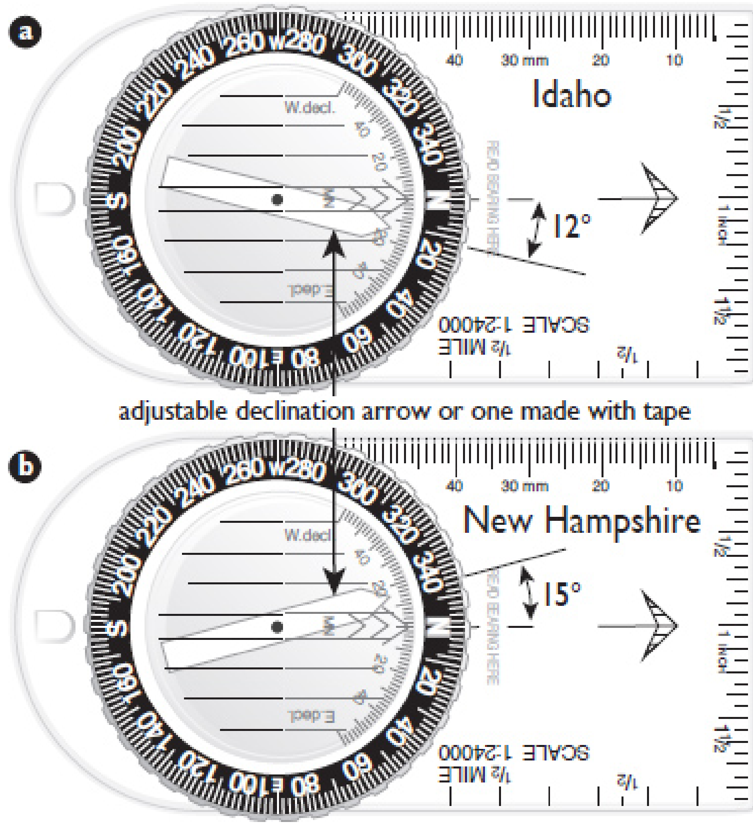

Fig. 5-15. Compass declination corrections (magnetic needle omitted for clarity): a, for an area west of the zero-declination line (Idaho); b, for an area east of the zero-declination line (New Hampshire).

Taking or following bearings in the field. To take or to follow a bearing (that has been adjusted for magnetic declination) in the field, follow exactly the same procedure used in the earlier examples from Arkansas (see "Bearings in the Field" above), where the declination is near zero. The only difference is that you will now align the magnetic needle with the adjustable declination arrow or the taped declination arrow instead of with the orienting arrow.

Note: From here on, this chapter assumes you are using a compass with a declination arrow—either an adjustable arrow or an added tape arrow. For all bearings in the field, align the needle with this declination arrow. Unless otherwise stated, all bearings referred to in this chapter are true bearings, not magnetic.

COMPASS DIP

The magnetic needle of the compass is affected not only by the horizontal direction of the earth’s magnetic field but also by its vertical pull. The closer a compass user gets to the magnetic North Pole, the more the north-seeking end of the needle tends to point downward, toward the ground. Near the equator, the needle is level; at the magnetic South Pole, the north-seeking end of the needle tries to point upward. This phenomenon is referred to as *compass dip*.

To compensate for this effect, most compass manufacturers purposely introduce a slight imbalance to the magnetic needles of their compasses, so that their dip is negligible for the geographic area where they will be used. However, if a climber buys a compass in the northern hemisphere—say, in North America or Europe—and then tries to use it in the southern hemisphere—say, in New Zealand or Chile—the difference in dip may be enough to introduce errors in compass readings or even make it impossible to use. For this reason, if climbers bring compasses to a faraway place, as soon as they get to the country they are visiting, they must first try out their compasses in an urban area to make sure they work properly before heading out into the wilderness, and then purchase one balanced for dip in that area if they do not work.

Some compass manufacturers produce compasses that are not affected by dip. Some such compasses have the term “global” in their names or a notation on the package that the compass is corrected for dip anywhere in the world, though these are generally more expensive. Climbers who intend to go on worldwide climbing expeditions might consider such a compass.

COMPASS PRACTICE

Before counting on your compass skills in the wilderness, test them near where you live (see the “Map and Compass Checklist” sidebar). The best place to practice is someplace where you already know all the answers, such as a street intersection where the roads run exactly north-south and east-west. Avoid any location near metallic objects such as fire hydrants.

Take a bearing in a direction you know to be east. When the direction-of-travel line or arrow is pointed at something that you know is due east of you—such as the edge of the sidewalk or a road or a curb that is east of you—and the declination arrow is lined up with the magnetic needle, the number on the dial that intersects with the index line should be within a few degrees of 90. Repeat for the other cardinal directions: south, west, and north.

Then do the reverse: Pretend you do not know which way is west. Set 270 degrees (west) at the index line and hold the compass in front of you as you turn your entire body until the magnetic needle is again aligned with the declination arrow. The direction-of-travel line should now point west. Does it? Repeat for the other cardinal directions. This set of exercises will help develop skill and self-confidence at compass reading and also is a way to check the accuracy of the compass.

MAP AND COMPASS CHECKLIST

Do you understand how to use a map and compass? Run through the whole procedure once more. Check off each step as you do it. And remember the following:

- Never use the magnetic needle or the declination arrow when measuring or plotting bearings on the map.
- When taking or following a bearing in the field, always align the pointed end of the declination arrow with the north-seeking (usually red) end of the magnetic needle.

Taking (Measuring) a Bearing on a Map

1. Place the compass on the map, with the edge of the baseplate joining the two points of interest.
2. Rotate the housing to align the compass meridian lines with the north-south lines on the map.
3. Read the bearing at the compass's index line.

Plotting (Following) a Bearing on a Map

1. Set the desired bearing at the index line by rotating the compass housing.
2. Place the compass on the map, with the edge of the baseplate on the feature from which you wish to plot a bearing.
3. Turn the entire compass to align the meridian lines with the map's north-south lines. The edge of the baseplate is the bearing line.

Taking (Measuring) a Bearing in the Field

1. Hold the compass level in front of you and point the direction-of-travel line at the desired object.
2. Rotate the housing to align the declination arrow with the magnetic needle.
3. Read the bearing at the index line.

Plotting (Following) a Bearing in the Field

1. Set the desired bearing at the index line by rotating the compass housing.
2. Hold the compass level in front of you and turn your entire body until the magnetic needle is aligned with the declination arrow.
3. Travel in the direction shown by the direction-of-travel line.

Look for chances to practice in the mountains. A good place is any known location—such as a summit or a lake-shore—from which identifiable landmarks can be seen. Take bearings as time permits, plot them on the map, and see how close the result is to the actual location.

CAUTIONS IN USING A COMPASS

It pays to understand some common errors made while using a compass and other factors that may affect its functioning.

Map and compass versus fieldwork. When measuring and plotting bearings on a map, completely ignore the compass needle. The compass is simply being used as a protractor, so just align the meridian lines on the compass housing with the north-south lines on the map. For taking and following bearings in the wilderness, however, the magnetic needle must obviously be used.

Metal interference. The presence of nearby metal can interfere with a compass reading. Ferrous objects—iron, steel, and other materials with magnetic properties—will deflect the magnetic needle and produce false readings. Keep the compass away from watches, belt buckles, ice axes, and other metal objects such as a vehicle. Iron content in nearby rocks can make the bearing information nearly useless. If a compass reading does not seem to make sense, move 10 to 100 feet (3 to 30 meters) and check to see if the bearing changes. If so, it is likely being affected by nearby metal.

Errors of 180 degrees. Keep your wits about you when pointing the declination arrow and the direction-of-travel line. If either is pointed backward—an easy thing to do—the reading will be 180 degrees off. (If outside, note where the sun is in the sky. That can often help jog your directional presence of mind.) If the bearing is north, the compass will say it is south. Remember that the north-seeking end of the magnetic needle must be aligned with the pointed end of the declination arrow and that the direction-of-travel line must point from you to the objective, not the reverse.

There is yet another way to introduce a 180-degree error in a compass reading: by aligning the compass meridian lines with the north-south lines on a map but pointing the rotating housing backward. The way to avoid this is to check that "N" on the compass dial is pointing to north (usually the top) on the map.

Trust the compass. If you are in doubt, trust the compass. The compass, correctly used, is almost always right, whereas a climber's contrary judgment may be clouded by fatigue, confusion, or hurry. If you get a nonsensical reading, check to see that you are not making one of those 180-degree errors. If not, and if there is no metal in sight, verify the reading with other members of the party and other navigation devices: altimeter and GPS. If other navigation devices provide the same answer, trust the tools over hunches and intuition.

CLINOMETER

Clinometers are useful tools for measuring the angle of a slope for orientation and for assessing avalanche risk (see Chapter 17, Avalanche Safety). Clinometers are a feature of some compasses; they are also available as small devices that attach to ski poles and on phones as smartphone apps.

The compass clinometer (see Figure 5-4b) consists of a small nonmagnetic needle that points, due to gravity, downward toward a scale calibrated in degrees. To use the clinometer, first set either 90 or 270 degrees at the index line. Then hold the compass on edge and with the direction-of-travel line level, so that the clinometer needle swings freely and points downward toward the numbered scale. The needle should then point to 0 degrees. Tilting the compass up or down then causes the needle to point to the number of degrees of inclination.

You can also align the baseplate edge with a distant slope in profile to measure its inclination (fig. 5-16), or set the baseplate edge on a ski pole or ice axe (aligned on the fall line) to measure the local slope. Phone clinometer apps measure slope angle by using the edge of the phone or, for distant points, the camera. The ski-pole clinometer is a small electronic device that attaches to ski and trekking poles with Velcro and measures slope angle when a button is pushed.

GPS

The US Department of Defense and similar agencies in other countries have placed satellites in orbit around the earth for space-based navigation systems. The systems that are most commonly used are the United States', referred to as the Global Positioning System (GPS), and the Russians', referred to as the Global Navigation Satellite System (GLONASS). Other countries have systems in development as well. These systems have revolutionized navigation. This chapter refers to all these systems collectively as GPS.

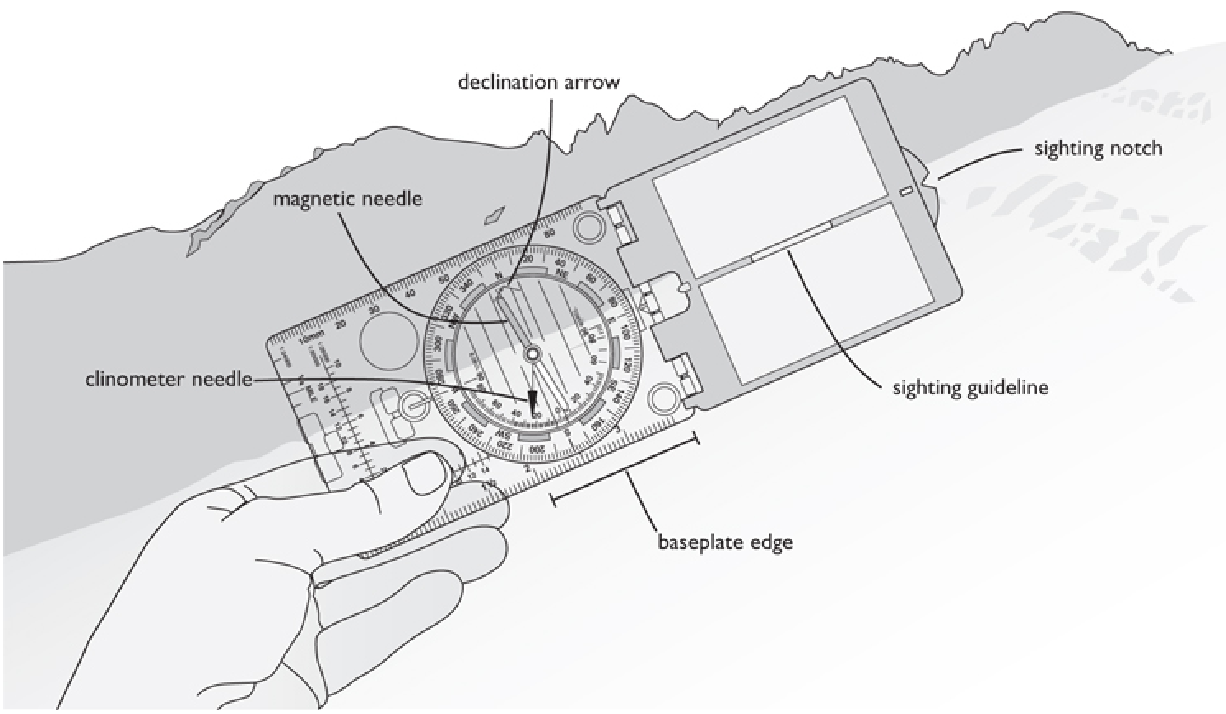

Fig. 5-16. Using a baseplate compass's clinometer to measure slope angle.

GPS DEVICES

This chapter uses "GPS device" to refer to both phones or tablets with GPS apps and dedicated GPS units. These devices can receive and simultaneously use the signals from both the US GPS and GLONASS satellites and give the user's position and altitude to within about 50 feet (15 meters). A GPS device has various features that allow users to display their specific positions (*waypoints*), determine the compass bearing and the distance between waypoints, plot out routes comprising a series of waypoints from one position to another, and record *tracks* (the actual route traveled along a path) as they travel. A party should seriously consider bringing a GPS device for every climb unless they are certain the route is straightforward, even in darkness or storm. GPS devices can cost from as little as $20 (to purchase a smartphone app) to hundreds of dollars for a more durable dedicated GPS unit. (For a device comparison, see Table 5-4 below.)

TABLE 5-4. COMPARISON OF GPS DEVICES				
FEATURES	PHONE WITH GPS APP	TABLET WITH GPS APP	DEDICATED GPS UNIT	GPS WRISTWATCH
Screen size (diagonal measurement)	4.7 to 6.2 in. (12 to 16 cm)	Up to 12 in. (30 cm)	2 to 4 in. (5 to 10 cm)	1 to 2 in. (3 to 5 cm)
Weight	4 to 6 oz. (110 to 170 g)	12 to 24 oz. (340 to 680 g)	5 to 8 oz. (140 to 220 g)	Approx. 3 oz. (80 g)
Internal map capability	All	All	Most	Some
Map libraries	Extensive map libraries available; mostly free		Map libraries available; some free	
Touch screen	All	All	Some	Rarely
Electronic compass	Most	Rarely	Some	Some
Barometric altimeter	Most	None	Some	All
Expandable memory	Some use microSD card		Some use microSD card	No
Water resistance	Some phones and cases provide water resistance; screens difficult to use when wet		Yes	Yes
Minimum operating temperature	-4°F to 32°F (-20°C to 0°C)		-4°F to 14°F (-20°C to -10°C)	-5°F to 0°F (-21°C to -18°C)
Maximum operating temperature	95°F to 122°F (35°C to 50°C)		140°F to 158°F (60°C to 70°C)	130°F to 140°F (54°C to 60°C)
Battery type	Mostly nonreplaceable lithium-ion		Mostly replaceable AA	Nonreplaceable
Battery life while using GPS	Variable depending on usage strategy (can help to bring a portable battery pack, but adds weight)		14 to 25 hours	20 to 200 hours
Cost	$20 for app (plus cost of phone)		$100 to $700; no recurring cost, unless more maps needed	$100 to $600; no recurring cost, unless more maps needed

Some special preparations prior to a trip are necessary (see "Tips for Using GPS in the Mountains" later in this chapter). Phones and dedicated GPS units break or are lost, and batteries die, so having two or three GPS devices in the party reduces the risk of depending on any single unit. When trees or mountains block your view of the sky and satellites, adequate satellite signals can sometimes not reach you, resulting in poor GPS accuracy or sometimes even the inability to obtain a position at all. For this reason, always carry a detailed hardcopy topographic map of the travel area, an altimeter, and a baseplate compass.

Phones or Tablets with GPS App

Phones can receive GPS signals from US GPS and Russian GLONASS satellites, even far from cell tower coverage. To navigate by phone or tablet, you must first install a GPS software app and download the required digital maps while the device is still connected to the internet. The mapping app shows climbers where they are on a map within tens of feet or meters. Some programs offer free extensive libraries of maps; be sure to download needed subsets before each trip.

The phone's effectiveness as a GPS navigation device—inside or outside of cell phone range—allows its use for backcountry navigation on all climbs where navigation may take the climber off well-known paths. In more extreme conditions, the ruggedness of dedicated GPS units may be more appropriate.

There are cautions regarding using GPS-enabled phones and tablets. Most are powered by proprietary batteries that are usually not replaceable by users. Thrifty use of the phone battery power (see "Limitations of GPS Devices in the Backcountry" later in this chapter) is therefore necessary on full day trips or longer. However, external battery packs allow continuous use for days, or intermittent use for weeks, although they add to overall pack weight.

Dedicated GPS Units

Most handheld dedicated GPS units also receive GPS signals from both US GPS and GLONASS satellites. Manufactured by Garmin and Magellan, among others (fig. 5-17a and b), they are usually powered by a pair of readily available AA batteries. Dedicated GPS units are usually more rugged and more weatherproof and operable in lower and higher temperatures than phones and tablets, which makes dedicated GPS units a better choice in extreme environments. Detailed topographic maps can be added to most such devices, some by purchasing secure digital (SD) or microSD cards containing maps of specific areas (such as a large state or a number of smaller states), or by downloading maps from the internet or from supplied CDs. Some of the more expensive dedicated GPS units come with topographic maps already installed.

A wristwatch GPS device (fig. 5-17c) generally has similar functionality as other dedicated GPS receivers, though with an altimeter, barometer, compass, GPS, and timekeeping. Wristwatch GPS devices are usually powered by nonreplaceable proprietary batteries that can be charged from a USB port on a home computer or from an AC power adapter. Though wearable and functional, GPS watches have not gained as much popularity as dedicated GPS units and GPS-capable phones due to their small screens and high cost.

Fig. 5-17. Dedicated GPS units: a, Garmin eTrex series; b, Magellan eXplorist series; c, Suunto Ambit GPS watch.

The GPS Signal, the Cellular Network, and Wi-Fi

From orbits of about 12,000 miles (20,000 kilometers) above the earth, GPS satellite signals are available anywhere on the planet; cellular phone signals have a range of a few miles; and local Wi-Fi networks have a range of several hundred feet. Neither cellular phone signals nor Wi-Fi is dependably available in the wilderness.

For GPS navigation (though not for calls), phones and tablets work effectively even when they are out of range of cell phone towers—a condition frequently encountered in the wilderness. Tablets have some value in trip planning and documentation at home before and after a climb, particularly due to their large screen size, which allows a better view of topographic maps than the small screens of cell phones and other GPS devices. However, outside of expeditions, tablets are impractical to carry on most climbs due to their size, weight, and battery power limitations.

It is easy and inexpensive to find and install one or more GPS apps onto a phone. Access to the internet is needed for downloading apps, maps, routes, tracks, and trails, but cell service is not needed for these downloads. Many forms of maps are free through phone GPS apps, allowing the mountaineer to easily download multiple map types as well as satellite images for a trip. Free map sources can also be downloaded to dedicated GPS units.

To get the most benefit from a GPS device, be sure to read the instruction manual carefully to master all of its features. In addition, several good books and useful websites are available that explain GPS in greater detail (see Resources). Table 5-4 provides a snapshot comparison of the different types of GPS devices based on information at time of publication; note, this technology changes rapidly.

Basics of Using GPS

First, select which units to use: miles or kilometers, feet or meters, magnetic or true bearings, et cetera, and enter these preferences in the "settings" screen. Next—very important—select the datum that agrees with the datum for the topographic map you will be using. Many GPS devices use WGS84 as the default datum, which is the same default datum used on the new USGS "US Topo" maps published as PDF files. The USGS "Historical" topographical maps (more useful for climbers), which were published on paper prior to 2007, use the NAD27 datum. (See "Datums" earlier in this chapter.) The difference in position between these two datums can be as much as 500 feet (160 meters), so it is essential to check the datum and change it, if necessary, prior to using a GPS device with a map.

Try the GPS device out around home, in city parks, and on trail hikes before taking it on a climb. Talk with friends familiar with GPS use. Take a class, if possible, to obtain helpful hints in using GPS.

MOUNTAINEERING WITH A GPS DEVICE

GPS devices are marvelous tools for the mountaineer. Using them can significantly aid in navigation. Keep in mind, however, that they are not foolproof and that topography, forest cover, battery life, electronic failure, extremely high or low temperatures, and inadequate user knowledge can prevent their effective use. The first rule of using a GPS device is to avoid becoming dangerously dependent on this battery-powered electronic apparatus that can fail or whose batteries may become depleted (see "The Importance of Maintaining Situational Awareness" sidebar).

Some GPS devices have built-in electronic compasses, which also depend on battery power. These can lose accuracy over time or when the batteries are replaced, requiring occasional recalibration. GPS devices are not complete substitutes for an ordinary baseplate compass or physical maps. Climbers should always carry a physical topographic map and a nonelectronic baseplate compass (see “Compass,” earlier in this chapter), even if the GPS device has a compass and/or topographic map capability.

In addition, for complex routefinding, carry route-marking materials such as flagging and wands, regardless of whether a GPS device is being carried or not. GPS devices display their altitude, in feet or meters above sea level, along with their horizontal position. Since this GPS function is also dependent on limited battery power, and GPS devices can fail, it is recommended that all party members bring separate altimeters (see “Altimeter” earlier in this chapter) so that the party will always know its altitude.

When using a dedicated GPS unit, start each trip with a fresh set of batteries and carry spare batteries. Rechargeable nickel–metal hydride (NiMH) batteries are a good choice for use in a dedicated GPS unit. These batteries, as well as a spare backup pair, should be fully charged prior to a trip. For even better battery performance, use disposable lithium cells. They cost more but last longer, perform better at cold temperatures, and weigh considerably less than alkaline or NiMH cells. A pair of lithium AA cells weighs about 1.1 ounces (31 grams), compared with about 1.9 ounces (53 grams) for a pair of alkaline or NiMH cells. When using a phone with GPS app, be sure to fully charge the phone at home prior to the climb. Make sure to conserve valuable power while driving to the climb, and carry a rechargeable battery pack and/or a solar charger for multiday climbs.

THE IMPORTANCE OF MAINTAINING SITUATIONAL AWARENESS

Experienced navigators both respect and are wary of using a GPS device or app to navigate. Too often they see climbers “heads down” following their tiny screen unaware of their surroundings. When the navigator simply follows the GPS device and ignores cues from the passing terrain, “situational awareness”—and, therefore, safety—is diminished. The climber using GPS must fight this tendency by using the following techniques.

Observe. Start by observing the surroundings and updating your mental map of the landscape. Where have you come from? Where are you now? Where are you going? What are the dangers?

Orient. Correlate the surroundings with the physical map to see if they are in agreement. Study myriad details, including slope, sun position, ridges, and terrain features. Then confirm your understanding using multiple tools from the navigation toolset. Confirm the elevation with an altimeter, the cardinal directions with the compass, and your position with GPS.

Decide. Where do you go from here? Decide on your next steps.

Act. Climb on! And maintain your heightened sense of situational awareness by repeating the observeorient-decide-act cycle with close observation and by continually updating your mental map while moving through the landscape.

Maintaining situational awareness is not just a topic of navigation but of safety in general: What is happening with the weather? What is the condition of the party? How many hours of daylight remain? Maintaining a high level of situational awareness can help keep climbers on course and safe, thus enabling everyone to fully enjoy the experience.

Never rely solely on a GPS device for wilderness navigation. Carry a conventional map, compass, and altimeter. And keep your terrain navigation skills sharp so you maintain a high level of situational awareness and can rely on your terrain navigation skills.

Download Maps Before You Go

Most modern phones, when combined with a good app, have the same GPS capability as a dedicated GPS unit. They can display your position on a map, as shown in Figure 5-18. However, as with most dedicated units, the digital maps themselves are not downloadable to phones or tablets through a GPS signal. Maps for the area in which the party will be traveling must first be downloaded from the internet while in range of Wi-Fi or the slower cellular network of land-based towers. Downloading maps to a phone app is usually seamless, simple, and free; be sure to do this in an area with a strong internet signal, since attempting to download data-rich, detailed maps while driving to remote trailheads can be slow and frustrating, if possible at all. Test this action before depending on it. Map sources allow downloading of several types of maps and satellite-sourced images.

If the party has not previously downloaded a map of the area, the device will show its location as a dot on a blank grid (fig. 5-19). The GPS apps nevertheless allow them to find their location by displaying the latitude and longitude or (preferably) UTM coordinates, even if a map is not displayed. Then the party can find its position on the physical map they are carrying. Alternatively, they can take and save a series of waypoints along the route from the camp to the summit, then follow this "bread crumb trail" back to the starting point.

Tips for Using GPS in the Mountains

GPS devices have a wide variety of features that can be applied in many different ways in the mountains. How a GPS device is used on a climb depends on user knowledge, user navigational preference, terrain, weather, intended destination, type of climb, length of climb, and other factors. This section provides some examples of how using a GPS device can help in mountaineering situations. These examples cover the most commonly used features but are not an all-inclusive list.

Identify a location. The primary feature of a GPS device is to provide its user with a location, usually in latitude-longitude or UTM coordinates or as a symbol on a map on the screen of the GPS device. An example is provided in "Orientation by Instrument" later in this chapter.

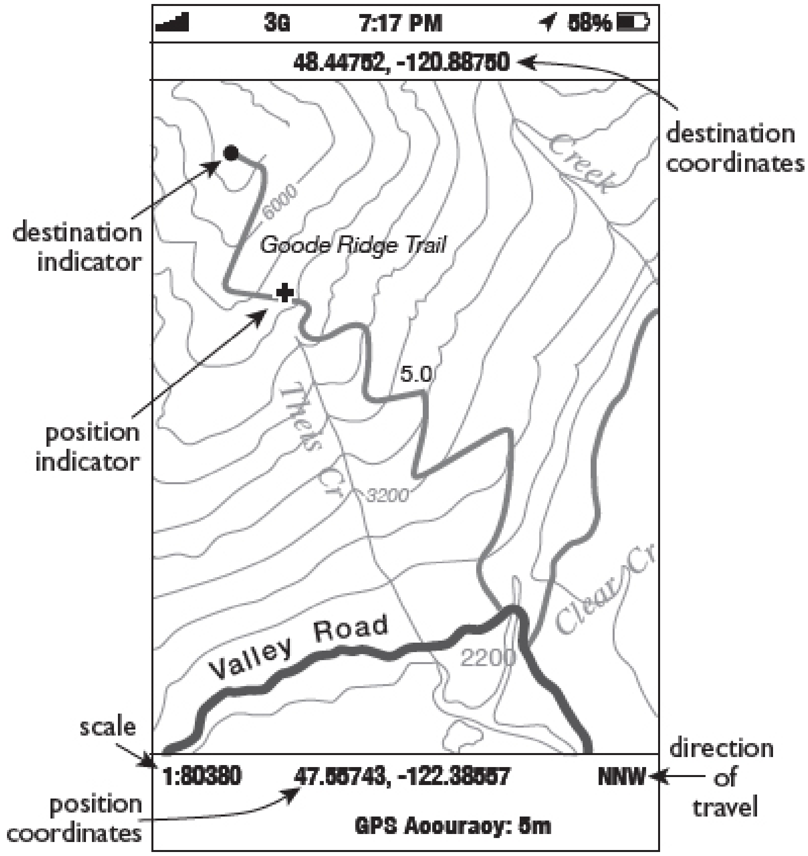

Fig. 5-18. Position and latitude/longitude coordinates shown on a phone within cell range or using a previously downloaded topo map.

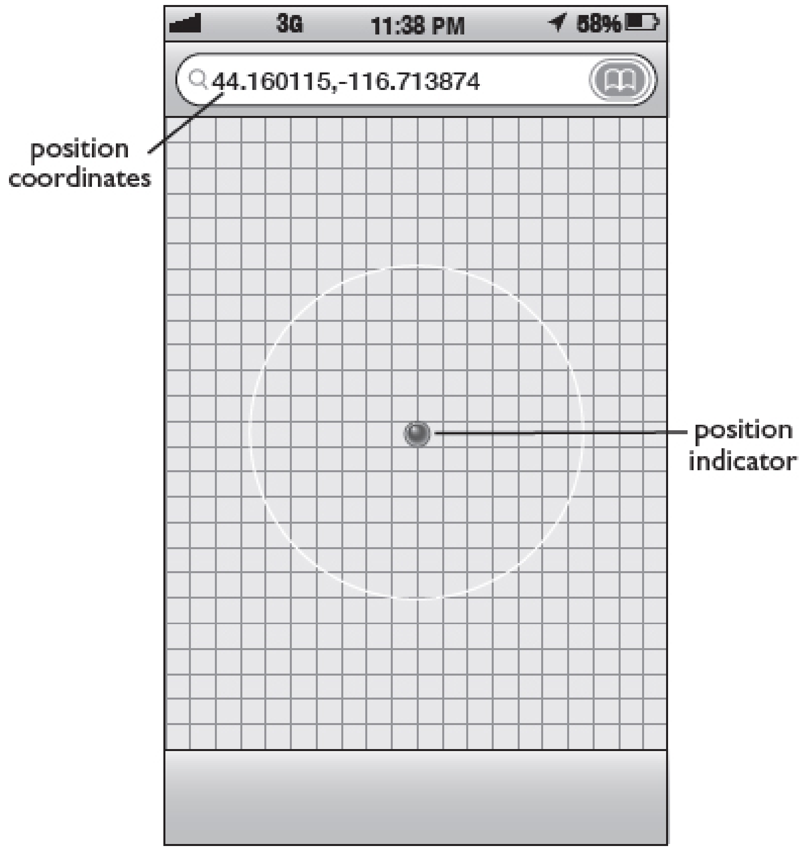

Fig. 5-19. Position and coordinates shown on a phone that is out of cell range and has no downloaded map.

Create and follow waypoints. Another basic feature of a GPS device is the ability to create and use waypoints for point-to-point navigation. Waypoints can be locations such as trailheads, trail intersections, summits, campsites, gear stashes, and other locations the user would like to pinpoint or remember. The coordinates for waypoints can be obtained from maps, guidebooks, websites, mapping software, and other sources; waypoints can also be entered into the GPS device during a trip. It is essential to take (or *mark*) a waypoint at any place to which the party will want to return, such as a car, camp, or any crucial point along the route. At any later time, it is then possible to tell the GPS device to "Go" to that waypoint, and the device will display the distance and direction to that waypoint. Climbers can then travel to that destination either by observing the GPS screen or by setting the bearing on a baseplate compass and following its direction of travel while turning the GPS device off to save battery power. An example of this is provided in "Navigation by Instrument" later in this chapter.

Provide trip data. Most GPS devices have a "trip computer" feature that displays data such as the number of satellites in use by the device, its current location, speed of travel, time of day, trip odometer, remaining battery power, and other items. Although this information can be useful, if the device loses satellite reception for part of the trip (which can happen in thick forests, narrow canyons, or when it is turned off to conserve battery power), some items, such as the trip odometer, may not be accurate.

Create a track. Another useful feature of GPS devices is the ability to create a track. If the GPS device is left on continually during an entire climb or during a critical portion of it, another party can later follow the tracks that were created by the device. Or the original party can follow the track back to the trailhead. For example, in Figure 5-20, a track was made from the trailhead to the summit of West Tiger Mountain, and the track was saved. Later, another user can follow the same track from the trailhead to the summit of West Tiger Mountain; see "Use GPS data in mapping software" below for how other users can access the information in these tracks.

If you are making tracks with your GPS device and are leaving the device on, attach the device or its case to a pack strap to avoid having to hold it in your hand. You might need to use that hand for climbing or for holding an ice axe or a trekking pole. A GPS watch can also be used to record a track.

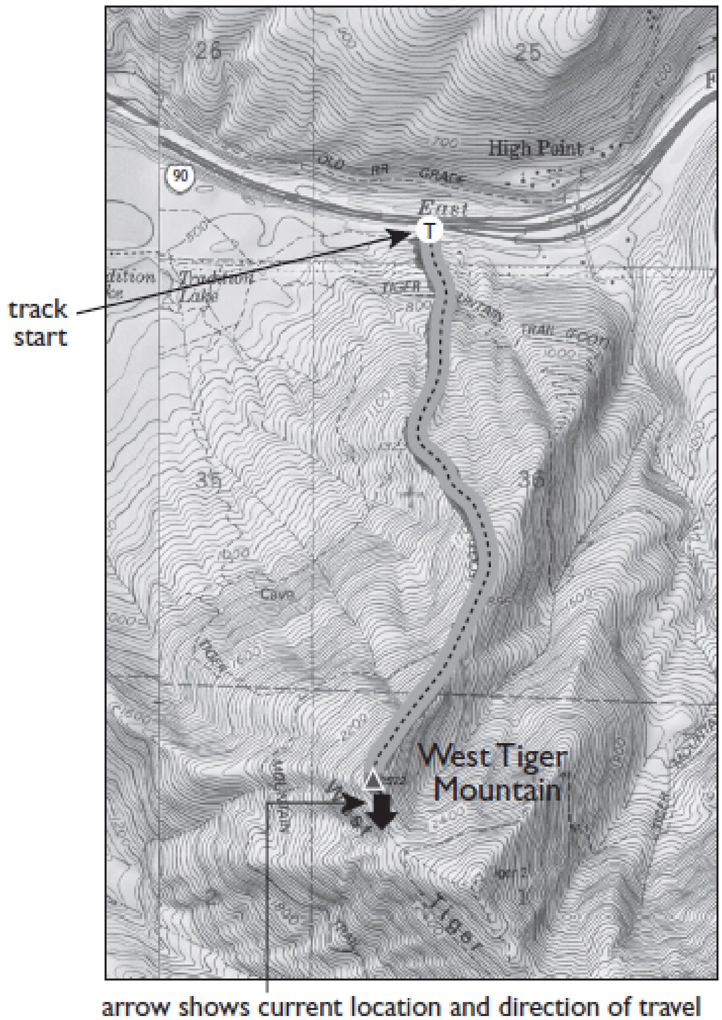

Fig. 5-20. GPS tracks: saved sample track, which can be reused and shared with other users later.

Use GPS data in mapping software. The waypoints and tracks can later be downloaded to mapping services such as CalTopo or GaiaGPS or with software that comes with particular GPS device models, such as Garmin's BaseCamp. This allows climbers to see the entire route on the screen of a home computer and to save it for future reference. Using mapping software, tracks can usually be saved in the universal GPX or KML file format. This provides the ability to transfer tracks into another GPS unit so that other users can follow these tracks on their climbs. Additionally, with mapping software, they can view and print a map of the area that will show the route that was taken by the original user. This is useful both while planning a trip and while on the actual climb.

Conserve batteries. Most dedicated GPS receivers operate on a pair of AA batteries that are readily available almost anywhere, so it is easy to buy a few extra batteries and carry them as spares. Phones, on the other hand, often operate on nonreplaceable proprietary batteries, so using a phone's GPS function requires special attention to saving power and prolonging battery life (see the next section).

Carry battery-recharging gear. Fortunately, lightweight battery packs and solar panels are available to recharge cell phones, if you are willing to carry some additional weight and spend time waiting for them to recharge. The most common way of recharging a device on a trip is with external battery packs. Solar panels are awkward when a party is mobile but are common at expedition base camps.

Limitations of GPS Devices in the Backcountry

A GPS device is essential for navigation, but it should be used along with the other four essential tools: map, altimeter, compass, and a PLB (or other device to contact emergency first responders). Some important limitations of GPS devices are described below.

They can be damaged. A GPS device may fail during a climb. Protect the device from impact by using a sturdy case and perhaps a lanyard. Most dedicated units and some phones are waterproof; protect them against water and sweat as necessary. Have the party carry two or more devices in case a single unit fails.

They are not a subsitute for a physical map. GPS devices can plot a route straight from one point to another, but they cannot automatically find a route around rivers, lakes, or cliffs. Such tasks, including large-scale planning, require careful map reading, often best accomplished on a physical map, which allows for a better understanding of surrounding terrain.

They won't work in extreme temperatures. Some GPS devices (mainly phones and tablets) will not work at temperatures much below freezing (see Table 5-4). Lithium batteries are helpful in extending cold-weather battery life for dedicated GPS units. Phones and tablets are more heat sensitive than dedicated GPS units and may not function at temperatures near or above about 95 degrees Fahrenheit (35 degrees Celsius).

They are unreliable if they can't pick up enough signals from satellites. A GPS device must be able to pick up signals from at least four satellites in order to provide an accurate position. Because GPS devices use both US and Russian satellites, this is usually not a problem, but under some conditions, such as in caves or deep canyons or under dense forest cover, a GPS device may not be able to receive signals from enough satellites to accurately determine its position. When this occurs, the device sacrifices altitude information in favor of horizontal position.

They are battery dependent. Battery life is limited to a day or two, depending on the model and how it is used. The best way to conserve power for any GPS device, whether a dedicated device or one enabled by a GPS app, is of course to turn it off completely when it is not needed. When navigation is straightforward, such as on easy trails or roads or at rest stops or camps, turn off the device. Then turn it on only at key locations, obtain an accurate position that makes sense, save the waypoint, and turn it off again. GPS devices connect these waypoints to create tracks spanning time periods while they are switched off. You can also use the GPS device to take a needed travel bearing, shut off the device, and follow the bearing using a baseplate compass. Using the GPS device as little as necessary conserves the battery.

Reducing the track point resolution also saves energy. Disabling the device’s compass or barometer also helps extend battery life. Other useful tricks are to turn down the brightness of the display and to decrease the amount of time the auto-lock feature allows before automatically putting the device into sleep mode. The display consumes much energy, and even a slight dimming correlates to increased battery life. (That said, on a bright day above tree line, while wearing sunglasses, climbers will find the dimmed display harder to read.) Experiment with different settings for screen brightness to see just how bright the screen really needs to be in order to be usefully visible outdoors. Viewing the screen in the shade, such as in a shadow, may help.

The GPS function in a phone is a significant battery drain, especially when used continually, as when recording tracks. To extend a phone’s battery life while the GPS function is powered up, first disable the cellular communication function by putting the phone into “airplane mode.” This action retains GPS and camera functionality. With the cellular communication function disabled, batteries should last longer than during city use. It is also wise to completely turn off any unnecessary apps while using a cell phone’s GPS function on a climb, since open apps running in the background consume additional power.

NAVIGATION WORKFLOW USING GPS

When a climbing party is using GPS, they should still perform route planning (see "Trip Preparation") and trip execution (see "Routefinding with a Map") as described earlier in this chapter. With GPS there is now additional work that must be done at home, at the trailhead, and en route, as well as after the trip. For a summary of this additional work, see Table 5-5, "Navigation Workflow with GPS Devices," which provides cross-references to locations in this and other chapters where these tasks are described in detail.

ORIENTATION BY INSTRUMENT

The goal of orientation is to determine the precise point on the earth where you are standing. That position can then be represented by a mere dot on a map, which is known as the point position. There are two less-specific levels of orientation. One is called *line position*: the party knows it is along a certain line on a map—such as a river, a trail, or a bearing or elevation line—but does not know where it is along the line. The least specific is *area position*: the party knows the general area it is in, but that is about it.

POINT POSITION

The primary objective of orientation is to determine an exact point position. First steps are simple: just look around and compare what you see with what is on the map. Sometimes this is not accurate enough, or there is nothing much nearby to identify on the map. The usual solution then is to get out the compass and take bearings on landscape features. This is an example of orientation by instrument. Orientation by GPS, which is different, is described later in this chapter. When point position is known, climbers can proceed to identify on the map any major feature visible on the landscape. They can also identify on the landscape any visible feature shown on the map.

For example, climbers on the summit of Forbidden Peak know that their point position is at the top of Forbidden Peak (see Figure 5-1i on the topographic map). The climbers see an unknown mountain and want to know what it is. They take a bearing on it and get 275 degrees. They plot 275 degrees from Forbidden Peak on their topographic map, and it passes through Mount Torment (see Figure 5-1d). They conclude that the unknown mountain is Mount Torment.

In reverse, if the climbers atop Forbidden Peak want to identify which mountain in the distance is Mount Torment, they must do the map work first.

They can measure the bearing on the map from Forbidden Peak to Mount Torment and come up with 275 degrees. Keeping 275 at the index line on the compass, they turn the compass until the magnetic needle is aligned with the declination arrow. The direction-of-travel line then points to Mount Torment, and they can identify it.

Finding Point Position from a Known Line Position

With line position known, the goal is to determine point position. When climbers know they are on a trail, ridge, or some other identifiable line, they need only one more trustworthy piece of information. For example, a climbing party knows it is on Unsavory Ridge—but exactly where? Off in the distance to the southwest is Mount Majestic. A bearing on Majestic reads 220 degrees. Plot 220 degrees from Mount Majestic on the map. Run this line back toward Unsavory Ridge, and where it intersects the ridge is the point position where the climbers are (fig. 5-21).

TABLE 5-5. NAVIGATION WORKFLOW WITH GPS DEVICES

Modern navigation tools offer climbers more certainty, but coordinating map, altimeter, compass, and GPS requires careful work. It is helpful to think of this effort as a workflow that begins at home, continues at the trailhead and en route, and then wraps up after the trip.

AT HOME AND/OR WHILE STILL CONNECTED TO THE INTERNET

1. Research routes from guidebooks and other sources.
2. Purchase relevant topographical maps, if available and time allows. Otherwise, download topographical maps from the internet. Customize them with collected routes, tracks, waypoints, and notes, and then print. Be sure the map includes the data, such as the UTM grid, that you will need.
3. Download helpful maps and satellite images to a GPS device at the appropriate level of detail. Include an area that surrounds the intended travel area in case plans change; the larger map can be at a lower level of detail if storage space is an issue.

4. Research weather trends, road and trail conditions, and avalanche conditions (see Chapters 6, Wilderness Travel, and 17, Avalanche Safety).
5. Confirm that electronics are ready: data downloaded, batteries charged, PLBs registered and the preset ("canned" or user-definable) messages on satellite communicators updated (see "Communication Devices" later in this chapter).
6. Leave the trip itinerary, including trailhead, vehicle description, and license plate, with a responsible person (see "Organizing and Leading a Climb" in Chapter 22, Leadership).

AT THE TRAILHEAD

1. Confirm the party is at the right place to begin the climb: Orient the map to the surroundings—do they correlate? Confirm using GPS.
2. Set a GPS waypoint at the trailhead.
3. Set the GPS device's datum to match that of the physical map.
4. Have the party calibrate all barometric-based altimeters to the trailhead elevation using a map or GPS device.
5. Note magnetic declination, and adjust compasses as needed. (See "Magnetic Declination," earlier.)
6. Turn off electronics or configure them to extend battery life to last the length of the trip.

EN ROUTE

1. Actively engage the entire party in navigation, including assessing whether the current position and planned path through the landscape continue to appear safe and can be correlated to the map using multiple navigation tools. (See "The Importance of Maintaining Situational Awareness" sidebar, earlier.)
2. Familiarize the party with the appearance of the return trip.
3. Occasionally recalibrate barometric-based altimeters at known locations shown on map or a GPS device.
4. Gather GPS waypoints and tracks en route if they may be helpful later, especially if the party may need to renegotiate complex terrain.

AFTER THE TRIP

Gather together and organize all the digital and physical navigation information that will help the party—or the next climbing party—safely navigate the same area on another trip.

Finding Point Position from a Known Area Position

Suppose a climbing party knows only its area position: the general area of Fantastic Crags (fig. 5-22). To move from knowing area position to knowing point position, two trustworthy pieces of information are needed. The climbers want to determine line position and then, from that, point position.

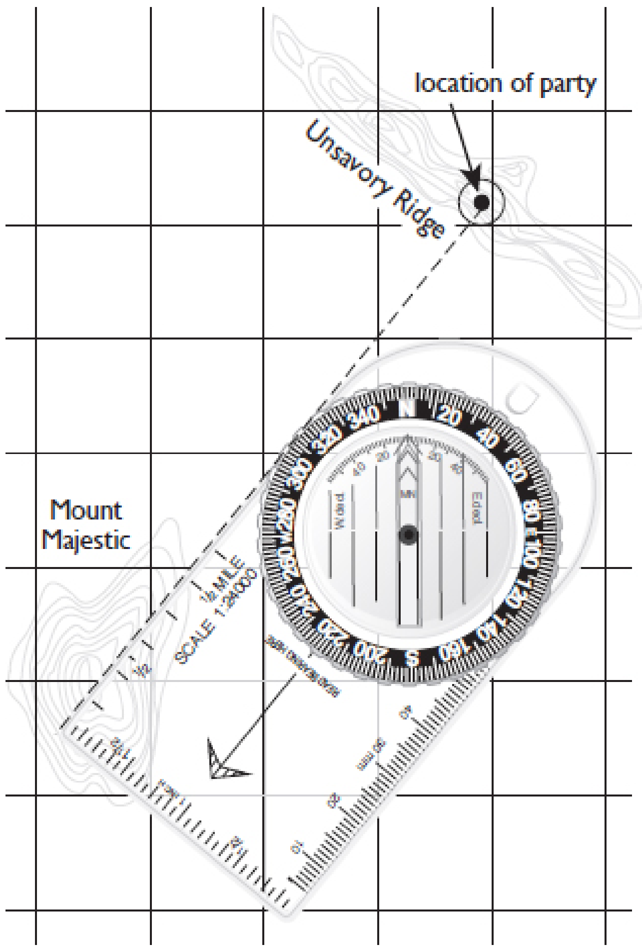

Fig. 5-21. Orientation from a known line position to determine point position (magnetic needle omitted for clarity).

Climbers may be able to use bearings on two visible features. Suppose they take a bearing on Fantastic Peak and get a reading of 39 degrees. They plot a line on the map, through Fantastic Peak, at 39 degrees. They know they must be somewhere on that bearing line, so they now have their line position.

They can also see Unsavory Spire. A bearing on the spire shows 129 degrees. They plot a second line on the map, through Unsavory Spire, at 129 degrees. The two bearing lines intersect, and that shows their point position. (The closer an angle of intersection is to 90 degrees, the more accurate the point position will be.)

Climbers should use every scrap of information at their disposal, but they must be sure their conclusions agree with common sense. If they take bearings on Fantastic Peak and Unsavory Spire and find that the two lines on the map intersect in a river, but they are on a high point of land, something is wrong. They should try to take a bearing on another landmark and plot it. If the lines intersect at a map location with no similarity to the terrain where you are, something is wrong. There may have been an error in taking or plotting bearings, there might be some magnetic anomaly in the rocks, or the map may be inaccurate. And who knows? Maybe those peaks are not really Fantastic and Unsavory in the first place.

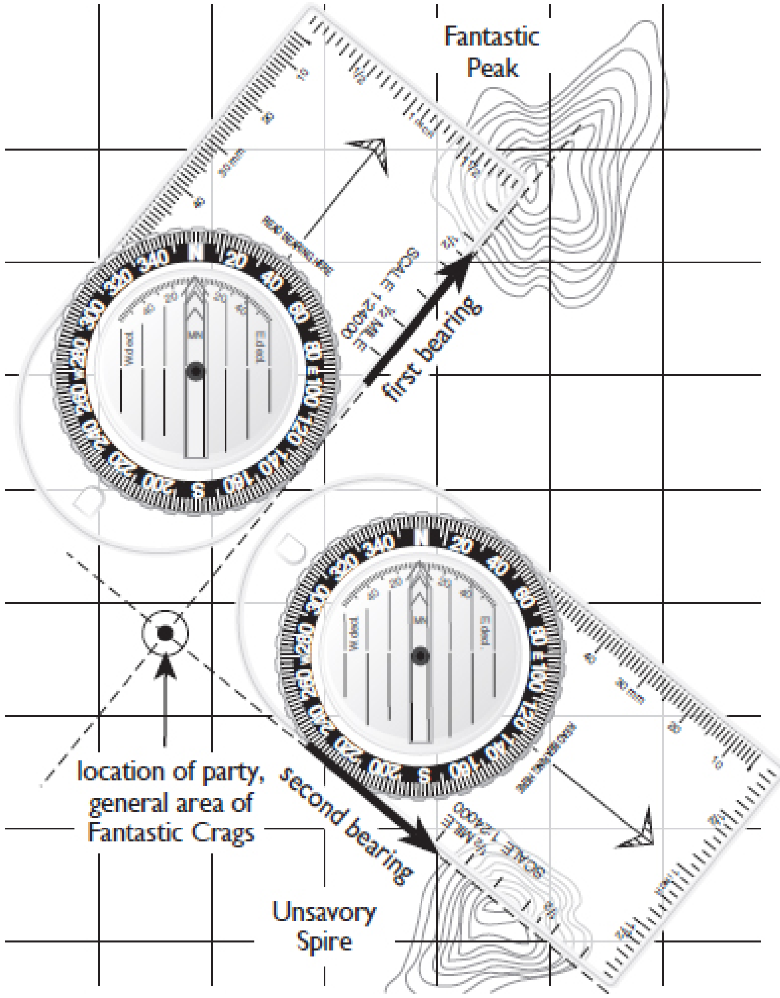

Fig. 5-22. Orientation from a known area position to determine point position (magnetic needle omitted for clarity).

FINDING LINE POSITION FROM A KNOWN AREA POSITION

When the area position is known and there is just one visible feature to take a bearing on, the compass cannot provide anything more than line position. That can be a big help, though. If the climbers in the preceding example are in the general vicinity of Fantastic River, they can plot a bearing line from the one visible feature to the river and then know they are near where the bearing line intersects the river. Perhaps from a study of the map, the climbers can then figure out their point position. They can also read the altimeter and find the spot on the map where the bearing line intersects the contour line for that elevation, which may provide an unambiguous position.

ORIENTING A MAP

During a climb, it frequently helps to hold the map so that north on the map is pointed in the actual direction of true north. This is known as orienting the map, a good way to gain a better feel of the relationship between the map and the countryside.

It is a simple process. Set 0 or 360 degrees at the index line of the compass, and place the compass on the map near its lower-left corner (fig. 5-23). Put the edge of the compass's baseplate along the left edge of the map, with the direction-of-travel line pointing toward north on the map. Then turn the map and compass together until the north-seeking end of the magnetic needle is aligned with the pointed end of the compass's declination arrow. The map is now oriented to the scene before you. (Map orientation can give a general feel for the area but cannot replace the more precise methods of orientation described above.)

ORIENTATION USING GPS

Suppose a climbing party wants to identify its point position on a topographical map. Take out the GPS device, turn it on, and let it acquire an accurate position. The device is probably reading latitude-longitude, the usual default coordinate system. For mountaineering use, the UTM system is easier and more accurate for manual plotting because the UTM reference lines are much closer together (1,000 meters = 0.62 mile) than the reference lines for latitude-longitude (about every 2.5 minutes—approximately 2 to 3 miles or 3 to 4 kilometers).

Using the GPS device's setup screen, the climbers should be able to change the coordinate system from latitude-longitude to UTM. They can then correlate the UTM numbers on the device's screen with the UTM grid on the map. Without using a scale or a ruler, climbers can usually "eyeball" their position to within about 100 meters (about 300 feet), which is often close enough to get to within sight of an objective. If greater accuracy is desired, use the "meters" scale at the bottom of the map, the Romer (interpolation) scale on some compasses, or a separate plastic Romer scale.

For example, suppose a party is climbing Glacier Peak and clouds obscure all visibility. They reach a summit but are not sure if it is Glacier Peak. They turn on a GPS device and let it acquire a position. The UTM numbers on the screen of the device are as follows: 10 U640612E, 5329491N. (fig. 5-24)

The “10” is the UTM zone number, which can be found in the lower-left corner of the USGS topographic map. The “U” is a latitude band, used by most, but not all, GPS devices; each letter indicates a certain range of latitudes. The first long number, 640612E, is called the easting and indicates that the climbers’ position is 640,612 meters east of the reference line for their area. Along the top edge of the map, they can find the number $^{6}40^{000\mathrm{m}}$E. This is the *full easting* (except for zone number and latitude band). To the right of this on the map is the number $^{6}41$, a *partial easting*, with the “000” meters omitted. The climbers can see that the number 10 U640612E on the screen of the GPS device is approximately six-tenths of the way between 640000 and 641000. Their east-west position is therefore about six-tenths of the way between the $^{6}40^{000}$ and the $^{6}41$ lines.

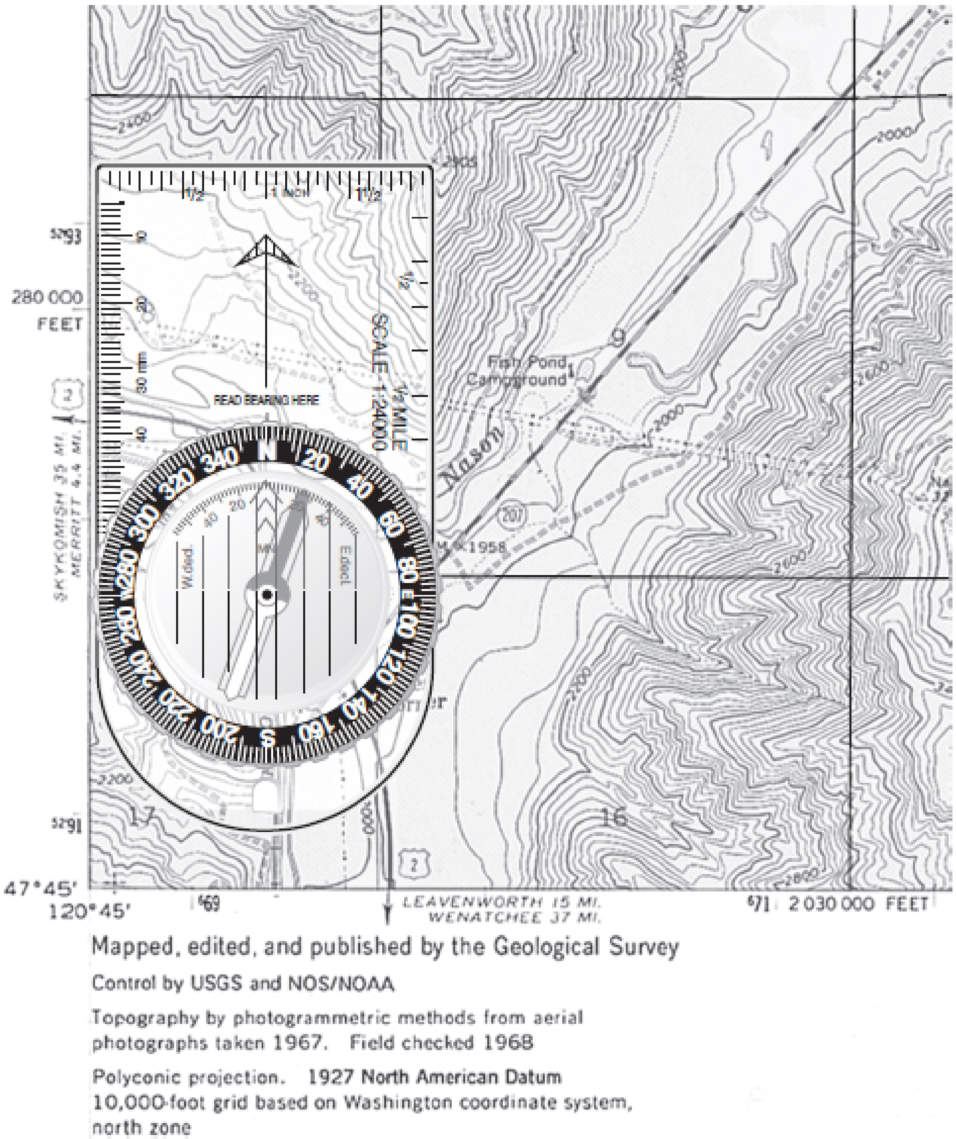

Fig. 5-23. Using a compass to orient a map in an area with 20 degrees east declination.

Along the left edge of the map is the number $^{53}31^{000\text{m}}$N. This is the *full northing*, which indicates that this line is 5,331,000 meters north of the equator or South Pole. (Northings being measured from the South Pole are sometimes designated with a minus sign.) Below this is a line labeled $^{53}30$ and another labeled $^{53}29$. These are *partial northings*, with the "000" meters omitted. The second (lower) number displayed on the GPS device screen in this example is 5329491N. This is a horizontal line about halfway between $^{53}29$ and $^{53}30$. The point where the easting and northing lines intersect is the climbers' point position. Finding this point in Figure 5-24 shows that they are on Disappointment Peak, not Glacier Peak.

The internal topographic map capability of some GPS devices can be useful in quickly identifying a location without having to interpolate the UTM position, though the maps can be difficult to interpret because the screens are very small. Zooming in to observe the contour lines causes climbers to lose sight of the surrounding area. Zooming out to observe the surrounding area causes the contour lines to disappear. Electronic maps are therefore useful supplements to conventional physical maps but cannot fully replace physical maps.

NAVIGATION BY INSTRUMENT

Getting from point A to point B is usually just a matter of keeping an eye on the landscape and watching where you are going, helped by an occasional glance at the map. However, if the current objective is out of sight, take compass in hand, set a bearing, and follow the direction-of-travel line as it guides you to the goal. This is navigation by instrument.

Navigation by instrument is sometimes the only practical method for finding the way. It also serves as a supplement to other methods and as a way of verifying that the party is on the right track. Again, use common sense and question a compass bearing that defies reason. (For example, is the declination arrow pointing the wrong way, sending the party 180 degrees off course?)

USING MAP AND COMPASS

The most common situation requiring instrument navigation comes when the route is unclear because the topography is featureless or because landmarks are obscured by forest or fog. In this case, if the climbers know exactly where they are and where they want to go, they can identify on the map both their current position and their destination. They must simply measure the bearing to the objective on the map and then follow that bearing.

Suppose you measure a bearing of 285 degrees on the map (fig. 5-25a). Read this bearing at the index line and leave it set there. Then hold the compass out in front of you as you rotate your body until the north-seeking end of the magnetic needle is aligned with the pointed end of the declination arrow. The direction-of-travel line on the compass now points to the objective in the terrain (fig. 5-25b). Start walking in that direction.

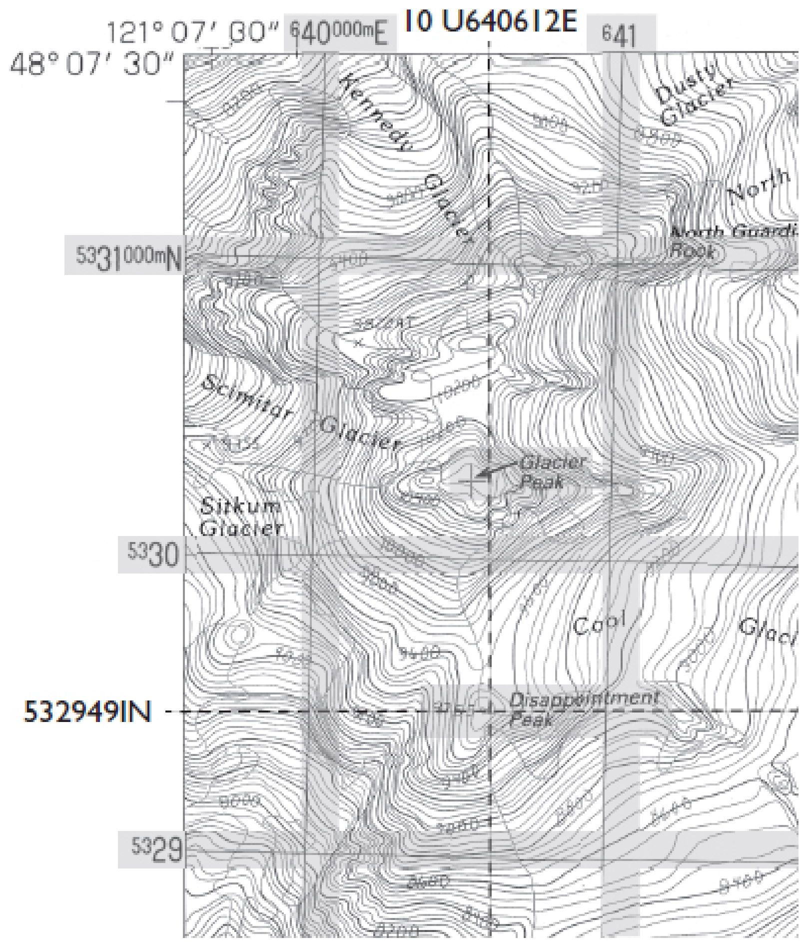

Fig. 5-24. Example of orientation using a GPS receiver and a topo map.

USING COMPASS ALONE

Navigators of air and ocean often travel by instrument alone; so can climbers. For example, if a party is approaching a pass and clouds begin to obscure it, they can take a quick compass bearing on the pass. Then they follow the bearing, compass in hand if desired. It is not even necessary to note the numerical bearing; just align the magnetic needle with the declination arrow and keep it aligned, and follow the direction-of-travel line.

Likewise, if climbers are heading into a valley where fog or forest will hide the mountain that is the goal, they can take a bearing on the peak while it is still visible, before dropping into the valley (fig. 5-26). Then they navigate by compass through the valley. This method becomes more accurate if two or more people travel together with compass in hand, checking one another's work.

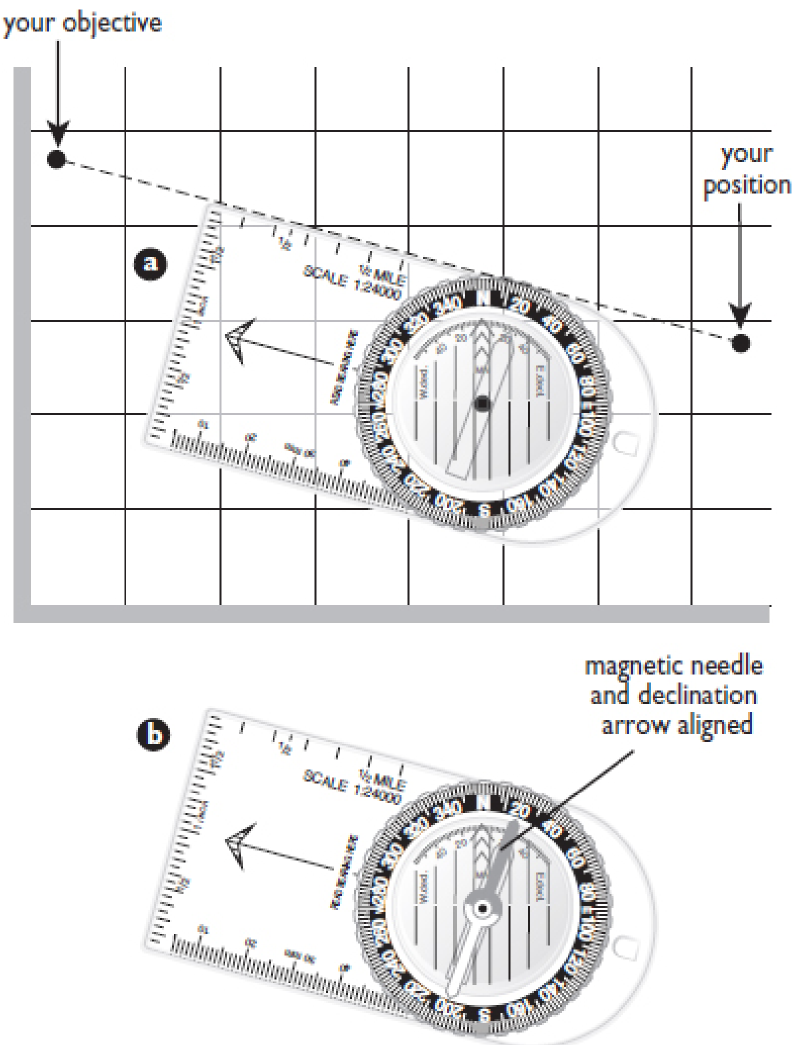

Fig. 5-25. Navigation using the map and compass: a, measure the bearing on the map from your position to your destination and, maintaining the bearing at the index line, pick up the compass (magnetic needle omitted for clarity); b, follow the bearing and direction-of-travel line, lining up the magnetic needle to the declination arrow.

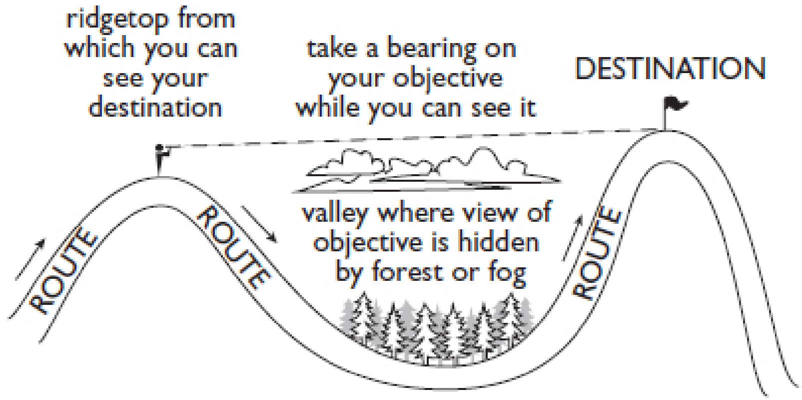

Fig. 5-26. Following a compass bearing when the view of the objective is obscured by forest or fog.

USING INTERMEDIATE OBJECTIVES

The technique of using intermediate objectives is handy for those frustrating times when climbers try to stay exactly on a compass bearing but keep getting diverted by obstructions such as cliffs, dense brush, or crevasses. They can sight past the obstruction to a tree, a rock, or another object that is exactly on the bearing line between their position and the principal objective (fig. 5-27a). This is the intermediate objective. Then they scramble over to the tree or rock by whatever route is easiest. When they get to the intermediate objective, they can be confident that they are still on the correct route. Then they repeat the process toward the next intermediate objective. The technique is useful even when there is no obstruction. Moving from one intermediate objective to another means it is possible to put the compass away for those stretches, rather than having to check it every few steps.

Sometimes on snow, on glaciers, or in fog, there are no natural intermediate objectives, just an undifferentiated white landscape. A similar situation can occur in a forest, where all the trees may look the same. Then another member of the party can serve as the intermediate objective (fig. 5-27b). That person travels out to near the limit of visibility or past the obstruction. The rest of the group waves that party member left or right until the person is directly on the bearing line. That person can then improve the accuracy of the route by taking a back bearing on the rest of the party. (For a back bearing, keep the same bearing set at the index line, but align the south-seeking end of the magnetic needle with the pointed end of the declination arrow.) The combination of a bearing and a back bearing tends to counteract any compass error.

USING GPS

Suppose a climbing party can identify its desired destination on the map but cannot actually see it in the field. They can read the UTM position of the destination off the map and then enter it into the GPS device's memory as a waypoint.

Going back to the Glacier Peak example shown in Figure 5-24, suppose the climbers wish to find a route to the summit of Glacier Peak. They can see that this point is about halfway between the eastings of 640000 and 641000, so they could estimate the easting as 10 U640500E (the zone number is 10 in this example). They can also see that the summit is about three-tenths of the way between the northings of 5330000 and 5331000, so they can estimate the full northing to be 5330300N. They can now enter these coordinates into the GPS device by simply turning it on, activating its "create waypoint" function, and entering the UTM coordinates of 10 U640500E and 5330300N. They can then name the waypoint (for example, "GLPEAK") and save it. When using a phone or dedicated GPS device that displays topographic maps, a climber can simply tap or click on the desired location on the screen to mark and save a waypoint, without having to interpolate the UTM position from the map.

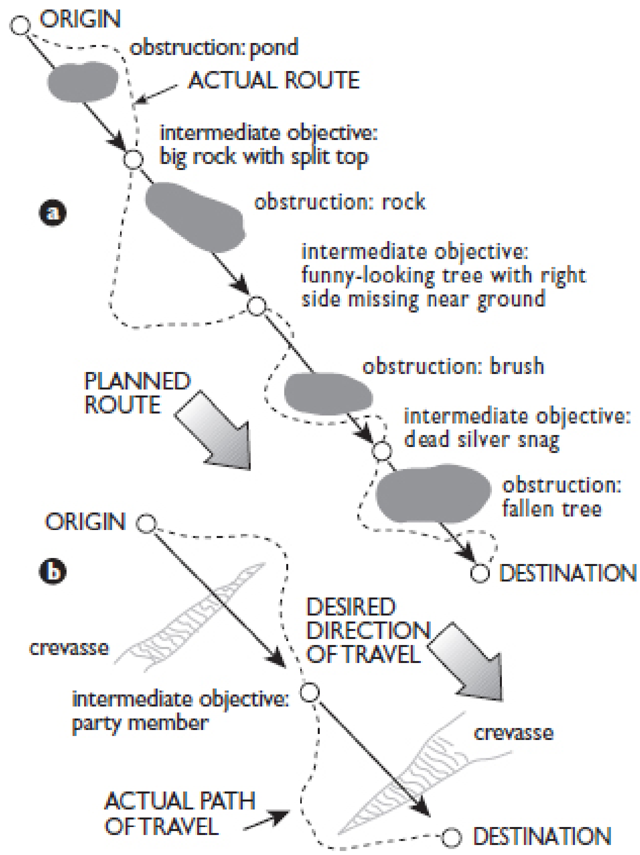

Fig. 5-27. Using intermediate objectives: a, in a forest; b, on a glacier.

Once they have entered their destination into the GPS device's memory, they let it acquire a position. Then they ask it to "Go" to the name of the new waypoint ("GLPEAK" in this example), and the device will tell them the distance and compass bearing from wherever they are to the summit of Glacier Peak. Then they can set this bearing on their baseplate compasses, turn off the GPS device and put it away, and follow the compass bearing until they arrive at Glacier Peak. Alternatively, some devices have a built-in compass that can be used, but it may need to be calibrated prior to use and may not be as accurate as a baseplate compass.

What if a party gets off route due to a crevasse or other obstruction? After passing the obstruction, turn on the GPS device, acquire a position, and again ask it to "Go" to the waypoint that is the destination. The device will then display the new distance and compass bearing to the destination. Set the new bearing on the compass and follow it to the destination.

COMMUNICATION DEVICES

Historically, the mountaineer has needed to be completely self-reliant, and that ethic should dominate the thinking of those entering the wilderness (see the “Ethic of Self-Reliance” sidebar). But when, despite good tools, preparation, and training, life becomes threatened, most climbers welcome help from emergency responders. The climbing party in need of outside assistance has several means of requesting help.

Cell phones. As both a navigation and a communication device, phones are the obvious first choice for requesting outside help—*when the climbing party is within cell phone range*, which is the only time they will work for this purpose. In such cases, phones can dramatically shorten the time it takes to summon rescuers. They are also useful for telling people back home that the party will be late but is not in trouble, and thus can forestall unnecessary rescue efforts. However, unless the climbing party is certain to the contrary, they should *assume that phones will not function for making calls from the backcountry.*

Satellite communications. Since the pulse of the original Sputnik satellites suggested early versions of GPS to its inventors, satellites have simplified communications and navigation. In 1982 an international satellite-based search and rescue system came online for aviation and maritime uses, the latter using devices known as EPIRBs (emergency position-indicating radio beacons). Satellite phones have come down in price and weight, and so they have become a reasonable option, although they are expensive per minute of call time.

ETHIC OF SELF-RELIANCE

Understanding the limits of PLBs and other communication tools is as important as understanding their usefulness: Batteries deplete; electronics fail; cell phone service is limited in most mountain locations; a rescue may not be possible due to weather conditions or availability of rescuers. A PLB or satellite communicator is not a substitute for self-reliance. No party should set out ill prepared or inadequately equipped, nor should they attempt a route beyond their ability and assume that emergency help can be summoned.

The climbers who wrote the early editions of this book had no easy options for rescue in the mountains. They knew that the freedom of the hills could come at great cost and that a safe return would depend on the party’s experience, preparation, skill, and judgment.

PLBs and satellite communicators. In 2003, PLBs were introduced using the same government-based system but intended for those away from normal emergency services on land. These PLBs determine a party's coordinates using GPS and transmit them through international satellites to the appropriate emergency responders. Registration is required, but there are no subscription fees for PLBs using the government-based system. Avoid older PLBs that rely on radio homing beacon technology without GPS.

Since 2008, two commercial companies have introduced devices that function similar to PLBs, known as satellite communicators. The ones currently available are: the SPOT Satellite GPS Messenger, which allows one-way messaging, and the Garmin (formerly DeLorme) inReach Satellite Communicators, which allows two-way messaging.

These devices determine the party's position using GPS and then send a message out using commercial satellite networks. Some units allow for short, preset, nonemergency text messages to be sent (for example, "Camping here tonight"); some allow free-form text messages to be sent; and some allow for two-way texting. Satellite communicators require subscriptions for using their systems, and each manufacturer offers plans whose cost varies based on factors such as the number of messages transmitted, tracking, or other services used.

Some users find the distinction between PLBs and satellite communicators important, but both are commonly referred to as PLBs. PLBs are currently more powerful, but satellite communicators have additional functionality; see Table 5-6 for a comparison. PLBs and satellite communicators have saved many lives, and *all climbers should strongly consider carrying one in order to increase the climbing party's margin of safety.*

Other alternatives. Modern handheld amateur radios, also called "ham" radios, are inexpensive, lightweight, and compact in size but cannot be consistently relied upon for emergency communications from the backcountry. These battery-powered amateur radios can communicate either directly from radio to radio or, in many locations worldwide, via "repeaters." Repeaters are electronic devices stationed at high locations that receive the ham radio signal and retransmit it at a higher power level so that communication can occur over longer distances. In some locations, ham radio repeater coverage is equal to or better than cell phone coverage, but, like cell phone coverage, cannot be consistently relied on in the backcountry.

Family radio service (FRS) two-way radios are useful as local communication devices. See “Local Communication Devices” in Chapter 2, Clothing and Equipment.

LOST

Why do people get lost? Some travel without a map because the route seems obvious. Some people trust their own instincts over the compass. Others do not bother with the map homework that can start them off with a good mental picture of the area. Some do not pay enough attention to the route on the way in to be able to find it on the way out. Some rely on the skill of their climbing partner, who may be getting them lost. Some are lost when they become separated from their party. Some do not take the time to think about where they are going, so they miss trail junctions or wander off on game paths, charging ahead despite deteriorating weather and visibility or fatigue. Some are lost due to an overreliance on technology—for example, assuming that their GPS device will somehow keep them from getting lost, without having saved the necessary waypoints and downloaded the appropriate map while connected to the internet.

Groups of two or more rarely become dangerously lost, even if they have no wilderness experience. The real danger is when a single individual is separated from the rest of the party. For this reason, always try to keep everyone together, and assign a sweep (or rear guard) to keep track of stragglers. Good navigators are never truly lost—but, having learned humility through years of experience, they always carry enough food, clothing, and bivouac gear to get them through a few days of temporary confusion.

WHAT IF YOUR PARTY IS LOST?

If your party becomes lost, the first rule is to stop. Avoid the temptation to plunge hopefully on. Try to determine where the party is. If that does not work, figure out the last time the party knew its exact location. If that spot is fairly close, within an hour or so, retrace your steps and get back to that point. But if that spot is hours back, the party might instead decide to head toward the baseline they established when they started out. If darkness falls or your party tires before it has found its way out, safely bivouac for the night.

TABLE 5-6. COMPARISON OF PLBS, SATELLITE COMMUNICATORS, AND SATELLITE PHONES			
	SATELLITE SYSTEM	FUNCTIONALITY	ADVANTAGES AND DISADVANTAGES
PLBs	Dedicated government search and rescue system	• Sends location to emergency responders	• Requires registration • Somewhat stronger signal than satellite communicators
Satellite Communicators	Commercial systems	• Sends location to emergency responders via private companies • One or two-way messaging options, depending on model • Can send location to friends and family • Some models are also GPS navigation devices. One model, the Garmin inReach Explorer+, includes a digital compass, barometric altimeter, and internal mapping capability, making it suitable as a GPS device too.	• Requires subscription fees (cost varies depending on services) • Some models also function as a full mapping GPS device
Satellite Phones	Commercial systems	• Two-way backcountry telephone communications	• Expensive call time

WHAT IF YOU ARE LOST ALONE?

The first rule if you are lost while alone is, again, to stop. Look for other members of the party, shout or sound a whistle, and listen for a response. If the only answer is silence, sit down, regain your calm, and combat panic with reason.

Once you have calmed down, start doing the right things. Look at the map in an attempt to determine your location, and plan a route home in case you do not connect with the other climbers. Mark your location with a cairn or other objects, and then scout in all directions, each time returning to the marked position. Well before dark, prepare for the night by finding water and shelter. Go to an open area so that you can be seen from the air. Spread out some brightly colored clothing or other material to give searchers something to see. Staying busy will raise your spirits; try singing—it will give you something to do and searchers something to hear.

The odds are that you will be reunited with your group by morning. If not, fight terror. After a night alone, you may decide to hike out to a baseline feature picked out before the trip—a ridge, stream, or highway. If the terrain is too difficult for you to travel alone, or if you are injured or sick, it might be better to concentrate on letting yourself be found. It is easier for rescuers to find a lost climber who stays in one place in the open and shouts periodically than one who thrashes on in hysterical hope, one step ahead of the rescue party.

FINDING THE FREEDOM OF THE HILLS

The mountains await those who have learned the skills of orientation, navigation, and routefinding. In large part, navigation is the subject of this entire book because it is so essential to all off-trail adventure.

In medieval times, the greatest honors a visitor could receive were the rights of a citizen and the freedom of the city, sometimes even today symbolized by presenting a guest with the "keys to the city." For the modern alpine traveler, navigation is the key to wandering at will through valleys and meadows, up cliffs and over glaciers, thereby earning the rights of a citizen in a magical land—a mountaineer with the freedom of the hills.