Field Navigation and Trip Planning

Range of Light Group

Toiyabe Chapter, Sierra Club

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SIERRA CLUB

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Foreword

This is a manual for those wishing to learn field navigation, either for personal use or for leading Sierra Club trips. It is intended mainly for general hiking and backpacking use in the Eastern Sierra. It draws from the Angeles Chapter Leader's Reference Book, but is not primarily aimed at peakbagging and has been substantially reorganized. It also contains some information about the use of Global Positioning System (GPS) units and mapping software.

In memory of Bill T. Russell, Navigator Rxtraordinary.

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Introduction to Field Navigation and Trip Planning

Field navigation requires using a map and compass to guide yourself on backcountry trips. To plan such trips, you can estimate distances, times, and effort required using the map. When in the field, a number of tricks help locate your group and proceed safely to your destination.

Because the ability to use a map and compass is fundamental, we begin with those aspects, and go on to cover the planning and conduct of trips in more detail. Some people are more geometrically inclined than others, so we've tried to include even the simplest fundamentals.

***Map Skills* -** For field navigation in the mountains, the most useful map is the topographic map, mainly provided in the USA by the United States Geological Survey (USGS). These have contour lines that show elevation and landforms. To use a topographic map successfully, you must be able to interpret the contour lines and other markings to plan and follow the desired route. In the field, you must know how to orient the map to identify landmarks. It takes practice to develop the skills to correlate what you see on the map with the actual terrain. The secret is to use all the clues, and not jump to conclusions.

***Compass* -** For use with a map, you need a protractor-type compass. These have a see-through base and a rotating dial, so that you can place the compass on a map and take bearings. See Figure 1. Wrist or dial compasses with opaque bases and fixed dials are not as useful. The main makers are Silva, Suunto and Brunton. Very inexpensive compasses of this type can be used but do not have adjustments for magnetic declination. For almost the same price, you can get a model with an adjustment. It is also desirable to have scales corresponding to USGS maps (1:24,000, 1:62,500), so that you can read distances directly off the map. The Suunto model shown costs $16 from REI. A similar Brunton compass has been sold in the local drugstore for $8.99, but is unsatisfactory because the dial is not transparent. The Silva Explorer and almost identical Suunto M-3D have the desired map scales. These sell in the $20-$25 range. Little is gained by paying more. The top-of-the-line Silva Ranger sells for $45. It has a mirror for accurate sighting, shaving, or applying makeup. Very handy for the upscale or slovenly navigator.

***Compass Skills* -** See the list opposite. First learn to set the declination from the map (it will be about the same for all maps in the area). Then learn how to use the compass as a protractor to take bearings on a map (that is, to determine the bearing from one point to another on the map). Then, how to take bearings of distant points and transfer them to the amp to determine your location, or to set a course. Other wrinkles include taking bearings on roads, ridges, and gullies to make sure you are on or in the right one.

***Trip Planning Skills* -** From the map, learn to pick the easiest route and estimate travel time and energy from distance and vertical gain, on trail or off, and to pick good campsites.

***Putting It All Together* -** Learn to use map and compass in the field to pick the right route, determine location, and get home safely.

***Leadership Skills* -** Leaders must have the ability to judge a group's skills, and to guide the group in the field.

Navigation Skills

Map Skills

- Use of map coordinates and symbols.
- Identifying terrain features on the map.
- Determining distance and elevation gain.
- Orientation of the map in the field.
- Correlating features on the map with the real features in the field.

Compass Skills

- Setting declination from the map.
- Determining bearings and distance from point to point on the map.
- Taking bearings with the compass and plotting them.
- Determining position by triangulation.

Trip Planning Skills

- Selecting the easiest (or most interesting) route.
- Determining time and energy requirements from distance and elevation gain

Combined Skills

- Combined use of map and compass in the field.
- Field execution and modification of trip plan.
- Navigating in difficult terrain and weather.

Leadership Skills

- Keep the group together.
- Maintain visible connection to the rear leader. Every 30 minutes,or so, let the rear catch up.
- Mark or wait at turning points

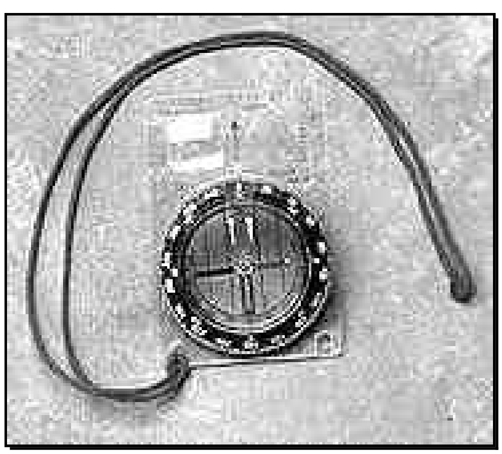

Figure 1. An inexpensive protractor compass (Suunto M-2D).
The transparent base and dial are essential for plotting bearings on a map.

Field Navigation and Trip Planning

About Maps

The topographic map is the most fundamental tool of the navigator. With a compass alone you can go in any direction you choose, but if you do not know what is in front of you, you may walk off a cliff.

On a topographic map, also called a "topo" or "quad" (short for quadrangle), you can see more things than on a regular political or road map, because the map has contour lines that show the vertical relief.

Kinds of Topo Maps **-** The principal maps used in the field are the USGS topo maps in either the 7.5' (minute) or 15' series. The 15' maps are being replaced by 7.5' maps, and in 1990 the USGS stopped printing the 15' maps, but they are so useful other services reprint them (Forest Service wilderness maps are 15'). The maps cover a region of 7.5' (or 15') in latitude and longitude. Each quadrangle map has a unique name taken from some prominent feature. The area covered by the quadrangles in California is roughly 7 x 8 statute miles for the 7.5' maps and 14 x 17 miles for the 15' maps.

USGS topographic maps contain a number of conventional symbols and colors. Water features appear in blue, vegetation in green and man-made objects in black. Contour lines are reddish-brown. Public land survey boundaries appear as dashed red lines. The USGS pamphlet, "Topographic Map Symbols" contains a list of symbols, examples of map features and much useful information. Other free USGS pamphlets available are "Map Accuracy," "Map Scales," and "Finding Your Way with Map and Compass."

USGS 1:250,000 maps cover an area of I degree latitude by 2 degrees longitude at a scale of about I inch on the map to 4 miles on the ground. They are topographical maps with 200 foot contour intervals. New USGS 1: 100,000 maps (30 x 60 minute series) will cover the entire state. These topographical maps have contour lines at 50 meter (164 foot) intervals, at a scale of about I inch on the map to 1 1/2 miles on the ground. Because USGS is no longer updating or printing the 15' maps, these new maps provide the useful tie-in or overview for the 7.5' maps, with 1980's road information.

Other Maps **-** Other maps that are particularly useful are Forest Service (USFS) maps that show private and public land. The Forest Service has also reprinted the older USGS combined them into wilderness maps (for example, Hoover, Ansel Adams, John Muir) that show additional information such as camping restrictions. Road maps, particularly those published by the Auto Club, are useful in finding trailheads. The Auto Club maps of desert areas show amazing details of back roads, including distances along minor dirt roads.

Big Picture Maps **-** The Automobile Club of Southern California maps are excellent for the automobile part of the trip. They are particularly useful for showing roads in desert regions. They also show the locked gates on roads leading into National Forests, military reservations and private property.

Mexican Government topo maps have a scale of 1:50,000 and cover a region of 20' in longitude by 15' in latitude. Maps for Baja California may be obtained from the government agency in Mexicali and from the San Diego Map Center.

Where Can You Get These Maps? In our area, in the bookstores, ranger stations, and sporting goods stores. The USGS quads cost about $5 each. They can also be downloaded online. Computer software allows one to print out only parts of a map, analyze routes, and communicate with a GPS receiver. It would be helpful to buy a 7.5' map and use it to follow along.

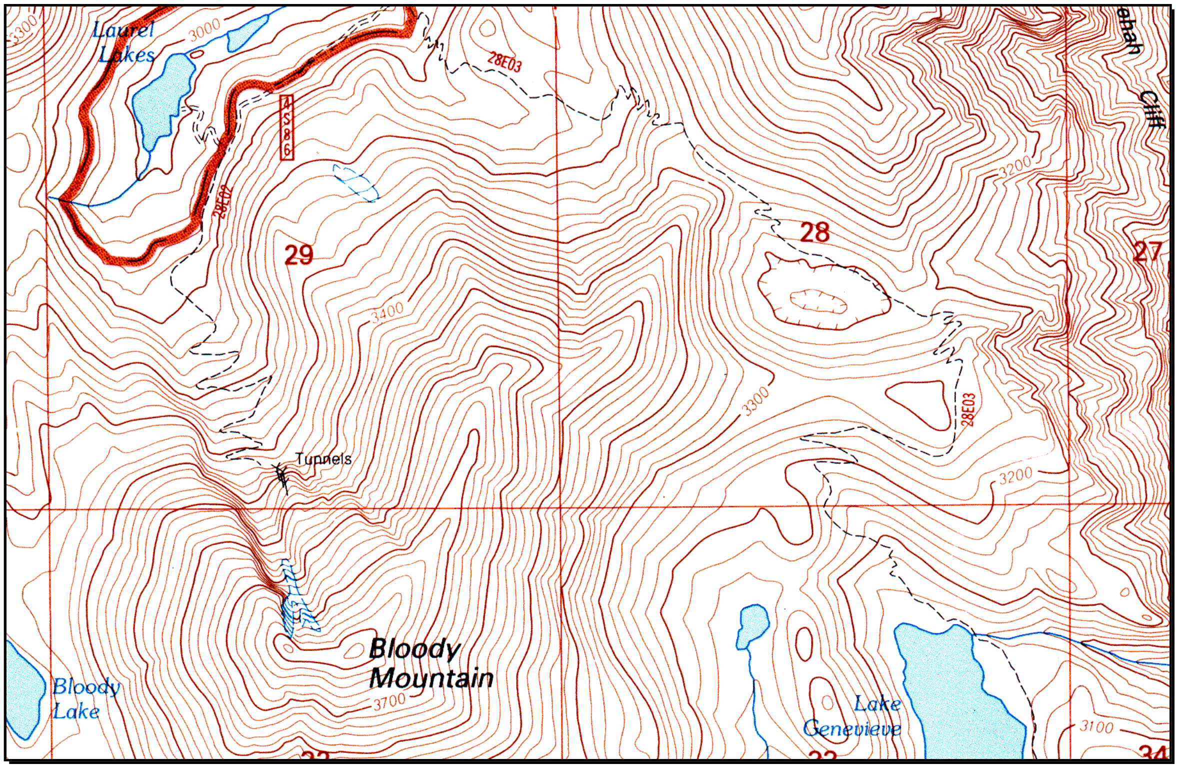

Figure 2. Fragment of the USGS 7.5' Bloody Mountain quad.
Note the contour lines closed at top of the mountain and at the sink belowsection 28 number.

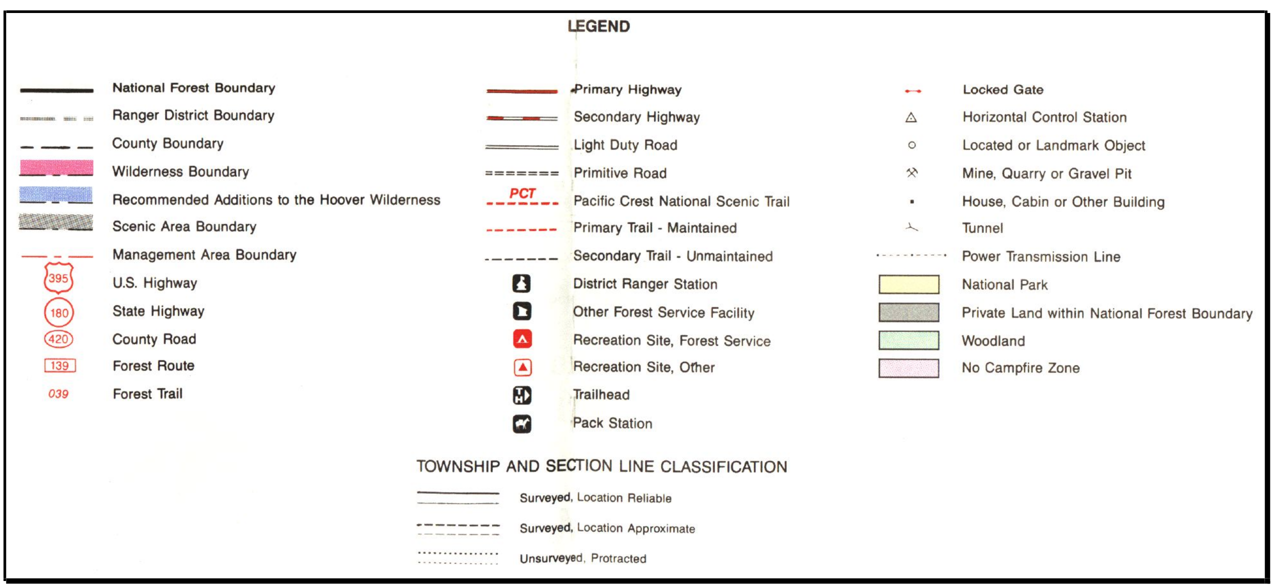

Figure 3. Map symbols from USFS Hoover Wilderness map.

About Map Scales and Coordinates

Unlike the average road map, a topographic map is a quantitative tool with exact horizontal and vertical scales and references. Such a map has both English and metric scales and shows the latitude and longitude, land lines. and the Universal Transverse Mercator Projection (UTM) grid (metric)

Let's look at some of the information to be found on such a map. Figure 4 opposite shows the northwest fragment of the USGS 7.5' (minute) Tower Peak quad east of Bridgeport. Note the contour lines. This is south of Sonora Pass and Kennedy Meadows. You can see part of the Pacific Crest Trail coming south from Sonora Pass. The top of the map is north (N), the right side east (E), the bottom south (S), and the left side west (W). If you face north, the sun rises in the east, to your right, and sets in the west, to your left.

Scales and Coordinates - There are several different systems for locating things on the map and measuring distance. You will probably mostly use one system, but here's a review of what you see.

Quadrangle maps have meridians of longitude and parallels of latitude as boundaries. Black tick marks 1/3 and 2/3 of the distance along each edge and four small crosses in the map interior mark intermediate meridians and parallels. These tick marks can be joined to give accurate north-south and east-west reference lines for measuring bearings. Additional north-south lines can be drawn as needed. Because meridians converge to the North Pole, and because of the kind of projection used, the width of a quadrangle map at the top is slightly less than at the bottom, and the two sides are not quite parallel.

Notice the latitude and longitude at the northwest (NW) corner in Figure 4: 38° 15' N latitude, 119° 37' 30" W longitude. Latitude is measured up to 90° N or S from the equator, longitude 180° E or W from Greenwich, England to the International Date Line. Remember there are 60 minutes (') in a degree (°) and 60 seconds (") in a minute. The little cross shows where they think the corner of the map really was in 1983, as opposed to 1927, when the "datum", or reference for latitude and longitude, was set up. Quick, what is the latitude and longitude of the southeast (SE) corner? Hint: this is a 7.5 minute quad (7' 30"). Answer: 38° 7' 30" N, 119° 30' W. What are these numbers at the other two corners (SW, NE)?

Quadrangle maps show range, township, and section lines of the United States public lands survey. The dashed lines (red on the map) are land lines, showing the boundaries of sections numbered in red, in case you want to buy a farm. This is not exactly a farming area. Yosemite was once a sheepherding area, until the cavalry drove out the sheepherders in the late 1800s. Sheep are still herded near Sonora Pass.

Many section lines are sufficiently close to true north to permit use as bearing reference lines. Others are obviously skewed and unusable. Most sections are one square mile and you can use the section grid as a ready scale for distance estimating. Accuracy should be checked.

Quadrangle maps have the Universal Transverse Mercator or UTM grid indicated by blue tick marks on the boundaries. The tick marks are spaced one kilometer apart and each has a unique number. A location is given by the coordinates of the point, giving the easting first and then the northing. The convention of east (right) first, then north, (up) starting from the southwest comer can be remembered by the mnemonic "read right up." The digits printed in small type denote the hundreds and thousands of kilometers from the zone baseline. Topo maps also have black tick marks on the margins at 10,000 ft. intervals. They refer to the California State grid system, an older system than the UTM.

Later maps have black grid lines defining the metric UTM grid with 1 kilometer squares. The grid lines may be tilted with respect to the latitude and longitude. This system is more convenient than the latitude and longitude, because they drew the grid for you and because dividing by 10 is easier than 60. More about using UTM later. Little rulers are available that make it easy.

Trivia Items - One minute of latitude is one nautical mile or 6080 feet (by definition, with tiny corrections). Also, by definition, 10 million meters (m) or 10,000 kilometers (km) is supposed to be the distance from the equator to the north pole, although they didn't get it exactly right. That means that one degree of latitude is 10,000 km/90, or 1111.1 km. One minute is 1.85 km, one mile 1.61 km.

Map Legends - There is a lot of information at the bottom of the map (not all shown here). Some of it everybody uses, some of it is technical stuff that GPS receivers use. Besides the name and scale of the map, the legend gives the scale of miles, meters, and feet, and often the names of nearby maps, and the magnetic declination (15° east for this map). See Figure 5.

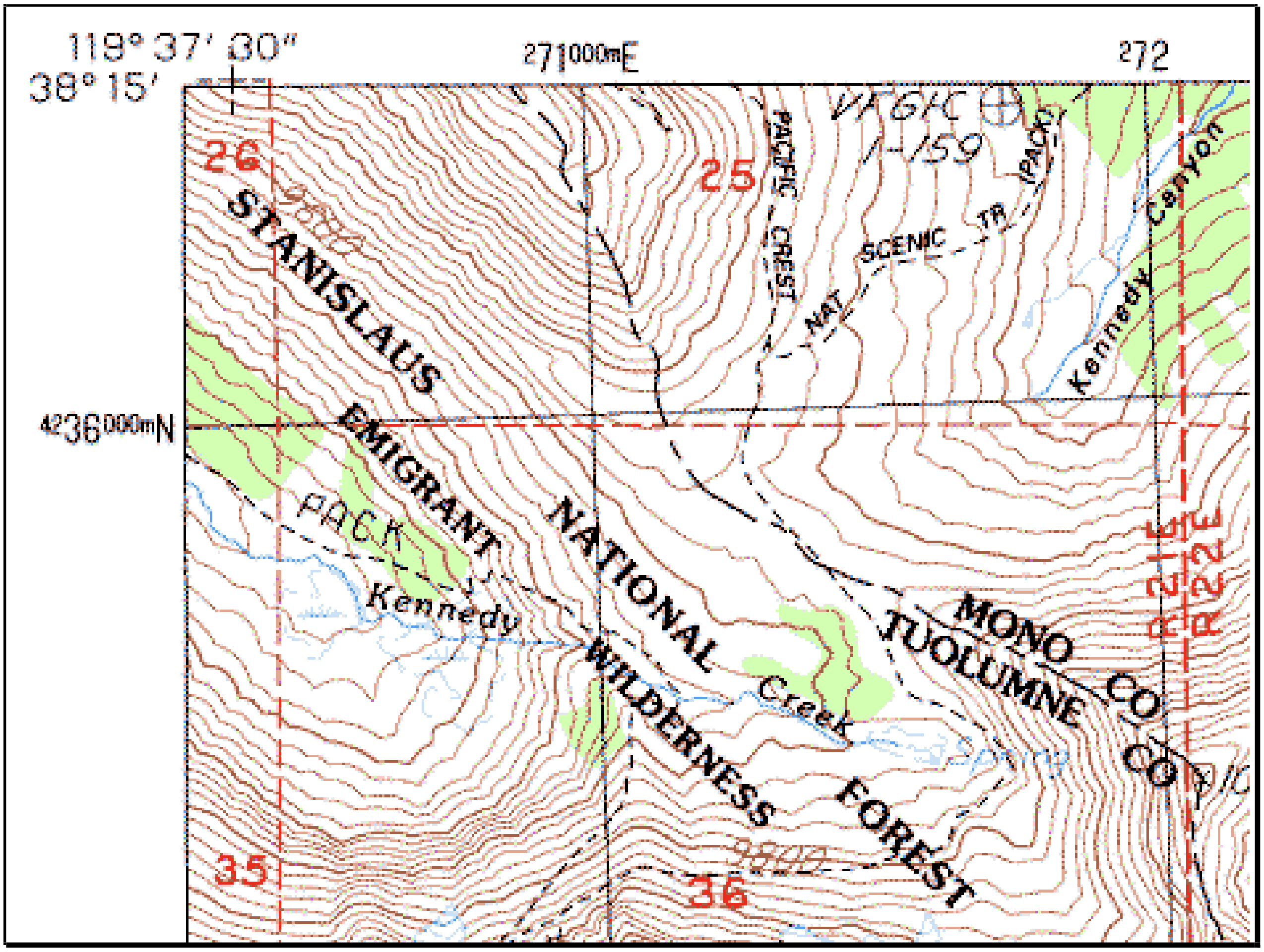

Figure 4. NW Corner USGS 7.5' Tower Peak quad.
Latitude and longitude of corner, 1983 datum reference (cross).
Land lines and section numbers are red. Kilometer UTM grid squares are black.

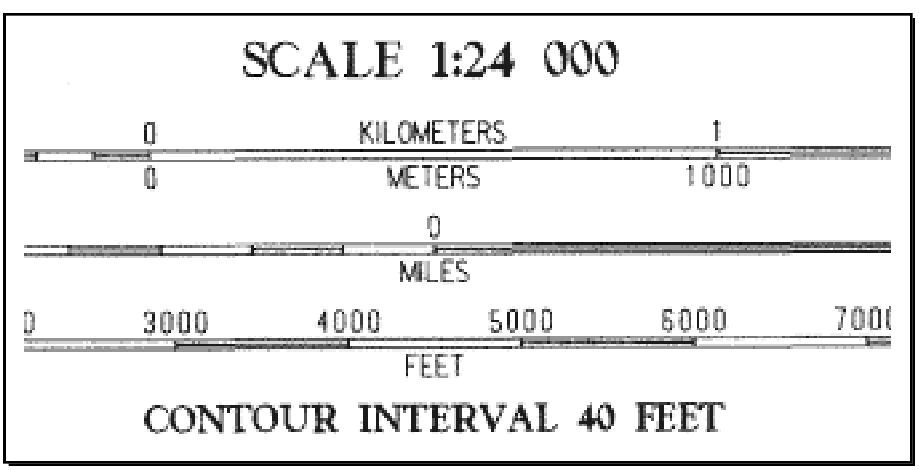

Figure 5. Portion of 7.5' map legend showing scale.

Recognizing Terrain Features

A topographic map shows terrain features and vertical relief by the use of contour lines. The bending of the contour lines indicates such features as ridges and gullies. The spacing of the lines indicates the steepness. With practice in comparing maps to the actual features, you can tell what the terrain must be like from looking at the map.

A contour line is an imaginary line on the ground that traces out a path of constant elevation. The contour line would be the shoreline of the sea should the sea rise to that elevation. Contour lines on a map never cross and always close on themselves, sometimes beyond the borders of the map. A direction straight up or down a slope is perpendicular to the contour lines. A traverse at constant elevation is parallel to contour lines.

To understand this, we need to look at an actual map. The map fragment opposite (Figure 6) shows some features on the Bloody Mountain quad with labels added. The map is in color. The lakes and stream are blue, the contour lines reddish-brown. The shading in the meadow is green. The snowfield is white with blue contour lines. The trail and feature labels are black. The grid shown is in red, and shows the boundaries of square-mile 640-acre land sections (not always exactly square on a map, or north-south either). A section number appears in the center of each section. To direct a search party with this map, one would give the section number for a coarse location. This map does not show the 1-kilometer UTM grid, but the grid numbers and tick marks do appear at the side of the map.

On this map as on many 7.5' mountain-area quads, the vertical contour interval is 20 meters, so the distance between each line represents 20 meters uphill (or downhill, depending on your degree of optimism). Every fifth line is heavier. The distance between these lines, called major contours, is 100 meters (328 feet). Occasionally there is a label showing the elevation. To the south of the peak there is a major contour labeled as 3700 meters or 12,139 feet (elevations on this map are in meters; some maps use feet).

On either a peak or a depression (hole), the contour lines form closed circles. Notice the peak on the map. The top is shown by a little circle. East of the saddle between Bloody and Laurel there is a depression, shown by a cross-hatch)

How high is Bloody Mountain? Count up from the labeled line 1 major contours and one minor one. That's 1 x 100 + 1 x 20 = 120 meters above the 3700 meter contour, or 3820 meters, or more — at least 12,532 feet. The accepted elevation is 12,552', so the summit is almost at the next contour. Notice the symbol for feet ('). This is the same symbol used for minutes of angle, so you have to figure it out from the context. Any writeup will use the symbol both ways, so be warned.

On a ridge, the bends in the contour lines point downhill (lines convex downhill). Notice the contour lines on the ridges. Other terms for a ridges of varying shapes are arète, buttress, crest, divide, rib, and spur.

In a gully, the bends in the contour lines point uphill. The snow field to the NW of the peak is in a steep narrow gully (the Bloody Couloir). Notice the contour lines around Lake Genevieve. It's in a basin, with an outlet to the east at the north end of the lake. The stream feeding the lake runs down from Edith Lake, which itself is fed by two streams, both running down broad gullies. Other terms for a gully-like feature are basin, bowl, canyon, couloir, chute, draw, gulch, ravine, valley, and wash. Each term has a different shade of meaning. The steep, narrow Bloody Couloir is a famous backcountry ski descent.

A saddle runs uphill in two directions and downhill in the other opposite two. Note how the lines squeeze together at the top. There is another saddle on the map just south of the peak. Other names for saddle are notch, pass, or col.

How can you be sure you are looking at a ridge instead of a gully? There are lots of clues. Streams run in gullies, and run downhill. The numbers on the contours get bigger as you go up a ridge, and smaller as you go down a gully. Also, ridges lead to peaks; the tops of peaks have closed contours ***without*** cross hatches.

These are the qualitative things you can see on the map, but these maps are also quantitative tools. By using the scales you can judge exactly how far you have to go across, up, or down.

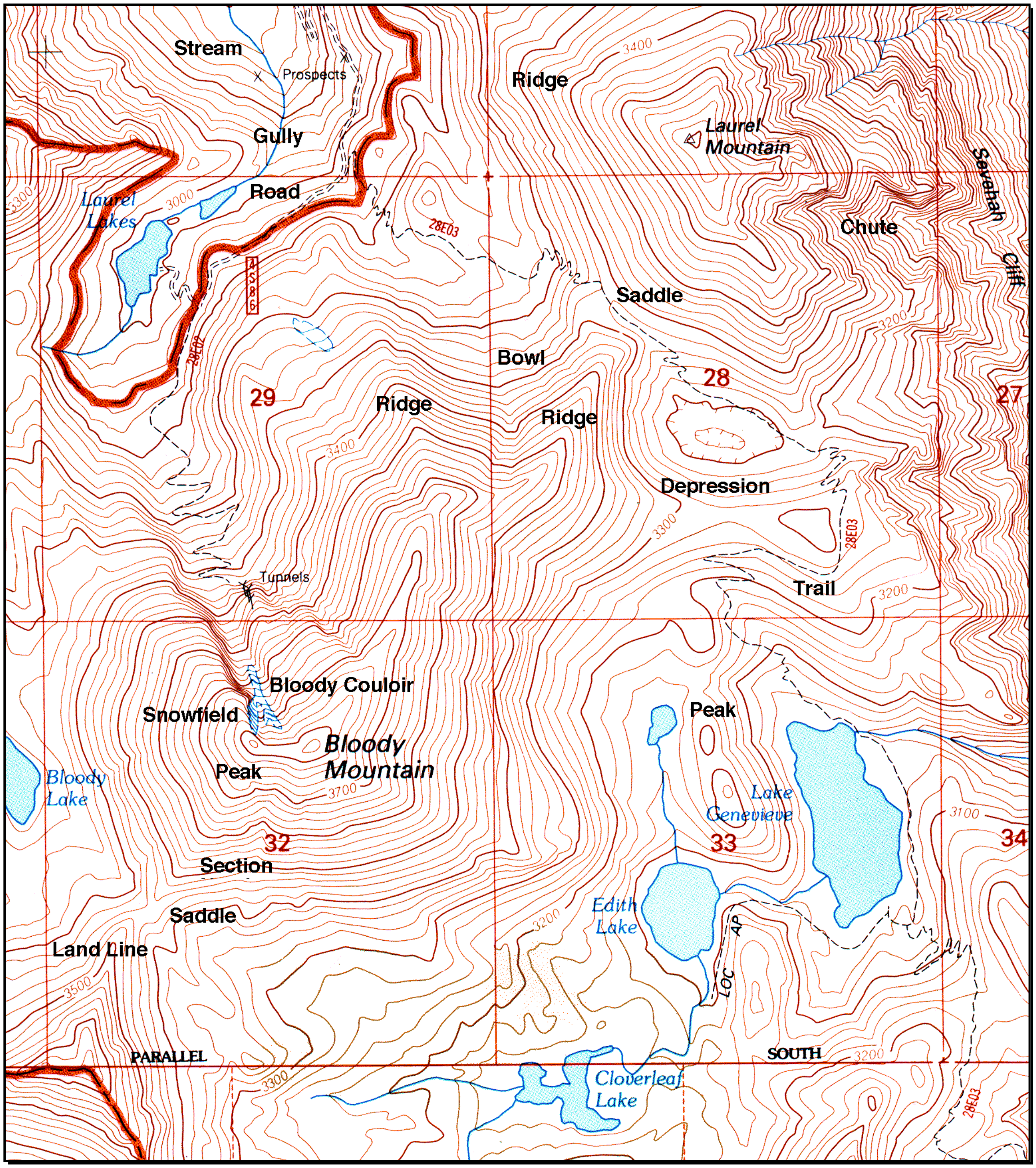

Figure 6. Fragment of 7.5' Bloody Mountain quad with terrain features labeled.
Contour interval is 20 meters (65.6 feet).

Estimating Distance, Gain, Steepness, and Slope Conditions

Climbers, skiers, and backpackers on trail all need to judge distance and steepness of slopes from the map. The map scale can be used to estimate both horizontal distance and steepness. If the contour lines are close together, it's steep!

Inexperienced navigators usually underestimate difficulty and distance. By learning to be more quantitative, you can avoid making such blunders, and your friends will still go out with you.

***Estimating Distance* -** The scale of the map appears in the bottom margin, both graphically and as a ratio. The 7.5' map scale is 1:24,000, which means that one unit of map distance corresponds to 24,000 horizontal units of ground distance. For example, one map inch represents 24,000 ground inches or 2,000 feet, which is about 2 1/2 inches to one mile. The 15' map scale is 1:62,500, which is about one inch to one mile.

***Trails* -** Guide books or trail signs often give the distance along trails (often with errors, sometimes inconsistently). A map will show an accurate trail distance only if all the turns in the trail are accurately shown. Trails on most maps do not accurately show small switch backs nor the ins and outs caused by small feeder gullies when traversing the side of a major ridge. These minor "squiggles" can increase the trail distance considerably by a "squiggle factor." For instance, a trail built with switch backs to have a comfortable 20% grade is 3 times longer than a route straight up a slope with 60% grade. This is a squiggle factor of 3. Minor gullies on a side hill, large boulders, or thick brush clumps may contribute a squiggle factor of 1.5 to 2 times the distance scaled from the map.

***Estimating Gain* -** "Gain" is the total vertical distance that a hiker must ascend on a route. "Loss" is the opposite, the total distance descended. To a first approximation gain can be obtained from the difference in elevation of the contour lines at the beginning and end of the route — if the slope is uniform. Watch out for ups and downs, which can add quite a bit of gain.

Estimating Steepness*-** You may want to estimate the steepness of a trailless slope to see how hard it is to climb or ski. The slope or steepness of terrain can be expressed either as the ***grade, the ratio of vertical to horizontal distance change, or as the ***angle*** from the horizontal. Grade is easier to get from a map.

Using the ruler on the compass or a piece of paper, and a pencil, measure the distance between major contours on the slope you re interested in and compare to the map scale. If the horizontal distance is the same as the vertical (in the same units, meters or feet), then the grade is 100% and the slope angle is 45°.

Roads are usually no steeper than 6%; trails 10% to 20%. Most natural hillsides such as sand, loose dirt, scree and talus have grades of 67% to 75%, corresponding to slopes of about 35° to 37°, called the ***angle of repose***.. Such a slope is relatively safe to climb because a human body, like a loose rock, tends to stay put rather than to slide. Rock walls and the dirt sides of stream channels may have steeper slopes. You can spot an angle-of-repose slope pretty easily on a map; it usually the steepest uniform slope. The slope to the south of Bloody Mt in Figure 6 (previous page) is almost exactly 75% grade, which tells you it's probably dirt or loose rock (it's loose shale).

Steeper slopes represent cliffs or rock. Warning: some of the vertical detail on these maps is not very good. After all, the contour interval is 40', and that can easily hide a cliff.

Table 1 shows the climbing and downhill skiing difficulty of slopes of different steepness, while Figure 7 shows the relationship between percentage grade and angle. For those who were exposed to trigonometry, this function is the tangent of the angle. The plot also shows what fraction of the gravitational pull is downward along the slope (downslope). For a 45-degree slope more than 70% of your weight is directed down the slope, the reason why rocks slide. A 45° ski slope is for experts and gets a double black diamond. This function is the sine of the angle.

Table 1
Steepness and Typical Difficulty
Use the distance scale at the bottom of the map to measure hoizontal distance..

Percent Grade	Slope Angle	Climbing Difficulty	Skiing Ability	Ski Trail Rating
0	0.0	None (flat)	Cross Country	●
5	2.9	Road	Beginner	●
10	5.7	Trail	Beginner	●
20	11.3	Steep Trail	Low Intermediate	■
30	16.7	Class 1-2	Intermediate	■
40	21.8	Class 1-2	High Intermediate	■
50	26.6	Class 1-2	Advanced	◆
60	31.0	Class 2-3	Advanced	◆
70	35.0	Class 2-3	Advanced - Expert	◆◆
80	38.7	Class 3-4	Advanced - Expert	◆◆
100	45.0	4th - low 5th Class	Expert	◆◆
>100%	>45°	5th Class and up	Expert	◆◆

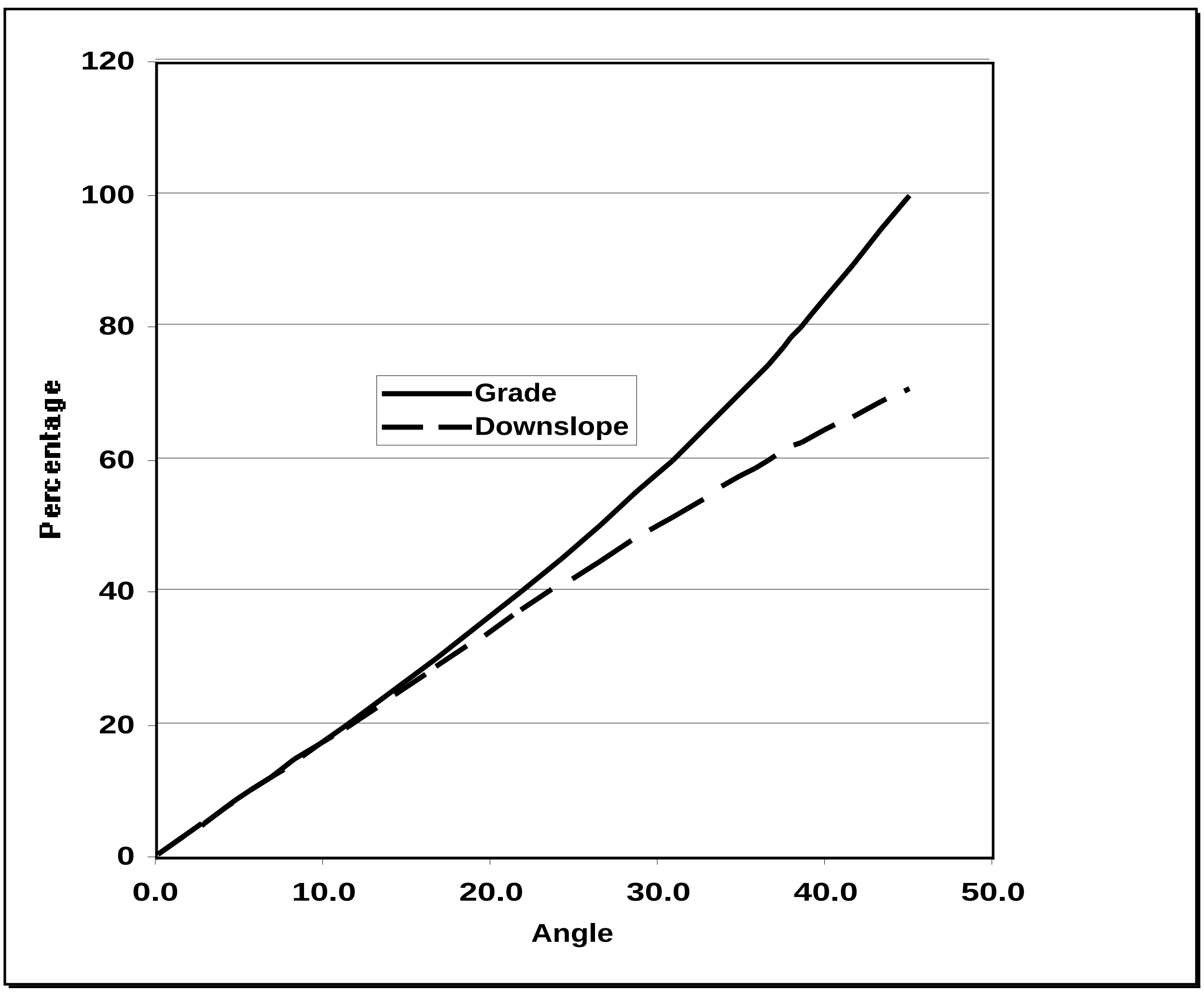

Figure 7. Grade and downslope component of gravity vs slope angle.
The grade is the tangent of the angle.

Field Navigation and Trip Planning

Estimating Time and Energy Needed

In trip planning and field navigation you will need to estimate the time required to travel to your goal, using the rules available to make such an estimate.

Distance - In the previous pages, it was pointed out that trail miles are not line-of-sight miles. Neither are cross-country miles, because you need to zig-zag around rocks and bushes. As a rule of thumb, you should multiply line-of sight distance obtained by laying a ruler on the map by a "squiggle factor" of at least 1.4 (45° zigzags). For switchbacks the factor can be as much as 3.

Speed and Time - A very hurried walk on a level or downhill trail is about 4 mph. A brisk walk such as that used in descending an easy trail is 3 mph, and a good steady mountain pace on easy level ground with a light pack is about 2.5 mph. Level hiking with a backpack is about 2 mph. Navigators should measure speed under various conditions in order to improve their skill in speed estimation. These numbers vary with conditioning and age.

It is often convenient to think of speed in terms of minutes per mile. Thus, 2.5 mph (220 feet per minute) is 24 minutes per mile. On a 7.5' map, this hiking speed is a movement on the map of about 0. 1 inch per minute. Average speed will be lower, because people take breaks, look at maps and scenery, and so on.

Naismith's Rule - Speed when climbing varies with the slope. Naismith's rule is valid for people in good condition walking on trails with a light pack and omitting rest stops:

$$T = R/3 + 2C/3 + H/2,$$

where T = time in hours, R = road or trail distance in miles, C= cross-country distance in miles, and H = elevation gain in thousands of feet.

By this formula, hiking up a 20% (11 degree) slope, which is about 1,000 ft of elevation gain per mile of distance, gives:

$$T = 1/3 + 1/2 = 5/6 \text{ hour per mile, 50 minutes per mile, or 1.2 mph.}$$

This is an elevation rate of 1267 feet / hour. This formula works pretty well, but it underestimates the time required to climb steep slopes. It also needs to be corrected for backpacking. A good rule of thumb is to multiply by the ratio of total weight (backpack plus amount overweight) to ideal weight. Fat people should carry light packs (trust me). There are no rest stops in this time estimate.

Energy - There is also a formula for calculating energy consumption:

$$E = 100\ (10 + R + 2C + 4H) \text{ calories,}$$

where R is road or trail distance in miles and H is elevation gain in thousands of feet as before, but C is cross-country distance in miles, so that cross-country travel takes twice as much energy as on-trail travel. If this formula is divided by the rate of expenditure of energy in calories per hour, the result will be the time in hours. The rate of expenditure of energy varies as shown in Table 2:

Table 2
Calorie Consumption

Activity	**Calories per hour**
Basal Metabolism	50- 100
Ordinary Walking	300
Fast Hiking	600-800
Average Athlete	1000- 1200
World-Class Athlete	1500+

The metabolic rate is one of the best measures of general fitness or conditioning that we have. Using 300 calories per hour, we get a more conservative off-trail version of Naismith's rule:

T= R/3 + 2C/3 + 4H/3.

This version weights gain much more heavily — 750 feet per hour instead of 2000!

Another simple and useful rule for ascending steadily upward over moderate hiking terrain with slopes of 10% or greater, is to assume an elevation rate of 1000 ft / hr, irrespective of the slope of the terrain or of the path chosen, corresponding to an calorie expenditure rate of about 600 calories per hour. People in good condition will typically hike at 1200 ft / hr to 1600 ft / hr (average 700 calories / hr). Many people find that ascending a slope in a series of zig-zags is less fatiguing than climbing straight up a slope. Experience shows the time required is the same for both paths.

Time for rest stops should be added to times calculated by these formulas. Five minutes per hour may be sufficient for breathers, with a longer break for lunch or snacks. Formula times should be increased for long trips to account for the fatigue factor. To sustain speed, it is better to rest half the time every half hour. A few minutes is sufficient for most people to eliminate lactic acid from muscles and joints.

Adverse conditions such as brush, soft snow, talus and scree, high winds, swamps, blow downs, and avalanche path debris will slow the speed and increase the time considerably. The leader should know the actual conditions and use experience to estimate time. Times for fighting through thick brush or floundering through deep snow could be 4 hours per mile or more. Speeds for descending vary considerably among individuals. A group which might vary 25% in ascending time could vary 50% or more in descending times. This is partly the effect of relatively greater fatigue on the less strong people. There is also a large variation among individuals in ability to descend talus blocks and loose scree.

The larger the group the longer the trip time. The more people there are the more chance that someone will hold up the group through some adverse circumstance. For a group of say 25 people, trip times should be increased by up to 25% over that estimated by the formulas.

Bottlenecks can add a major amount of time for a large group. For example, 30 people each taking 2 minutes to cross a stream will add one hour for zero distance traveled. Fifteen people each taking 6 minutes to be belayed up and down a 20-ft class 3 pitch will add 3 hours to the round-trip time. Signing peak registers can add considerable time to a multi-peak hike.

Naismith's Rule

T= R/3 + 2C/3 + H/2

Off-Trail Version

T= R/3 + 2C/3 + 4H/3

Energy Expenditure (Calories)

E = 100 (10 + R + 2C + 4H)

Symbol	Meaning
T	Time in hours.
R	Trail distance in miles.
C	Cross-country distance in miles.
H	Altitude gain in feet - Use zero for downhill!
E	Energy used in calories

All About Compasses

Compasses haven't changed much in the past hundreds of years. But besides the required magnetic needle, they are now also made of plastic, and they have features that make them easier to use for navigation.

The essential features of a compass are a magnetic needle and some numbers to show you the bearing. Old-fashioned compasses used "compass points," 32 in all, 11.25° each, described by such picturesque names as NNE by 1/2 E, or 33.75 E of N. This was good enough for sailing but not for naval artillery, so we use numbers now.

The elements of a modern compass are shown in Table 3 and Figure 8 opposite. The image shows a Suunto M3. The Silva equivalent is the Explorer, and it is ***very*** similar, except that some new Explorer models do not have declination adjustments. Both are available from REI and Campmor and in local stores. These are not expensive items (about $20). They are built on transparent plastic.

On the left of the picture we see scales for the two most-used USGS topo maps, the 7.5' and 15' quads. If you lay this compass on the map you can read miles directly. Line-of-sight miles, not trail mile, which are longer because trails aren't straight. More about that later. It would be nice if there were metric scales too. There are inch and centimeter scales on the top and bottom, and if you lay those on the map you can figure out distances. On a 1:24000 map, 10 millimeters (mm) on the map is 240 meters (m) on the ground, and one inch is 2000 feet. Probably the USGS uses this scale because Americans think in inches. European maps have 1:25000 scales, 40 mm/km.

Moving to the right, there is a magnifying glass, and above it little pencil templates for people who like to draw perfect circles and triangles on their maps. Further to the right there are two white circles at 40° and 320° on the dial. These are rubber feet to keep the compass from sliding around on the map.

The black dial turns. You can set the bearing to whatever you want (the index is that little white triangle, which glows in the dark). Here it's set to true north or 0° (almost, about a degree off to the W, so the bearing is 359°).

About compass bearings: they are measured in degrees, clockwise, If you took analytic geometry in high school, angles were measured counter-clockwise. Forget that for navigation. It you ever get confused, just look at the compass. Remember, the directions are N E S W. East is to the right of north. Angles go in the same order: 0° (N), 90° (E), 180° (S), 270° (W).

Inside the black circle is the needle itself, which is enclosed in a damping fluid that prevents it from wiggling. The fluid-filled moving chamber is sealed with an o-ring.

To obtain this image, the compass was placed so that the magnetic needle lined up approximately with the black arrow on the rotating base. The angle between this arrow and the black dial can be set with the magnetic declination adjustment (small black scale inside the black ring). Here it is set to about 16° E. When the magnetic needle is above the black outline arrow, you can read the bearing off the dial. Because it is set to zero (nearly), the compass is pointing to true north. There is a luminous point on the needle, and two at the sides of the arrow so this can be done in the dark.

Now we need to learn how to use the compass.

Table 3
Compass Features

Importance	**Feature**
Necessary	Clear base, rotating dial with clear base, needle damped in fluid, fixed declination scale, inch and millimeter scales ($7-$20).
Desirable	Declination adjustment (not a fixed scale), luminous markings, magnifying lens, 1/24,000 and 1/62,500 scales ($20-$30).
Frilly	Flip-top sighting mirror, needle for sensing vertical to get slope angle, map measuring wheel, special GPS scales ($30-&70).
Nice Accessories	- A bag that is fuzzy inside to keep the compass in (REI). - More string, so you can make the lanyard longer (if you change the lanyard, keep the tiny screwdriver that adjusts the declination!). - A 1/24,000 metric scale to use with a GPS.

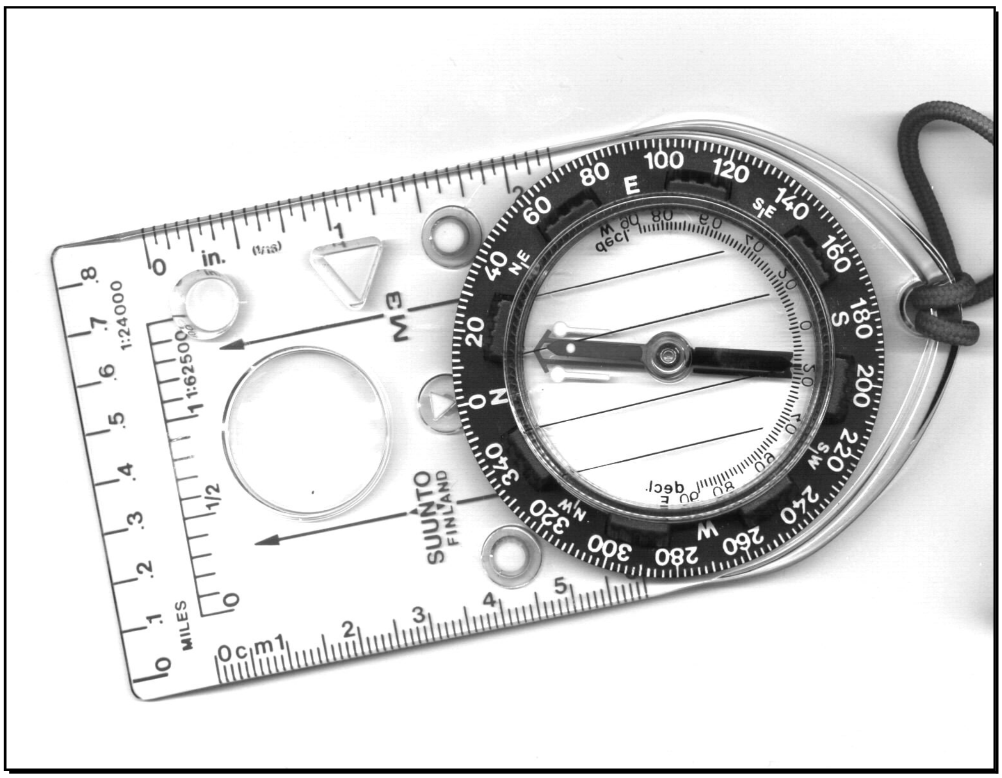

Figure 8. Suunto M3 pointing (almost) to true north with declination set for the Eastern Sierra.
The magnetic needle points to magnetic north, about 15 degrees east of true north in this location.
This compass has 1:24000 and 1:625000 scales in miles, and luminous points for night use.

Using A Compass

Use the compass to measure and plot bearings on a map and in the field, and as a ruler, protractor, and to determine local slope angle. Measure all bearings relative to true north. Because maps have no magnetic north reference lines, it is harder to take and plot bearings using magnetic north.

You will need reasonably accurate north-south reference lines on the map. These may be section lines, map folds, map edges, or parallel pencil lines drawn at about 1 inch intervals. Be the first person you know to draw the lines ***before*** leaving home!

Measuring and Plotting Bearings on a Map **-** To measure a bearing on a map, the map need not be oriented with any compass direction, and the compass is used only as a protractor (the needle is completely ignored). Align the edge of the base plate along the line whose bearing is to be measured. Turn the dial so that the lines inside the dial are aligned north-south parallel to the edge of the map or a pencil line you have hopefully remembered to draw. Then read the bearing from the dial. See Figure 9 for an actual example. The inverse process is used to plot bearings. The dial is set to the desired bearing, and the compass is placed on the map so that the lines are aligned true north-south. The base plate will be aligned in the desired direction and you can draw a line along it if you wish. Practice doing these things on a map.

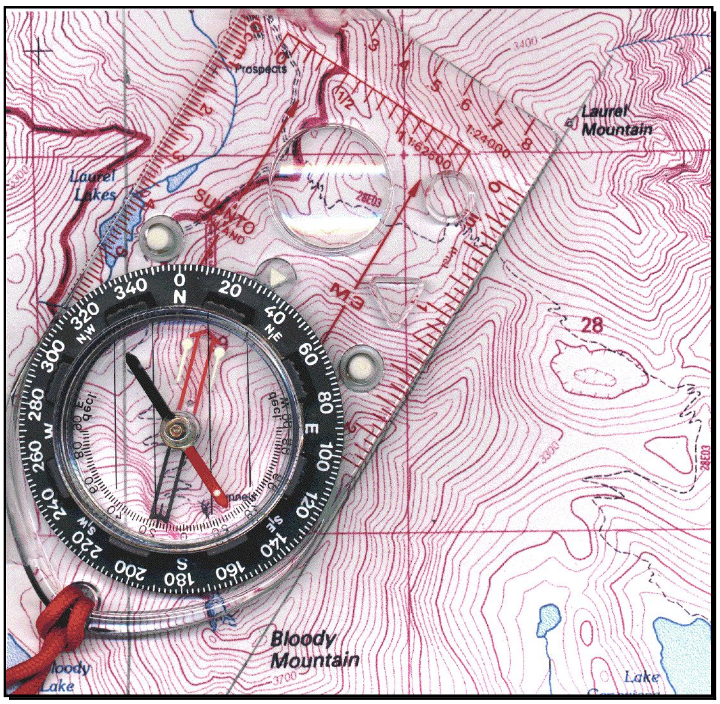

Figure 9. Measuring or plotting a bearing on the map with the compass.
The north-south lines inside the dial are aligned with true north-south on the map (pencil line).
The bearing from Bloody to Laurel is 33°.

Using a Compass to Take Bearings in the Field **-** First, you must learn to handle magnetic declination, the deviation of the compass needle from true north. If you used magnetic bearings, then you'd have to draw those lines at an angle to the map, toward magnetic north. The only reference you have is the tiny picture on the bottom of the map (Figure 10). When you use your compass to take a bearing in the field, you want the magnetic needle to line up with magnetic north when the compass points to true north, so that the compass looks like the diagram. Don't try to remember the sign: just make it look like the picture. Some maps don't have a picture; for those, remember east is to the right. Be sure the red end of the magnetic needle is lined up with magnetic north. Errors of 180° in direction are embarrassing.

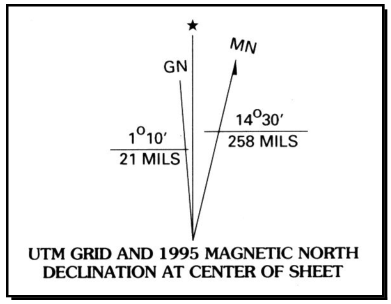

Figure 10. Typical declination diagram.
Magnetic north (MN) for this map is 14° 30' east of true north (★). GN is UTM grid north.

Using a Compass with a Declination Adjustment **-** On a better compass you can set an arrow outline on the dial off true north by the declination angle. Then, to take a bearing, point the compass at the target and rotate the dial until the red part of the magnitude needle is over the arrow outline. See Figure 11 (it's off a bit). In this picture, the compass is pointing almost due north (0°) but the relationship of needle and dial should look the same no matter what the bearing is. To point at something whose bearing you know, set the bearing in the dial and rotate the compass (and yourself) until the needle lines up with the arrow outline. Then look where the compass is pointing and hope you see what you expect to see.

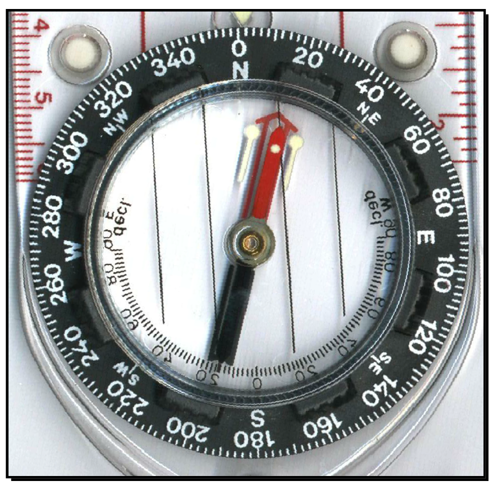

Figure 11. How a compass should look when taking a bearing.
The magnetic needle lines up with the declination so it looks like the diagram on the map (Figure 10).
Adjustable compasses have an arrow outline as shown to make it easy.

Using a Fixed-Declination Compass **-** Simple compasses do not have an adjustable reference arrow. You can point the needle to the right angle on the fixed declination scale by keeping an eye on the target, the needle, and the scale at the same time, a bit of a trick. It's easier to put a little arrow of tape on the bottom of the dial pointing to the right declination. Then, whenever the N (red) end of the magnetic needle is over this tape arrow, the parallel lines inside the dial and the 0° point on the dial will point to true north.

Caution **-** Because the compass needle follows the local magnetic field, nearby iron, automobiles, knives, belt buckles, mechanical pencils, reinforcing steel, or iron-containing rocks can cause errors in bearings. Take bearings at least 15 ft. from automobiles. There are a few peaks that contain iron and that causes significant compass variation within distances of hundreds of feet. If in doubt, take bearings from several spots in the vicinity to verify that the bearing does not change.

About Altimeters and Their Use

An altimeter is a device that measures altitude, usually from air pressure. Although not as essential as a compass, altimeters are useful navigation tools in mountainous terrain, particularly when visibility is limited. They are subject to errors in altitude that can be 100 feet or more, and so should not be absolutely relied on but be used primarily as a guide. If your altitude is 500 feet off, you are probably not where you think you are. If you are only 100 feet off, don't trust the altimeter.

To use an altimeter effectively requires understanding how it functions, what affects its readings, and what its accuracy limitations are. A typical altimeter is really a portable barometer, an instrument that measures air pressure but reads out in elevation units (feet or meters). Because air pressure decreases with increasing altitude, an altimeter indicates altitude by sensing the air pressure. There are two kinds: the older mechanical kind, in which air pressure compresses a spring connected to a pointer, and the new electronic kind, which senses pressure by the piezoelectric effect. The leading mechanical brand is Thommen, and these are both accurate and expensive. Electronic sensors are frequently built into wristwatches. Figure 12 opposite shows one such Casio watch. Recent watches have temperature-compensated altimeters that work quite well.

Air pressure changes with the weather and with air temperature. A pressure change of 1% at any altitude corresponds to about 320 ft of elevation change. In a major storm, the pressure can change by several percent. Because of the weather effect, altimeters can and should be reset at points of known altitude. If the weather is changing rapidly, this should be done fairly often, whenever you arrive at a place where the altitude can be read off the map (stream crossing, lake, peak, pass). A mechanical altimeter is reset by rotating the scale, mounted on a movable ring. The electronic kind is reset like a digital watch by pushing buttons.

Assuming that the errors in the altimeter itself have been corrected, there are still two effects that produce errors: aerodynamic effects and air temperature.

***Aerodynamics* -** The flow of air over the crest of the mountains produces an aerodynamic effect that is similar to the lift on an airplane wing. This effect can produce errors of some tens of feet.

***AIr Temperature* -** The expansion and contraction of the atmosphere with temperature produces another error. An altimeter is calibrated using the International Standard Atmosphere (ISA), which assumes that the atmosphere has a certain profile of temperature vs altitude (see Figure 13). The temperature change with altitude is about 3.5°F per 1000 feet. This profile is colder than what we experience in summer in eastern California most of the time. The air is less dense than the altimeter thinks it is, and so the pressure change with altitude is less. If you set your altimeter at the trailhead, and then walk uphill, the altimeter will read low, so that altimeter will say you have climbed less than you have.

The percentage error in the altitude gained is proportional to the percentage change in ***absolute*** temperature (measured from absolute zero at -459°F). An approximate formula for the percentage error is

Percentage Gain Error = 0.22%/°F x Temperature deviation from ISA(°F).

Suppose you are climbing out of Mammoth at 8000' on a 70°F summer day. The ISA temperature at 8000' from Figure XX is only 30°F, so the temperature is 40°F higher than the altimeter was calibrated for. If you climb 1000', at the end of the climb your altimeter will show an error in gain of 0.22% x 40 = 8.8%, or 88'. The altimeter will claim you are 88 feet lower than you are. For a 2500' climb, the error would be 220', which is substantial.

To minimize the air temperature error, the climber may use this error estimate or reset the altimeter at known elevations. When using an altimeter as a locator for important turning points upon descent, to avoid a mistake it may be wise to make no further resets after getting a reading on ascent. In the face of an incoming storm front a recent reset of the altimeter may be critical.

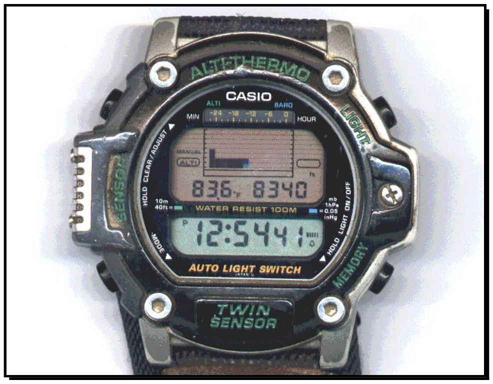

Figure 12. Casio altimeter watch. It plots the altitude continuously.

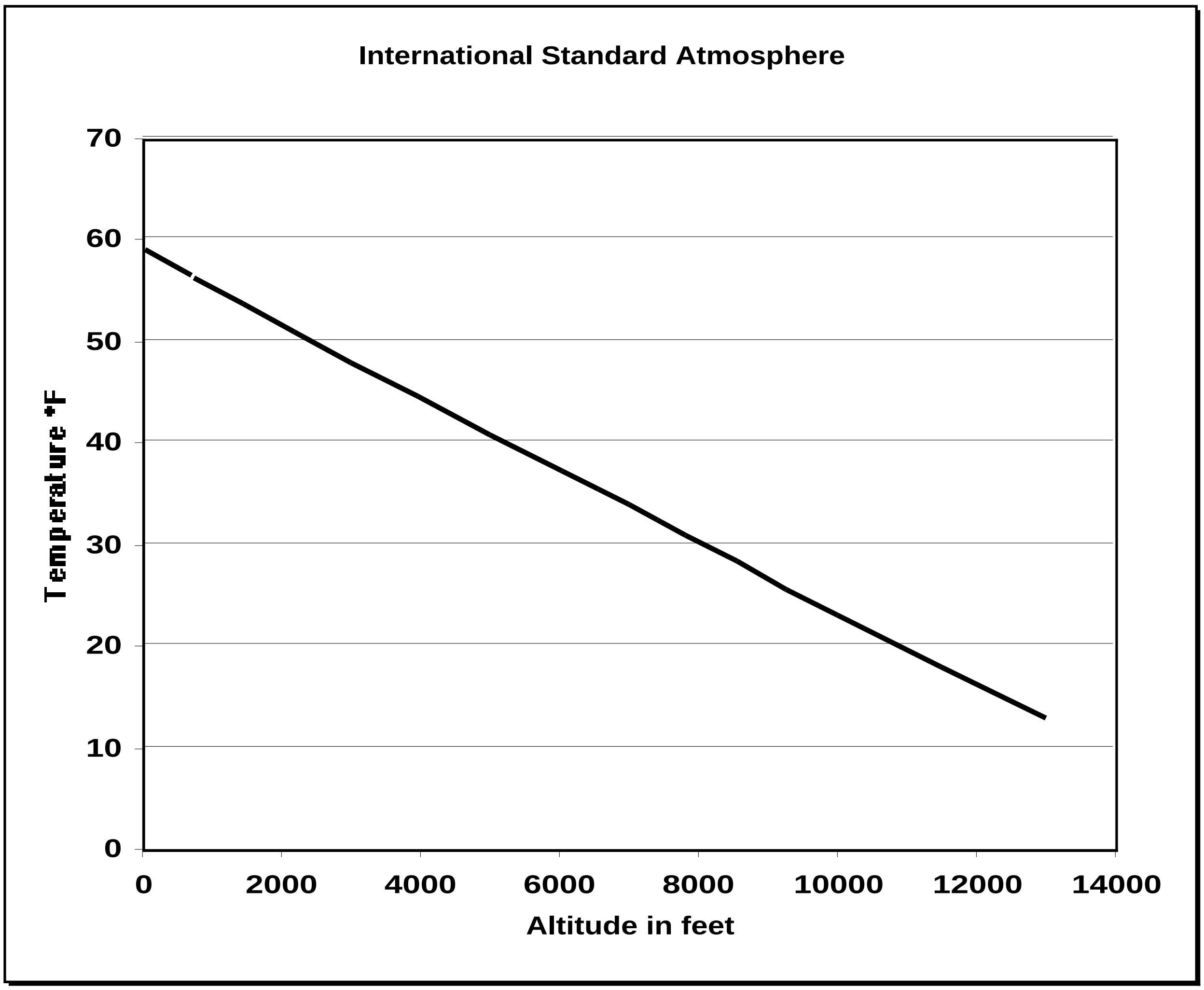

Figure 13. International Standard Atmosphere temperature versus altitude.

Field Navigation and Trip Planning

About GPS Units and Mapping Software

The Global Positioning System uses satellites to transmit their position to navigational units carried in boats, planes, cars, backpacks, or smart bombs. Relatively inexpensive handheld units for field navigation permit precise location and navigation. They need to be supplemented with a compass in the field, because they determine position well but not direction. These units can be combined with mapping software to plan routes. The typical position uncertainty of simple civilian units is tens of meters, but more sophisticated units can reduce this uncertainty can be improved down to a few centimeters by measuring relative to a known location.

The receivers themselves are extremely high-tech and pack a great deal of computing power in a small unit. Figure 14 shows a typical highly-rated backpacking unit, the Garmin GPS-12 ($150). There are a number of different displays. Figure 14 shows some of the main ones (scanned from the manual). The displays are selected from a menu reached by pressing the PAGE button.

Map Screen **-** The screen shown on the unit itself is the map screen, which shows the location of several different features that have been defined as "waypoints" by entering a name and location. The two numbers at the top are the bearing and distance to a selected waypoint or a spot on the screen. The lower numbers are the current course and speed.

Satellite Display **-** The first display shows the satellite positions and signal strengths. This is the first screen the unit has not been used for a while).

Position Display **-** Once the unit has decided it can see enough satellites, the position display appears. This shows the location of the unit, shown as latitude and longitude here although the UTM system can be used as well. The time shown is derived form Greenwich Mean Time (Zulu Time), and is exact. The heading and track are derived by differencing successive positions on the ground. If you are not moving, this display does not mean much.

Mark Position **-** GPS units can store locations as "waypoints." The present position can be marked. named, and stored. One important use for this function is to store the waypoints on the way to a destination, so that you can find your way back. Waypoints can be added to a list called a route, with different routes for different hikes or ski tours. Dorothy and Toto could have used one of these to get back to Kansas.

Waypoint Lists **-** There are several ways to display lists of waypoints. One useful screen displays the nearest waypoints, which are usually on the route you are following. The list shows the straight-line bearing and distance between waypoints. When the list is a route, after you reach your destination, you can reverse the order of the waypoints to follow the route back ("traceback"). Because distances between waypoints are straight-line, you should figure out the squiggle factor from the map to get a time estimate. It is a bad idea to define a route in such a way that you can walk off a cliff. Do not use a GPS to follow a course from the top of Whitney to Lone Pine, unless you have a very long rope.

Go To Waypoint **-** Different screens allow you to determine the distance to a waypoint. The GoTo screen shown gives a list of waypoints to choose from. Note that these waypoints have names, not numbers, and have map symbols. There is another screen that allows you to name the waypoints and assign symbols. The symbols can even be customized.

Compass Page **-** This page shows the bearing and distance from the present position to the selected waypoint ("RIDGE"), as well as your current speed and direction of travel. In this case you are heading slightly south of west (261°), but the waypoint is further north (291°). It is 3 miles away, but because you are hustling along at 3.9 mph, you can expect to get there in a little under an hour (54^m 14^s).

This should give a fair idea of what these units can do. Warning: it takes time to put information into them, and if your companions are impatient you will become unpopular as you sit there pushing buttons. If a whiteout or night comes on, though, you may have better friends.

Mapping Software **-** Programs are available that read maps from CD-ROM or the web, or even a scanned image, and allow you to do trip planning by analyzing routes for distance and gain. The GPS receivers such as the Garmin described here have computer interfaces. It is possible to read or write waypoint files and other data (such as your own map symbols). Entering routes taken from a map before a trip saves time compared to keying the numbers in by hand (maybe). Some people (such as pizza deliverers and research scientists) use a GPS in a moving vehicle to find addresses and remote locations.

Table 4 lists a few software applications. Topo is highly regarded and used by many people. Of the two Mac programs, GPSy is the more powerful. MacGPSPro operates with Garmin units only, but CDROM maps are available for it.

Table 4
Mapping & GPS Software

Name	Mac/Windows	Company	WWW URL
Topo	Windows	Wildflower Productions	http://www.topo.com
GPSy	Mac	GlobalMapping Systems. Karen Nakamura	http://www.gpsy.com
MacGPS Pro	Mac (Garmin only)	James Associates	http://www.sni.net/~lwjames/

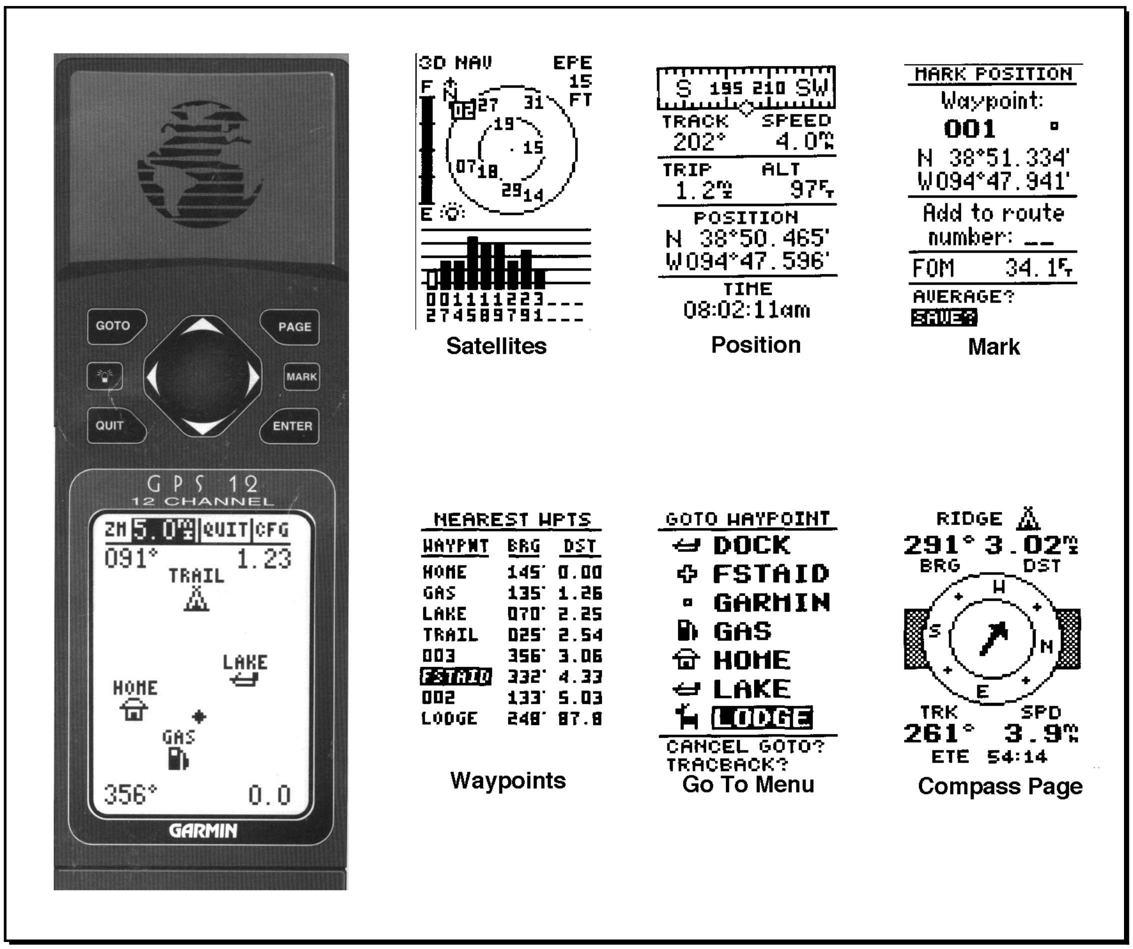

Figure 14. Garmin GPS 12 and some display screens.

Planning and Leading Trips

Outing leaders must be able to plan trips that can be done by the group reasonably, safely and within the time available. This entails selection of the route, estimation of times required for the various phases, selection of equipment which will be needed, and screening of group members for the necessary skill and physical condition. The plan should provide ample reserves for contingencies.

The techniques of trip planning and route finding, map reading and navigation are not difficult in theory. However, the achievement of proficiency under the stress of real operations takes practice and experience. Would-be navigators should practice their skills on all trips in which they participate.

Route Selection - A route is normally desired which allows reaching the goal with the least effort and in the minimum time, unless you are intentionally taking the scenic route. Unintentional delays occur often enough, even in familiar terrain. Some route selection tips:

- Make a search of all available route information. Talk to other climbers, consult guide books and past trip write-ups, check with authorities for new trail information.
- Trails are usually best, fastest, and safest, particularly with a heavy pack.
- In Southern California and desert areas, ridges are usually good. In the Sierra they may have impassable pinnacles and notches.
- A route immediately along a stream will usually encounter brush. A route through a Sierra basin is usually good. Dry watercourses in desert areas are frequently the best approach.
- Gullies at the angle of repose may furnish good routes in the Sierra but may have rock fall problems. They may be quite good when filled with snow.
- Snow is fine if it is consolidated. Hiking in deep, soft snow is an abomination. Consider avalanches, consider ice.
- Traverses along a side hill vary from very bad to okay depending on the terrain. A traverse around a hill from one saddle to another may take longer and be more effort than a route over the top of the hill.
- Consider stream crossings -- they can be difficult, dangerous or impossible.

Prepare a table or a graphic profile showing distance, type of terrain, elevation change and hazards for each leg of the trip. The legs of the trip are the segments that are more or less homogeneous and which permit the use of a single calculation for time required. Estimate times for each leg and plan the trip in a conservative manner allowing at least one hour of daylight reserve.

- Scout the trip whenever warranted by conditions or uncertainties. Be alert to private property restrictions, washed-out roads and real estate developments.
- Document the plan in a form that can be given to participants.
- Plan the campsites -- make sure that reasonable camping spots exist. Camping on talus blocks at the edge of a lake can be unpleasant.
- Consider parking areas for automobiles.
- Be conservative, be safe. Do not attempt too much. Most people are very tired after 10 hours of hiking.
- Be flexible, have alternate objectives should the group be faster or slower than estimated.
- Communicate trip agenda and requirements clearly. Screen the group with care and courage. Do not permit unqualified people to participate.
- Plan to start early. Daylight is too precious to waste.

***Leading the Trip* -** The ability to choose a good path along a planned route grows with experience. With experience, one develops a sense of the terrain from a quick glance and is able to pick a reasonable path through brush, over talus or up a ridge.

- Study the map before a trip and during the trip. Have the big picture of major ridges, canyons, and roads well in mind. Be alert while hiking. Look around -- let the terrain register in your brain. Develop a two or three dimensional image of the terrain. Grow above the one dimensional, head-down, trail following mode.
- Be concerned about the return trip. Stop and look back frequently. Make mental notes of key turning points. Make pencil and paper notes as to appearance, time, location, and altitude. Leave route markers as appropriate (ducks, branches, marks in the dirt, survey tape, or wands).
- Pick a distant view landmark in the direction of travel and guide on it. Do route following -- estimate times of arrival at identifiable points along your route to confirm your location.
- Don't worry about momentary loss of the trail in the Sierra. If you are correct about the general route of the trail, you and the trail will find each other in good time.
- Keep the group together. Maintain visible connecting ties to the rear leader, particularly at turning points where people may go astray. Every 30 minutes, or so, let the rear catch up and verify that all is well.

Example of a Trip Plan

As an example of a trip plan, consider a trip in the Angeles National Forest from Vincent Gap (V-G) over Mt. Baden-Powell (B-P) to Mt. Burnham (B) and return. See Figure 15, which is a 7.5 minute (1:24000 scare) map.

The trip will use the available trails, and it is assumed that the small amount of cross-country required near the peaks is easy (it is). The group will have 20 people, all presumably qualified but not known personally to the leader. Table 5 and the notes summarize the trip data and planning considerations. In addition to this data, the trip starting time must be chosen as a compromise between reserve time at the end of the day and driving time from Los Angeles at the start of the day.

Table 5
Sample Trip Plan

Segments of the Trip	Gain/Loss(ft)	Distance (mi)	Time (hr)	Notes
V-G to B-P	+2800	3.5	3.3	1,2
At B-P	0	0.0	0.7	3
B-P to saddle west of 9086'	-600	0.8	0.3	4
Saddle to B	+200	0.3	0.2	5
At B	0	0.0	0.2	6
B to Saddle	-200	0.3	0.1	
Saddle to near B-P	+400	0.8	0.6	7
Near B-P to V-G	-2600	3.4	1.7	8
Total:	≠3400	9.1	7.1	

***Note 1* -** Map study shows that the route from V-G to elevation 9200' is steadily upward by a trail with many switch backs on a broad ridge. The distance along the ridge crest is about I mi. (5280 ft) and hence the average slope is 2600/5280 = 50% (27 degrees). One can assume that a popular trail such as this is constructed with a slope of about 15% (8 degrees). This slope checks with measurement of some of the trail segments on the map. This gives a squiggle factor of 50115 = 3.3, or a trail distance of 3.3 x I mi. = 3.3 mi. The distance from elev. 9200' to B-P is.2 mi. and therefore the distance from V-G to B-P is 3.5 mi.

***Note 2* -** The time required estimated by the 1000 ft/hr rule would be 2.8 hr. That estimated by Naismith's rule is 3.5/3 + 2.8/2 = 2.6 hr. A group size factor of 20% seems reasonable, which adds.5 hr. About.2 hr is allowed for rest stops. Therefore the time for V-G to B-P is 2.6 + 0.5 + 0.2 =3.3 hr.

***Note 3* -** It is assumed that lunch will be eaten on B-P.

***Note 4* -** The downhill trip along the ridge trail is assumed at 2.5 mph or 0.4 hr/mi. The distance of 0.8 mi. is scaled from the map. Hence the time is (0.8 mi.)(0.4 hr/mi.) = 0.3 hr.

***Note 5* -** The distance is scaled from the map and the time is calculated by Naismith's rule.

***Note 6* -** Assume 12 minutes to sign peak register and get the group turned around. (It may be longer.) Note 7: The group will stay on the trail and will not re-ascend B-P.

***Note 8* -** The descent is on a good trail, but some people may have blisters. To be conservative, estimate an average speed of 2 mph (0.5 hr/mi.), which should provide for rest stops if needed.

The planning process for a multi-day trip with significant cross-country travel is similar to that for this simple illustrative example. In fact, for such a simple trip, such a detailed plan is hardly warranted.

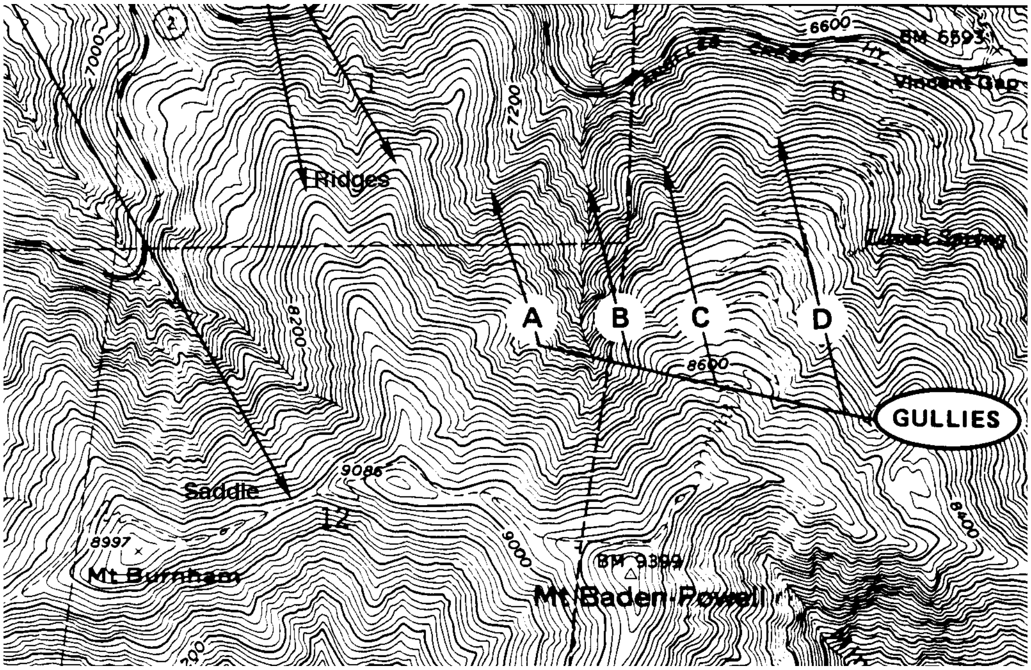

Figure 15. Mt. Burnham and Mt. Baden Powell.
Map scale is not shown, but the dashed section lines define one mile.

Field Navigation and Trip Planning

Field Navigation - Combined Use of Map, Compass, and Altimeter in the Field;

Use the map, compass, and altimeter to determine your position in the field and decide on a route to follow. These skills require practice to develop. It's worth doing a little navigation practice on every hike so that you will have the skills when you need them.

In the field, the leader must navigate and find the route. The leader must know where the group is, where it is going, and how to select an appropriate route to get there. Leaders should know, or be able to quickly determine, the location on the map and how to relate the corresponding features on the map and the terrain. Leaders should have the skill and experience to select a good route initially and to change the route if necessary as the terrain unfolds. They must not only get to the destination but, what is frequently more difficult, be able to return with assurance.

Navigation is easy for a hike in good weather over a trail in terrain with large relief. It is far from easy for a cross-country trip through featureless terrain with limited visibility. Even a trip that starts out as an easy navigational problem can become quite challenging if a wrong ridge is picked on descent or if the weather produces a sudden white-out.

Map Orientation -Orient a map to the terrain by rotating it until its features are parallel to the corresponding features on the ground, and the north-south direction of the map is aligned with the true north- south direction of the earth. You may also place a compass on the map with the compass north-south line parallel to a map north-south line and then rotate the map and compass together until the compass needle points to magnetic north (use the magnetic declination angle on the compass dial).

You may orient a map by inspection without the use of a compass by rotating the map so that corresponding map and terrain features are parallel. If an observer knows the map location of the current position and the map location of some recognized distant terrain feature, Rotate the amp so that the terrain feature on the map is in the same direction as the terrain feature on the ground.

Position by Map Inspection - You can determine your position on a by correspondence between the map and the terrain. A common sense back-and-forth process is employed using all the clues that are available. The process can be very easy, as for example when standing on the shore of a lake whose shape obviously matches one shown on the map. It can be more difficult if you are in a canyon bottom and must identify observed side canyons with those shown on the map.

An oriented map can provide a position fix by intersection of two lines of sight or an intersection of a line of sight and a known line of position such as a trail, ridge or gully. The representation of a visible terrain feature is identified on the map and the oriented map is moved so that the line of sight from the observer to the terrain feature passes over the map representation of the feature. The observer's position on the map then lies on the projection of the line of sight onto the map.

Skill in estimating distances to terrain features and in estimating elevation differences helps considerably in map to terrain correlation (and vice versa). For example, the fact that a cliff is judged to be 1000 ft high and 2 miles distant may help considerably in searching the map for the corresponding feature. In climbing a ridge or slope, you can often fix altitude by noting neighboring peaklets or saddles that are level with one's position and whose elevation you can determine from the map.

In working from the map to the terrain and vice versa, use all the clues that are available. For example, note the width, height, direction, curvature and length of a gully on the map and compare this with estimates made while looking at a physical gully to check for correspondence. Gully A in Figure 15 extends for about 800' elevation above the highway before it curves away to the left and disappears. It is about 400 ft wide above the highway and has an azimuth of 215 degrees. These are sufficient clues to make its identification easy from the highway. Gully B is more pronounced, being deeper and spanning more elevation than A. Gully D has considerable vertical height but it is quite shallow, and if there are many trees its identification from the highway might be difficult.

Other characteristics to note are distances to land forms, relative elevations, and of course, the general shape of the terrain. For example, the map in Figure 15 shows that from Baden-Powell, Mt Burnham is about one mile distant, about 400 ft. lower and is a high point on a ridge that makes a curve through an intermediate high point (9086'). When viewing the terrain, all of these clues should be verified.

Some gullies are shown with blue line symbols for intermittent streams. Presumably this symbol is used for the more important channels in a given watershed. Most of the time in Southern California and the desert regions there is no water in any of the intermittent streams. Furthermore, the canyons without this marking may be just as prominent from the ground as those that have the marking.

Map and Compass **-** You can determine your location in the field by taking at least two bearings to identified features and then plotting these bearing lines on the map. Their intersection is the observer's location. For maximum accuracy the bearings should be as nearly perpendicular as possible. If the observer's position is known to be on some identified line such as a trail, road, gully or ridge, then only one bearing is needed. It should be as nearly perpendicular to the known line as possible. If you observer know the location on the map, measure the bearing from the map and use the compass to locate the features in the field. Conversely, take a bearing to an unidentified physical feature and then draw a line on the map through the current position to identify the feature.

Navigation in terrain of distinctive relief with USGS maps and a compass such as the Silva or Suunto can be done with surprising accuracy. Most of the time, most people can achieve accuracy in taking bearings and in making plots within 3 degrees. At a distance of one mile, an error of three degrees amounts to about 280 ft of perpendicular error. One degree is about the angle subtended by a little- finger-thickness at arm's length.

Navigation Tricks

How to Make Sure Where You Are

- Be wary – don't jump to conclusions.
- Take cross bearing on known landmarks.
- Compare terrain to map completely.
- Compare compass bearing to map for ridges, canyons or gullies. and road segments.
- ***Use all the clues and make sure they agree!***

Field Navigation and Trip Planning

Techniques for Field Navigation;

Ther are a number of techniques and wrinkles that are useful: taking abearing on a linear feature, dead reconing, and continuous tracking of postiion with frequent checks. Develop skills by practice, and ***use all the clues.***

***Bearing of a Local Route Segment* -** Navigation technique frequently is most needed in conditions of limited visibility such as in a forest, in fog or at the bottom of a gully or valley. For these cases, a very useful and important technique is to use the compass to measure the bearing of the local route you are following, e.g., a segment of a ridge or dry creek bottom, or of a trail or of a hillside slope. You should also observe as much as possible about the surrounding terrain, get an altitude reading if appropriate, and then searche the map for a segment with corresponding attributes, thus fixing the position. To repeat, this is a very important technique!

***Dead Reckoning* -** Dead reckoning is the process of moving from a known point for an estimated distance in an estimated direction to reach a desired destination. The process may be done in distance, in direction, or in both. Dead reckoning is used in featureless terrain or at times of limited visibility.

Obtain distance traveled by estimating the speed of travel and multiplying by elapsed time. If you know the distance to a desired destination, travel for the required time to reach that destination.

For direction dead reckoning with limited visibility as in timber, darkness or fog, navigators must carry a compass in hand and walk as closely as possible along a compass course. It helps to pick out an object, such as a tree or rock, which lies on the compass course and as far ahead as visibility permits and to walk to the object. Then repeat the process with another object. This method gives greater accuracy than trying to follow an exact compass course and it allows one to pick a good path and to move around obstacles. When moving over a snow field in a fog, it may be useful to send another person ahead, to the limit of visibility, and to then move to the person and repeat the process. However, a better technique is to deliberately offset the chosen direction so that there will be no doubt about which way to turn when reaching the road if the cars are not immediately in sight.

As an example, a navigator/leader descends from a desert mountain at dusk. The automobiles are known to be out on the desert I mile away at an azimuth of 88 degrees. The leader estimates that in crossing the desert, the group will move at 25 min./mi. The leader sets the compass dial at 88 degrees, notes the departure time on a watch (or starts a stopwatch), aligns the compass needle, selects a (unique) Joshua Tree about 1/3 mi. away to home on, and starts off. After 25 minutes of walking and a few more homing points, the group should encounter the vehicles.

***Position Tracking* -** An excellent way to determine position is to never lose track of position from the start of the trip. Keep track of location on the map at all times. Look at the terrain, recognize the features on the map and carry a mental image of movement and location on the map. Study and read the minor features shown by the fine detail in the contour lines. Carry the map close at hand, and look at it often.

To confirm a map position it is useful to predict future fixes based on distance (or time) from a known or presumed position. For example, when hiking on a trail through timber in the western Sierra at an estimated speed of 30 min./mi. the group crosses a small stream that is believed to be correctly identified on the map. About.6 mi. further (.6 inch on the 15' topo map) the map shows another small stream crossing the trail. The leader thus predicts that the second stream will be reached in 18 min. The time is noted, or the stopwatch started, and if in fact a stream is reached in about 18 minutes, the leader has a strong confirming clue that the original stream identification was correct.

Depth perception as to ridges and gullies can be gained by moving one's head back and forth over a distance of a few feet or by walking a few tens of feet and noting how terrain in front seems to move relative to terrain behind. Send out local scouts as appropriate to find the best local route; but maintain control —tell them how far to go, when to stop or come back, and how to communicate.

Be especially careful in descending ridges to keep to the correct ridge at branch points. Ridges diverge coming down and a mistake of a few feet at a branch point high up can lead to a mistake of a few miles at the bottom of the mountain. Conversely stream beds diverge going up and choice of the wrong gully can lead to a surprise at the top of a secondary ridge far from the summit objective.

Learn to track footprints and to follow your footprints upon return. Know how to locate the North Star and to recognize the Big Dipper. Make use of the fact that the sun rises in the east and sets in the west. For the leader to lose a map is embarrassing; carry a spare!

Stress and Emergencies* -** Navigating is much more difficult under stressful conditions than under usual conditions. Stress may occur in the leader for a variety of reasons: The party is delayed and darkness is near, the trail on the topo is wrong, the map blew away, or someone in the party may challenge the leader and create uncertainty as to the route. Stress may destroy memory and make judgment faulty. It takes conscious mental work for the leader to keep cool and clear. Take time, write things down and consult with knowledgeable people in the party. Experience is the best preventative for stress and practice is the way to obtain experience. Try navigating on the assumption that the map or compass is lost. ***Practice!

If unsure of location, stop and analyze the situation. Do not count on "lucking out" only to get further at sea. Study the map and try to reconstruct what might have happened. Form hypotheses as to position methodically look for a match between the observed terrain and a corresponding place on the map. Climb a tree or a nearby hill to get a different view. Compose a plan and try it out on other members of the group. Maintain control, communications, and composure. Resist snap decisions, think it through.

Does it All Add Up? Use all navigational techniques to support one another. Redundancy of information is good. Does all of the evidence as to position add up - bearings to features, altitude, terrain shape, distances to features, size of features, bearings of local route segment, successive fixes along the route?

Use all the clues! Do all the clues confirm the position? Practice!