Advanced Vectors

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I. Location and Distance on Earth

Objectives:

1. Explain the grid system used for locating places and features on Earth.
2. Use Earth's grid system to accurately locate a place or a feature.
3. Explain the relationship between latitude and the angle of the North Star (Polaris) above the horizon.
4. Explain the relationship between longitude and solar time.

A. Introduction

Globes and maps each have a system of north-south and east-west lines called the **Earth's grid** that forms the basis for locating points on Earth (Figure 1). The grid is, in effect, much like a large sheet of graph paper that has been laid over the surface of Earth. Using the system is very similar to using a graph; that is, the position of a point is determined by the intersection of two lines.

Latitude is north-south distance on Earth. The lines (circles) of the grid that extend around Earth in an east-west direction are called **parallels of latitude**. *Parallels of latitude mark north and south distance from the* ***equator*** *on Earth's surface*. As their name implies, these circles are parallel to one another. Two places on Earth, the North Pole and the South Pole, are exceptions. They are **points** of latitude rather than lines.

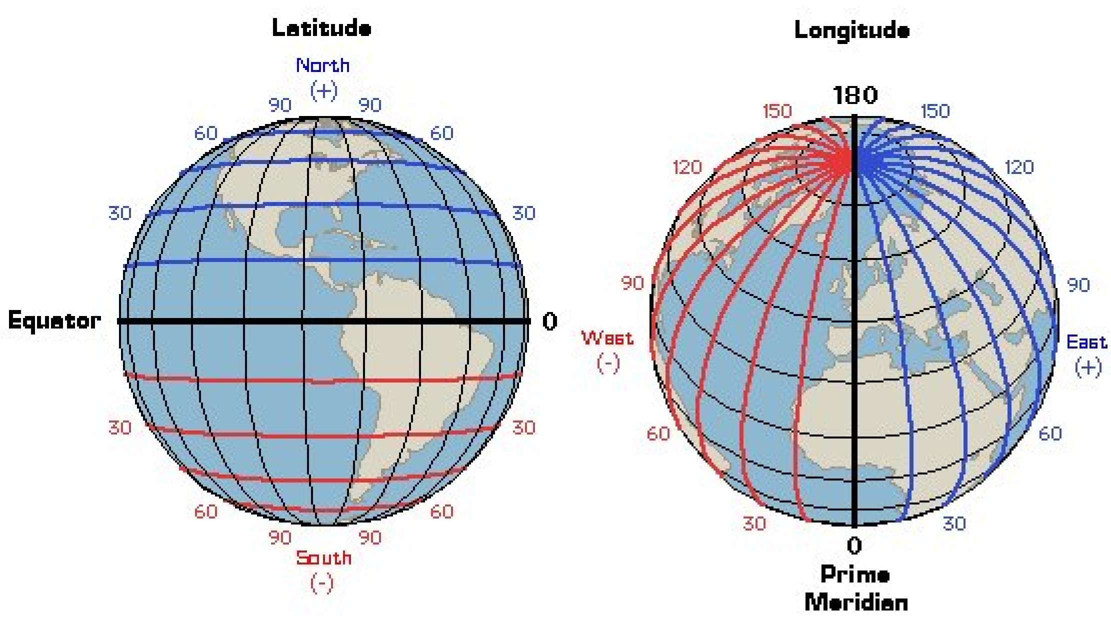


Figure 1 - Earth's grid system

Longitude is east-west distance on Earth. **Meridians of longitude** are each halves of circles that extend from the North Pole to the South Pole on one side of Earth. *Meridians of longitude mark east and west distance from the* ***prime meridian*** *on the Earth's surface.* Adjacent lines of longitude are farthest apart on the equator and converge as they approach the poles.

The intersection of a parallel of latitude with a meridian of longitude determines the location of a point on Earth's surface.

Earth's shape is nearly spherical (actually, it is an *oblate spheroid*). Since parallels and meridians mark distances on a sphere, their designation, like distance around a circle, is given in *degrees* (º). For more precise location, a degree can be broken down into sixty equal parts called *minutes* (') and a minute of angle can be divided into sixty parts called *seconds* ("). Thus, 31º10'20" means 31 degrees, 10 minutes, and 20 seconds.

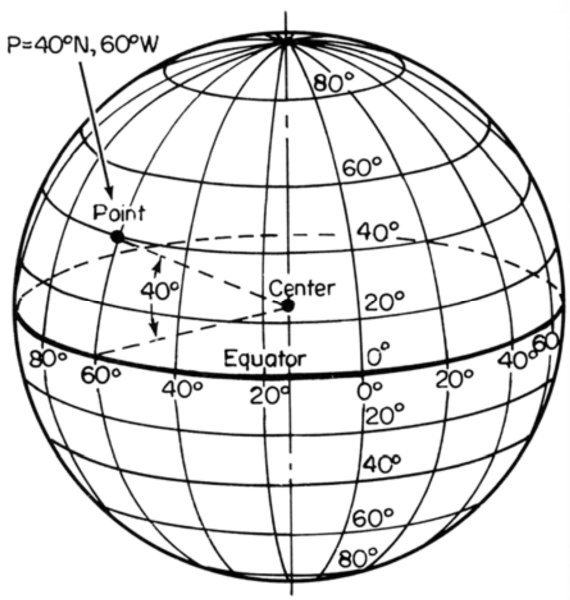


Figure 2

The type of map or globe used determines the accuracy to which a place may be located. On detailed maps, it is often possible to estimate latitude and longitude to the nearest degree, minute, and second. On the other hand, when using a world map or globe, it may only be possible to estimate latitude and longitude to the nearest whole degree or two.

In addition to showing location on Earth, latitude and longitude can be used to determine distance. Knowing the shape and size of Earth, the distance in miles or kilometers covered by a degree of latitude or longitude has been calculated. These measurements provide the foundation for navigation.

B. Determining Latitude

The equator is a circle drawn on a globe that is equally distant from both the North and South poles. It divides the globe into two equal halves called **hemispheres**. The equator serves as the beginning point for determining latitude and is assigned the value 0º00'00" latitude.

Latitude is distance north and south of the equator measured as an angle in degrees from the center of the Earth (Figure 2).

Latitude begins at the equator, extends north to the North Pole, designated 90º00'00" N latitude, and also extends to the South Pole, designated 90º00'00" S latitude. *With the exception of the equator, the poles and all parallels of latitude are designated either N (if they are north of the equator) or S (if they are south of the equator).*

1. Refer to a globe or map and locate the equator. Figure 3 represents Earth with point B at its center. Sketch and label the equator on the diagram in Figure 3. Also label the north and south hemisphere.

2. On Figure 3, make an angle by drawing a line from point A on the equator to point B (the center of the Earth). Then extend the line from point B to point C in the Northern Hemisphere. The angle you have drawn (<ABD) is 45º. Therefore, by definition of latitude, Point C is at 45º N latitude.

3. Draw a line on Figure 3 parallel to the equator that also goes through Point C. All points on this line are 45º N latitude.

4. Using a protractor, measure <ABD on Figure 3. Then draw a line parallel to the equator that also goes through point D. Label the line with its proper latitude.

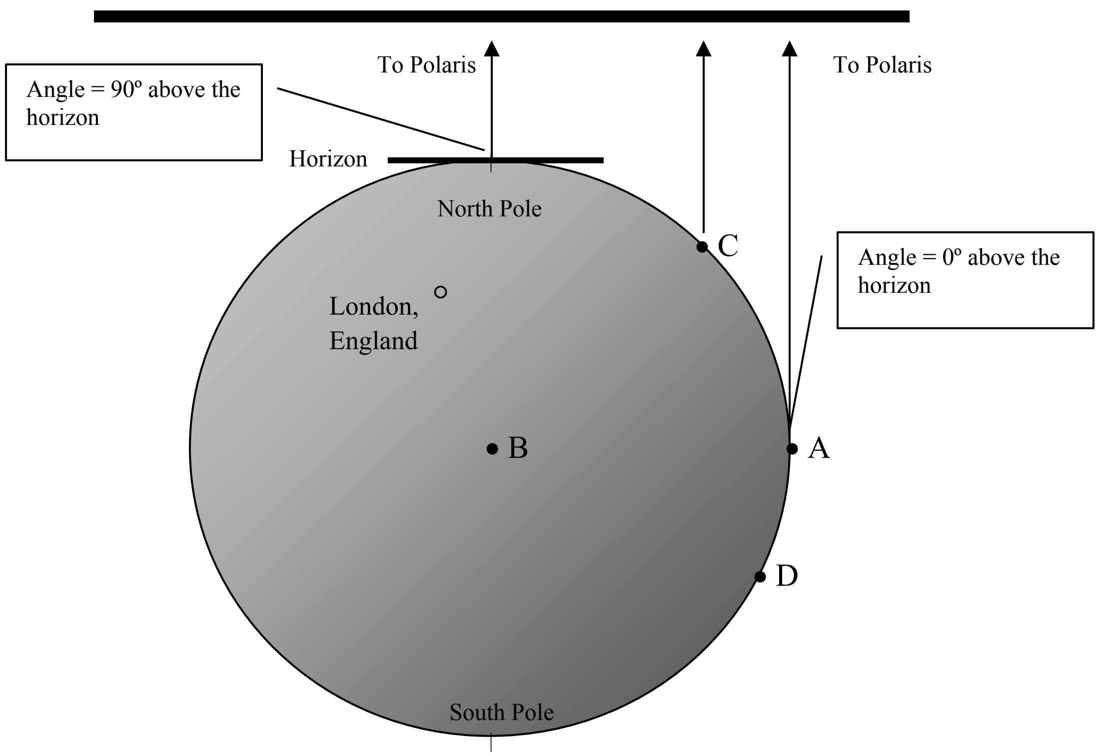


Figure 3

On a map or globe, parallels may be drawn at any interval.

5. How many degrees of latitude separate the parallels on the map you are using?

____

6. Keep in mind that the lines of latitude are parallel to the equator and each other. Locate some other prominent parallels on the map. Sketch and label a few of these parallels on Figure 3.

7. Use Figure 4 to answer the following questions:

a. Accurately draw and label the following additional parallels of latitude:
5ºN latitude   10ºS latitude   25ºN latitude

b. Write out the latitude for each designated point as was done for points **A** and **B**

Point A	30ºN	Point D	_______
Point B	5ºS	Point E	_______
Point C	_____	Point F	________

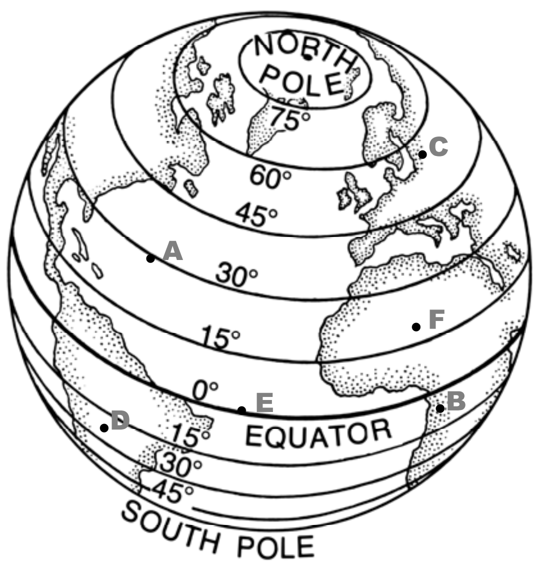


Figure 4

8. Use a globe or map to locate the cities listed below and give their latitude to the nearest degree. Indicate N or S and include the word "latitude".

Moscow, Russia: ________________________________

Durban, South Africa: _____________________________

Braintree, MA: ____

Quito, Ecuador: _______________________________________

9. Use a globe or map and give the name of a city or feature that is as far south of the equator as Braintree is north.

____

10. The farthest one can be from the equator is:

a. 45º of latitude   b. 90º of latitude   c. 180º of latitude

11. There are four special parallels of latitude marked and named on most globes. Use a globe or map to locate the following special parallels and indicate the name given to each.

66º30'00" N latitude _______________________________________

23º30'00" N latitude _______________________________________

66º30'00" S latitude _______________________________________

23º30'00" S latitude _______________________________________

Latitude and the North Star

These days, most ships use GPS devices to determine their location. However, early explorers were well aware of the concept of latitude and could use the angle of the North Star (Polaris) above the horizon to determine their north-south position in the Northern Hemisphere. As shown on Figure 4, someone standing at the North Pole would look overhead (90º angle above the horizon) to see Polaris. Their latitude is 90º00'00" N. On the other hand, someone standing on the equator, 0º00'00" latitude, would observe Polaris on the horizon. Use Figure 4 to answer the following questions.

12. At what angle above the horizon would someone standing at Point C see Polaris? ____________________.

13. What is the angle (measured from the horizon) for Polaris at the following cities?

Fairbanks, AK: ____________________________________

St. Paul, MN: _____________________________________

New Orleans, LA: ___________________________________

Sao Paulo, Brazil: ___________________________________

Braintree, MA: _____________________________________

C. Determining Longitude

Meridians are the north-south lines on the globe that converge at the poles and are farthest apart on the equator. They are used to determine longitude, which is distance east and west on Earth. Each meridian is a half circle on one side of the globe.

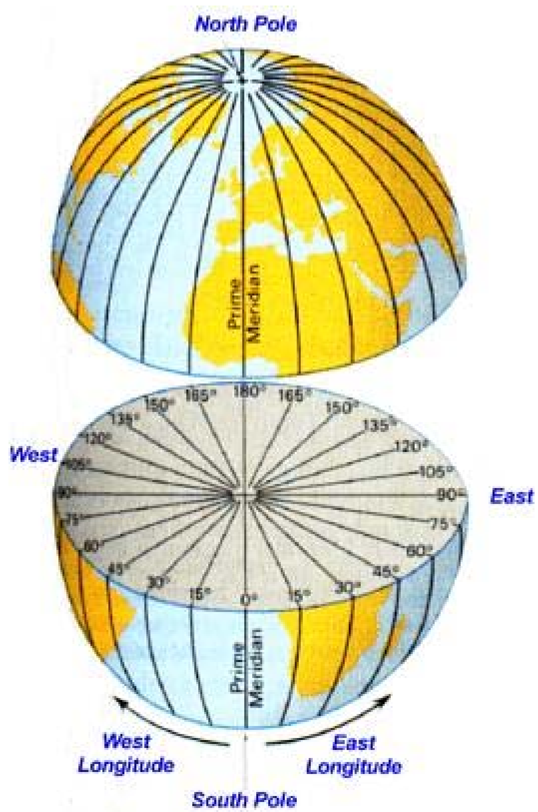


Figure 5

Notice on the globe that all meridians are alike. The choice of "zero longitude" was arbitrary. The meridian that was chosen by international agreement in 1884 to be 0°00'00" longitude passes through the Royal Astronomical Observatory at Greenwich, England. This internationally accepted reference for longitude is named the Prime Meridian.

> Longitude is distance, measured as an angle in degrees east and west of the prime meridian.

Figure 6 - The Prime Meridian

Longitude begins at the prime meridian and extends to the east and to the west, half way around the Earth to the 180°00'00" meridian, which is directly opposite the prime meridian. All meridians, with the exception of the prime meridian and the 180° meridian are designated either E or W.

14. Locate the prime meridian on a globe or map. Sketch and label it on the diagram of the Earth, Figure 3.

15. Label the Eastern Hemisphere and Western Hemisphere on Figure 3.

16. How many degrees of longitude separate each of the meridians on the globe or map you are using? ______________________.

17. Keep in mind that meridians are farthest apart at the equator and converge at the poles. Sketch and label several meridians on Figure 3.

18. Use Figure 7 to answer the next two questions.

a. Accurately draw and label the following additional meridians of longitude on Figure 7:

- 35° W longitude   10° E longitude   40° W longitude

b. Write out the longitude for each designated point as was done for points **A** and **B**.

Point A	30ºE	Point D	_______
Point B	5ºS	Point E	_______
Point C	_____	Point F	________

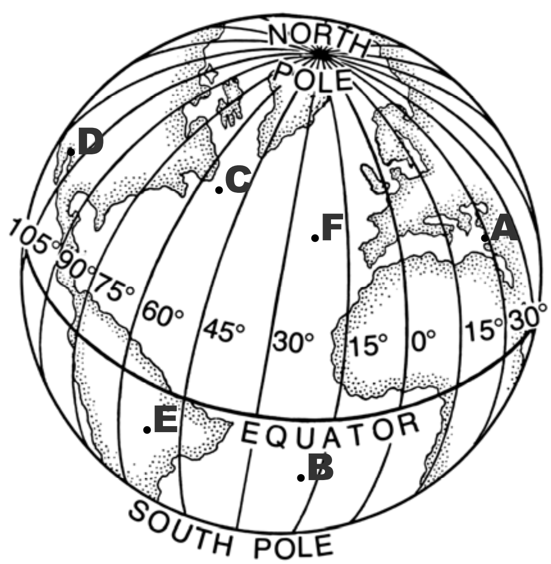


Figure 7

19. Use a globe or map to locate the cities listed below and give their longitude to the nearest degree. Indicate either E or W and include the word "longitude"

Wellington, New Zealand: ____________________________

Honolulu, Hawaii: _________________________________

Braintree, Mass.: ____________________________________

20. Give the name of a city or feature that is as far east of the prime meridian as Braintree is west.

____

21. The farthest one can be east or west of the prime meridian is:

a. 45º of longitude   b. 90º of longitude   c. 180º of longitude

Longitude and Time

Time, while independent of latitude, is very much related to longitude. This fact allows for time to be used in navigation to accurately determine one's location. Knowing the difference in time between two places, one with known longitude, the longitude of the second place can be determined.

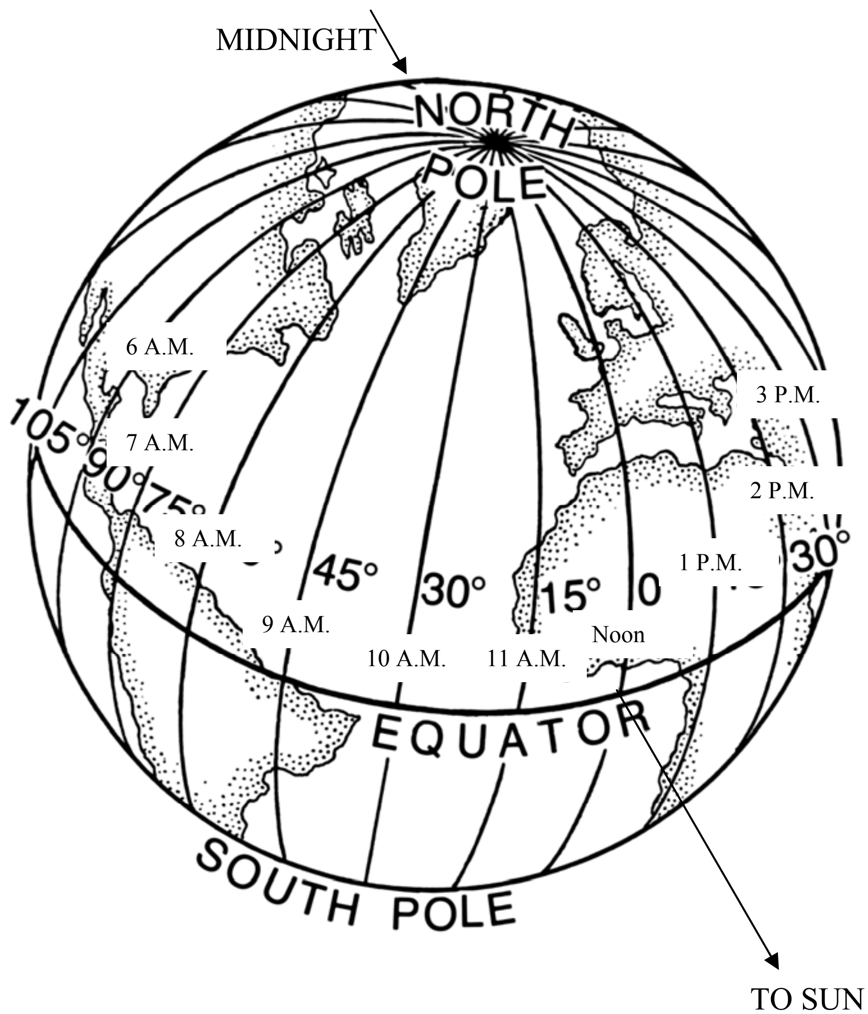
Time on Earth can be kept in two ways. **Solar time** uses the position of the sun in the sky to determine time. **Standard time**, the system used throughout most of the world, divides the globe into 24 standard time zones. Everyone living within the same standard time zone keeps the clock set the same. Of the two, solar time is used to determine longitude.

The following basic facts are important to understanding time:

- Earth rotates on its axis from west to east or counterclockwise when viewed from above the North Pole.
- It is noon, solar time, on the meridian that is directly facing the sun (the sun has reached its highest point in the sky or *zenith*) and midnight on the meridian on the opposite side of Earth.
- The time internal from one noon by the sun to the next noon averages 24 hours and is known as the *mean solar day*.
- Earth turns through 360° of longitude in one mean solar day, which is equivalent to 15° of longitude per hour or 1° of longitude every 4 minutes.
- Places that are east or west of each other, regardless of the distance, have different solar times. For example, people located to the east of the noon meridian have already experienced noon; their time is afternoon [P.M -

post (after) *meridiem* (the noon meridian)]. People living west of the noon meridian have yet to reach noon; their time is before noon [A.M. - *ante* (before) *meridiem* (the noon meridian)]. *Time becomes later going eastward and earlier going westward.*

Figure 8



22. What would be the solar time of a person living 1° of longitude west of the noon meridian?

Solar time: __________ (A.M., P.M.)

23. What would be the solar time of a person locate 4° of longitude east of the noon meridian?

Solar time: __________ (A.M., P.M.)

24. If it is noon, solar time, at 70°W longitude, what is the solar rime at each of the following locations?

SOLAR TIME

72°W longitude ____

65°W longitude ____

90°W longitude ____

110°E longitude ____

Early navigators had to wait for the invention of accurate clocks called *chronometers* before they could determine their longitude. Today, most navigation is done using GPS but ships still carry chronometers as a back-up system.

The ship-board chronometer is set to keep the time at a known place on Earth, for example, the prime meridian. If it is noon by the sun where the ship is located, and at that same instant the chronometer indicates that it is 8 A.M. on the prime meridian, the ship must be 60° of longitude (4 hours difference X 15° per hour) east (the ship's time is later) of the prime meridian. The difference in time need not be in whole hours. Thirty minutes difference in time between two places would be equivalent to 7.5° of longitude, twenty minutes would equal 5° and so on.

25. It is exactly noon by the sun at a ship's location. What is the ship's longitude if, at that instant, the time on the prime meridian is the following (Note: Drawing a diagram showing the prime meridian, the ship's location east or west of the prime meridian, and the difference in hours may be helpful):

6:00 P.M. ___________________________________

1:00 A.M. ___________________________________

Midnight ___________________________________

2:30 P.M. ___________________________________

3:30 A.M. ___________________________________

D. Using Earth's Grid System

Using both parallels of latitude and meridians of longitude, you can accurately locate any point on the surface of Earth.

26. Using Figure 9, determine the latitude and longitude of each of the lettered points. As a guide, Point A has already been done for you. Remember to indicate whether the point is N or S latitude and E or W longitude. Convention dictates that latitude is listed first.

Point A: <u>30°N latitude</u> <u>60° E longitude</u>

Point B: ___________ ____________

Point C: ___________ ____________

Point D: ___________ ____________

Point E: ___________ ____________

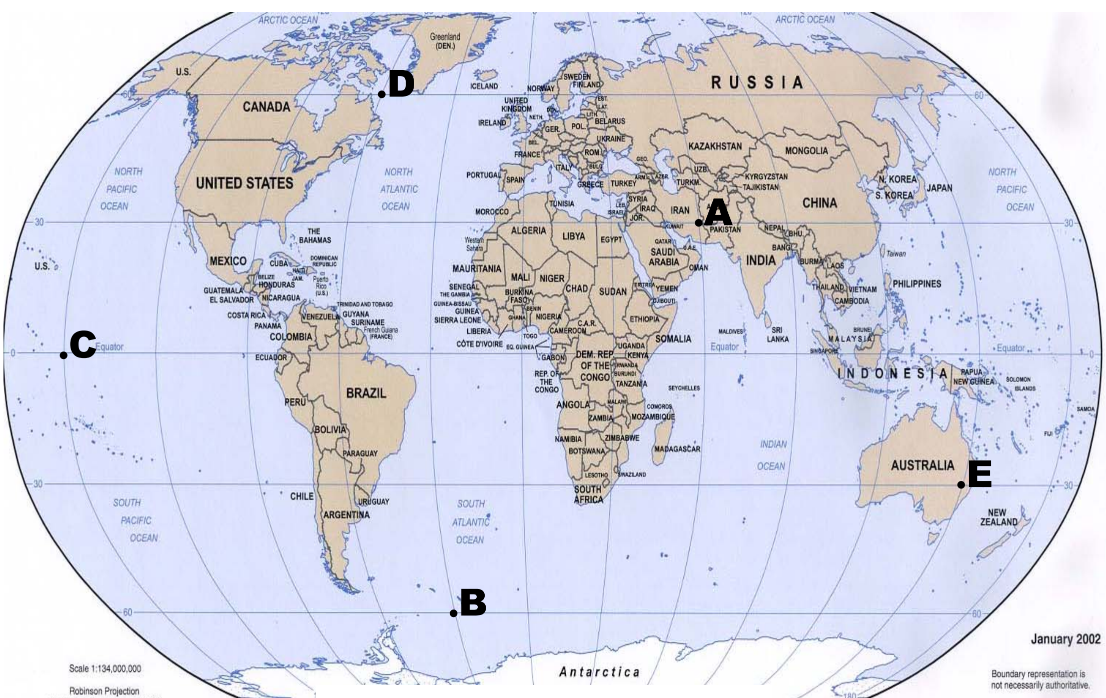


Figure 9

27. Label the following points on Figure 9:

Point F: 15° S latitude, 75° W longitude
Point G: 45° N latitude, 0° longitude
Point H: 30° S latitude, 60° E longitude
Point I: 0° latitude, 30° E longitude

28. Use a globe or map to determine the latitude and longitude of the following cities:

Kansas City, MO: ________________________________

Miami, FL: ____________________________

Oslo, Norway: __________________________________

Auckland, New Zealand: ________________________________

Quito, Ecuador: _____________________________________

Cairo, Egypt: ______________________________________

29. Determine the city or feature at the following locations:

19°28' N latitude, 99°09' W longitude ____________________________

41°52' N latitude, 12°37' E longitude ____________________________

1°30' S latitude, 33°00' E longitude ____________________________

E. Extension

Explore Google Earth (download at http://earth.google.com/). This is a great way to explore places around the globe from a "bird's eye" view.

II. Map Reading and Land Navigation

Objectives:

1. Explain the different types of maps and their usage.
2. Explain the concept of *map scale.*
3. Explain how contour lines are drawn and be able to use contours to determine elevation, relief, and slope.
4. Accurately measure horizontal and vertical distance on a topographic map.
5. Identify the parts and explain the function of an orienteering compass.
6. Accurately orient a topographic map.
7. Use a map and compass to determine an *azimuth.*
8. Explain the difference between magnetic north, grid north, and true north.
9. Given a map and compass, accurately triangulate your position.
10. Use an orienteering map and compass to locate points within a woodland environment.

A. Introduction

Several years ago I was hiking in the White Mountains when I came across two backpackers who were obviously in distress. One was nursing a leg injury and the two were trying to get back to the trailhead by the shortest route possible. They had a GPS device (that they didn't know how to use) and a *road* map (that they didn't know how to read) and they were tremendously lost and beginning to panic. After a brief conversation, I determined that these two had been stumbling through the woods for hours moving in exactly the wrong direction. I gave them an extra compass I had along with a quick period of instruction on how to use it and the map and sent them on their way.

If you don't know where you are, you can't get where you're going (you can read that literally and metaphorically). The purpose of this unit is to provide you tools that you can use to avoid getting lost and to navigate in any environment.

B. Maps

Road maps (Figure 1) work just fine if you are in a car but they are *planimetric* which means they show topography in a dead-flat perspective. Hills and valleys don't mean much if you are in a car but they sure do if you are walking. For any kind of wilderness travel, you need a map that shows all the ups and downs. This is where topographic maps come in handy.

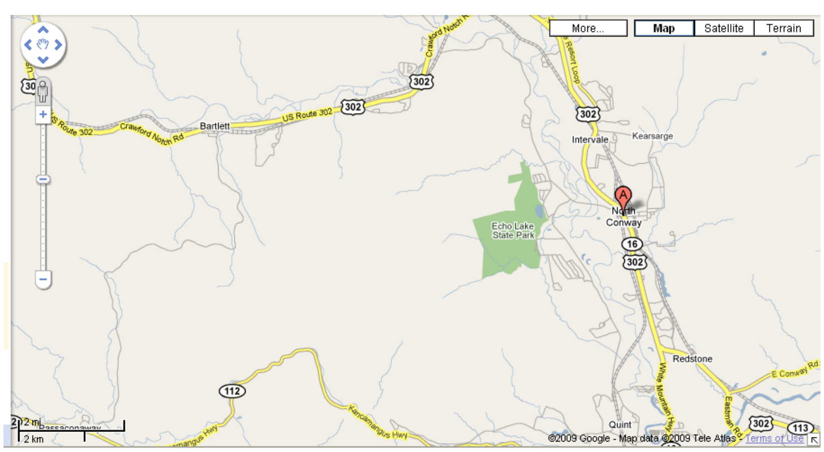


Figure 1

Figure 2 shows the same area in relief. It should be obvious why there are no roads leading directly west from North Conway. All modern maps are made from aerial photographs that give a precise picture of the land (Figure 3). Cartographers (map makers) use these photos to construct topographic maps in a variety of scales.

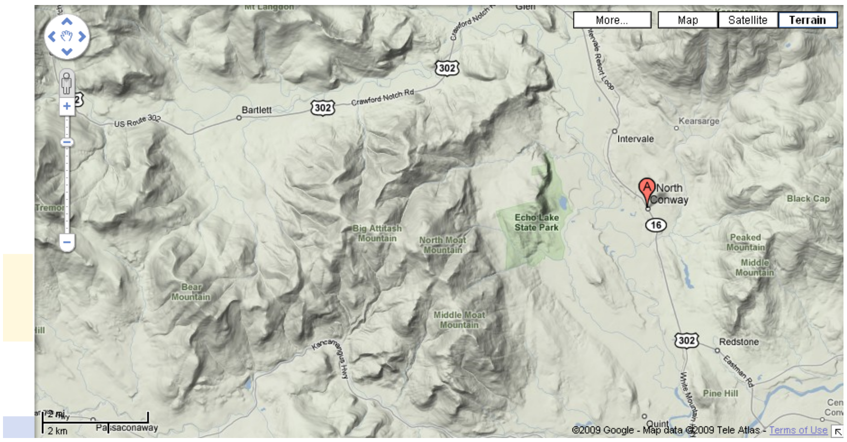


Figure 2

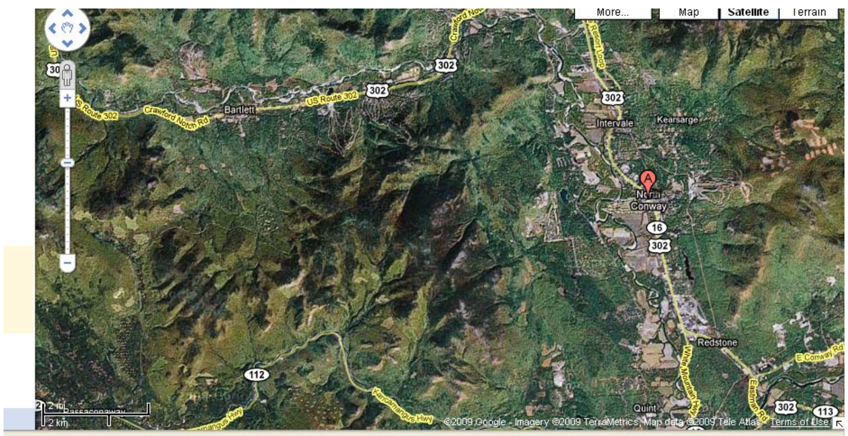


Figure 3

Topography means "shape of the land". Each topographic map shows, to scale, the width, length, and variable height of the land above a datum or reference plane - generally average sea level. The maps, which are also referred to as quadrangles, are two-dimensional representations of the three-dimensional surface of Earth.

To facilitate their use, topographic maps follow a similar format. In addition to standard colors and symbols, each contains information about there area mapped is located, date when the mapping was done or revised, scale, north arrow, and names of adjoining quadrangle maps.

Obtain a copy of a topographic map and examine it. Use this map to answer questions below. DO NOT WRITE OR MAKE MARKS ON THE MAPS!!!!

1. What is the name of the map? ____

Notice the small reference map and compass arrow in the lower margin of the map.

2. In what part of the state (North, Central, Southwest, etc.) is the area covered by your map located? ____

The names of adjoining maps are given along the four margins and four corners of the map.

3. What is the name of the map that adjoins the northeast corner of your map?

____

Information about when the area was surveyed and the map published is provided in the margin of the map.

4. When was the area surveyed? When was the map published? If the map has been revised, when was the revision complete?

Surveyed: _______ Published: _______ Revised: _______

Since the geographic North Pole and the magnetic North Pole of the Earth do not coincide, the north arrow on a topographic map often shows the difference between true north (TN) and magnetic north (MN) for the map area. This difference in degrees is called the magnetic declination.

5. What is the magnetic declination of the area shown on your map? __________

Map Colors and Symbols

Each symbol and color used on a U.S. Geological Survey topographic map has a meaning. Refer to Appendix II and examine the standard USGS map symbols. Use these to answer the following questions:

6. In general, what color(s) are used for the following types of features?

Highways and Roads ____

Buildings: ____

Urban Areas: ____

Wooded Areas: ____

Water Features: ____

Scale

Many people have built or seen scale model airplanes or cars that are miniature representations of the actual objects. Maps are similar in that they are "scale models" of Earth's surface. Each map will have a **map scale** that expresses the relation between distance on the map to the true distance on Earth's surface. Different map scales depict an area on Earth with more or less detail. On a topographic map, scale is usually indicated in the lower margin and is expressed in two ways.

Fractional scale (e.g. 1:24,000 or 1/24,000) means that a distance of one unit on the map represents a distance of 24,000 of the *same* units on the ground. For example, one inch on the map represents 24,000 inches on the ground. One of your thumb lengths on the map equals 24,000 of your thumb lengths on the ground. Etc. Maps with small fractional scales (fractions with large numbers in the denominator, e.g. 1/250,000) cover large areas. Those with large fractional scales (fractions with small numbers in the denominator, e.g. 1/1,000) cover small areas. See Figure 4.

Graphic or **bar scale** is a bar that is divided into segments that show the relation between distance on the map to actual distance on Earth. (See Figure 6). Scale showing miles, feet and kilometers are generally included. The left side of the bar is often divided into fractions to allow for more accurate measurement of distance. The graphic scale is more useful that the fractional scale for measuring distances between points. Graphic scales can be used to make your own "map ruler" for measuring distances on the map using a piece of paper or string.

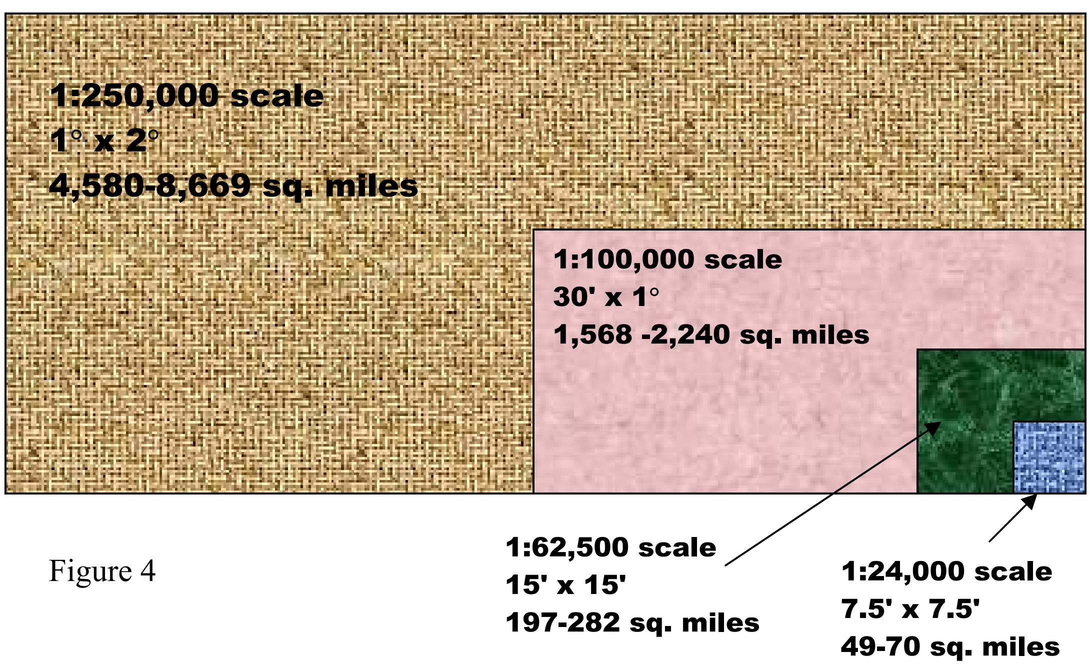


Figure 4

7. Examine the topographic map as well as the large wall maps and write out the fractional scale for each in the spaces below:

Topographic map: ______________________________

Wall map: ____________________________________

A. Which of these maps has the smallest scale (largest denominator in the fractional scale)? ________________________

B. Which of these maps covers more square miles? _________________

8. Depending on the map scale, one inch on a topographic map represents various distances on Earth. Convert the following scales:

Scale	**1 inch on the map represents**
1:24,000	________________________
1:63,600	________________________
1:250,000	________________________

9. Use the graphic scale provided on your topographic map to construct a "map ruler" in miles and measure the following distances that are represented on the map.

Width of the map along the south edge = __________________ miles

Length of the map along the east edge = ___________________ miles

10. How many square miles are represented on your topographic map?

_______________________ $miles^2$

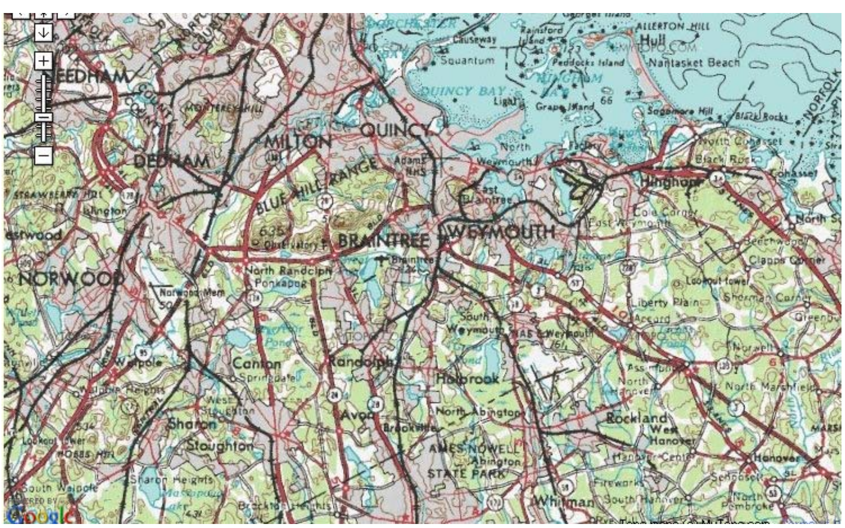


Figure 5 - small scale map of Braintree.

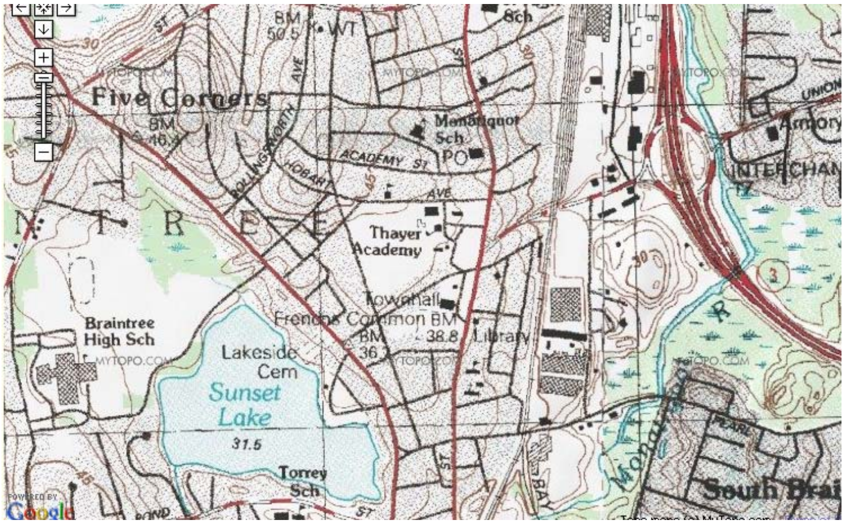


Figure 6 - large scale map of Braintree.

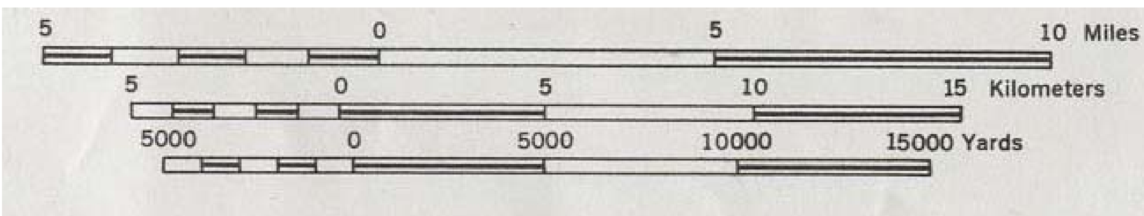


Figure 7 - Typical graphic scale

Location

One of the most useful functions of a topographic map is determining the precise location of a feature on Earth's surface. The most common method for designating the location of a point is latitude and longitude. Other methods include the Universal Transverse Mercator system (UTM) and the Military Grid Reference System (MGRS).

Latitude and Longitude. Topographic maps are bounded by parallels of latitude on the north and south and by meridians of longitude on the east and west. The latitudes and longitudes covered by the quadrangles are printed at the four corners of the map in degrees, minutes, and seconds and are indicated at internals along the margins. Maps that cover 15 minutes of latitude and 15 minutes of longitude are called *15-minute series topographic maps*. A 7 1/2 minute series topographic map covers 7 1/2 minutes of latitude and 7 1/2 minutes of longitude.

Use the North Conway West Quadrangle topographic map to answer the following questions:

11. What are the latitudes of the southern edge and the northern edge of the map to the nearest 1/2 minute of latitude?

Latitude of southern edge: _____________________________

Latitude of northern edge: ______________________________

12. How many total minutes of latitude does the map cover? ________________

13. What are the longitudes of the eastern and western edges of the map to the nearest 1/2 minute of longitude?

Longitude of eastern edge: ____________________________

Longitude of western edge: ___________________________

14. How many minutes of longitude does the map cover? __________________

15. The map is a ________- minute series topographic map because it covers _________ minutes of latitude and _________ minutes of longitude.

*16. The total minutes of latitude and total minutes of longitude covered by the map are equal. Why is the appearance of the map rectangular rather than square?

____

____

17. Use the North Conway West Quadrangle map to determine the latitude and longitude (to the nearest minute) for the following features:

Gravel pit, western edge of map: ____________ ____________

North Conway Hospital: ____________ ____________

Summit of North Moat Mountain: ____________ ____________

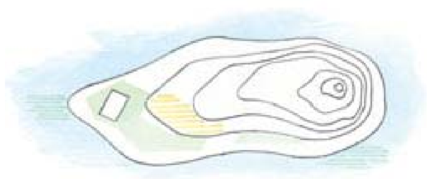
Intersection of Ellis and Saco rivers: ____________ ____________

Contour Lines

Depicting the height or elevation of the land, thereby showing the shape of landforms, is what makes a topographic map unique. A contour line is a line drawn on a topographic map that connects all points that have equal elevations above or below a datum or reference plane on Earth's surface. The reference plane from which elevations are measured for most topographic maps is mean sea level (MSL).

The Landscape

A Relief Model



Contour Lines

Contour lines must conform to certain guidelines. Here are the most important ones:

1. A contour line connects points of equal elevation.

2. A contour line never branches or splits.

3. Steep slopes are shown by closely spaced contours.

4. Contour lines never cross.

5. Hills are represented by a concentric series of closed contour lines.

6. When contour lines cross streams, they form a "V" that points upstream.

The **contour interval** is the vertical difference in elevation between adjacent contour lines. All contour lines are multiples of the contour interval. For example, for a contour interval of 20 feet, the lines may read 420', 440', 460', etc. Most maps use the smallest contour interval possible to provide the greatest detail for the surface that is being mapped. The contour interval of a topographic map is usually indicated in the lower margin on the map. The contour interval should always be known before using a topographic map.

To help determine the elevation of the contour lines on most topographic maps every fifth contour line, called an **index contour**, is printed as a bold line and the elevation of the line is indicated. Reference points of elevation, called **bench marks** (BM), are also often present on the map and can be used to establish elevations.

Contour lines that are close together indicate a steep **slope** (vertical change in elevation per horizontal distance or, rise over run!), while widely spaced lines show a gradual slope. Consequently, the "shading" which results from closely spaced contour lines allows for the recognition of such features as hills, valleys, ridges, etc.

Relief is defined as the difference in elevation between two points on a map. *Total relief* is the difference between the highest and lowest points on a map. *Local relief* refers to the difference in elevation between two specified points, for example, a hill and a nearby valley.

(For extra review on contour lines go to: http://reynolds.asu.edu/topo_gallery/movies/topowat_nrm.mov)

Figure 8

Shaded relief photo of Mt. St. Helens, Washington. North is towards the lower right.

Figure 9 - Topographical map of Mt. St. Helens. North is at the top of the map. Notice how close together the contour lines are around the inside of the crater.

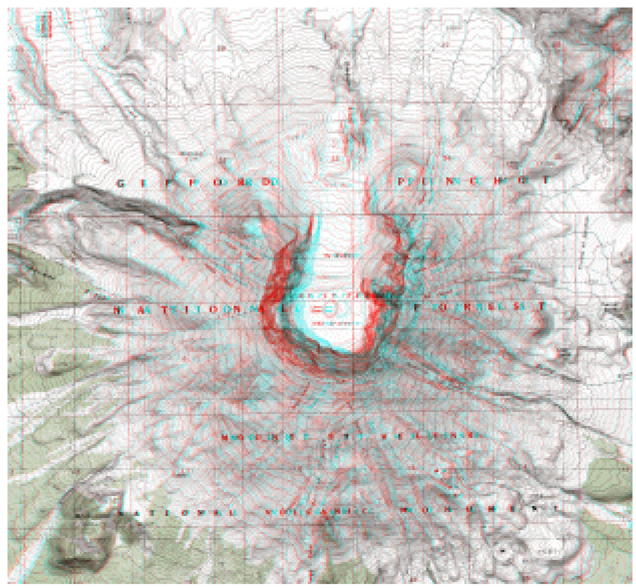


Figure 10 - Ground photo of Mt. St. Helens. The camera is pointing almost due south.

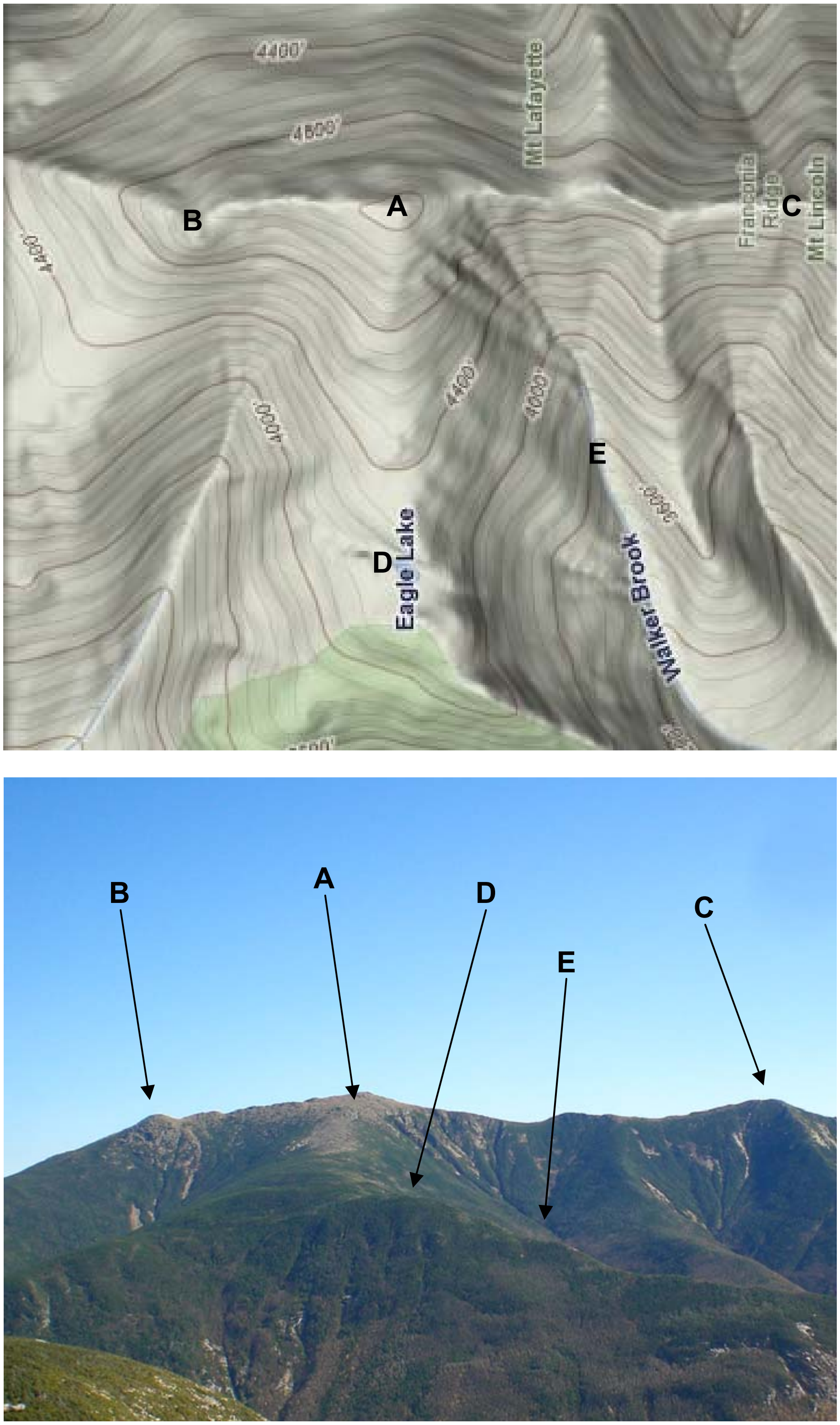


Figure 11 – Topographic Map and corresponding photograph of Franconia Ridge, New Hampshire. North is to the left. Eagle Lake (**D**) is located on a spur or finger leading west from the summit of Mt. Lafayette. Notice how the contour lines "V" upstream for Walker Brook (**E**).

Examining Contour Lines

Use the topographic map in Figure 11 to answer the following questions:

18. What contour interval has been used on the map? _____________

19. Write the letter "S" on the map in the area that has the steepest slope.

20. Give the elevations for the following points:

    Summit of Mt. Lafayette: __________________

    Eagle Lake: ________________________

    The "W" in Walker Brook: ________________________

21. What is the total relief shown on the map (highest elevation minus lowest elevation): _______________________

Use the North Conway West Quadrangle topographic map to answer the following questions:

22. What is the datum that has been used for determining the elevations on the map? ___________________________

23. What is the contour interval of the map? ___________________________

24. What is the total relief shown on the map? _________________________

25. What is the elevation of the exact center of the map? _________________

26. Determine the elevation for the following features:

    Gravel pit, western edge of map: ____________

    North Conway Hospital: ____________

    Summit of North Moat Mountain: ____________

    Intersection of Ellis and Saco rivers: ____________

27. West of its intersection with the Ellis River, in what general direction is the Saco River flowing? __________________________________

28. In what general direction is the Swift River (lower left corner of map) flowing? ___________________________

29. What is the straight-line distance, in feet, between the summit of North Moat Mountain and Thorn Hill (north-central part of map). _______________

30. What is the straight-line distance, in miles, between the summit of Mt. Pickering (north western part of map) and the summit of White Horse Ledge (central part of map). _____________________

C. Terrain Features

Terrain features are identified in the same manner on all maps, regardless of the contour interval, but you must realize that a hill in the Rocky Mountains will be much bigger than one in south Florida. You must be able to recognize all the terrain features to locate a point on the ground or to navigate from one point to another.

The five major terrain features are: **Hill, Ridge, Valley, Saddle, and Depression**. The three minor terrain features are: **Draw, Spur (or Finger) and Cliff.**

Terrain features can be learned using the fist or hand to show what each would look like on the ground.

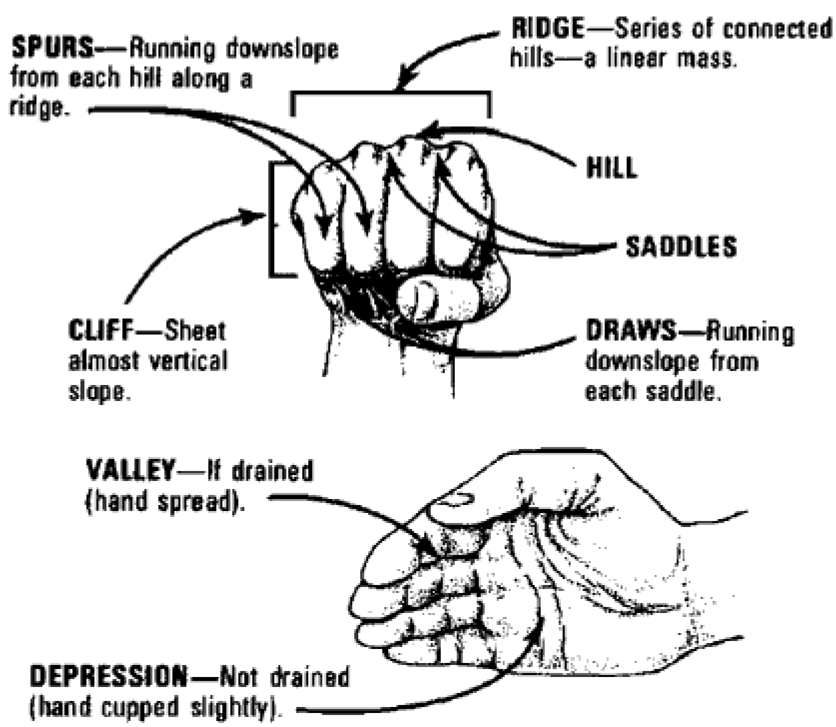
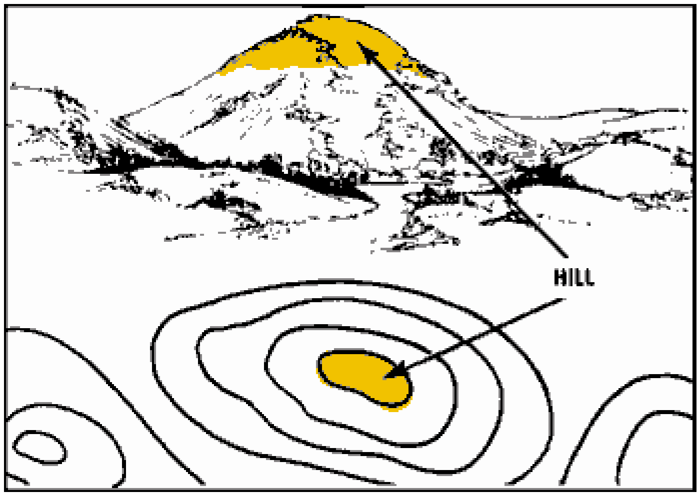


Figure 12

Hill - a point or small area of high ground. When you are on a hilltop, the ground slopes down in all directions.



Ridge - a line of high ground with height variations along its crest. The ridge is not simply a line of hills; all points of the ridge crest are higher than the ground on both sides of the ridge.

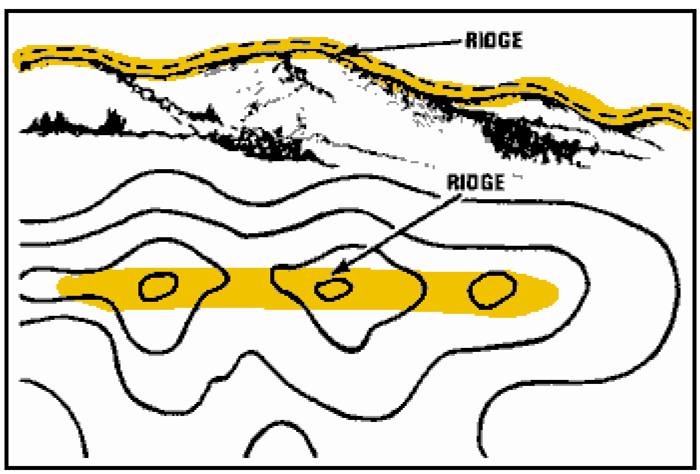


Figure 12

Valley - reasonably level ground bordered on the sides by higher ground. A valley may or may not contain a stream course. A valley generally has maneuver room within its confines. Contour lines indicating a valley are U-shaped and tend to parallel a stream before crossing it. The course of the contour line crossing the stream always points upstream.

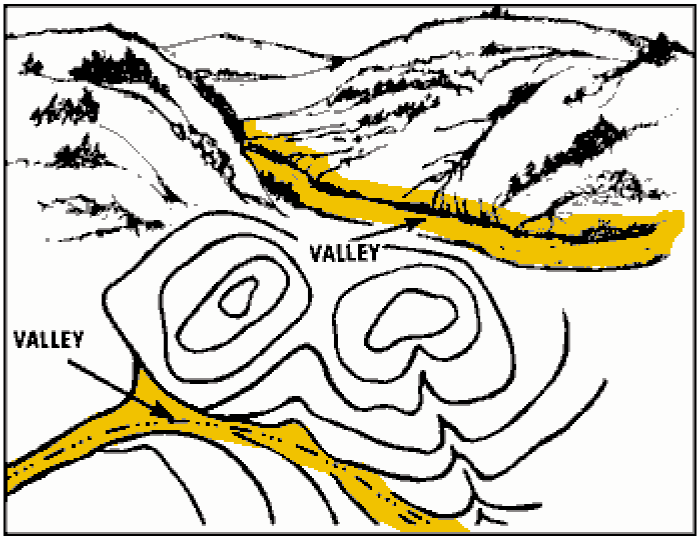


Figure 13

Saddle - a dip or low point along the crest of a ridge. A saddle is not necessarily the lower ground between two hilltops; it may be a break along an otherwise level ridge crest. *When you are standing in a saddle, the land slopes up in two directions and down in two direction.*

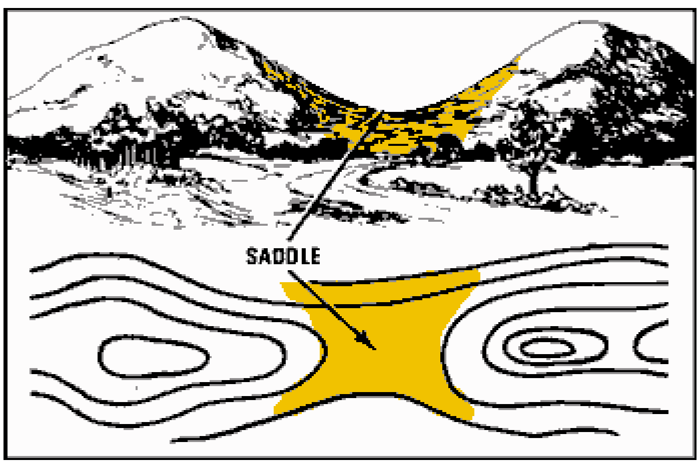


Figure 14

Depression - a low point or hole in the ground, surrounded on all sides by higher ground.

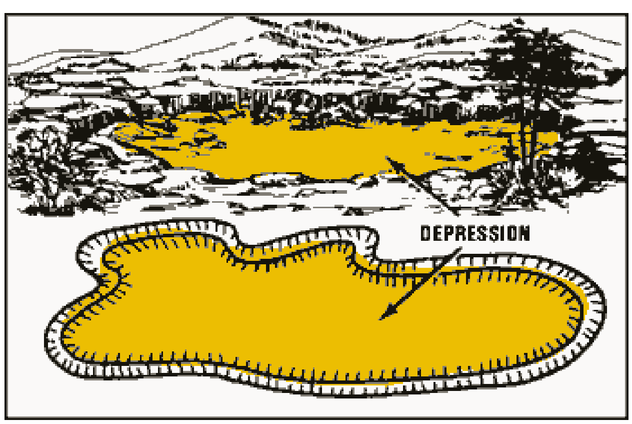


Figure 15

Minor terrain features
Although these features are not as important as the major terrain features, navigators can plan routes more successfully if they can identify all the terrain features their routes will cross over.

Draw - similar to a valley but smaller. Draws are often found along the sides of ridges and usually have water flowing in them (stream beds). Contour lines indicating a draw are shaped like a "V" with the point of the "V" toward the head of the draw (high ground). *When you are standing in a draw, the land slopes down in three directions and up in one direction.*

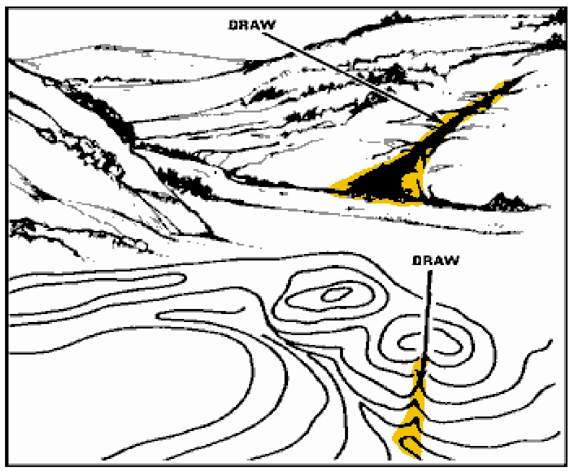


Figure 16

Spur (or Finger)—a usually short, continuously sloping line of higher ground, normally jutting out from the side of a ridge. A spur is often formed by two thoroughly parallel streams cutting draws down the side of a ridge. *When you are standing on a spur, the land slopes down in three directions and up in one direction.*

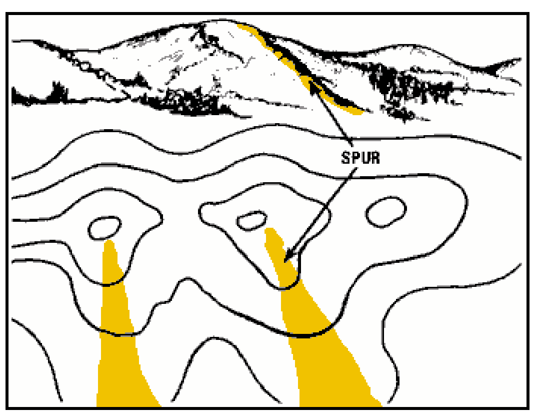


Figure 17

Cliff—a vertical or near-vertical slope. A cliff may be shown on a map by contour lines being close together, touching, or by a ticked "carrying" contour line. The ticks always point toward lower ground.

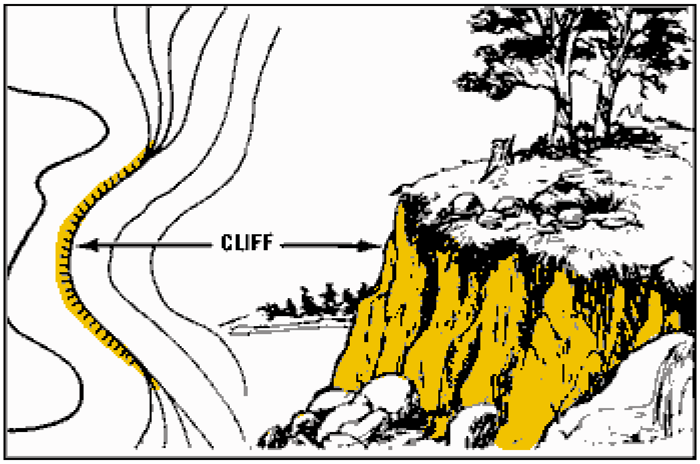


Figure 18

31. Refer to the north part of the North Conway Quadrangle map and the figure below to identify the terrain features associated with the letter.

A. ______________ B. _________________

C. ______________ D. _________________

E. ______________ F. _________________

G. ______________ H. _________________

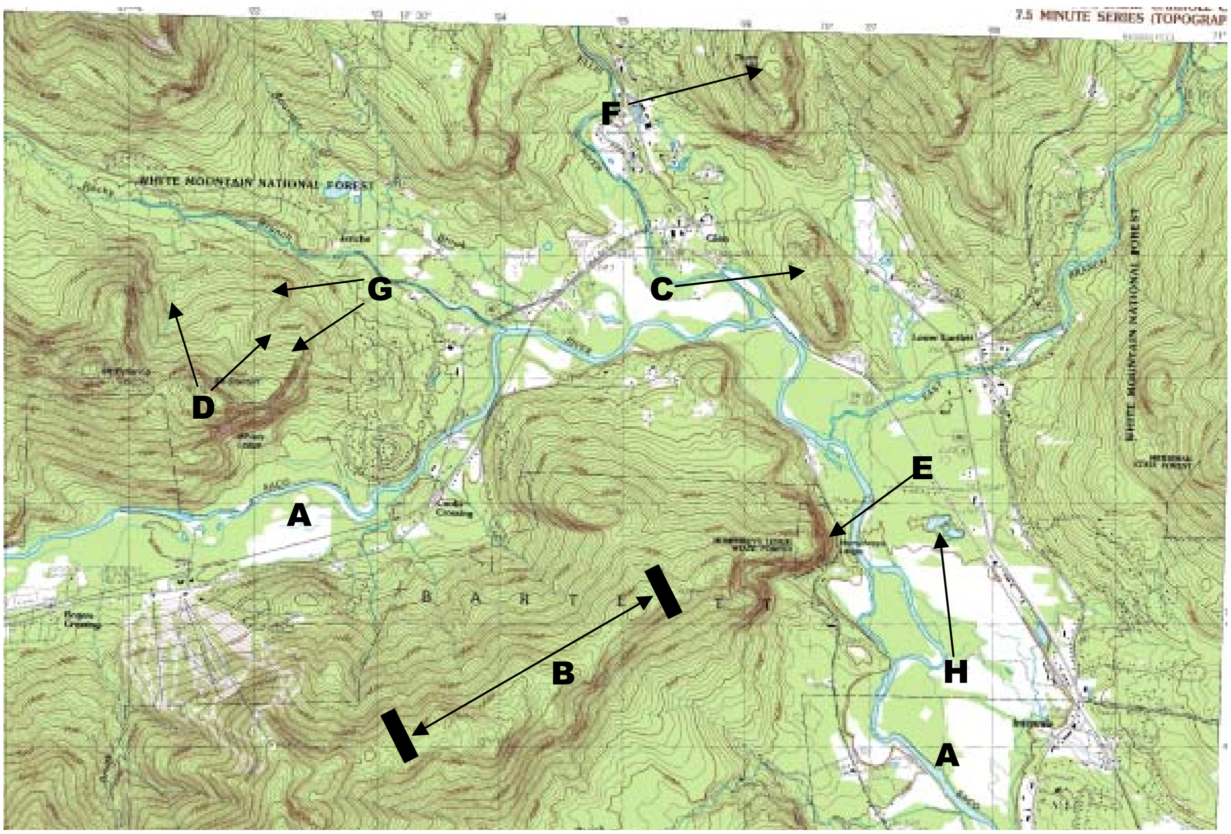


Figure 19

D. The Orienteering Compass

The compass was originally discovered by the Chinese 5000 years ago. Today, compasses come in a variety of forms for use on land, above and below the sea and in the air. Examples of activities in which compasses are used include:

- Hiking
- Cycling
- Driving
- Sailing
- Flying
- Mountaineering
- Surveying
- Military
- Scuba Diving
- Orienteering

The compass is graduated in degrees. There are 360° in the compass circle or *rose*. (Some military compasses are graduated in *mils* with 6,400 mils in the compass circle but, that degree of accuracy is not often needed). The cardinal directions North, South, East, and West are each 90° apart.

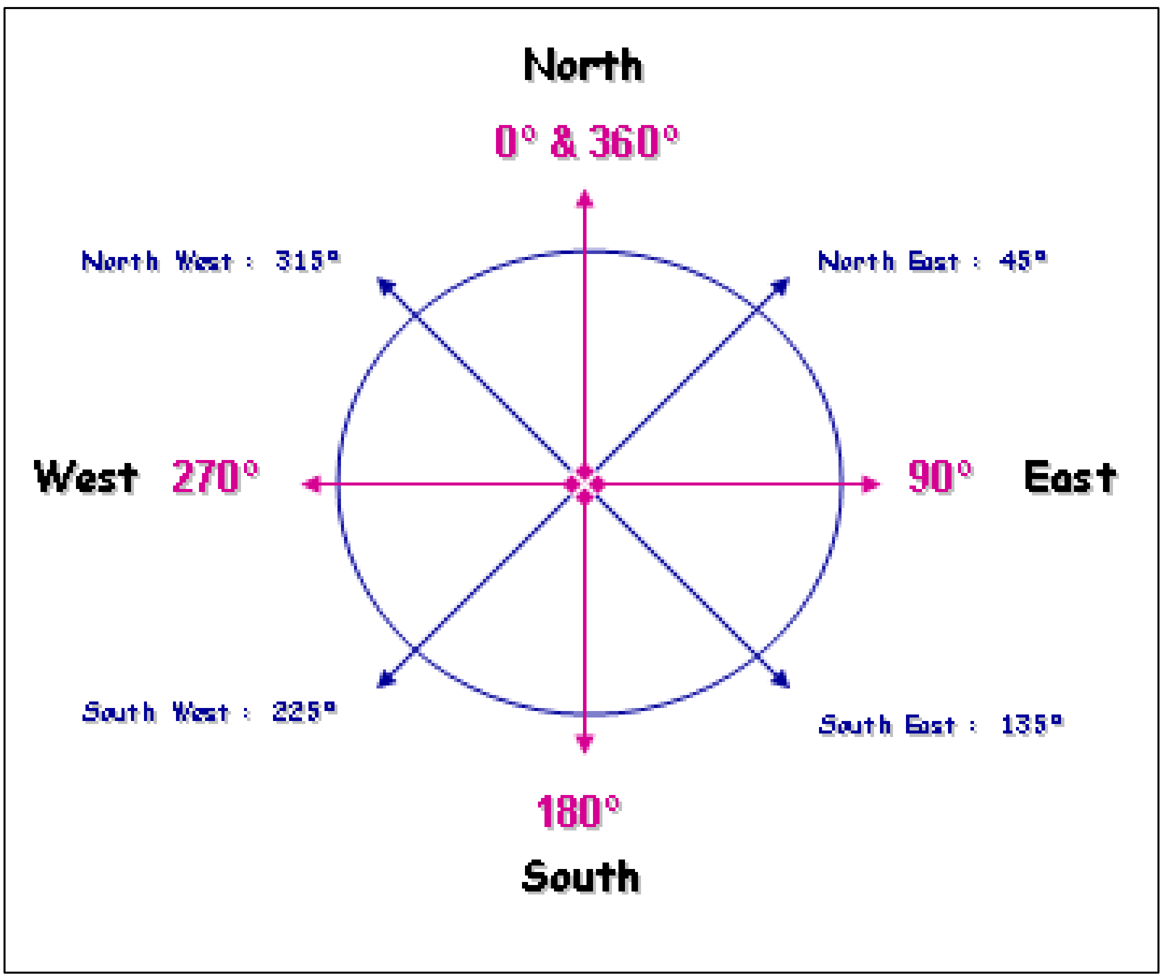


Figure 20

Parts of the orienteering compass

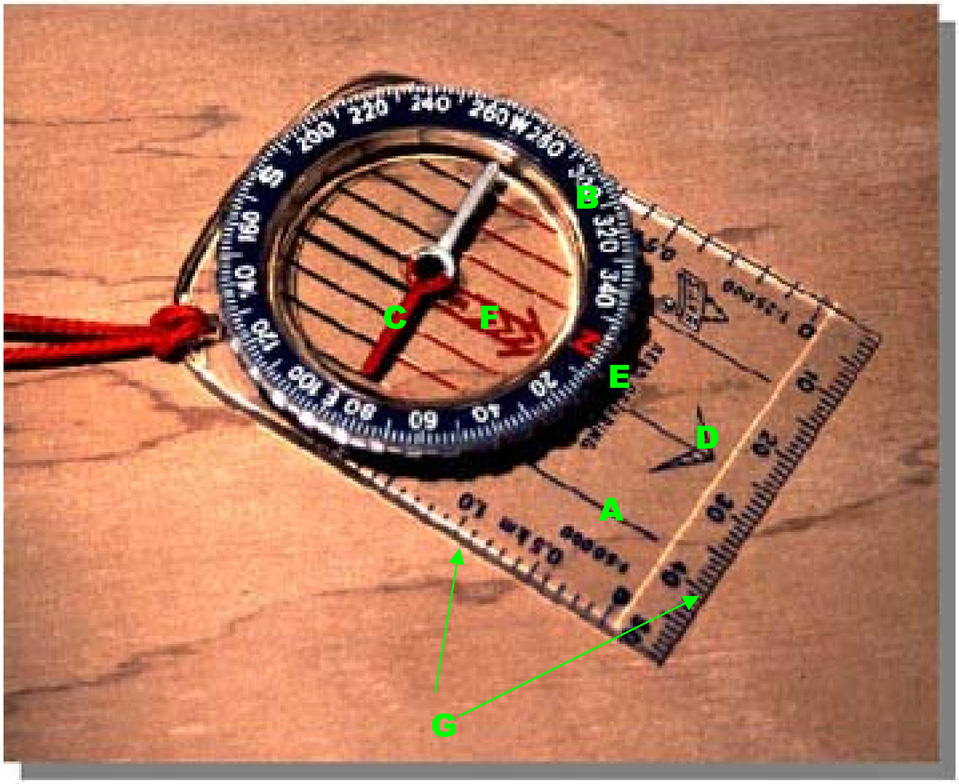


Fig. 21

A - Base Plate. This is the mounting for the Compass Housing. It also displays other information such as a scale and a ruler.

B - Compass Housing. Contains a magnetic bar called the **needle** and defines the points of a compass on a rotating **bezel ring**.

C - Needle or **North Seeking Arrow**. The needle is magnetized and always aligns itself with the Earth's magnetic field. The red end of the needle *always seeks north*.

D - Direction of Travel Arrow. Indicates the direction along which you wish to travel or take a bearing. The arrow is fixed within the base plate and the sides of the base plate run parallel to the arrow.

E - Index Line - Line used to set compass bearings. It is connected to the Direction of Travel Arrow. "Read Bearing Here" is a big hint.

F - Orienting Arrow. Fixed to the compass housing, usually in red.

G - Compass Scale. Nearly all compasses have a centimeter scale along the edge of the base plate to enable you to measure distances. Used in conjunction with the scale at the bottom of the map, the compass scale enables you to calculate the distance on the ground.

Points to note:

- Stand clear of metal objects when using the compass. They will cause the needle to deviate and create inaccurate bearings. Objects as small as belt buckles can make a difference.
- Don't stand beneath high-tension power lines when using your compass. These power lines can generate strong magnetic fields which can cause the needle to deviate.
- Hold the compass as flat as possible to allow the needle to move freely.
- Look after your compass - try to avoid dropping or knocking it.
- Store away from other compasses and electrical equipment.
- Your compass may need replacing if a large air bubble forms in the Compass Housing.

Setting a bearing or azimuth

Say, for example, you want to travel directly west (270°) from your current location. Setting your compass is a simple process:

Step 1 - Hold the compass parallel to the ground and spin the rotating bezel ring until 270° lines up with the Index Line.

Step 2 - Rotate your whole body (not just your hand or arm) left or right until the needle lines up with the orienting arrow in the compass housing ("Red in the Shed". You are now facing due west (magnetic).

To measure a bearing to a particular landmark or object, simply reverse the procedure above. Hold the compass parallel to the ground and point the Direction of Travel Arrow directly at the landmark. Without moving the compass housing, rotate the bezel ring until the orienting arrow lines up underneath the magnetic needle ("Red in the Shed"). Read your bearing off the index line ("Read bearing here").

Declination or **Magnetic Variation**

The Geographic North Pole (or True North) is defined by the latitude 90° N and is the axis of the Earth's rotation. The Magnetic North Pole is where the Earth's magnetic field points vertically downward. To the chagrin of many navigators, these points are generally, but not precisely, aligned.

The lines of longitude that border a typical topographical map are aligned with True North. Other lines on the map, Universal Transverse Mercator (UTM) or Military Grid Reference System (MGRS) lines are aligned toward Grid North.

Figure 22

The difference in degrees between True North, Grid North, and Magnetic North is called *magnetic variation* and it must be accounted for when navigating with a map. In the marginal data on the North Conway West Quadrangle (Figure 23), you can see information on the UTM Grid Declination and the 1987 Magnetic North Declination. What this means is that on this map, UTM Grid North is located 1°31' West of True North. Magnetic North is located 16°30' West of True North. Doing the math, Magnetic North is located approx. 15° West of UTM Grid North. In other parts of the country or the world, the magnetic variance differs so it is vital to know this information any time you are navigating in a particular area. It can always be found in the marginal data on a quality topographical map.

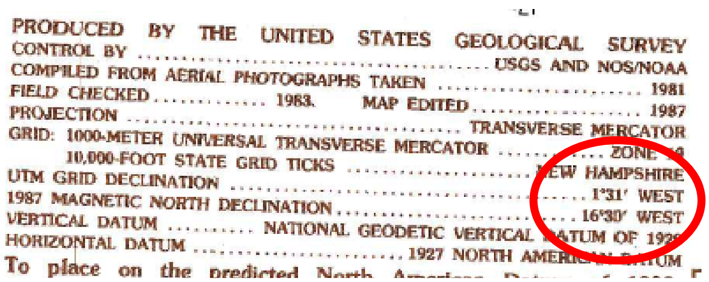

PRODUCED BY THE UNITED STATES GEOLOGICAL SURVEY
CONTROL BY .... USGS AND NOS/NOAA
COMPILED FROM AERIAL PHOTOGRAPHS TAKEN 1981
FIELD CHECKED .... 1983. MAP EDITED 1987
PROJECTION .... TRANSVERSE MERCATOR
GRID: 1000-METER UNIVERSAL TRANSVERSE MERCATOR .... ZONE 19
10,000-FOOT STATE GRID TICKS .... NEW HAMPSHIRE
UTM GRID DECLINATION .... 1°31' WEST
1987 MAGNETIC NORTH DECLINATION .... 16°30' WEST
VERTICAL DATUM .... NATIONAL GEODETIC VERTICAL DATUM OF 1929
HORIZONTAL DATUM .... 1927 NORTH AMERICAN DATUM

Figure 23

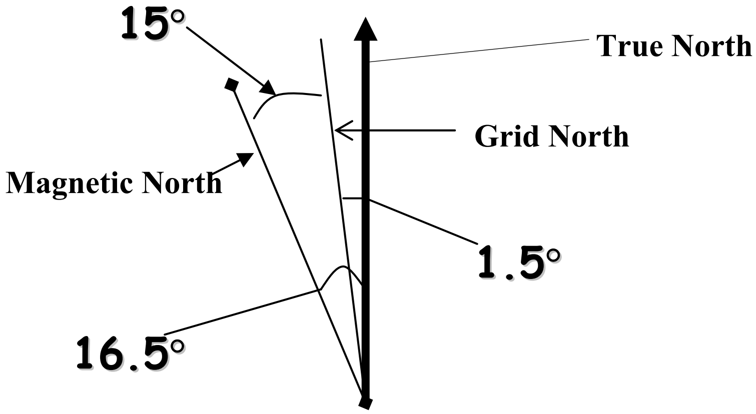
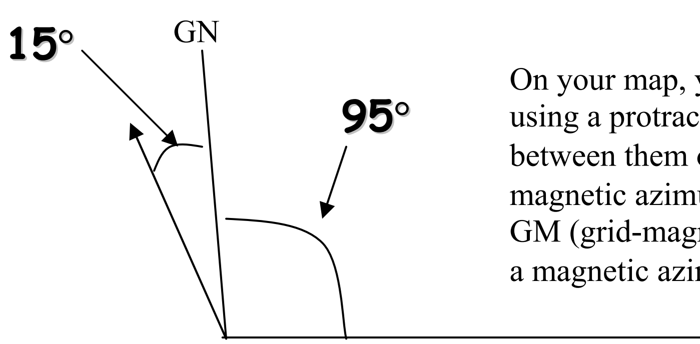


Figure 24 - Magnetic Variance for North Conway West Quadrangle

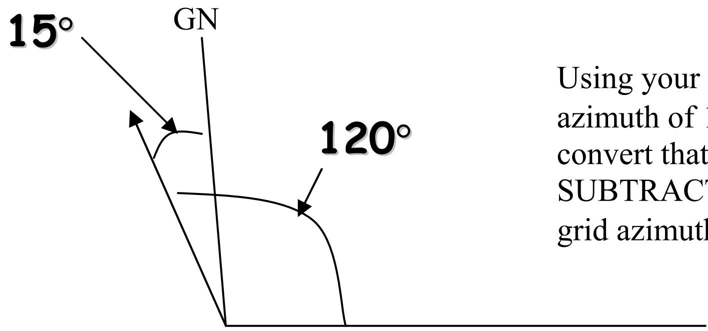
E. Putting it together - Using the Map and Compass

Since most topographical maps are marked with Grid lines, it is usually far easier to navigate using Grid North as your reference line vice True North. Any azimuth you measure from the map must be converted into a magnetic azimuth before you can use it on the ground. Any azimuth you measure with your compass must be converted into a grid azimuth before you can use it on the map. Here's an example:



On your map, you select two points and, using a protractor, you measure an angle between them of 95°. To convert that to a magnetic azimuth, you must ADD the 15° GM (grid-magnetic) angle. This gives you a magnetic azimuth of 110°

To go from magnetic to grid, do the opposite.



Using your compass, you measure an azimuth of 120° to a particular hill top. To convert that to a grid azimuth, you must SUBTRACT the GM angle giving you a grid azimuth of 105°.

Use the North Conway West Quadrangle and a protractor to answer the following questions:

32. You are located at the summit of North Moat Mountain. What are the grid and magnetic azimuths to the following points?

	Grid	Magnetic
Summit of South Moat Mountain	______________	______________
Summit of White Horse Ledge	______________	______________
Summit of Mt. Pickering	______________	______________

Why is this useful? If you are traveling through an area (hiking, biking, canoeing, attacking military foes, etc.), there may not be too many road signs. You'll need to read the map and be comfortable converting grid azimuths to magnetic azimuths and vice versa.

Triangulation

Using the process described above in reverse provides you with the skill to locate or confirm your position on a map. Refer, once again, to the North Conway West Quadrangle. Let's say you have been floating down the Saco River for a few hours and you are not exactly sure of your location. You suspect that you are somewhere south west of North Conway but you are not exactly sure where. Your goal is to determine where you are as accurately as possible.

Pulling up on a sand bar and looking to the west, the Moat Mountain Range is the dominant terrain feature. There are three prominent peaks on this ridgeline: North, Middle, and South Moat Mountains. You are going to use two of these prominent terrain features to triangulate your position.

Step 1

Using your compass (which, as you'll recall, measures *magnetic* azimuths), you take the following readings:

Magnetic Azimuth to North Moat Mountain: 289°
Magnetic Azimuth to South Moat Mountain: 259°

Step 2

Convert the magnetic azimuths to grid azimuths. In North Conway, Magnetic North is 15° West of Grid North so you have to SUBTRACT the GM angle.

Grid Azimuth to North Moat Mountain: 274°
Grid Azimuth to South Moat Mountain: 244°

Step 3

Up to this point, you have the angle measurements from your location to the two known points. It is more helpful to have the angle measurements from the two known points to your (unknown) location. To find these, you take the BACK AZIMUTHs of the grid azimuths you just converted. This is done by adding or subtracting 180° to the grid azimuths. If your azimuth > 180°, SUBTRACT 180°. If your azimuth is < 180°, ADD 180°. (If the number you come up with is > 360° or a negative number, you've screwed it up).

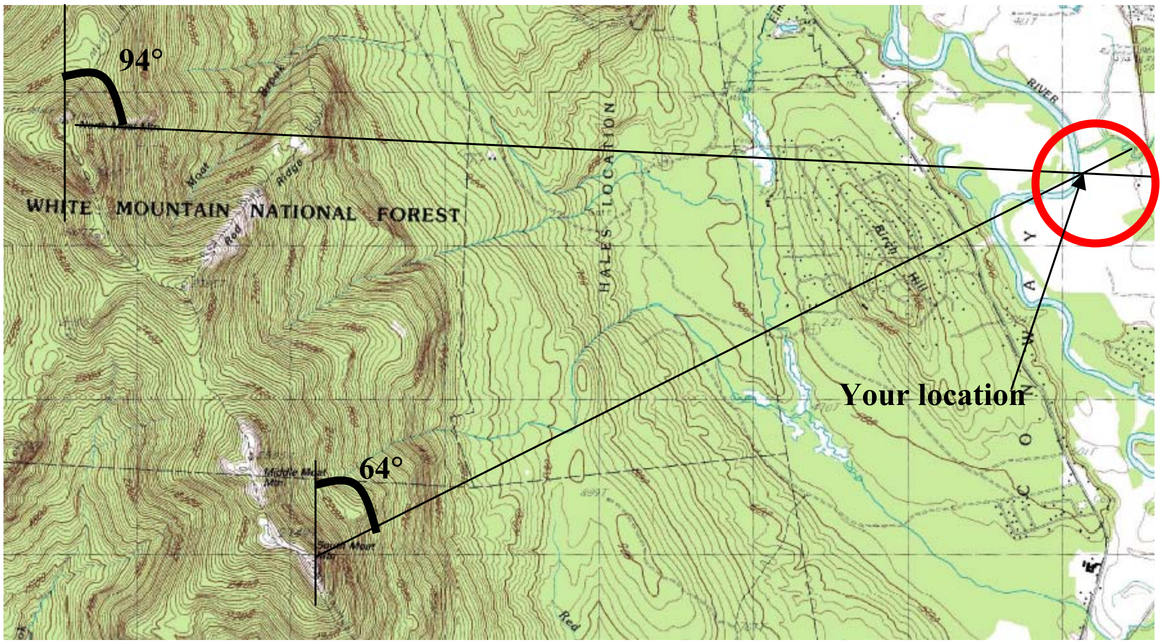
Back Azimuth from North Moat Mountain: 94°
Back Azimuth from South Moat Mountain: 64°

(Picture it this way: You have two buddies, one at the summit of North Moat Mountain and the other at the summit of South Moat. The guy on North Moat would measure a grid azimuth to your position of 94°; the guy on South Moat would measure 64°)

Step 4

Place a protractor over the summit of North Moat Mountain and tick off an angle of 94°. Extend a line (LIGHTLY! IN PENCIL ON MY MAPS!) from the summit of North Moat through the 94° tick, and across the Saco River. Do the same with the data for South Moat. The intersection of these two lines is your location.

Like any outdoor skill, you can only become good at this if you practice. You will only practice this if you have a need to be good at it. That's enough on triangulation…



F. Navigating by Terrain Features

The last type of map we will look at is an orienteering map (see Appendix 1). Listed below are some key differences between orienteering maps and USGS quadrangle maps:

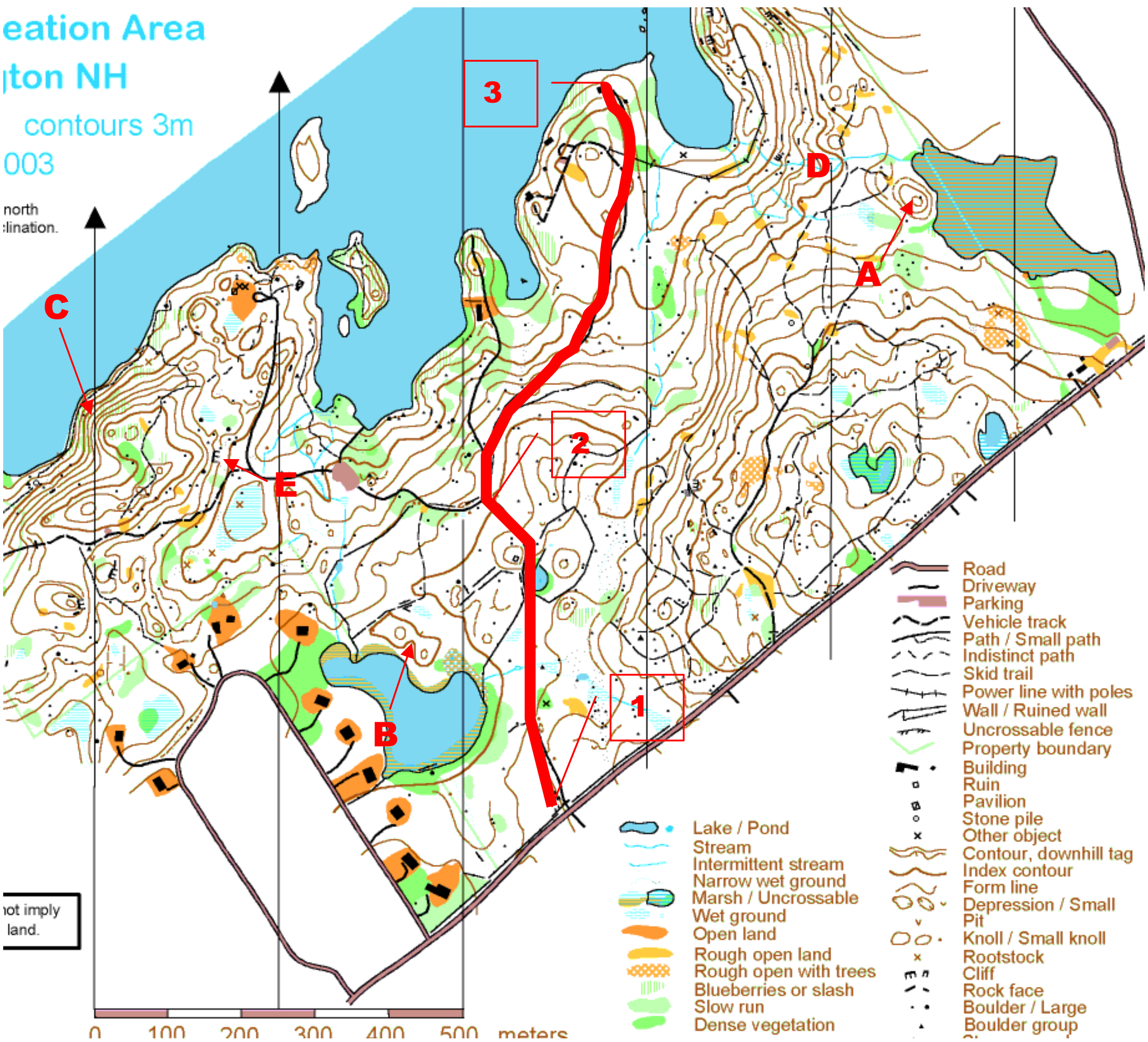
	USGS	**Orienteering**
Purpose	3D representation of terrain for general purposes	3D representation of terrain for fine navigation purposes
Scale	1;24,000+	1:5,000 - 1:15,000
Contour Interval	25 feet or greater	Typically 5 meters
Orientation	True North	**Magnetic North** (no declination!)
Survey Method	Primarily aerial photography	Aerial base map, extensive field surveh
Update period	10-50 years	1-5 years
Accuracy	Often very inaccurate, particularly with man-made structures, roads, etc.	Very accurate

Orienteering is a sport where the athletes run through the woods to try and find a series of control points as quickly as possible. Being able to recognize terrain features on the go (along with being a fast runner!) is the key to success in this sport.

Another key to success in orienteering is to keep your map (and yourself) "oriented". Since orienteering maps are oriented towards magnetic north, this is a simple process:

Step 1 - set your compass so that 0° is aligned with the index line.
Step 2 - lay the edge of the compass along one of the north-south lines on the map.
Step 3 - spin both map and compass until the needle lines up with north.

If you know where you are and know where you want to go, an oriented map will keep you on the right path.



33. Identify the terrain feature associated with the letter on the orienteering map above.

A. ____________________________

B. ____________________________

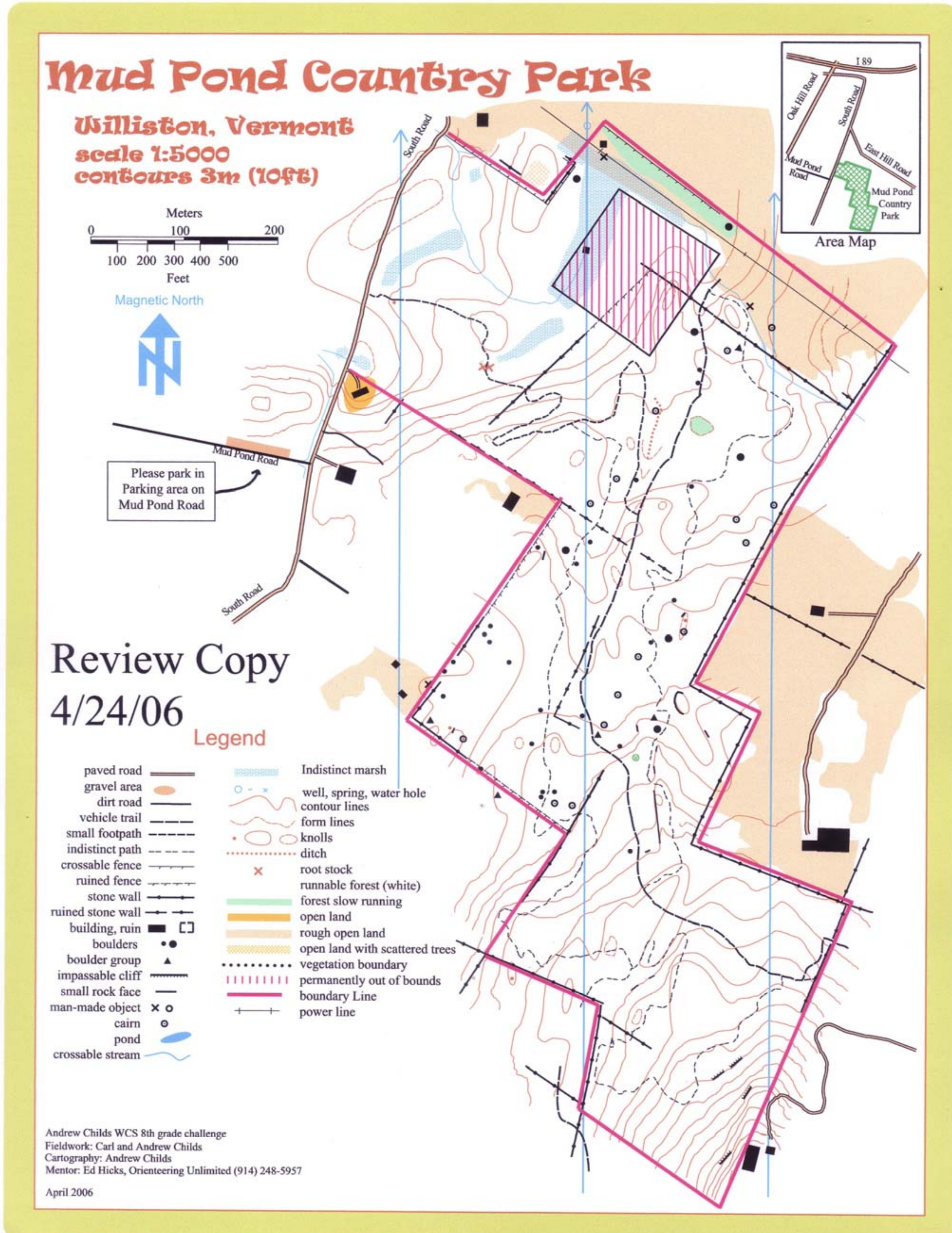
C. ____________________________

D. ____________________________

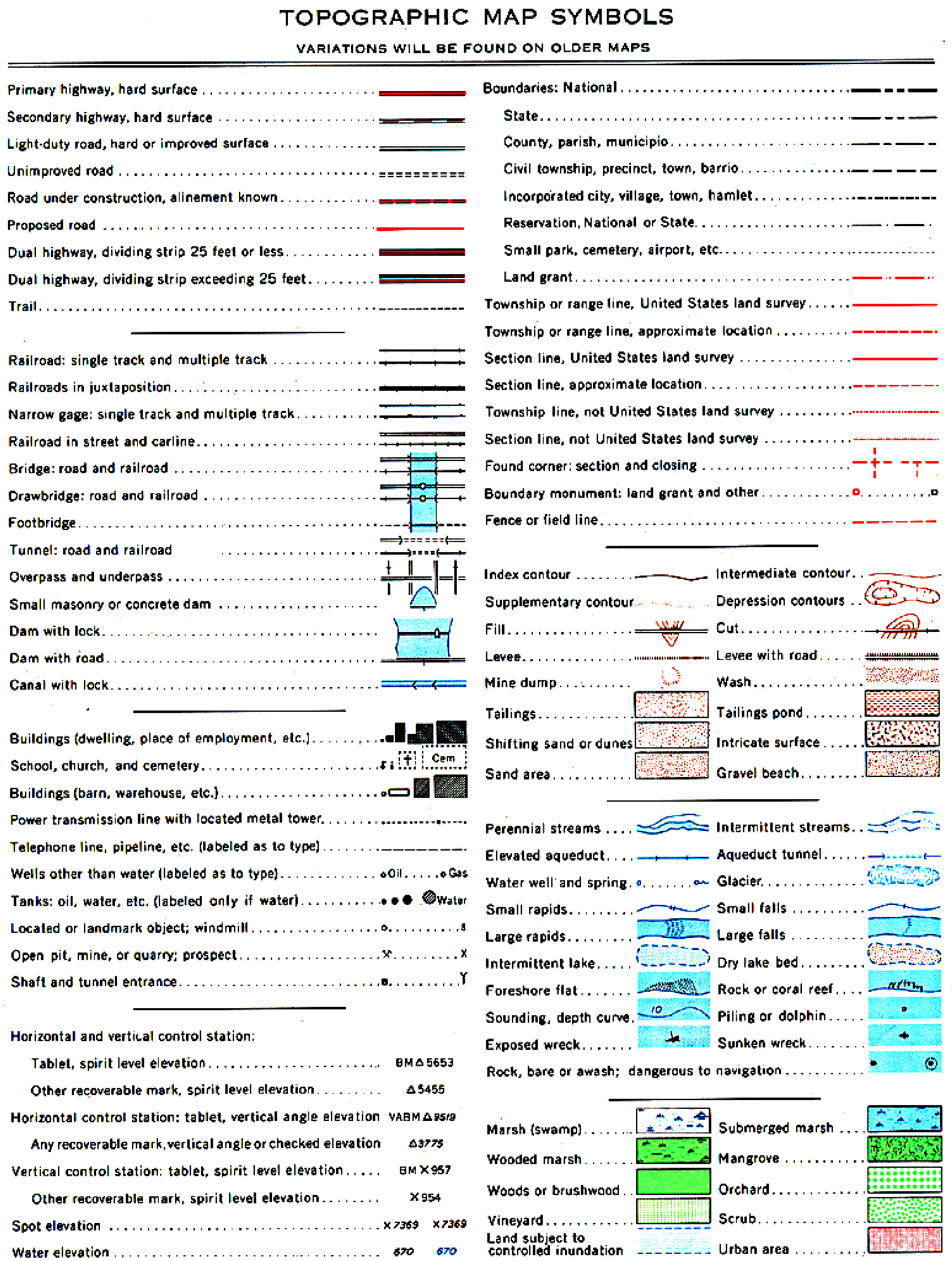
E. ____________________________

34. In a well-written paragraph, describe a walk along the path (in red) above. Start at point 1 and then proceed to 2 and 3. Describe the general direction you would be heading, the rough distance you would cover, the slope (steep/gentle, uphill/downhill), the type of vegetation you would be moving through, and at least four prominent terrain features (hill, saddle, spur, etc) you would encounter along the way. Refer to the marginal data in the lower right part of the map for assistance. More detail is better than less.

Appendix 1


Mud Pond Country Park
Williston, Vermont
scale 1:5000
contours 3m (10ft)
Meters
0
100
200
100 200 300 400 500
Feet
Magnetic North
Area Map
I 89
Oak Hill Road
South Road
East Hill Road
Mud Pond Road
Mud Pond Country Park
South Road
Mud Pond Road
Please park in Parking area on Mud Pond Road
Review Copy
4/24/06
Legend
paved road
gravel area
dirt road
vehicle trail
small footpath
indistinct path
crossable fence
ruined fence
stone wall
ruined stone wall
building, ruin
boulders
boulder group
impassable cliff
small rock face
man-made object
cairn
pond
crossable stream
Indistinct marsh
well, spring, water hole
contour lines
form lines
knolls
ditch
root stock
runnable forest (white)
forest slow running
open land
rough open land
open land with scattered trees
vegetation boundary
permanently out of bounds
boundary Line
power line
Andrew Childs WCS 8th grade challenge
Fieldwork: Carl and Andrew Childs
Cartography: Andrew Childs
Mentor: Ed Hicks, Orienteering Unlimited (914) 248-5957
April 2006

Appendix 2


TOPOGRAPHIC MAP SYMBOLS
VARIATIONS WILL BE FOUND ON OLDER MAPS
Primary highway, hard surface
Secondary highway, hard surface
Light-duty road, hard or improved surface
Unimproved road
Road under construction, alinement known
Proposed road
Dual highway, dividing strip 25 feet or less
Dual highway, dividing strip exceeding 25 feet
Trail
Railroad: single track and multiple track
Railroads in juxtaposition
Narrow gage: single track and multiple track
Railroad in street and carline
Bridge: road and railroad
Drawbridge: road and railroad
Footbridge
Tunnel: road and railroad
Overpass and underpass
Small masonry or concrete dam
Dam with lock
Dam with road
Canal with lock
Buildings (dwelling, place of employment, etc.)
School, church, and cemetery
Cem
Buildings (barn, warehouse, etc.)
Power transmission line with located metal tower
Telephone line, pipeline, etc. (labeled as to type)
Wells other than water (labeled as to type)
Oil
Gas
Tanks: oil, water, etc. (labeled only if water)
Water
Located or landmark object; windmill
Open pit, mine, or quarry; prospect
Shaft and tunnel entrance
Horizontal and vertical control station:
Tablet, spirit level elevation
BM Δ 5653
Other recoverable mark, spirit level elevation
Δ 5455
Horizontal control station: tablet, vertical angle elevation
VABM Δ 9519
Any recoverable mark, vertical angle or checked elevation
Δ 3775
Vertical control station: tablet, spirit level elevation
BM × 957
Other recoverable mark, spirit level elevation
× 954
Spot elevation
× 7369
× 7369
Water elevation
670
670
Boundaries: National
State
County, parish, municipio
Civil township, precinct, town, barrio
Incorporated city, village, town, hamlet
Reservation, National or State
Small park, cemetery, airport, etc.
Land grant
Township or range line, United States land survey
Township or range line, approximate location
Section line, United States land survey
Section line, approximate location
Township line, not United States land survey
Section line, not United States land survey
Found corner: section and closing
Boundary monument: land grant and other
Fence or field line
Index contour
Intermediate contour
Supplementary contour
Depression contours
Fill
Cut
Levee
Levee with road
Mine dump
Wash
Tailings
Tailings pond
Shifting sand or dunes
Intricate surface
Sand area
Gravel beach
Perennial streams
Intermittent streams
Elevated aqueduct
Aqueduct tunnel
Water well and spring
Glacier
Small rapids
Small falls
Large rapids
Large falls
Intermittent lake
Dry lake bed
Foreshore flat
Rock or coral reef
Sounding, depth curve
10
Piling or dolphin
Exposed wreck
Sunken wreck
Rock, bare or awash; dangerous to navigation
Marsh (swamp)
Submerged marsh
Wooded marsh
Mangrove
Woods or brushwood
Orchard
Vineyard
Scrub
Land subject to controlled inundation
Urban area