Lab 1: An Introduction to Topographic Maps

Learning Objectives:
- Understand how to read and interpret topographic maps and aerial photos
- Start thinking critically about landforms and the processes that create them
- Learn to use aerial photographs to identify and interpret landforms

This exercise is divided into the following sections:
Section One: Introduction
Section Two: Topographic map basics
Section Three: Information contained on topographic map
Section Four: Making a contour map

Important Note: For the remainder of the semester, you will need to bring a **pencil, eraser**, **calculator** and **ruler** to lab. These will not be provided. A **calculator** is essential.

Section One: Introduction

Within the discipline of geomorphology, topographic maps, whether paper-based or electronic, have historically dominated studies of large scale earth features. Within geomorphology, topographic maps were the essential databases from which a variety of pioneering studies in drainage basin morphology and processes were investigated. Topographic maps retain their value today, but recent advances in remote sensing appear to be leading us toward a future where topographic maps are, at least in part, supplanted by digital elevation models (DEMs). The latter offer the same information as topographic maps, but do not require interpolation between contour points. Rather, DEMs offer continuous data coverage for a given scale. Their primary limitation is principally one of availability (many are generated from proprietary satellite data not available to the poorly funded) and the difficulty of carrying technology in the field. The time will almost certainly come when geomorphologists carry more laptops into the field than rock hammers. Keep in mind, however, that a well kept map will almost always outlast a poor laptop if dropped off a waterfall.

To understand and use topographic maps, one must be familiar with some important terms and elements of topographic maps. This packet is a brief introduction to topographic maps and the information that they contain. True appreciation of the usefulness and limitations of topographic maps can only be gained through field use. If you lack such experience, you are strongly encouraged to attain it.

Section Two: Topographic Map Basics

Scale: As with all maps, **scale** is a fundamental element of topographic maps. Proper interpretation of a map is impossible without a firm grasp of the scale of the map and more importantly, scale determines the resolution and detail of a map. Map scales are typically expressed as **unitless** fractions. The most widely used maps are the 1:24000 topographic maps of

the United States Geological Survey. A fraction is a very useful way of reporting scale. In the case of a 1:24000 scale, the following relationships hold:

1 inch measured on map	= 24000 inches on actual ground
1 cm measured on map	= 24000 cm on actual ground
1 foot measured on map	= 24000 feet on actual ground
1 measurement unit on map	= 24000 measurement units on ground

Imagine that using a 1:24000 topographic map, you measure between two points of interest. The points prove to be one inch apart. You now know that in actuality the two points lie 24000 inches apart in real life. Given that most people do not commonly conceive of such large distances in inches, the distance should be converted into more easily interpreted numbers. Using the conversion table below and conversion values you should already know, we can easily convert any distance.

5,280 feet	= one mile
2.5 centimeters	= one inch
63,360 inches	= one mile
100 centimeters	= one meter
1.6 kilometers	= one mile
1000 meters	= one kilometer

In the case of 24000 inches, we know that 12 inches equals 1 foot. Hence,

$$\frac{2400 \text{ inches}}{12 \text{ in/ft}} = 2000 \text{ feet}$$

or

$$\frac{2000 \text{ feet}}{5280 \text{ ft/mi}} = 0.379 \text{ miles}$$

Thus, on all maps of 1:24000 scale one map inch equals 2000 feet or 0.379 miles 'on the ground'. Such conversions are easy and extremely useful for both accurate and quick distance estimates. Although fractional scales are the most useful and accurate means of conveying scale, other means are available. Below are examples of the three most common scales.

verbal scale	graphic scale	fractional scale
1" represents 1 mile	|_1 mile_|	1:63,360 or 1/63,360

You should now be able to convert the fractional scale 1:63360 into useful distance estimates. For example, how many feet are represented by one inch on a 1:63360 map? How many miles? Also, consider that a 1:200 map would be said to be large scale, while a 1:200000 map would be a small scale map. The 1:200 map covers less area, but is large scale because simple division shows that its fraction is larger.

Elevation and Contour Lines: Elevation, typically measured relative to sea level whose elevation is arbitrarily said to be zero, is represented by contour lines on topographic maps. A **contour line** is a line of equal elevation. Contour lines are vertically spaced using **contour intervals**. For instance, USGS topographic maps commonly space contour lines 5, 10, 20, 40, or 80 feet apart. Hence, using a 20 foot contour interval each contour line is represents a change in elevation of 20 feet relative to adjacent contour lines. Only one contour interval is used per map. The contour interval of a typical USGS topographic map is given beneath the graphical scale bar. Remember, contour lines never cross.

When the contour interval is not specified, the contour interval can be calculated by subtracting the value of two adjacent contour lines. In most cases, the contour interval is a multiple 5 or 10. Hence, one would not use a contour interval of, say, 17. The choice of a contour interval is dictated by **relief**. Relief is the absolute distance between the highest and lowest points on a map.

If one were making a topographic map of the low relief Florida Everglades, a 40 foot contour interval would show almost no topographic details (the highest and lowest points in an area might only be separated by 30 vertical feet) whereas a 5 foot interval would show much greater detail. Similarly, if one were making a topographic map in the Colorado Rockies, a contour interval of 5 feet would produce a crowded, almost illegible map. Thus, a 40 or 80 foot map would be more appropriate for terrain with such significant relief.

When determining the elevation of a point on a contour line, report it as the value of the contour line (e.g. 20 ft). When determining the elevation of a point between contour lines, interpolate the elevation to the closest foot. If this isn't possible, give a range of values, between the adjacent contour lines. For example, on a map with a 20 ft contour interval a house could be interpolated as having an elevation of about 32 ft or be reported as having an elevation of 21-39 ft.

Exact elevations are given for selected spots on many topographic maps. Such elevations are shown using the following tools:

bench mark - a point on a map where the elevation is given to the nearest foot and a bronze disk is placed at the location. The disk is intended for use by future surveyors or interested parties. These points, known as bench marks, are usually represented by a triangle or an X, with a number next to it. On the map a benchmark might appear as: **X BM 2031,** in which case the 'BM' denotes bench mark and the number 2031 is the elevation of the benchmark. In the field, finding a bench mark shown on map can be a difficult task. Most benchmarks are affixed to rock outcrops, buildings, or cement anchors.

spot elevation - a point on a map where the elevation is given to the nearest foot. Spot elevations are found atop summits, major landmarks, or convenient points. On a map, a spot elevation may appear as: **X 3281.** If an elevation value is given beside a road junction or similar confluence of streams, paths, etc... the elevation is a spot elevation for the intersection of the map features.

water surface elevation - the mean elevation of the surface of a body of water, such as a lake, may be given. The elevation of the water surface will be shown on the surface of the water body.

Coordinate Systems: There are many different systems for specifying positions on the earth's surface. The importance of such systems should be obvious. If you wish to precisely refer a person to a particular point, say a cave entrance, you could try and describe to them where the entrance lay on a map or you could simply give them the coordinates that specify the location. Use of common coordinate systems removes the uncertainty associated with verbal descriptions.

The most commonly used coordinate systems are: latitude and longitude, Universal Transverse Mercator (UTM), and township and range. Each is essentially an imaginary grid, or network of lines used to express the position on the earth's surface. Positions are determined and expressed in a manner similar to that of X-Y points on grid paper. With the advent of Global Positioning Systems (GPS), UTM and latitude/longitude positions are more in use today than ever before.

Latitude and longitude

The latitude/longitude coordinate system utilizes an imaginary, grid of lines called **meridians of longitude** and **parallels of latitude** (see Figure 1). Lines of longitude run north-south between the poles. Lines of latitude form parallel east-west rings across the globe.

The equator is assigned 0° degrees latitude. Latitude increases as one gets closer to a pole. The north pole has a latitude of 90° N(orth) and the south pole has a latitude of 90° S. Note that while latitude lines run east-west, they measure all positions relative to north-south. Longitude lines run around the earth in a north-south direction through the poles, but they measure distance east-west of the Prime Meridian. The Prime Meridian passes through Greenwich, England, a city near London. The Prime Meridian is assigned 0° longitude. Longitude values increase from 0° to 180° as one moves east of the Prime Meridian and decrease from 0° to -180° to the west. They may also be represented as 0 E to 180 E and 0 W to 180 W. Because the earth is a sphere, longitude values achieve their highest values on the side of the earth opposite the Prime Meridian. Note that longitude lines are not rings. Longitude lines are arcs beginning and ending at the poles.

The latitude/longitude coordinate system uses degrees. Latitude is actually the vertical angle from the equatorial plane to any place on the earth, while longitude measures the horizontal angle between that same position and the plane of the Prime Meridian (see Figure 3). Remember that distances around a circle are measured in degrees, with 1 revolution (circle) = 360 degrees. However, when you consider that the earth's circumference at the equator is 24,860 miles each degree must represent 69 miles! If you were to give someone the longitude and latitude of a point to the nearest degree they would know the location within about 49 miles (an area of roughly 9600 miles). Obviously, we need still more information to precisely locate a point on the earth's surface. Therefore, degrees are further divide into minutes and seconds. Degrees and minutes are divided into 60 increments. Thus, 1 degree equals 60 minutes and 1 minute equals 60 seconds. These proportions are also written using symbols: $1^o = 60'$, and $1' = 60''$, respectively. The division of units is very similar to time on a clock.

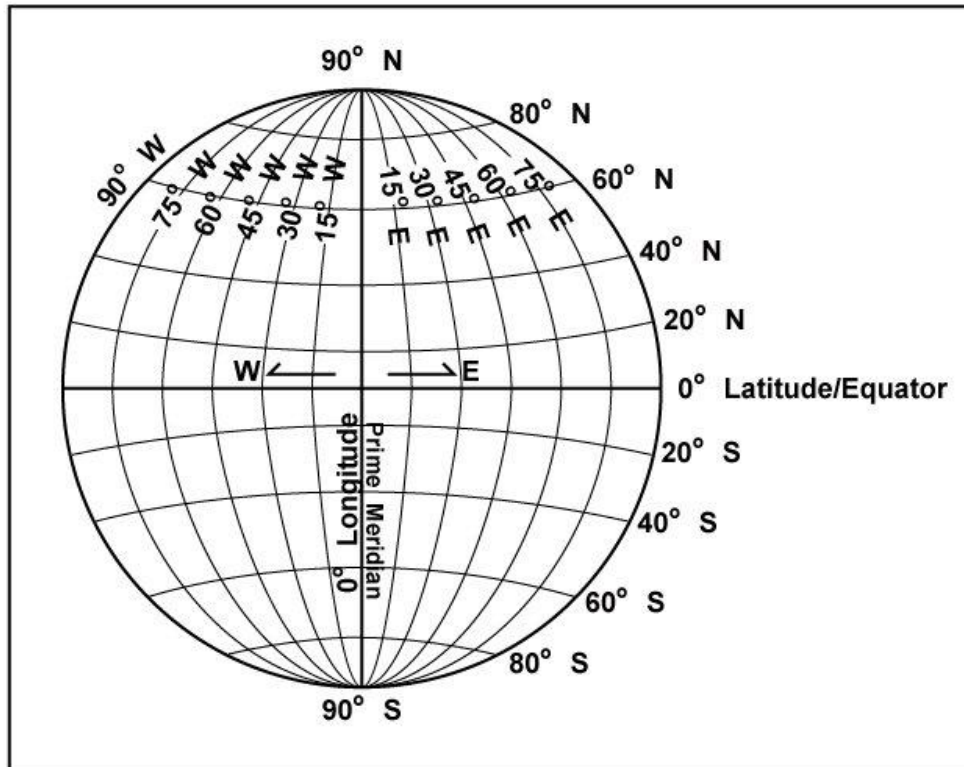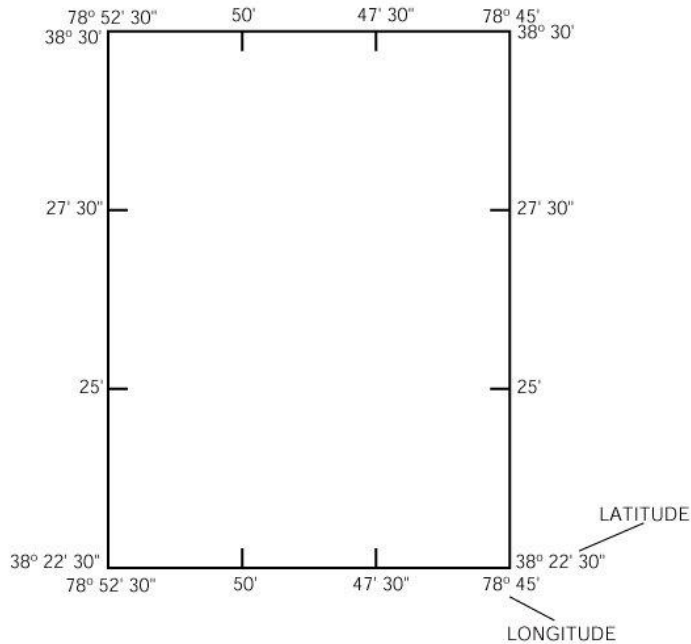**Figure 1:** The globe and longitude/latitude.

Figure 2: Latitude and longitude values as presented on a topographic map.

Topographic maps usually cover only a small area of the globe (2 degrees of latitude and longitude, or less). On topographic maps where longitude and latitude are less than a degree, they

are given in minutes and seconds. For example, 75° 35' 15" means seventy-five degrees [75°], thirty-five minutes [35'], and fifteen seconds [15"]. These readings of longitude and latitude are given at the corners of each topographic map, with smaller subdivisions, usually in minutes and seconds shown along the map edges (Figure 2). Note that a compass direction MUST be included with a latitude reading and can also be included with a longitude reading. For instance a latitude of 39° 23" 56' could be north or south of the equator. Latitude is either N or S, and longitude is E or W.

Actual determination of longitude/latitude points on a map requires (we will discuss this technique during laboratory):

1. Finding reference ticks on the map with given values of longitude and/or latitude that lie on both sides of the point of interest..
2. Measurement, with a ruler, of the location of the point of interest relative to the reference ticks.
3. Algebraic solution of the points latitude and longitude.

Points to Ponder: Because the earth is a spheroid, longitude lines converge at the poles. Thus, the distance between longitude lines is greatest at the equator and least at/near the poles. Latitude lines are not affected because they run east-west and are evenly spaced rings. As a result, a map covering a 1° X 1° area at the equator would be roughly square. A 1° X 1° from near a pole would be a very tall rectangle or sliver! For mid-latitudes, such as the contiguous United States, such a map would be a rectangle whose height is slightly greater than its width. Because of the systematic distortion of longitude line spacing, the grid of latitude/longitude lines is not rectangular. The boundaries of mass produced USGS topographic maps are coincident with longitude/latitude lines. For instance, the popular 7.5 minute topographic quadrangle series divides the contiguous United States into 7.5" X 7.5" areas. The USGS also prepares 1° X 2° and 15" X 15" maps. You should now be able to order these maps according to the amount of area each covers, their relative scale (small to large), and levels of resolution and detail.

Universal Transverse Mercator (UTM)

As previously described, the latitude/longitude grid is not rectangular. This presents several problems, not the least of which is accurately defining spatial relationships between points of longitude and latitude. To overcome the difficulties of using a non-rectangular reference system, the United States military devised the Universal Transverse Mercator (UTM) coordinate system. The UTM coordinate system utilizes a rectangular grid of reference lines and has subsequently been integrated with the Global Positioning System (GPS). Among the principal military uses for the UTM system are cruise missile and 'smart bomb' targeting as well as GPS-coordinated positioning of personnel and objects. Civilian uses include positioning of objects, GPS-coordinated route finding, and spatial analysis of both objects and terrain.

The base for the UTM coordinate system is, perhaps surprisingly, the longitude/latitude coordinate system. Between the latitudes of 84° N and 80° S, the earth's surface is divided into 60 zones, each of which span 6° of longitude. The zones are numbered east-to-west from 1 to 60, beginning at the 180° meridian (meridian opposite the Prime Meridian). Similarly, from north to

south, the zones are subdivided into lettered zones. Each lettered zone spans 8° of latitude. Thus, using the UTM system there are 1140 distinct zone quadrangles, each of which is described by a number and a letter [alphabetic from south to north] (e.g. UTM Zone S12).

Each zone quadrangle is further subdivided into rectangular grids 100,000 m on a side. Note that the grids are truly square and therefore the spatial relationship between points is not distorted. One can plot and manipulate points just as one would X-Y Cartesian coordinates with all locations specified by distance in meters from the origin. For the northern hemisphere, the y-axis origin is the equator. Thus, the equator has a value of 0 m north. The origin for the x-axis lies midway between the bounding lines of longitude. The x-axis origin is assigned a value of 500,000 m. Points to the west of this meridian have an easting value of less than 500,000 and points to the east have a value greater than 500,000 m. Thus, there are no negative UTM values.

In principal, determining UTM coordinates using topographic maps is identical to the method used to recover longitude/latitude values. The process is actually easier, relative to longitude/latitude, given that the UTM system utilizes the metric system. All calculations are done using values of base 10 whereas the longitude/latitude systems utilizes fractions of 60. On standard USGS topographic maps, UTM values are represented by blue ticks and lettering. The zone is provided in the map legend. Typically, the letter designation of a zone quadrangle is omitted because the northing value is measured relative to the equator and therefore unique for every line of latitude in a zone. UTM Zone designations are shown in Figure 3.5.

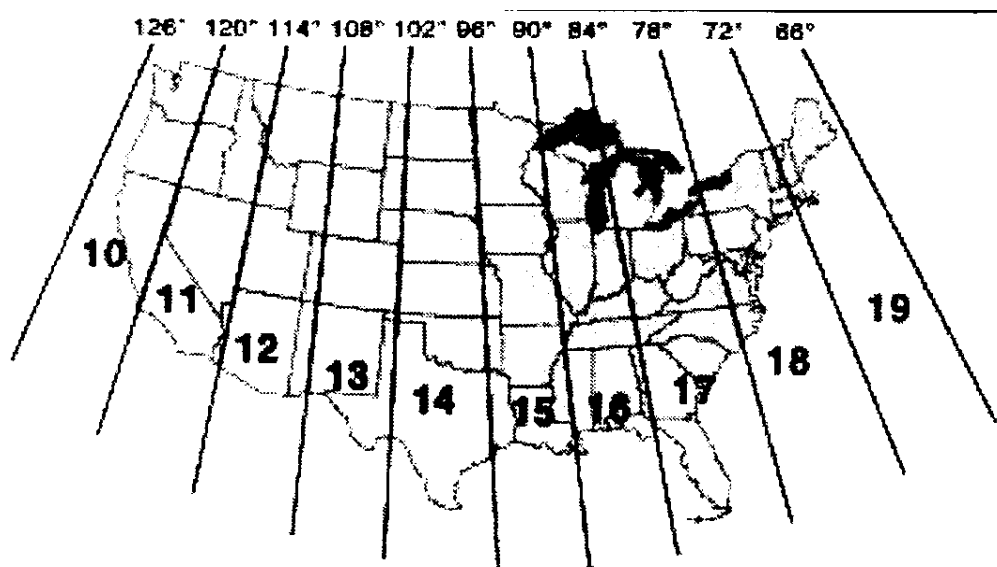We will discuss, in lab, the precise method for determining and plotting UTM coordinates on topographic maps.

Figure 3: UTM zones of the continental United States.

Township and Range (Public Land Survey System)
Within the United States and west of the 100° meridian, the Township and Range coordinate system is often utilized. Although it is a bit harebrained, it is a very fast way of locating oneself

on a map, and the Township and Range system was an integral part of 19th Century America's expansion into the western frontier. As such, the coordinate system survives in many surprising ways (e.g. in many western towns roads follow Township and Range boundaries and are therefore uniformly spaced). As the fundamental means for 'dividing up' the western United States, the Township and Range system is preserved in the region's legal and cultural realms.

The Township and Range system utilizes a grid of lines known as Baselines and Principal Meridians. Baselines run east-west and Principal Meridians run north-south. These lines were arbitrarily created by the Jefferson administration and most western states are pierced by at least one Baseline or Principal Meridian. Standard Parallels are drawn on each of these lines every 24 miles. As a result, 24 mile by 24 mile blocks are created (Figure 4). Each of these blocks is further divided into 16, 6 mile square blocks known as Townships and Ranges. These sub-blocks are designated by their relative Range (east-west) and Township (north-south) positions. Beginning at the junction of a Principal Meridian and Baseline, Townships are labeled according to their order and position (north or south) of the origin. Thus, they proceed to the north as T1N, T2N, etc... until another baseline is reached. Similarly, the Ranges are labeled according to their order and position east or west of the origin. Thus, the Ranges proceed to the east as R1E, R2E, etc... and the first range to the west would be R1W.
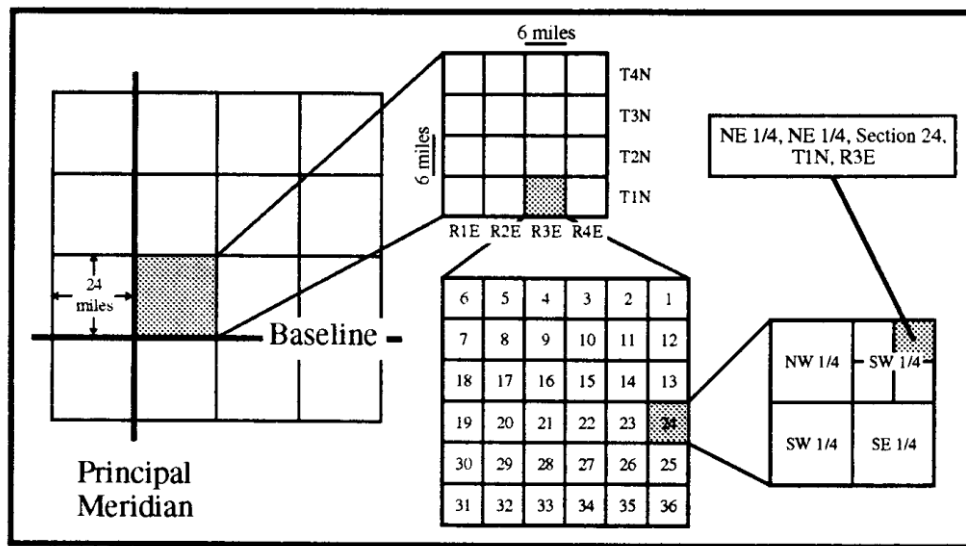

Figure 4: Township and Range coordinate system.

Each 36 square mile Township and Range is further subdivided into 36 one-mile squares known as Sections. Sections are designated by numbers with 1 being the northeastern-most Section. From Section 1, values increase to the west until Section 6. Section 7 lies beneath 6 and the values steadily increase to the east. By zig-zagging in this peculiar manner, Section 36 is eventually found in the southwestern corner of a Township and Range. Each Section is further divided into quarters which can be sub-divided into a theoretically infinite number of quarters whose values are given by their Cartesian position within the Section (e.g. SE 1/4, SW 1/4). Thus, from a technical standpoint this coordinate system does not specify points. Instead, it designates an area within which a point must lie. This severely limits the utility of the system for accurately locating points. However, we should consider the purpose of the Township and Range

coordinate system - to divide up land. As such, the system is specifically interested in identifying parcels of land and not points.

When reporting Township and Range, start with quarters/halves, then section, then T and R.

Declination: Virtually all maps are constructed with the geographic north pole (often called true north) aligned toward the top of the map and parallel to its edges. The geographic and magnetic north poles are **different**. Maps are generally oriented relative to the geographic north pole while compasses point to the earth's magnetic poles. Thus, almost anywhere you stand on the earth's surface, an angle is formed between the point where you stand and the true and magnetic poles. This angle is called declination. It is expressed in degrees **and** direction (the direction being E or W of true north). For example, a declination of $5^o30'$ W or 5.5^o W indicates that for the given location the angle between true north (TN) and magnetic north (MN) is $5^o30'$ and the magnetic pole appears to be to the **west** of true north.

Declination presents a problem when one wishes to navigate using a map and compass. If the map is oriented relative to true north, care must be taken to account for declination. Otherwise, compass readings will not correspond exactly to map azimuths. Surveying with a compass must also be supplemented with trigonometric correction for the difference between magnetic and true north. This is particularly important given that the earth's magnetic pole is not fixed and its strength varies. Thus, with time maps oriented to magnetic north will become inaccurate as route finding and research tools.

As a mental exercise, imagine that a map you are using displays a declination of 10° West (Figure 5). As the arrows indicate, the edges of the map are parallel (oriented to) true north. You wish to walk due north to reach your car. To compensate for the magnetic declination do you:

☐ Follow the compass bearing of 350° (10° west of north)? *or*
☐ Follow the compass bearing of 0° (due north)? *or*
☐ Follow the compass bearing of 10° (10° east of north)?

If you follow the compass bearing of 350°, you will be walking at an angle of 10° to the west of magnetic north and 20° to the west of true north. Thus, you are going the wrong way - in a big way. If you walk due north, relative to the compass, you are still walking 10° west of true north. So, once again you are off track. Finally, by walking 10° east of magnetic north you offset the 10° west magnetic declination and therefore are walking due north relative to the geographic north pole and your map. Always remember, if the magnetic declination is west - go east. If the declination is east - go west.
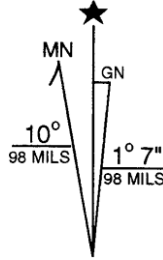
Figure 5: North symbols. The star denotes orientation of geographic north; GN denotes grid north (NOT geographic north); MN denotes magnetic north. In this case, magnetic north declination is 10 degrees West.

Section Three: Information contained on topographic maps
Topographic maps contain a wide variety of information about landscapes. The following are a few of the more general, but important values that can be determined using a topographic map. We will learn many more in a future laboratory.

Height (or depth) - the difference in elevation between the highest point and the lowest point of a local feature (e.g. a hill). For example, a hill with whose base lies at an elevation of 1000 feet and whose top lies at an elevation of 1200 feet is 200 ft high. People commonly refer to the height of a mountain as the elevation of its summit; do not confuse these two meanings! We will strictly refer to height as the distance between the elevation of the base of an object and its summit. If this seems confusing, remember that a six foot tall woman always has a height of six feet whether she is standing on a beach at sea level or atop a 14,000 foot peak.

Relief - the difference in elevation between the highest and lowest points in a **region or map**. Low relief is usually 10's to 100's of feet of difference and is found where the topography is relatively flat (e.g. a coastal plain). Moderate relief is 100's to 1000's of feet (e.g. Appalachian Mountains). High relief is 1000's to several 1000's of feet and is found where the topography is steep with large changes in elevation over short distances (e.g. Rocky Mountains). Extreme relief is many 1000's of feet (e.g. Everest).

Gradient - inclination of the ground surface (how steep or gentle the slope is). Gradients can be determined qualitatively by considering the spacing of contour lines and the contour interval. They can also be measured quantitatively by calculating the change in elevation (vertical distance) relative to horizontal distance. The gradient may be expressed verbally, e.g. a gradient of 528 ft per mile. Note that the unit for vertical distance (feet) is not the same as the unit for horizontal distance (mile).

The gradient may also be expressed as a ratio, e.g. a gradient of 1 in 10, with no particular units as long as the units are consistent. This is analogous to a fractional scale on a map. The ratio 1 in 10 may be read as: the ground descends 1 foot over a horizontal distance of 10 feet, or the elevation changes 1 mile over a horizontal distance of 10 miles, etc. Note that 1 mile = 5280 feet, so a gradient of 528 ft per mile is equivalent to a gradient of 1 in 10.

To determine the gradient of mountain sides or stream channels do the following:

1. Determine the upper and lower elevations of the object of interest. Find the absolute difference between the two elevations. Measure the horizontal distance between the two points. For hillslopes, measure along a straight line. For streams, use a string or map wheel to measure along the streams meandering course. Divide the change in elevation by the horizontal distance (making sure to use the same units). This will give you the fractional gradient.
2. Commonly, the fraction is multiplied by 1000 m or 5280 feet. Respectively, one gives the slope in meters per kilometer and the other in feet per mile. In doing so, one can easily compare any reported slopes regardless of their actual lengths or heights and in a manner that is easy to visualize.
3. To convert from unitless slope to degrees, take the inverse tangent of the slope (e.g., a .16 slope in degrees is $\tan^{-1}(.16)=9.09^{\circ}$

Section Four: Making a Contour Map

Contour maps are a means of showing a three dimensional surface on a two dimensional piece of paper or computer screen. Where a simple map (e.g. a road map) shows only horizontal relationships, contour maps show vertical relationships as well. As with road maps, the relative location of objects in east-west, north-south dimensions are shown on contour maps. However, contour and topographic maps also display earth's third dimension: elevation. Elevation is conveyed by contour lines (discussed previously). By reading the values of contour lines an experienced map user can actually visualize the three dimensional landscape the map represents (Figure 6).

A contour map can be made using a set of elevation points. The individual elevation points are known as **spot elevations** and these can be collected using a variety of methods. Contour lines are then drawn, theoretically, by connecting points of equal elevation. The qualification derives from the following example. Suppose you have 20 spot elevations with which to make a contour map whose contour interval is to be 20 feet. If all of the spot elevations conveniently have values of say 80, 100, and 120 contouring will be easy: simply connect all the 80's, 100's, and so forth. Reality, however, is rarely so attractive. The true distribution of points will probably include many values that are not even multiples of 20 (i.e. 72, 85, 91, 109) and may include NO multiples of 20. In such a case, how do you make a contour map? Obviously, you can not simply play connect the dots!

Given that spot elevations will rarely allow one to literally 'connect the dots', the process of contouring becomes one of interpolating. For example, consider Figure 7a. If we are to contour this map, using a contour interval of 20 feet, we will necessarily utilize contour intervals of 80, 100, and 120 feet (all even multiples of 20). However, few spot elevations possess elevations of the prescribed contour lines. The solution to our problem is simple. Consider the spot elevations whose values are 98 and 110 feet. The 100 foot contour line must pass between them and much closer to 98 than 110. Therefore, we can interpolate or 'guesstimate' the position of the 100 line between those points. The same process can be repeated between the values of 84 & 103 and 84 & 101. By connecting the inferred placement of the contour line between these three sets of

numbers we have made part of the appropriate contour. All that remains is to continue drawing the contour line using the same process until we reach the edge of the map (Figure 7b).

During this exercise you will contour a collection of spot elevations. Practice is essential and you must mind the guidelines below:

1. Both hills and depressions are represented by contour lines in the form of concentric contour lines (Figure 8). In order to distinguish hills from depressions, small marks, called **hachures**, are drawn on the contour lines within a depression (Figure 8).
2. Closely-spaced contour lines represent steep slopes, while widely-spaced contour lines reflect gentle slopes (Figure 9).
3. Contour lines bend across streams. The bend is usually so sharp that the contour forms a 'V' across the stream. The 'V' points **upstream** (Figure 10).
4. Given spot elevations, only those spot elevations that are of equal value to a contour line will have a contour line passing through them. For example, note that in Figure 7b the contour lines only touch a few of the points and only those that are equal to a contour elevation value! **Do not simply play connect the dots.**
5. Contour lines repeat across valleys, across depressions, and on opposite sides of hills (Figure 11).
6. **Contour lines do not cross or divide** (Figure 9). They may be closely spaced, but they do not touch or cross. To understand why, consider Figure 12. Suppose that as water lowers in a lake, we use a stick to trace the retreating shoreline at equal vertical intervals of two feet. These contour lines represent lines of equal elevation and always form nested 'rings'.
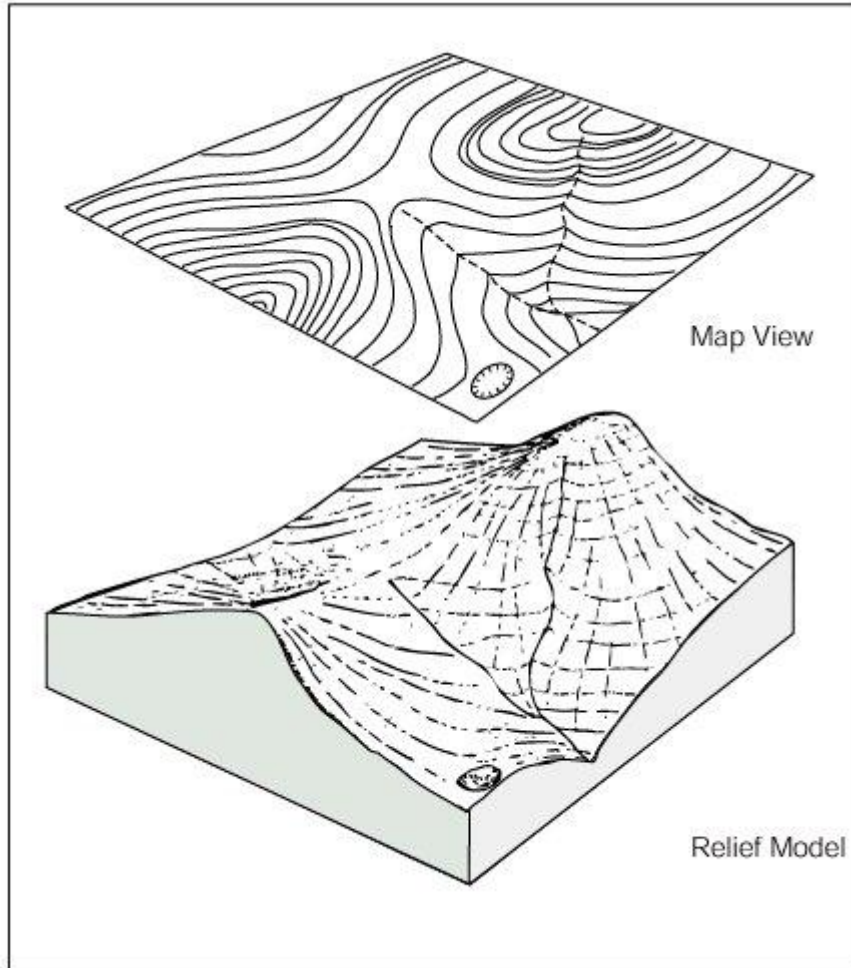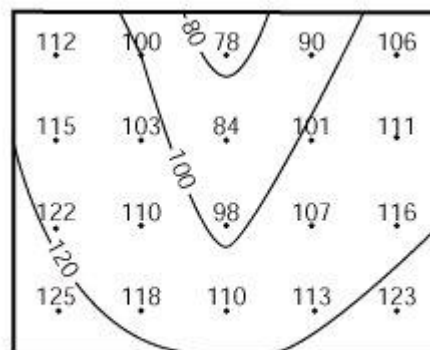
Figure 6: The relationship between topography and contour lines.

7a.

7b.

Figure 7a: Non-uniform spot elevations, before contouring.
Figure 7b: Map after contouring. Contour interval is 20 feet.

8.

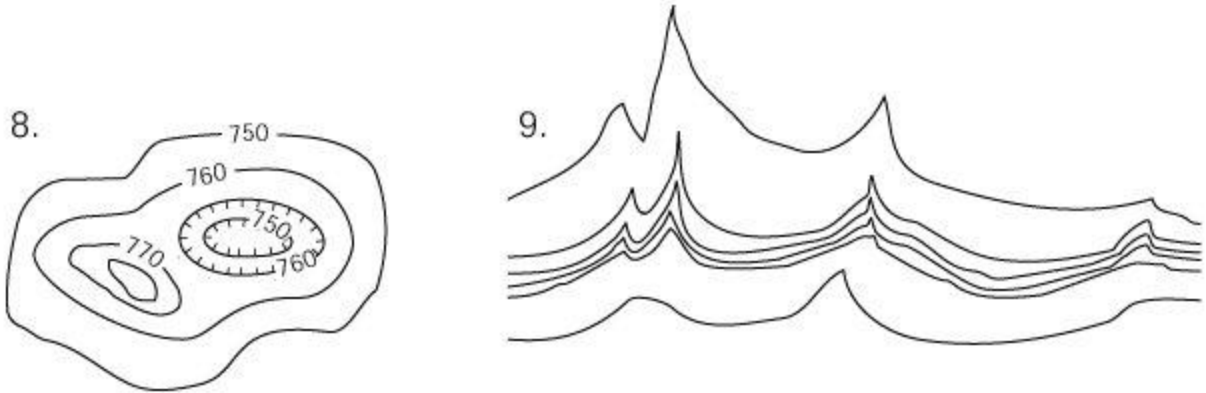760
750
770
750
760

9.

Figure 8: Hill and depression.
Figure 9: Closely spaced contour lines. Note that they do not split or cross.

520
510
500
490
480
470
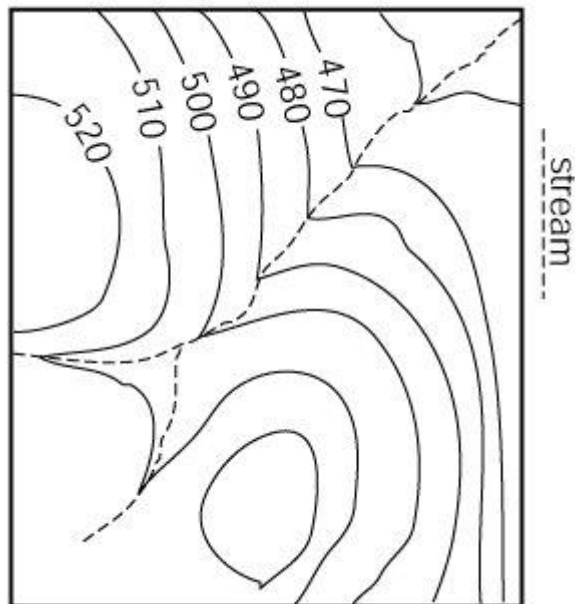
stream

Figure 10: Contour lines "V" where they cross a stream. The "V" points uphill/upstream.
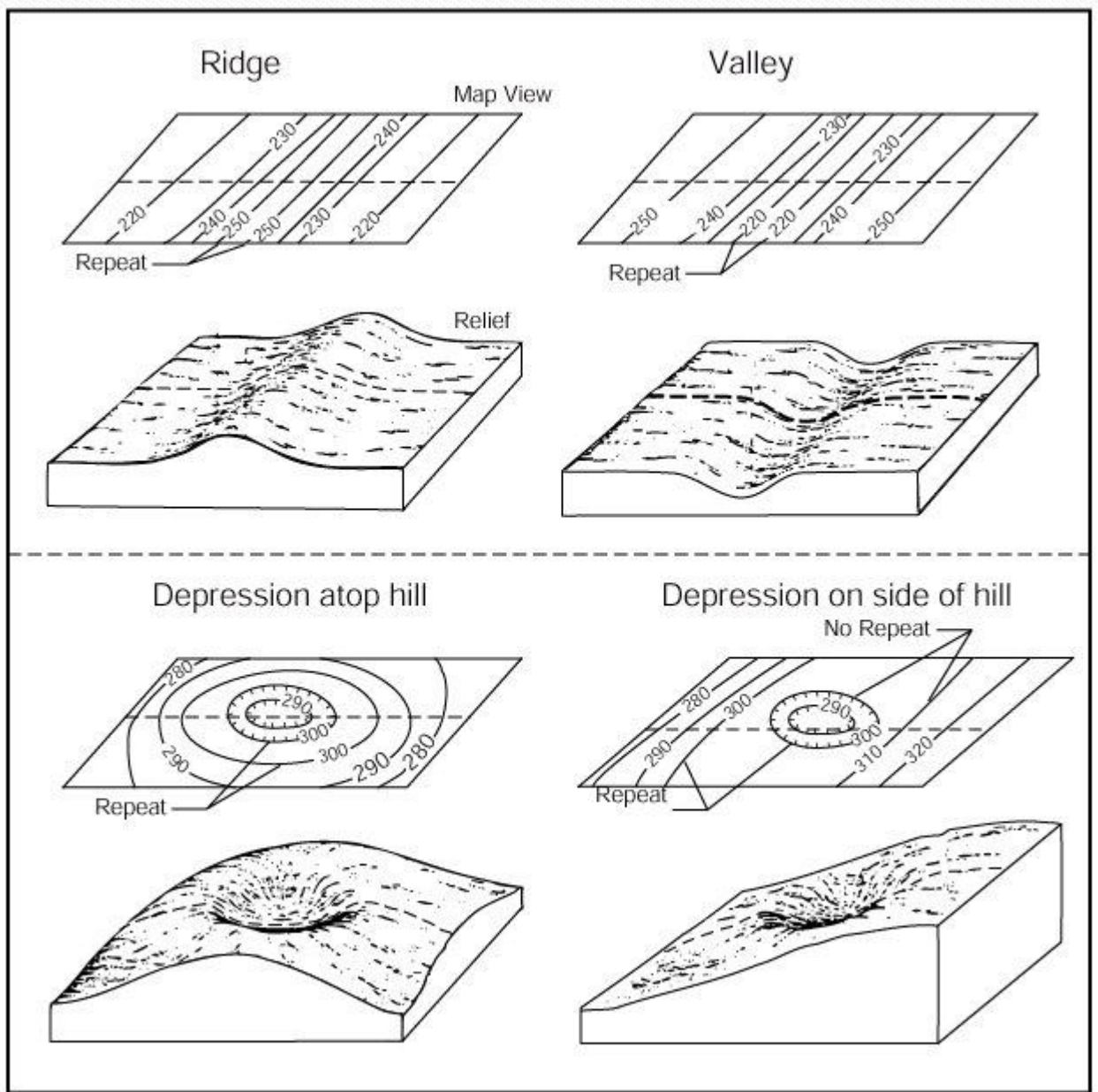
Figure 11: Topography as depicted by topographic maps. Note that contour lines may repeat when the slope of the land changes. Closed (circular) contour lines with hachures (tick lines) denote a depression. Dashed lines on the map views are also drawn in their corresponding positions on the relief views.
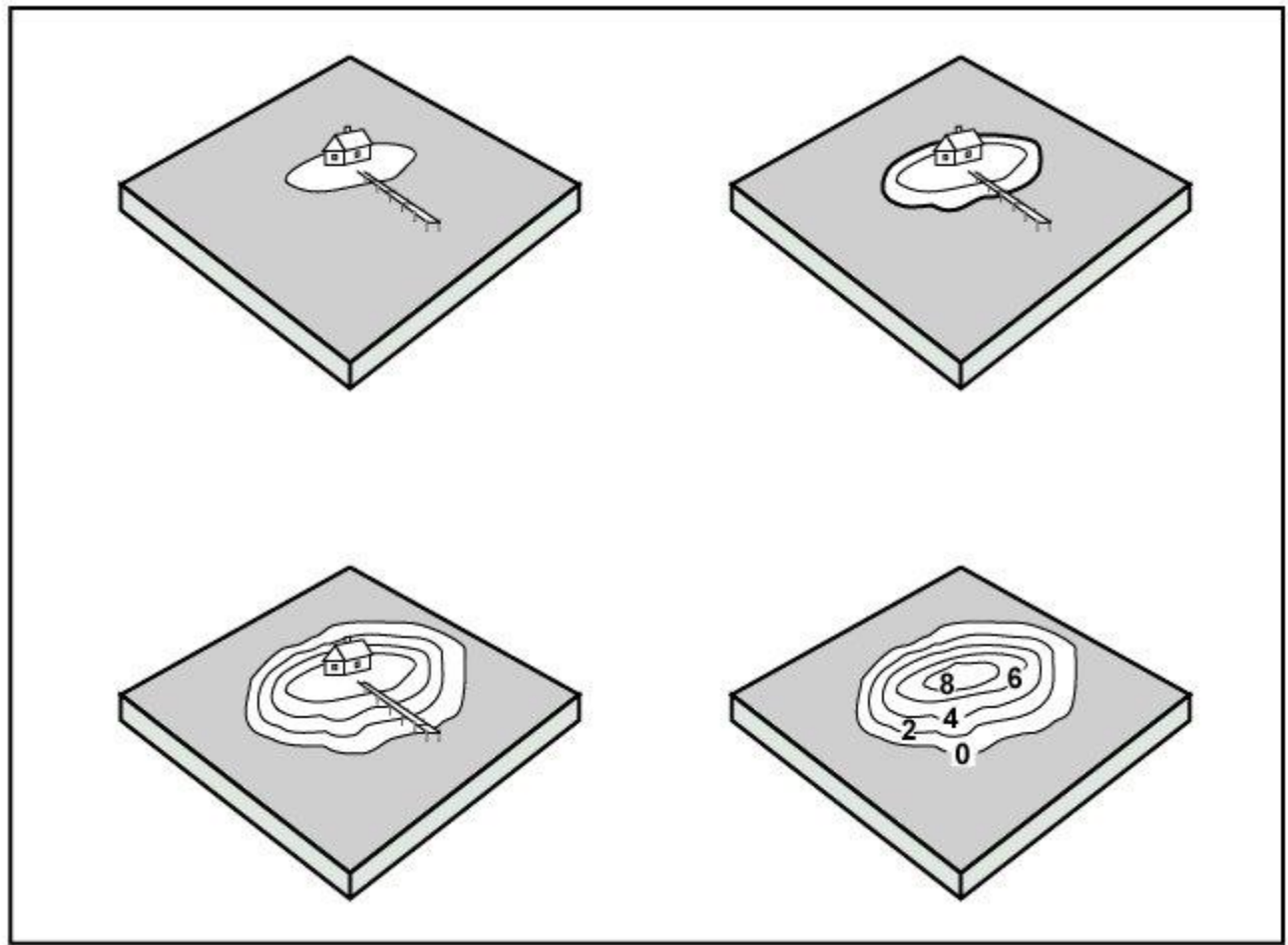
Figure 12: Diagram illustrating the concept of contour lines. By tracing the shoreline each time it drops two feet, we can construct a contour map of the island with a contour interval of two feet. Imagine taking a photograph of the island from the air and tracing the lines to create a contour map. Because each ring must lie within another, the lines can never split or cross.