

PLANET EARTH LABORATORY MANUAL Geology 001

13th Edition (2019)

by

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How to Get Help and Find Out More about Geology at Hofstra

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Geology Department: Pay us a visit!

We are located on the first floor of
Gittleson Hall, Room 143 (Geology Office, xt. 3-5564).

Our administrative assistant, Ms Edie Reilly, is available from 9:00 a.m. to 2:00 p.m. to answer questions and schedule appointments, but the department facilities are available all day long. Free **tutoring** is available throughout the semester and **lab materials** (mineral and rock specimens, maps) are available for additional study in **Gittleson 161**.

ACKNOWLEDGEMENTS

We thank the entire Geology Department faculty and all of our former Geology 001 students for helping us develop and improve these laboratory exercises and for pointing out errors in the text. We dedicate this manual to the memory of Professor John E. Sanders, whose inspiration and input are sorely missed.

Lab 1 - Introduction to Topographic Maps I: Location, Direction, and Distance

PURPOSE

The objective of this lab is to learn about United States Geological Survey (USGS) **topographic quadrangle maps** and how they are used. Topographic maps are used by a variety of different people (e.g. engineers, planners, soldiers, geologists, and hikers) who need accurate and detailed information about the landscape and geographic features of a region.

INFORMATION FOUND ON TOPOGRAPHIC MAPS

A **map** is a scaled two-dimensional (i.e. flat) representation of some part of the Earth's curved surface. Maps are designed to give the map user an accurate picture of the real world that in most cases emphasizes certain information of interest. Questions that can be answered with information read from a topographic quadrangle map include:

- (1) What buildings, roads, and surface features are present in the map area? (**map symbols**)
- (2) What location on the surface of the Earth is represented on the map? (**longitude and latitude**)
- (3) How can a point on the map be specified? (**UTM grid system**)
- (4) How can a direction of travel from one point to another be specified? (**bearing**)
- (5) What is the distance between points on the map? (**scale**)
- (6) What is the elevation of a point on the map? (**contour lines**)

Information shown on USGS topographic maps

A variety of information relating to each USGS topographic quadrangle is located along the lower margin of the map. For example, in the lower-right corner of a standard topographic map sheet, below the actual map, is an index map of the state showing the location of this quadrangle within it. In the extreme lower-right corner is found the name of the quadrangle. Below that is the date when the aerial photographs were taken and ground surveys made that were used to compile the map (with dates of revision, if any, indicated in purple).

What the map colors represent

White - most undeveloped areas lacking a tree cover (fields, parks, etc.)

Green - tree-covered areas (special patterns for orchards)

Blue - water features or marshes

Red - major roadways

Black - cultural features (schools, roads, railroads, place names)

Pink - urbanized areas (high concentrations of homes and buildings)

Brown - contour lines; used to show relief (changes in elevation).

Purple - used to show revisions in cultural features or changes in contours after original map was made.

What the map symbols represent

Map Symbols

Hard surface, heavy duty road, four or more lanes	
Hard surface, heavy duty road, two or three lanes	
Hard surface, medium duty road, four or more lanes	
Hard surface, medium duty road, two or three lanes	
Improved light duty road	
Unimproved dirt road and trail	
Dual highway, dividing strip 25 feet or less	
Dual highway, dividing strip exceeding 25 feet	
Road under construction	
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	
Important small masonry or earth dam	
Dam with lock	
Dam with road	
Canal with lock	
Buildings (dwelling, place of employment, etc.)	
School, church, and cemetery	
Buildings (barn, warehouse, etc.)	
Power transmission line	
Telephone line, pipeline, etc. (labeled as to type)	
Wells other than water (labeled as to type)	
Tanks; oil, water, etc. (labeled as to type)	
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 X 957
Other recoverable mark, spirit level elevation	X 954
Checked spot elevation	X 4675
Unchecked spot elevation and water elevation	X 5657, ... 870

Boundary, 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	
Section corner, found and indicated		Boundary monument: land grant and other	
United States mineral or location monument			
Index contour		Intermediate contour	
Supplementary contour		Depression contours	
Fill		Cut	
Levee		Levee with road	
Mine dump		Wash	
Tailings		Tailings pond	
Strip mine		Distorted surface	
Sand area		Gravel beach	
Perennial streams		Intermittent streams	
Elevated aqueduct		Aqueduct tunnel	
Water well and spring		Disappearing stream	
Small rapids		Small falls	
Large rapids		Large falls	
Intermittent lake		Dry lake	
Foreshore flat		Rock or coral reef	
Sounding, depth curve		Piling or dolphin	
Exposed wreck		Sunken wreck	
Rock, bare or awash; dangerous to navigation			
Marsh (swamp)		Submerged marsh	
Inundation area		Mangrove	

Figure 1.1 - Topographic map symbols. (United States Geological Survey.)

Laboratory Exercise 1.1
Reading Topographic Quadrangle Maps
Questions based on the USGS Freeport, N. Y.
7 1/2-minute quadrangle map, 1994

Identifying map features:

1. What type of surface area on the map is indicated by pink? _____
by green? _____ by white? _____

2. What is the most common type of building identified by name on this map? _____
What symbol is used to indicate it? _____

3. What other kinds of buildings are marked?

Why are these buildings (and not others) shown on the map?

4. A variety of information is found at the bottom of a topographic map. Can you find...
Name of the quadrangle
Date of production
Location of the quadrangle in the state
General road classification
Grid systems shown
UTM Zone number

5. On the map itself, can you find...
Hofstra University (College)
Axinn Library Building on the Hofstra campus
Roosevelt Field Shopping Center
Eisenhower County Park
Meadowbrook Parkway and Southern State Parkway
Sunrise Highway

LOCATING THE MAP ON THE EARTH - LONGITUDE AND LATITUDE

The first important question a user of a map must answer is: "What part of the Earth's surface is portrayed?" In order to answer this question, one must be able to specify location on the surface of the Earth. The location of points or areas on the surface of the Earth can be shown by means of two groups of intersecting circles known as **latitude** and **longitude** (Figure 1.2). Both latitude and longitude lines represent subdivisions of a circle and are therefore measured in **degrees, minutes, and seconds**. Remember that there are 60 minutes in a degree and 60 seconds in a minute.

Latitude lines are lines that encircle the Earth in east-west-parallel planes perpendicular to the Earth's axis (Figure 1.2). Latitude increases in either the **north** or **south** direction moving away from the zero degree line around the middle of the Earth (the **Equator**). Thus, latitude lines increase in value north and south from **0°** at the Equator to **90°** at the Earth's poles.

Longitude lines are lines that encircle the Earth from pole to pole in north-south-parallel planes parallel to the Earth's axis. Longitude increases in either the **east** or **west** direction away from the zero degree line called the **Prime Meridian**. Because there is no natural 'middle' to the Earth in a vertical-, axis-parallel orientation, the Prime Meridian is defined as the N-S circle that passes through the town of Greenwich, England (the reason for this is historical: Greenwich was the site of the British Royal Observatory and of the telescope used to make the astronomical observations on which the longitude system was originally based). Longitude lines increase in value from **0°** at the Prime Meridian to **180°** at the **International Date Line**.

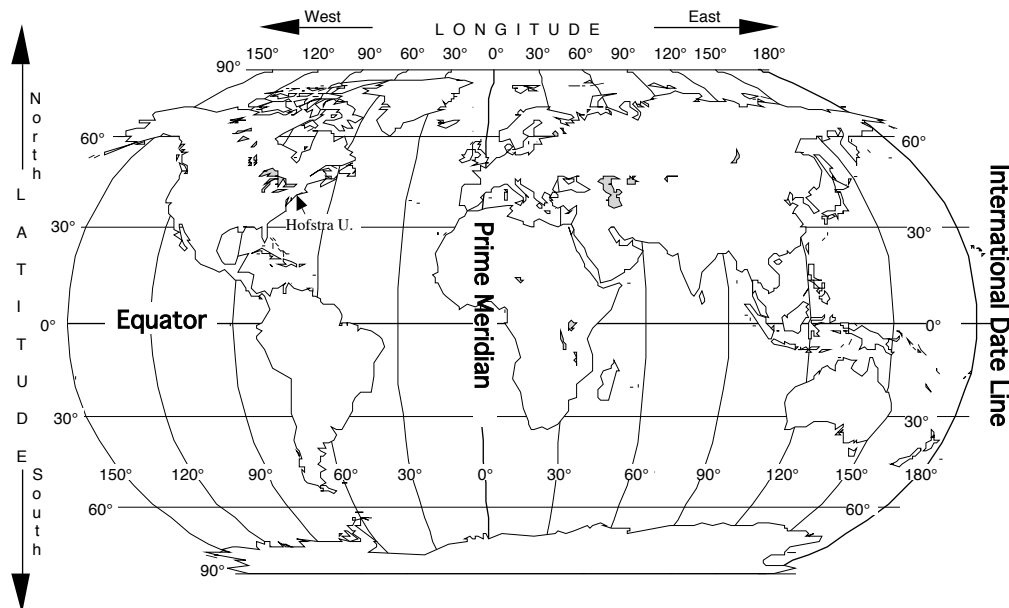


Figure 1.2 - Longitude and latitude lines on the Earth.

Longitude lines have an interesting relationship to time. Because the Earth rotates 15° every hour ($15^\circ \times 24 \text{ hours} = 360^\circ$) local time changes by one hour for every 15° of longitude

traveled. For example, when it is noon in Greenwich, England, it is 2:00 PM in Moscow, 30° to the east and 7:00 AM in New York, 75° to the west.

Using longitude and latitude, any point on the surface of the Earth can be assigned a unique coordinate. For example, New York City is located approximately 41 degrees **north** of the equator and 74 degrees **west** of the Prime Meridian. This would be written:

New York City: 41°N, 74°W

However, we can be much more accurate than this using degree subdivisions of minutes and seconds. For example, the American Museum of Natural History in New York City is located at these coordinates:

A.M.N.H.: 40° 47 min. 00 sec. N, 73° 57 min. 50 sec. W

MAP GRID SYSTEMS

Map grid systems allow the map user to locate- or report on a specific point on the map. For example, longitude and latitude lines on a Mercator-projection map form a rectangular grid system that can be used to identify locations. In the United States, four kinds of grid system are common found on maps: (a) map quadrangles based on longitude and latitude; (b) the universal metric grid system or UTM; (c) the United States Land Survey; and (d) the 10,000-foot grid system. Types (a) and (b) are used extensively in the United States and we will learn how to use them in this lab. Land-survey maps (c) are used extensively in the western states and the 10,000-foot grid system (d) is used by the New York State Department of Transportation.

LONGITUDE AND LATITUDE MAP-QUADRANGLE GRID

In the United States, four sizes of quadrangle-map grids are used. These are based on longitude and latitude measured in minutes or in degrees. The standard map-quadrangle sizes are: 7 1/2-minutes; 15 minutes; 30 minutes; and 60 minutes = 1 degree. Each map size covers an area bounded by an equal number of minutes of longitude and latitude. On a standard U. S. Geological Survey topographic quadrangle map, the information about methods of preparing the map, the map projection used (and its datum), and grid systems used appear in the lower left-hand corner of the map.

Reading Longitude and Latitude on a Topographic Map

The maps that we will be working with in lab are United States Geological Survey (USGS) 7 1/2-minute topographic quadrangle maps. On these maps the longitude and latitude coordinates are given at each corner of the map, and in thirds along the sides of the map at 2 minute, 30 second intervals (2' 30"). Figure 1.3 shows the longitude and latitude grid common to all 7 1/2-minute topographic maps. Complete longitude and latitude coordinates are shown at the corners of the map. Coordinates are also shown at two locations, spaced 2.5 minutes apart, along each side of the map. Notice that degree values are not shown if they remain the same

between corners and that seconds are usually not shown if they are 00. Notice also that each edge of the map covers 7-1/2 minutes of longitude or latitude.

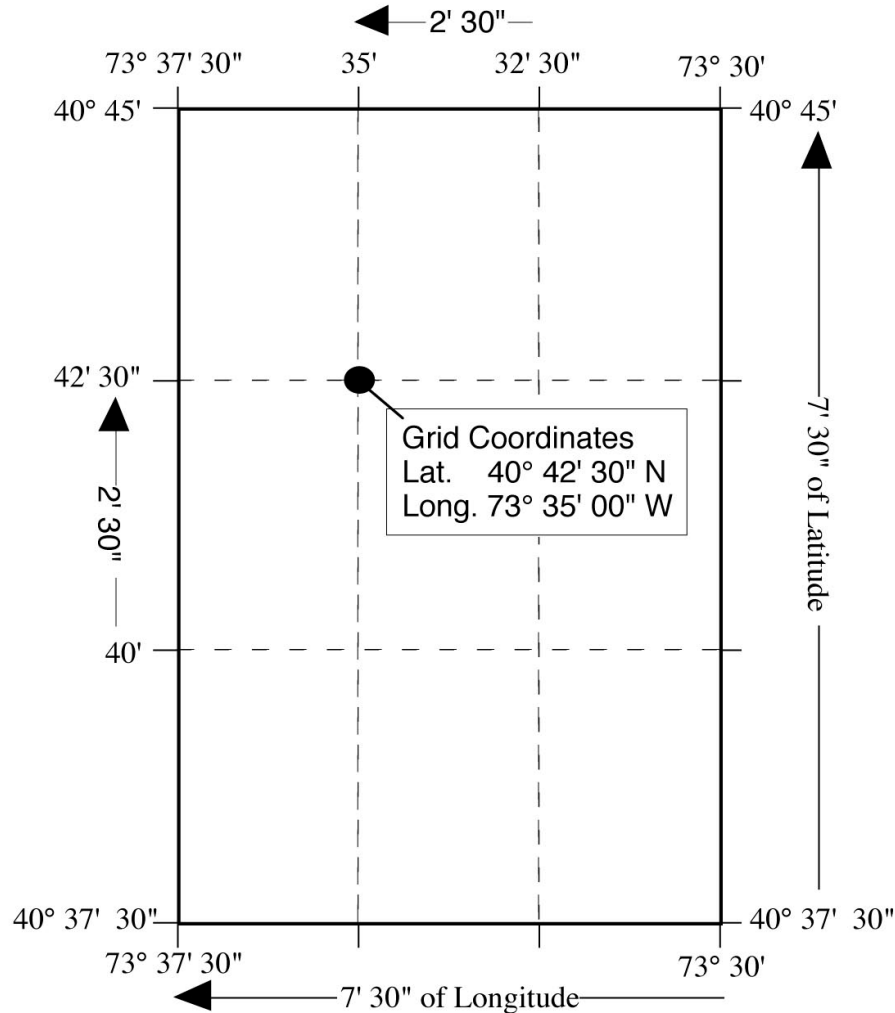


Figure 1.3 Longitude and latitude grid found on all USGS 7 1/2-minute topographic maps. (Coordinates for Freeport, NY quadrangle shown above.)

Remember, because the United States is west of the prime meridian and north of the equator, all longitude coordinates are west (W) and all latitude coordinates are north (N). Notice that the longitude numbers increase from right to left and that the latitude numbers increase from bottom to top.

The longitude and latitude grid is very useful for locating a map on the globe and for designating quadrants on a map. However, for specifying the location of a particular point on a topographic quadrangle map, longitude and latitude can be cumbersome because the 7 1/2-minute map shows only four marked lines each of longitude and latitude. It is difficult to quickly and accurately estimate the longitude and latitude of points that lie between the marked lines.

UNIVERSAL METRIC GRID (UTM)

An easier-to-use grid system for specifying a point on a topographic quadrangle map is the **Universal Metric Grid** or **UTM**. The Universal metric grid system is based on the Universal Transverse Mercator map projection (hence the name ‘UTM’) between 80° N and 80° S, and on the Universal Polar Stereoscopic projection between 80° and each pole. This grid system subdivides the map region into one-kilometer squares. Each marked UTM line on the map is exactly 1000 meters (1 kilometer) to the north or east of the last UTM line. Each UTM line has a number designation based on its distance from a reference point. One does not need to know where these reference points are to use the UTM grid. It is sufficient to specify the name of the map being used and the UTM coordinates read from the map to locate a particular point. Points that fall between the marked UTM grid lines can be accurately located by using the 1000-meter scale bar found at the bottom of the map.

Reading UTM Coordinates on a Topographic Map

UTM lines are marked on the margins of USGS topographic quadrangle maps as small, blue tick marks with numbers beside them (Figure 1.4). Newer versions of these maps also include black gridlines drawn across the face of the map.

The upper-left and lower-right corners of the map show the full UTM coordinates. These numbers are read simply as numbers of meters east or north of a reference line. The digits are printed at different sizes to accentuate the thousands and ten thousands places, which change as each new grid line marks 1000 meters of distance. Notice that the ones, tenths, and hundredths places are left off of most of the UTM coordinates printed on the map.

The precise UTM coordinates of any point on a map can be found by noting the coordinates of the nearest intersecting blue tick marks and then by using the kilometer scale at the bottom of the map to measure the number of meters away to the east and north the point is from the nearest tick marks (Figure 1.4).

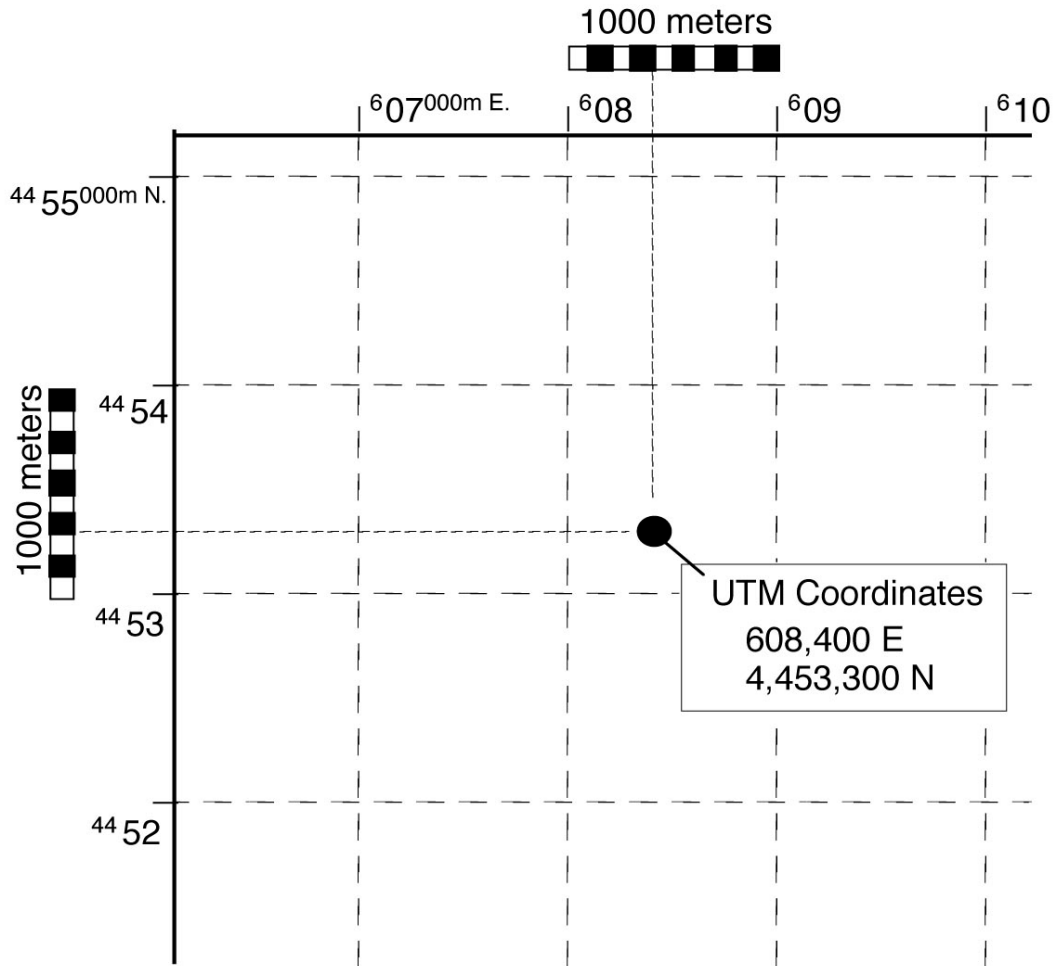
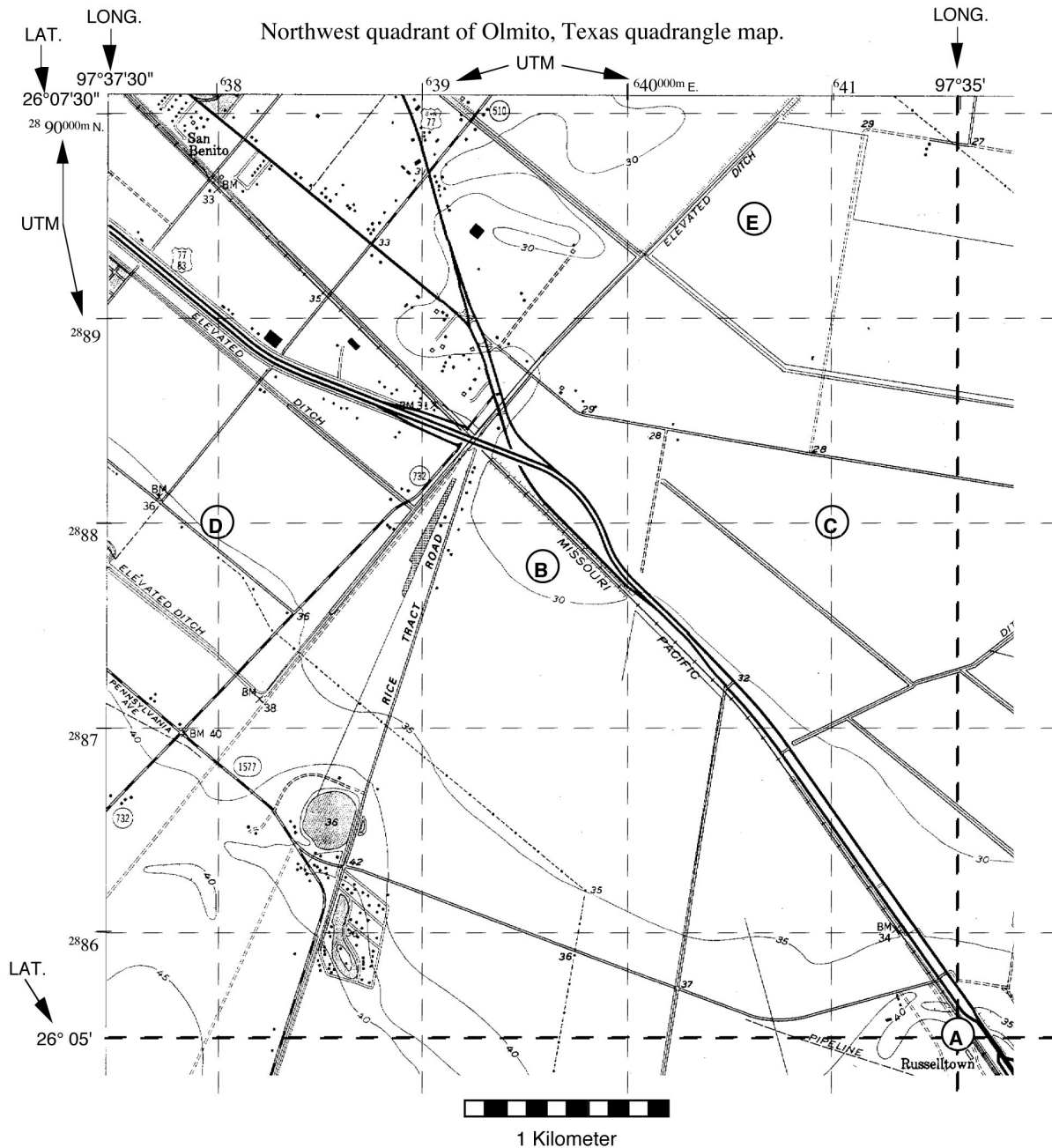


Figure 1.4 The upper left corner of a topographic quadrangle map showing the UTM grid.

Example: The upper left corner of Figure 1.4 is marked 607^{000}m E indicating that the tick mark associated with this number is 607,000 meters to the east of the reference line. Moving east, each UTM line increases by 1000 meters giving 608 , 609 , 610 , etc. The 100's of meters are left off because they are 000 at each tick. On the left side is a similar number 4455^{000}m N indicating that this mark is 4,455,000 meters north of the reference line. These numbers count down by 1000 meters going south (4455 , 4454 , 4453 , etc.) indicating a decrease in distance of 1000 meters toward the reference line with each UTM mark.

Laboratory Exercise 1.2a – Map coordinate systems



Determine the longitude and latitude or UTM coordinates of the points marked on the map.

A.: Long. _____ Lat. _____

B.: Long. _____ Lat. _____

C.: UTM. _____ E. _____ N. _____

D.: UTM. _____ E. _____ N. _____

E.: UTM. _____ E. _____ N. _____

Laboratory Exercise 1.2b

Using Topographic Quadrangle Maps
Questions based on the USGS Freeport, N. Y.
7 1/2-minute quadrangle map

Finding Locations Using Coordinate Systems

1. How many minutes of latitude and how many of longitude are encompassed by the map?

2. What is the name of the school located nearest to the following coordinates:

lat. $40^{\circ} 40' 00''$ N, long. $73^{\circ} 35' 30''$ W _____

3. What is the approximate **latitude** and **longitude** of Newbridge Pond, a small body of water located in the town of Merrick, just north of the Sunrise Highway?

Lat. _____ Long. _____

4. What is the approximate **latitude** and **longitude** of the town of Freeport, NY?

Lat. _____ Long. _____

5. What is the name of the school located at UTM **623,000 E.**, **4,508,000 N.** ?

6. What is the name of the school located at UTM **624,100 E.**, **4,503,600 N.** ?

7. Locate the campus of Hofstra University (labeled as “Hofstra College” on the map). As accurately as possible, determine the UTM coordinates for the **Axinn Library** (large “I”-shaped building next to Hempstead Turnpike).

Axinn: E _____ N _____

8. What is the approximate **latitude** and **longitude** of Hofstra University?

Lat. _____ Long. _____

DETERMINING BEARING AND MAGNETIC DECLINATION

A **bearing** is a compass direction from one point to another on a map or on the surface of the Earth. Bearings are defined by the angle between a line pointing north and the line connecting the two points. In the field, a bearing is measured using a compass, which is an instrument capable of measuring the angle between a sighted bearing (the direction the compass is pointed) and the direction to the Earth's magnetic pole. On a map, bearings are measured using a protractor, with north generally defined as the direction pointing straight to the top of the map.

The Compass Rose

The compass rose is the familiar north, east, south, west cross used to show direction on a map (Figure 1.5). There are two methods of designating a bearing, depending on which style of compass rose is used. The **Azimuth** method is based on a 360° circle. A bearing is reported as the angle between the bearing line and 0°, measured clockwise around the compass rose. The **Quadrant** method is based on a division of the compass rose into four quadrants. Bearings are read as the angle between north or south and the bearing line in either the east or west direction. For example, in Figure 1.5 a bearing line midway through the NW quadrant of the compass rose can be read as 315° (start at north, turn 315° clockwise - [azimuth method]) or as N 45° W (start at north, turn 45° to the west - [quadrant method].)

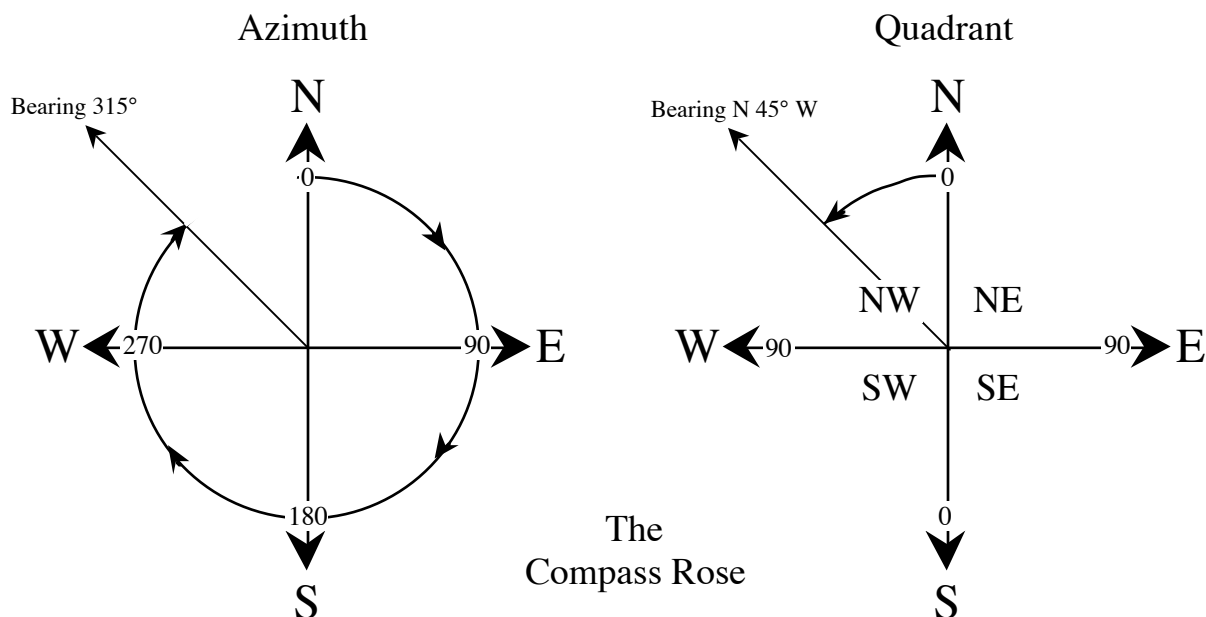


Figure 1.5 The Compass Rose showing both azimuth and quadrant bearings.

In general, the quadrant method of reporting bearings is easiest to use. One advantage is seen in converting from a bearing to its reverse in the opposite direction. For example, if a bearing from point A to point B is given as N 55° W, the reverse bearing from B back to A is S 55° E; one has only to reverse the compass directions while keeping the same angle. Azimuth bearings are advantageous if one needs to process them using a computer because each bearing can be represented by a single number.

Magnetic North and True North

North is shown along the lower margin of a standard topographic map by three arrows whose tips are marked MN, \uparrow , and GN (Figure 1.6). These refer to Magnetic North, True North, and Grid North, respectively. By convention, True North is toward the top of the map; it is defined by the meridians of longitude. Magnetic North is the direction toward which a compass needle points within the map area. The angle between Magnetic North and True North is known as the **magnetic declination**. Because the magnetic pole shifts westward with time, the declination needs to be monitored and updated for accurate navigation. Grid North shows the deviation between the rectangular grids overlain on the map and true geographic north. This deviation occurs because a map is a flat representation of the Earth's curved surface.

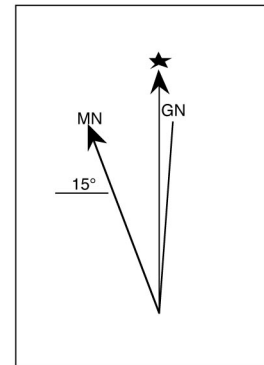


Figure 1.6

True North is different from Magnetic North because the Earth's geographic north pole and its north magnetic pole are not located at the same place (Figure 1.7). The apparent angle between them (magnetic declination) changes as you move to different places on the globe. All USGS topographic quadrangle maps show the amount and direction (east or west of north) of magnetic declination for a given map area. For compass bearings to agree with bearings measured from a map, the compass must be set to compensate for magnetic declination. Otherwise, map and compass bearings are being measured from different 0° (north) lines. One can convert from a True North map bearing to a magnetic north compass bearing, or visa-versa, by either adding or subtracting the magnetic declination value from the true north value (Figure 1.8).

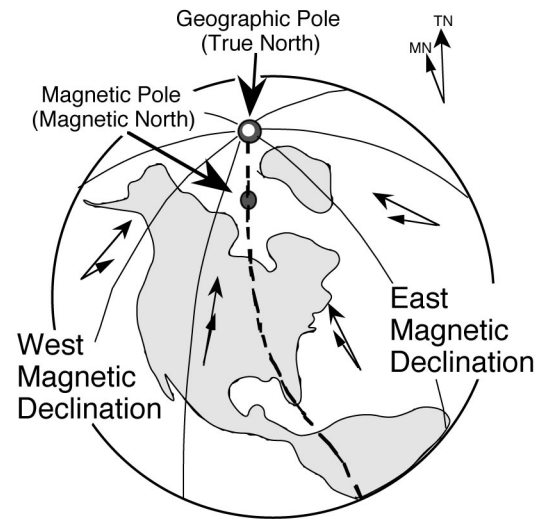


Figure 1.7

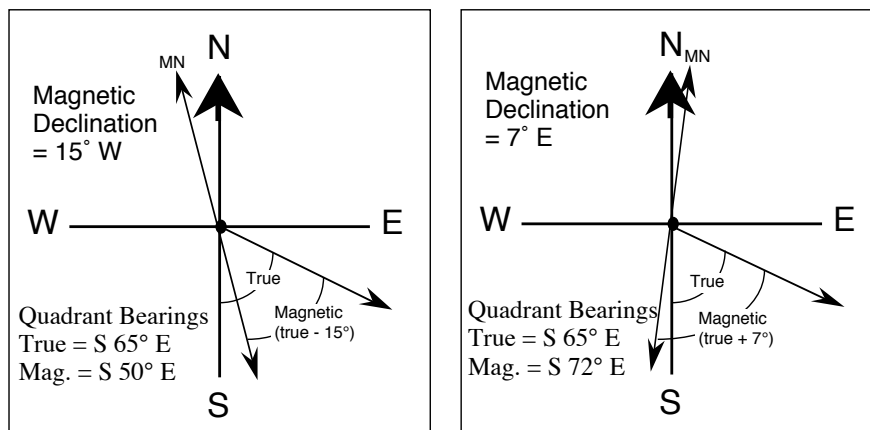
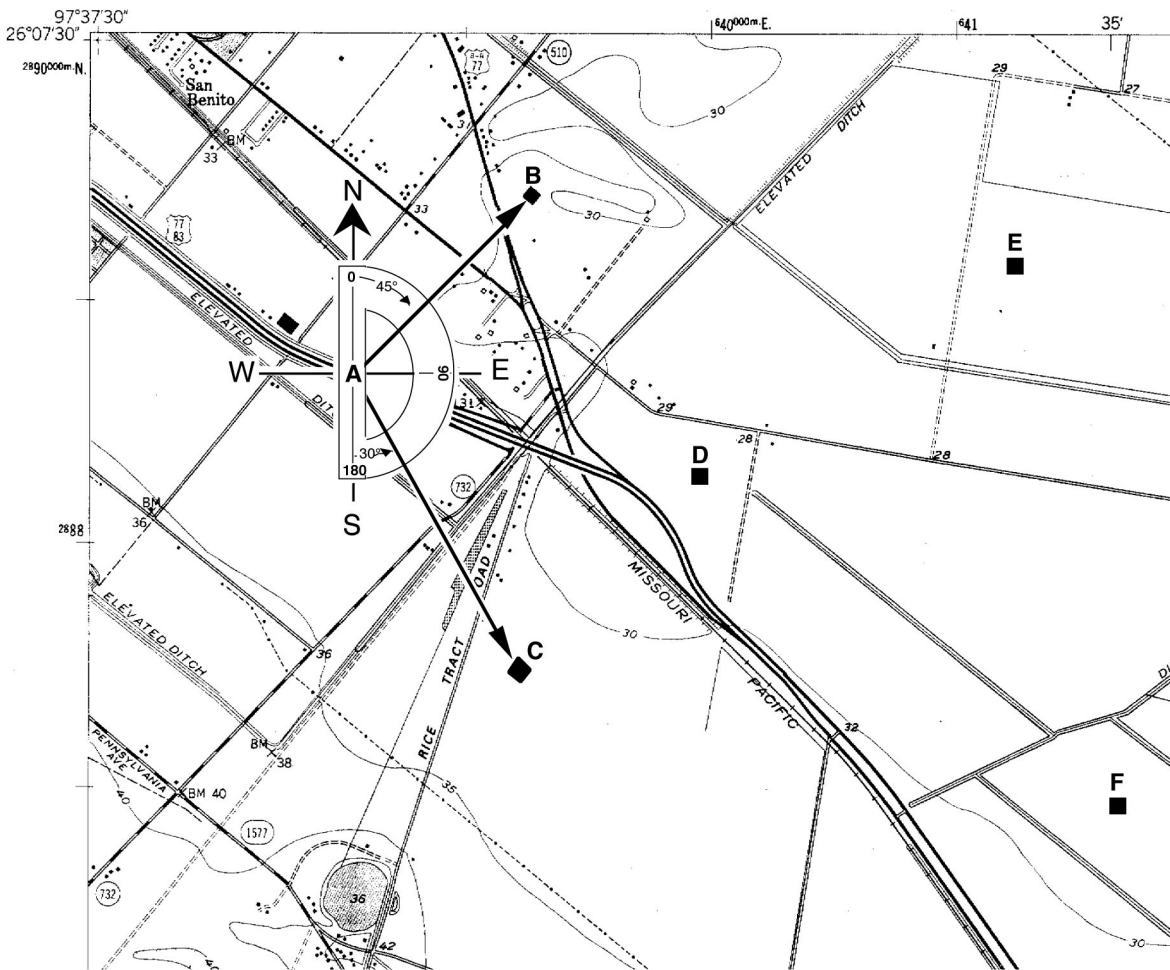


Figure 1.8 Converting between True North and Magnetic North.

Laboratory Exercise 1.3a - Measuring Bearings



Instructions: To measure a bearing between two points on a map, center the protractor on the map at the first point with the zero line (axis) of the protractor facing north (straight up the map) or south (straight down the map). With the protractor correctly oriented, read the angle between north or south and the bearing line to the second point. It is usually better to ignore the numbers marked on the protractor and simply use the protractor scale to count degrees away from the axis toward the line you are measuring.

Example (shown above):

Bearing A - B : N 45° E (quadrant) or 045° (azimuth)

Bearing A - C : S 30° E (quadrant) or 150° (azimuth)

Draw and then measure the following bearings using a protractor:

1. D - E :	_____	4. D - B :	_____
2. D - F :	_____	5. D - C :	_____
3. C - D :	_____	6. B - D :	_____
	Azimuth Quad.		Azimuth Quad.

Laboratory Exercise 1.3b
Using Topographic Quadrangle Maps
Questions based on the USGS Freeport, N. Y.
7 1/2-minute quadrangle map

Measuring Compass Bearings

1. What is the magnetic declination in the map area? _____

2. Locate the M8 interchange of the Meadowbrook State Parkway near Freeport. What is the **quadrant bearing** from the **M8** interchange to the **W5** interchange east along the Sunrise Highway?

3. In the northern region of the map, locate the **skating rink** inside of Eisenhower County Park and the **Roosevelt Field Shopping Center** next to the Meadowbrook Parkway.

What is the **quadrant** bearing from the skating rink to the shopping center?

What is the **quadrant** bearing from the shopping center back to the skating rink?

4. What is the **azimuth** bearing from the skating rink to the Axinn Library Building (large "I"-shaped building next to Hempstead Turnpike on the "Hofstra College" campus)? _____

5. What is the nearest school encountered along an **azimuth** bearing of **180°** from the skating rink? _____

MAP SCALES AND MEASUREMENT OF DISTANCE

A **map scale** is a **ratio** that expresses the relationship between distances on the map and corresponding distances in the real world, in the same units, whatever these may be. The standard map scale for topographic quadrangle maps in the United States is 1/24,000. This means that one unit on the map (centimeter, inch, shoe length, etc.) is equivalent to 24,000 of those units (centimeter, inch, shoe length, etc.) in the real world. It does not matter what units you use to make your measurement from the map, in the real world the equivalent distance will be 24,000 times the map distance on a standard topographic map.

If you measure a distance on a 1:24,000 scale map to be two inches, the corresponding actual distance is 48,000 inches. However, this is not a very useful way to report distance because very few people have any intuitive sense of how far 48,000 inches is. It is much more useful to convert 48,000 inches into the equivalent number of feet (48,000 inches / 12 inches per foot = 4000 feet) or miles (4000 feet / 5280 feet per mile = .76 miles). Below are the commonly used conversion factors for converting between inches and miles or between centimeters and kilometers.

Metric:

100 centimeters = 1 meter

1,000 meters = 1 kilometer

100,000 centimeters = 1 kilometer

English:

12 inches = 1 foot

5,280 feet = 1 mile

63,360 inches = 1 mile

When reporting a scale, the units of distance must be specified if they are not the same between the map and the real world. If they are the same then the scale can be expressed as a unitless fraction.

For example:

If 1 inch on the map equals 2000 feet on the ground, the scale is **1 inch : 2000 feet** or, because 2000 feet x 12 inches = 24,000 inches, **1/24,000**. If 1 inch on the map equals 1 mile on the ground, the scale is 1 inch/5280 feet x 12 inches/foot or **1/63,360**. The ratio expressing the scale of the map is named the **representative fraction**. This is sometimes abbreviated as **RF**.

U. S. Topographic map series

RF

7.5-minute

1/24,000

15-minute

1/62,500

30-minute

1/125,000

1-degree

1/250,000

4-degree

1/1,000,000

On each map will be found at the bottom center, and possibly also along one of the sides, a **graphic scale**, in which actual distances along the map are shown with their equivalent real-world units, such as thousands of feet, miles, or kilometers. Such a graphic scale (also known as a **bar scale**) is very useful because it will change size if the map is photocopied and either reduced or enlarged. The RF is valid only on the size of the map as originally printed.

Laboratory Exercise 1.4a
Calculating Distance Using a Ratio Scale

INSTRUCTIONS:

To estimate the actual distance between any two points on a map, use the **Measure-Multiply-Convert** procedure.

Step 1. Measure the map distance using a ruler.

If you want your final answer in **feet** or **miles**, measure in **inches**.

If you want your final answer in **meters** or **kilometers**, measure in **centimeters**.

Example: Two schools on the Freeport Quadrangle map are measured to be 6 inches in map distance from one-another. How far is their actual distance in miles?

Step 2. Multiply your measurement by the ratio (RF) scale of the map. This will give you the actual distance in the real world in the same units you measured in.

Example: The scale of the Freeport map is 1:24,000. 6 inches x 24,000 = 144,000 inches (actual distance between the two schools).

Step 3. Convert the actual distance from inches or centimeters to more useful units such as miles / kilometers.

To get miles from inches, divide by **63360** inches per mile.

To get kilometers from centimeters, divide by **100,000** cm per kilometer.

Example: 144,000 inches / 63360 inches per mile = 2.3 miles (actual distance between the two schools).

QUESTIONS:

1. Barbie and Ken rent a Malibu beach house, but because sales have been down, they can only afford one that is several blocks from the shore. Estimate the distance in miles from the house to the beach given the following information:

Map scale = 1:12,000; Measured map distance from the house to the beach = 2.7 inches

2. The distance from the north end of Central Park in Manhattan to the south end of the park is measured to be 17.2 cm on a 1:24,000 scale map. What is the actual distance in kilometers?

3. The same distance is measured in inches and found to be 6.75 inches. What is the length of Central Park in miles?

Laboratory Exercise 1.4b
Using Topographic Quadrangle Maps
Questions based on the USGS Freeport, N. Y.
7 1/2-minute quadrangle map

Estimating Distance Using the Bar Scale

Instructions: Answer the following questions **using the graphical or bar scale** shown at the bottom center of the map.

1. How many actual feet are represented by one inch of map distance? _____
2. How many actual meters are represented by one centimeter of map distance? _____
3. How many inches of map distance equal one actual mile? _____
4. How many centimeters of map distance equal one actual kilometer? _____
5. Using the edge of a piece of paper to mark off the distance and then compare it to the bar scale, estimate the straight-line distance along the Meadowbrook State Parkway from the M5 Interchange (Hempstead Avenue) south to the M6 Interchange (Southern State Parkway).

Miles _____ Kilometers _____

Measuring Distance Using the Ratio Scale

Instructions: Answer the following questions **using the ratio or RF scale** shown at the bottom center of the map, above the bar scale.

6. What is the ratio or RF scale of this map? _____
7. Measure and calculate the straight-line distance from the M5 Interchange south to the M6 Interchange on the Meadowbrook State Parkway. To do this, measure the distance on the map in both inches and centimeters. Multiply each measurement by the ratio scale and convert to miles and kilometers. Compare your measured distances to the estimated distances obtained using the bar scale.

Miles _____ Kilometers _____

8. Using the same method, measure the straight-line distance from the east edge of the map to the west edge of the map.

Miles _____ Kilometers _____

Lab 2 - Introduction to Topographic Maps II

Contour Lines, Profiles, and Gradients

PURPOSE

Today's laboratory is intended to acquaint you with topographic contour maps and topographic profiles. The basics of topographic maps, map scales, map grids, and symbols were covered in last week's lab. This week, we will focus on reading and interpreting these maps for information on **elevation**, **gradient**, and **landscape profile**.

CONTOUR MAPS

Topographic contour maps are maps that show the changes in elevation throughout the map area using lines of constant elevation called **contour lines**. By means of contour lines the three-dimensional "lay of the land" can be illustrated in two dimensions on a printed map. Standard USGS Topographic Quadrangle Maps include contour lines.

Contour Lines

Imagine, if you will, a small hill in the middle of a field. If we could get our hands on one of those chalk carts that are used to put lines on athletic fields, then we could use the cart to draw contour lines on the hill. We would do this by starting at the base of the hill and pushing the cart around the base, following a level line, but staying with the edge of the slope at the base of the hill. Then we would measure 10 feet of vertical distance (altitude or **elevation**) and move the cart to a point on the hill ten feet above the level ground. Starting from this point we would push the cart around the hill, never moving up or down the hill, but always staying exactly ten vertical feet above the level ground. We would go around the hill and eventually come back to where we started, having drawn a 10-foot contour line. Now, moving another ten feet up, we would do this again. Another ten feet after that, and we go around the hill again. If we keep making lines around the hill, moving up ten feet every time, eventually we will reach the top of the hill. Chances are that the actual summit of the hill would be a little above the last line we made, but below the next ten-foot interval.

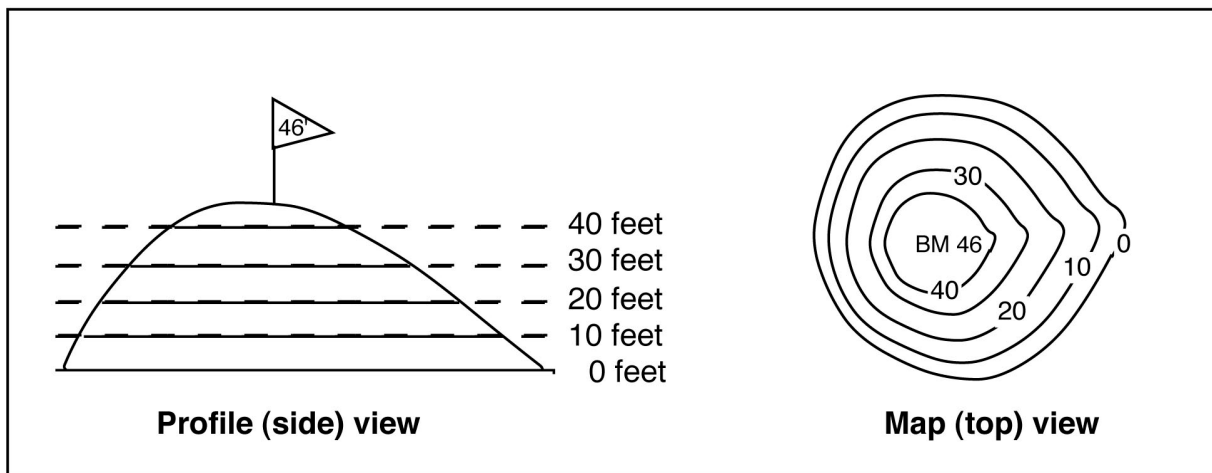


Figure 2.1 - Contour lines drawn on an imaginary hill viewed from the side and the top.

If we had a sensitive altimeter, we could measure the height of the top of the hill. Let's say that we make four lines above the base of the hill (that's five lines total, counting the one around the base) and that we measure the highest point at the top of the hill to be 46 feet high, marking it with a flag.

Now, if we flew over the hill in a helicopter and photographed it from above, the lines we have marked on the hill (side view, Figure 2.1) would appear as a series of concentric circles (top view, Figure 2.1). We could then mark each circle in the photograph with the height that it represents, and also mark the summit of the hill with the height that we measured.

Having done this, we have constructed a **topographic contour map**. Each line is called a **contour line**, and the change in height from one line to the next (10 feet in this case) is called the **contour interval**. The measured height marked at the top of the hill we call a **bench mark (BM)**. The base of the hill where we began measuring elevation is our zero elevation point or **datum**. In most cases, datum on topographic maps is defined as **mean sea level**.

Contour lines also indicate the **slope** of the Earth's surface. Where contour lines are closely spaced, slopes are steep. Where the contour lines are spaced widely apart, slopes are gentle. All of the land on one side of a contour is higher than the land on the other side of the contour. Therefore, when you cross a contour, you either go uphill or downhill. The basic determination in reading any contour map is to figure out the direction of slope of the land. Careful examination of stream-flow directions and bench marks will give you a general feeling for the overall slope of the Earth's surface in any given map area. Some general rules for contour lines are given on the following pages:

The Rules of Contour Lines

When reading contour maps, or trying to determine what the elevations of contour lines are, one must apply a few basic rules of contour lines. There are no exceptions to these rules!

1. Closed contour lines on a map indicate either a hill (peak, mountain, etc.) or a hole (depression, etc.). Closed contours that indicate that the land slopes down into a hole are marked by hachured lines to distinguish them from closed contours that indicate that the land slopes up over a hill (Figure 2.2).

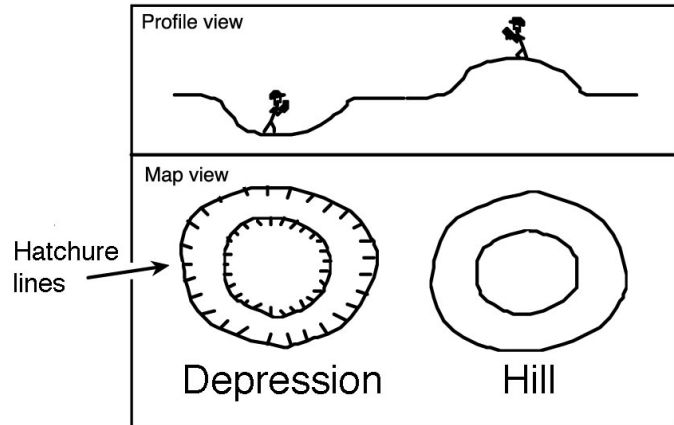


Figure 2.2

2. A **single contour line** represents a **single elevation** along its entire length. In other words, the elevations of all points along a contour line are the same.
3. Contour lines **never** split, cross, or intersect. A vertical cliff they do, however, come together and touch (Figure 2.3).

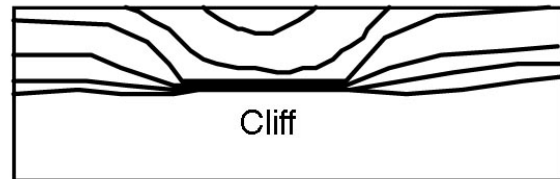


Figure 2.3

4. The elevation of a contour line is always a simple multiple of the contour interval. For ease of reading, by convention, each fifth consecutive contour line is an **index contour** (drawn as a thicker line than adjacent contours and also numbered somewhere along the trace of the contour line). Commonly used intervals are 5, 10, 20, 40, and 80 feet.
5. Widely spaced contour lines indicate a gentle slope. Closely spaced contours indicate a steep slope.
6. Every contour line eventually closes on itself. However, any one map will not be large enough to show the full extent of all contour lines, and some will simply end at the edge of the map. Where one closed contour line surrounds another, the inner contour line marks the higher elevation. If the contour lines are hachured, then the inner contour line marks the lower elevation.

7. Where a contour line crosses a stream or a valley, the contour bends to form a 'V' that points upstream or up the valley (Figure 2.4).

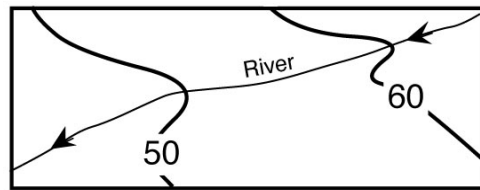


Figure 2.4

8. Where two adjacent closed contours indicate opposite slopes (hachured contour next to a normal contour) both are the same elevation (Figure 2.5).

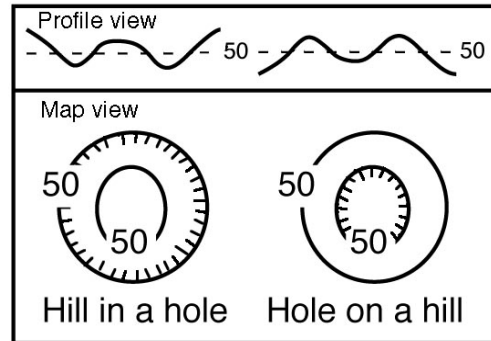


Figure 2.5

9. A hachured contour line, lying between two different contour lines, is the same elevation as the lower contour line (Figure 2.6).

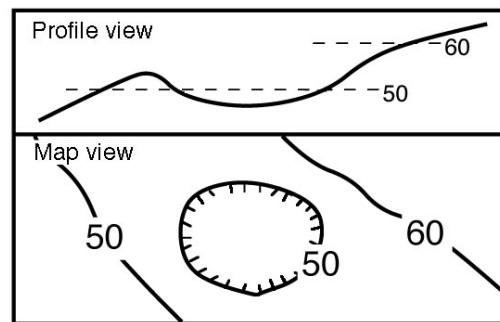


Figure 2.6

10. A closed contour line, lying between two different contour lines, is the same elevation as the higher contour line (Figure 2.7).

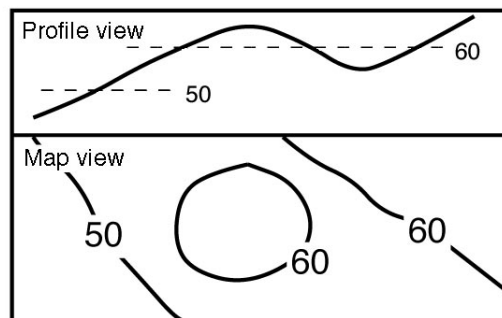
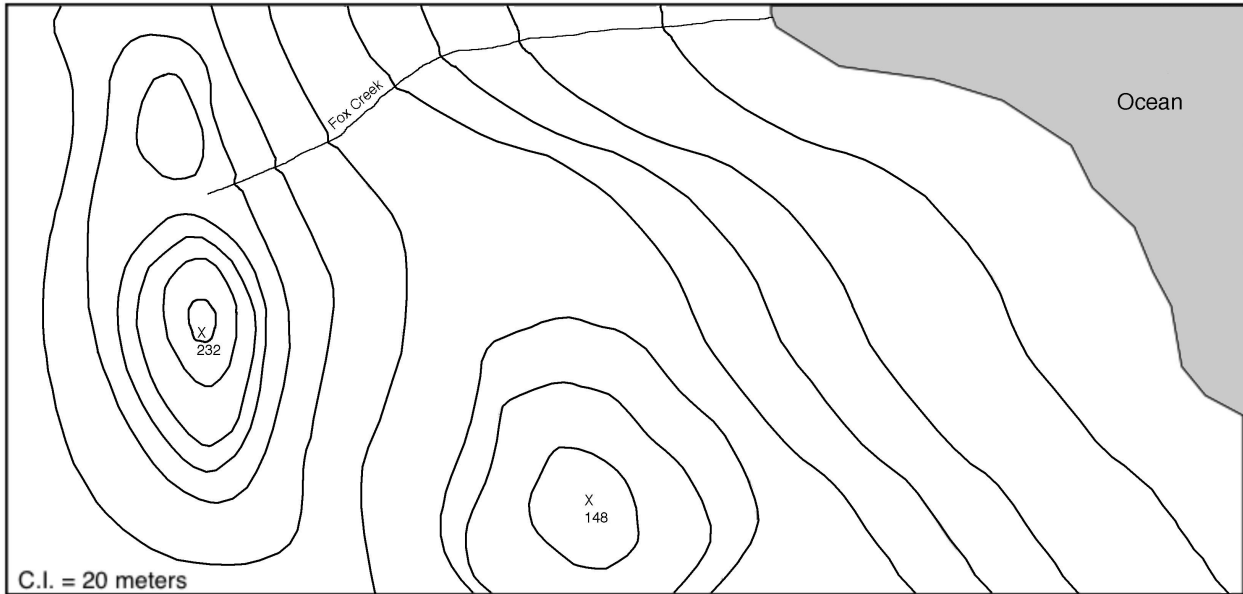


Figure 2.7

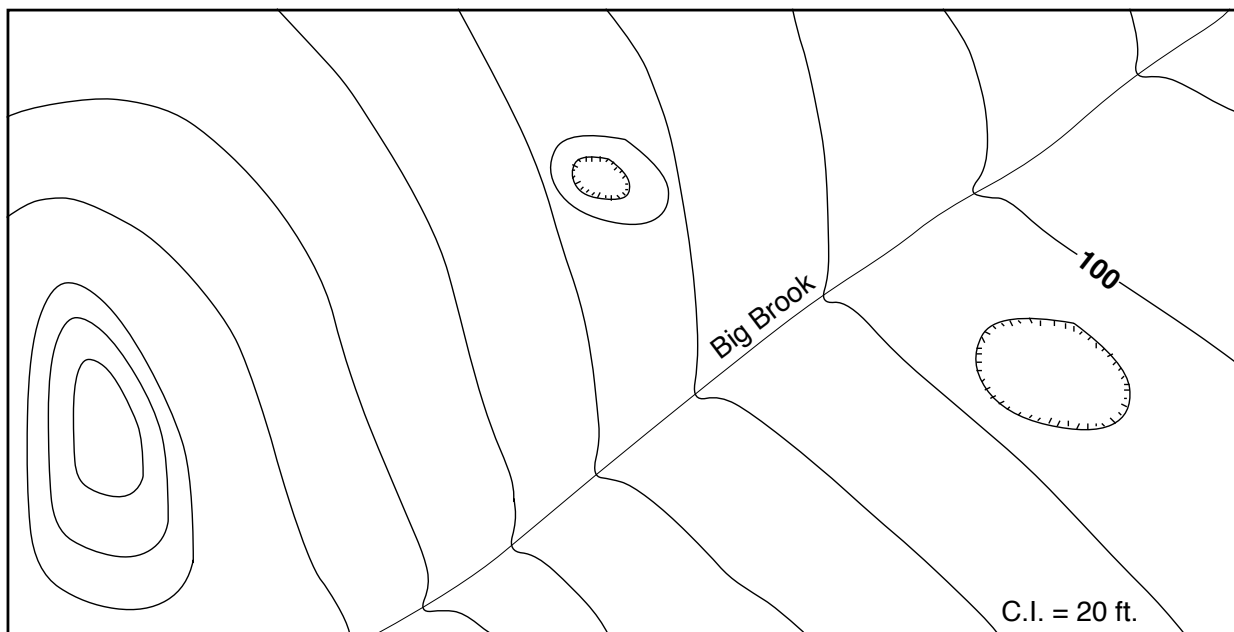
11. Finally, "Obey all the rules"!

LABORATORY EXERCISE 2.1 Determining topographic contour values

Using the rules of topographic contours listed above, label all of the topographic contour lines in the following maps (2.1a - 2.1b) with their correct elevations. Zero elevation is sea-level (shore line). Note the **contour interval** (C.I.) given on each map.

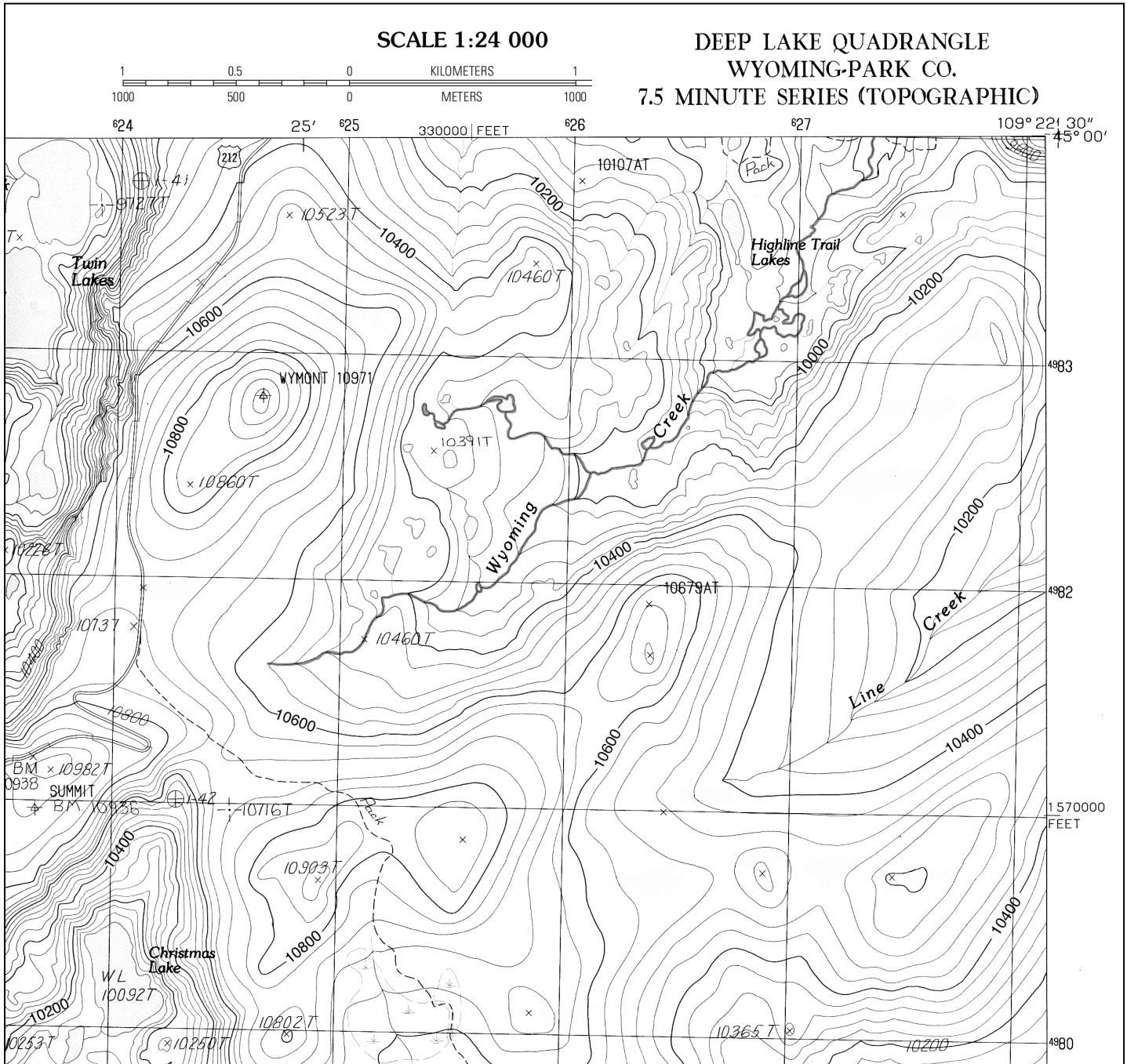


Exercise 2.1a



Exercise 2.1b

LABORATORY EXERCISE 2.2
Interpreting topographic contour maps



Using your knowledge of topographic contour maps, answer the questions based on the northeast quadrant of the Deep Lake Topographic Quadrangle, Wyoming Park, CO.

1. What is the **index contour interval** (thick contour lines)? _____ ft.
2. What is the **map contour interval** (thin contour lines)? _____ ft.

3. What is the approximate elevation of the mountain peak located at UTM 4980700N, 627500E? _____ft.
4. What is the approximate elevation of the mountain peak located at UTM 4981700N, 626400E? _____ft.
5. Which side of this mountain is the steepest? _____
6. What is the approximate elevation of Christmas Lake? _____ft.
7. Estimate the total change in elevation (relief) of Wyoming Creek from its headwaters in the center left of the map to where it exits the map in the top right. _____ft.
8. In what compass direction does Wyoming Creek flow? _____
9. Explain three different methods that you can use to determine which direction Wyoming Creek flows:
 - a. _____

 - b. _____

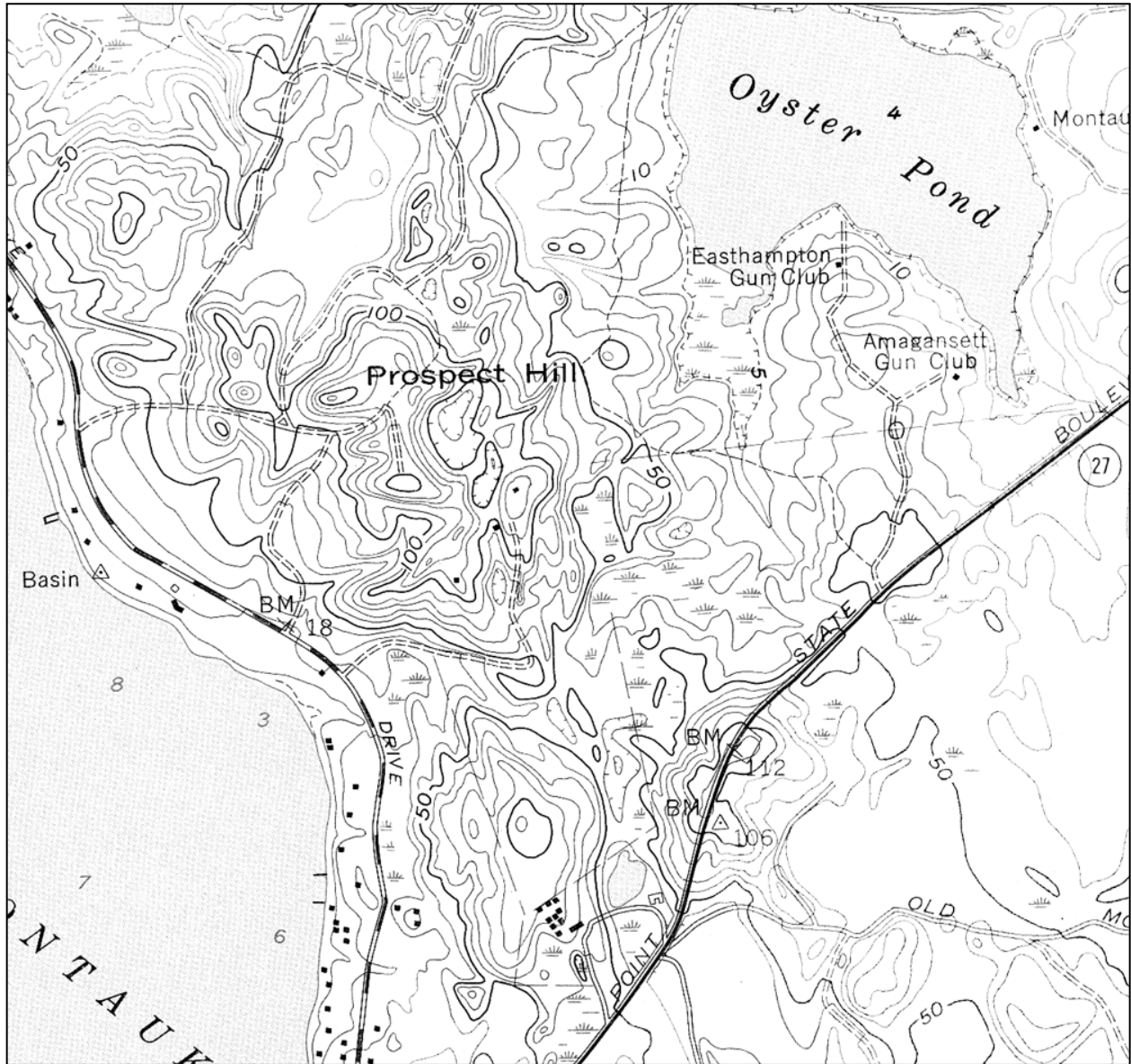
 - c. _____

10. What is the maximum elevation you would reach driving along Highway 212 on this map? _____ft.
11. Does Highway 212 go uphill, downhill, or remain level from north to south?

Laboratory Exercise 2.3

Reading Elevations from Topographic Quadrangle Maps

Questions based on the USGS Montauk, NY 7 1/2-minute quadrangle map.



1. What is the contour interval used on this map? _____ ft. Index contour? _____ ft.
2. What is the highest elevation reached at the top of Prospect Hill? _____ ft.
3. What is the approximate elevation of the bottom of the depression in the center of Prospect Hill?
_____ ft.
4. What is the approximate elevation of the Easthampton Gun Club building? _____ ft.

Topographic Profiles

A topographic profile is a vertical 'slice' through the landscape constructed along a straight **line of profile** drawn across a topographic map. A topographic profile shows changes in **relief** (change in elevation) in the vertical dimension as a silhouette. We construct topographic profiles to get a ground-level view of the lay of the land (Figure 2.8).

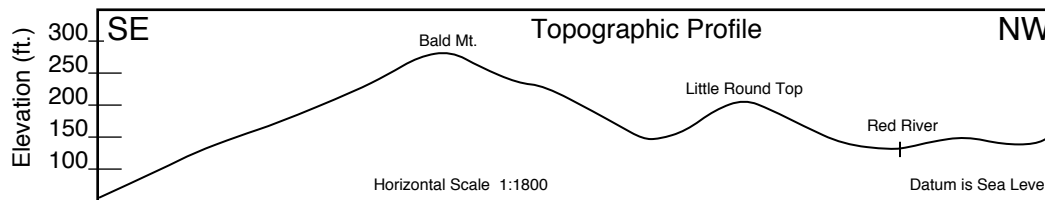


Figure 2.8 Example of a topographic profile.

A well-constructed topographic profile must also include the following information:

- A description of the line of profile, including the name of the map quadrangle from which the profile was derived and the compass directions at each end of the profile (i.e., SE and NW).
- Above the profile, letter in the names of prominent geographic features, such as rivers or mountains. The space below the profile line may be needed for showing geologic structure. Therefore, even though the profile line is intended to show the configuration of the land surface only, form the habit of keeping clear the space below the profile line.
- All profiles should be labeled with a horizontal scale (taken from the map), vertical scale (determined by the maker of the profile), a vertical exaggeration (see explanation to follow), and the datum used to control the vertical scale (usually sea level).

Instructions for drawing a topographic profile

(See figure 2.9)

A.. Select the line of profile on the map.

B. Place the edge of a blank strip of scrap paper along the line of profile. You may want to tape down the ends of this strip of paper so it will not move while you are working with it.

Using a sharp pencil point, make precise tick marks at places where contours and other features on the map (streams, tops of hills, etc.) intersect the edge of the paper strip. Label the tick marks with the elevation values of the contours.

C. Select a vertical scale. On a piece of graph paper, draw in a segment of the vertical scale having a range large enough to include the elevations all the points (= contours) to be plotted. Label the elevation of the datum (zero line) of the cross section (usually sea level).

Realign the edge of the strip that formerly lay along the line of profile so that it now lies along the bottom line of the graph paper.

Plot a point for each tick mark at the appropriate elevation directly above each contour tick mark. Connect the plotted points with a line that curves with the shape of the land (i. e., rounded hills, V-shaped stream valleys, etc.).

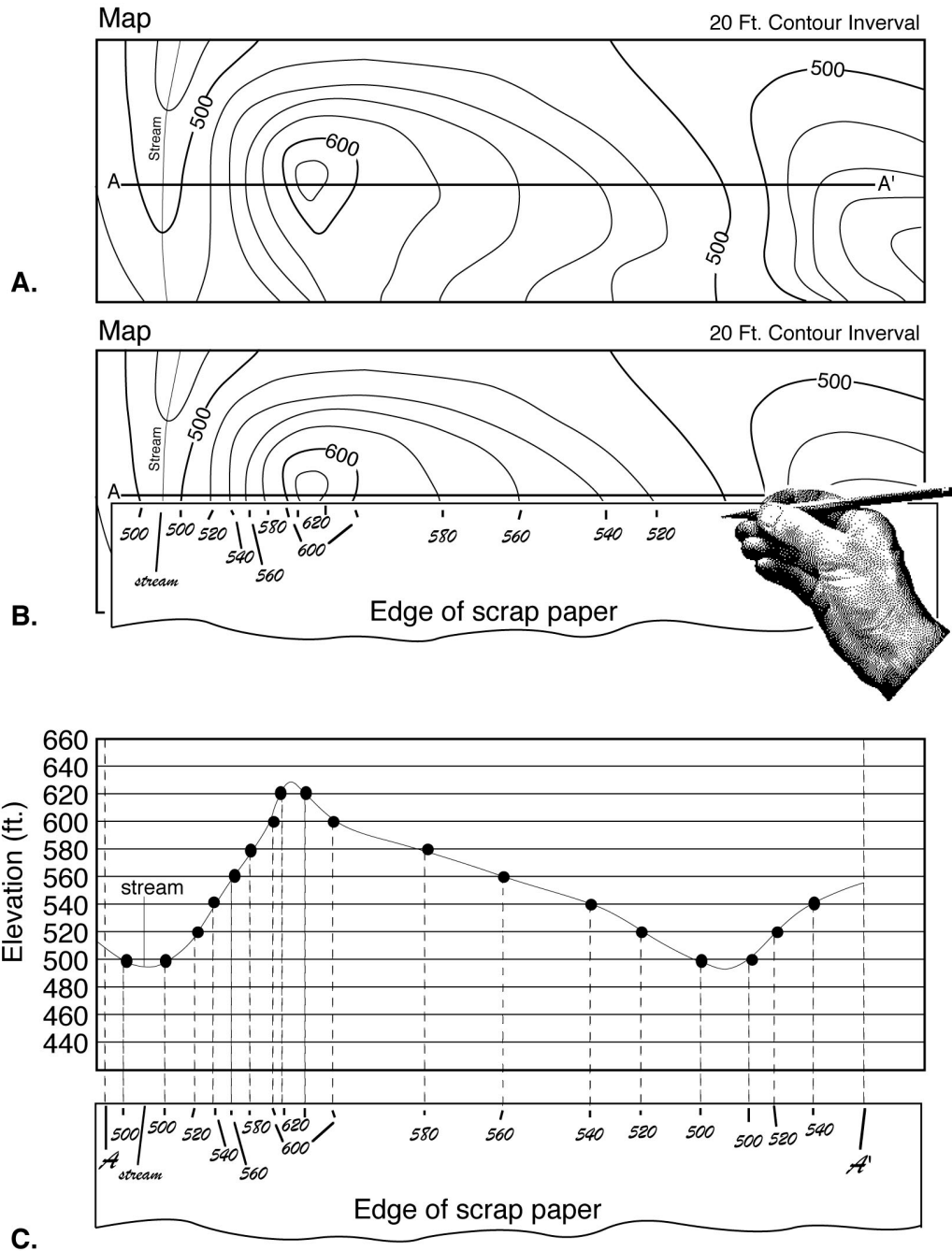


Figure 2.9 Diagrams illustrating the construction of a topographic profile.

Vertical Exaggeration (V.E.)

Vertical exaggeration is the ratio of the vertical scale of a topographic profile to the horizontal scale of the profile. One uses vertical exaggeration to show the shape of the land where the relief is so small that it does not stand out when the vertical scale equals the horizontal scale. In effect, what one does is to "stretch" the landscape according to the ratio (i. e. vertical exaggeration) selected. The choice of vertical exaggeration will vary depending on the relief of the area, the scale of the map, and the purpose of the profile.

If the vertical scale is larger than the horizontal scale (as is often the case), then the topographic profile will be 'stretched' in the vertical direction and steepnesses will be exaggerated. This has the effect of making peaks and valley seem larger and deeper than they really are.

A vertical exaggeration of 1 means that the horizontal scale and the vertical scale are equal so that the topographic profile is a realistic depiction of the actual shape of the features represented and, in effect, there is no vertical exaggeration.

To calculate V.E., first determine the fraction value of both the vertical- and horizontal scale (for example, 1:24,000 = 1/24,000). Dividing the vertical scale fraction by the horizontal scale fraction will give the vertical exaggeration.

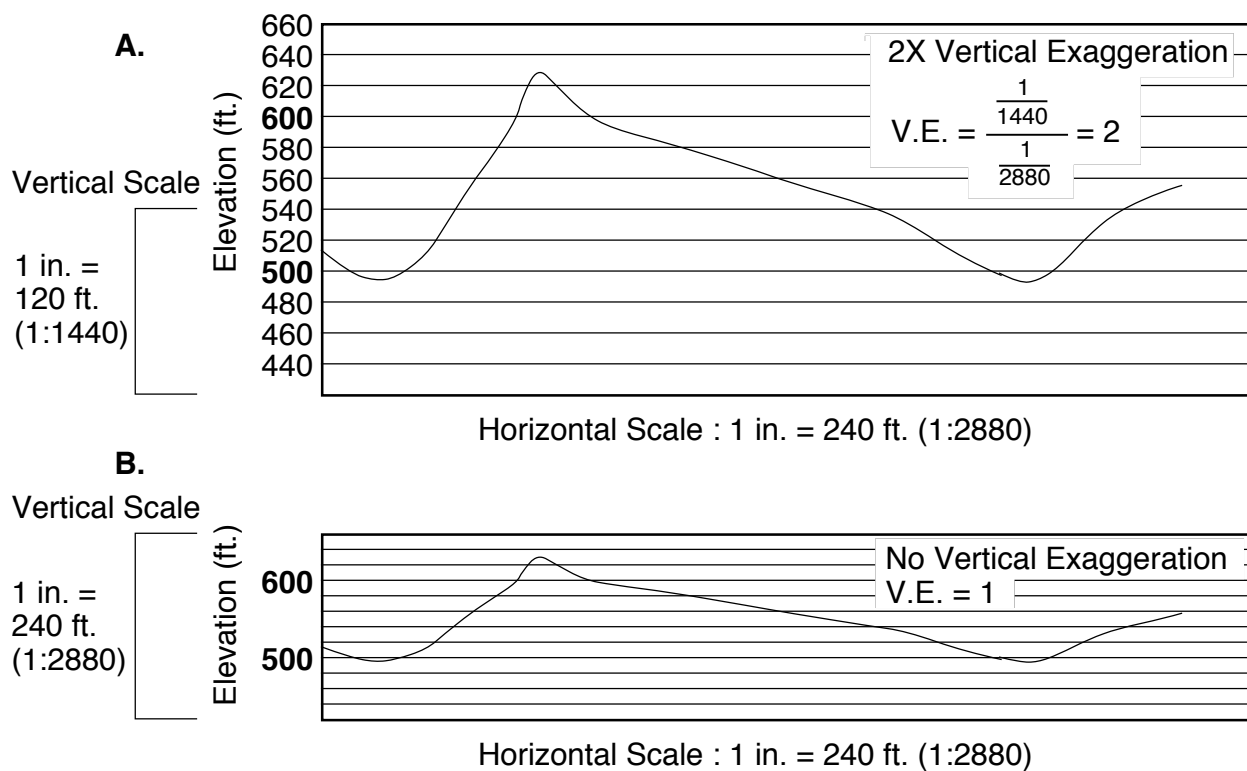


Figure 2.10 Vertical Exaggeration. A. Vertical scale is twice as large as horizontal scale ($1/1440 = 2 \times 1/2880$) so that $V.S. / H.S. = 2 = V.E.$ B. Vertical scale and horizontal scale are equal. $V.E. = 1.$

Topographic Gradients

A **gradient** is the ratio of vertical change in elevation to horizontal change in distance. Gradient can be thought of as ‘steepness’ and it answers the question “for every unit of horizontal distance I travel, how far vertically do I go up or down?”

A simple way to remember gradient is the think rise over run. A gradient can be expressed in whatever units are of interest. Typically, Americans express gradient in feet per mile. If the units of vertical and horizontal distance are the same, then gradient becomes a **percent ratio**.

For example:

The maximum steepness of a railroad track bed over any length of track is traditionally given as 2.5%, called ‘railroad grade’. This means that, for every mile of track, the elevation change in the rail bed can be no more that 2.5% of a mile. $2.5\% = .025 \times 5280 \text{ ft/mile} = 132$ feet. Thus, a gradient of 132 feet per mile (=2.5%) is the maximum gradient used for railroad lines.

Estimating a gradient from a map

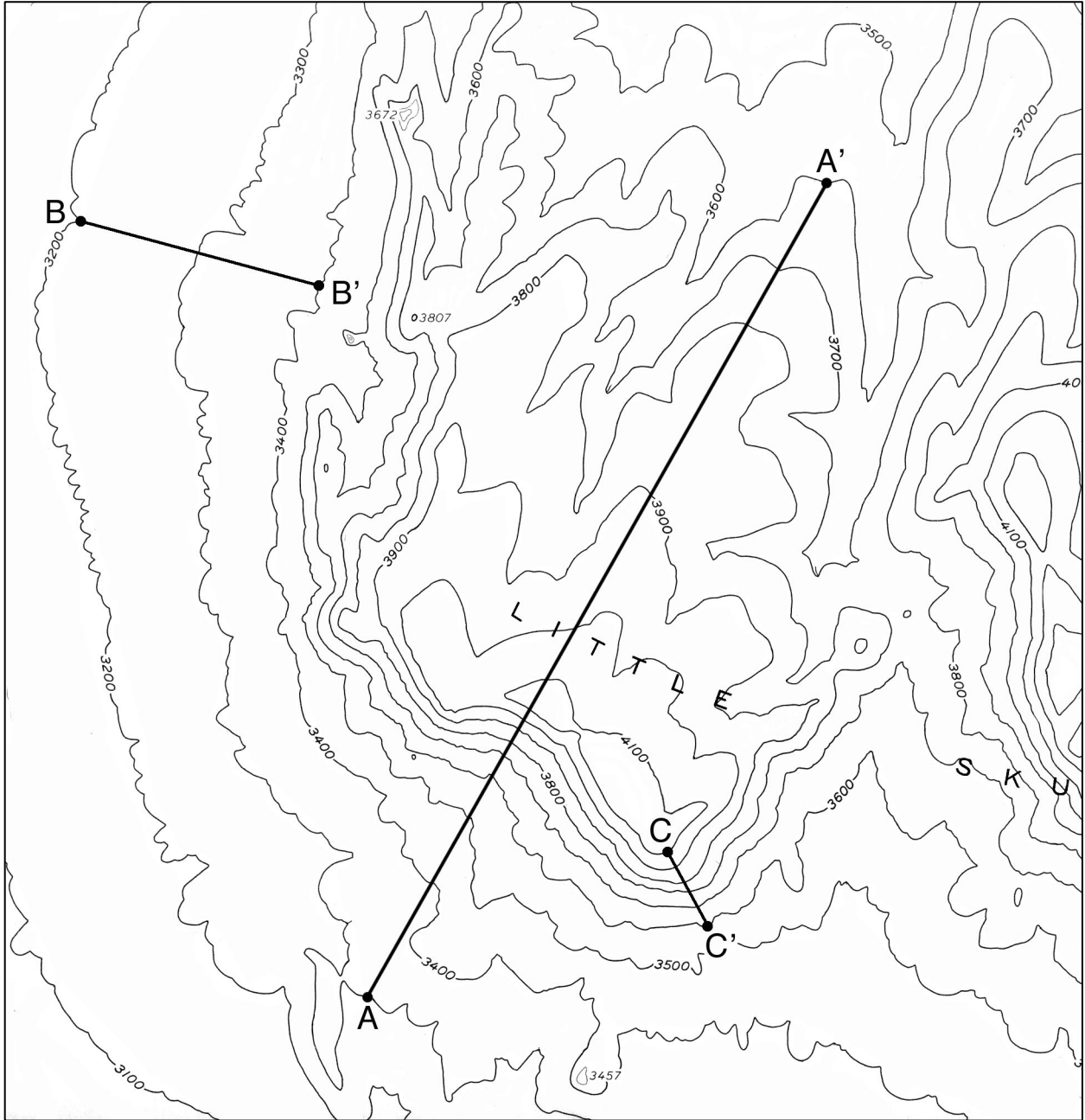
To estimate a gradient from a map, you must measure two quantities between two points on a map.

1. You must use the map scale to measure the **horizontal distance** (usually in miles or kilometers) between the two points.
2. You must use the contour lines to calculate the **change in elevation** (usually in feet or meters) from the first point to the last point.
3. Dividing change in elevation (rise) by horizontal distance (run) will give the gradient between the two points. If the horizontal distance- and elevation units are different they must be included in the gradient (as in feet per mile or meters per kilometer). If the units are the same they can be reported as a percent.

Laboratory Exercise 2.5
Drawing a Topographic Profile

Little Skull Mountain, Striped Hill, Nevada Quadrangle
C.I. = 100'

Map Scale 1:24,000 (1 inch = 2000 ft)



Instructions:

1. Using the profile grid provided on the following page construct a topographic profile along the section line A – A'.



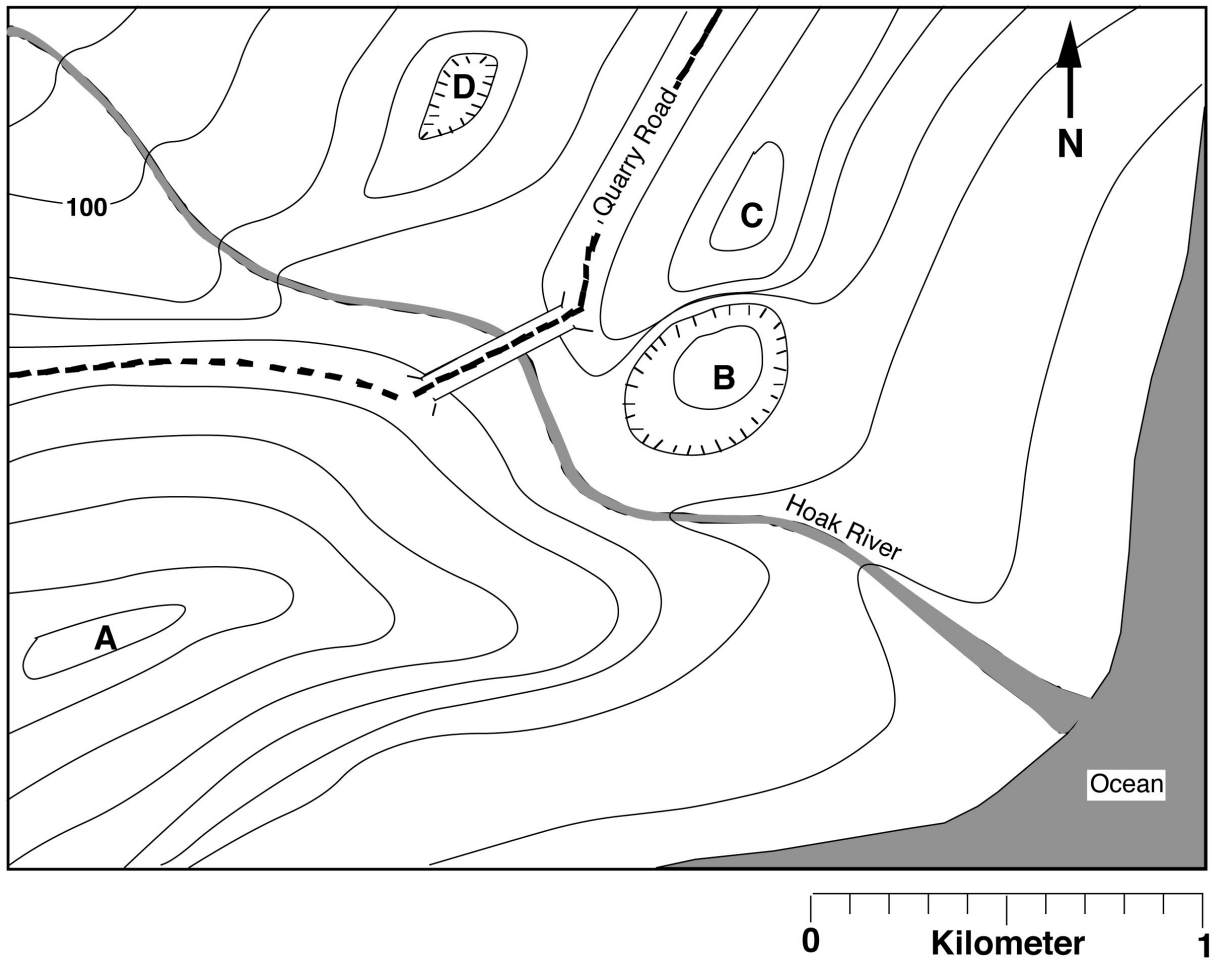
Profile Grid for Little Skull Mountain Topographic Profile

2. Calculate the **vertical exaggeration** of the Little Skull Mountain topographic profile.

3. Calculate the **gradient** across the **B – B'** section line.

4. Calculate the **gradient** across the **C – C'** section line.

PRACTICE TOPOGRAPHIC MAP EXERCISE 1
Interpreting topographic contour maps



Using your knowledge of topographic contour maps, answer the questions based on the above map. Maximum and minimum value answers should be rounded to the nearest meter.

1. What is the contour interval? _____ meters
2. What is the approximate elevation of point A? _____
3. What is the approximate elevation of point B? _____
4. What is the approximate elevation of point C? _____
5. What is the approximate elevation of point D? _____
6. Estimate the height of the Quarry Road Bridge above the Hoak River. _____

7. Which side of Ridge A is steepest?_____
8. In what direction does the Hoak River flow?_____
9. Explain three different methods that you can use to determine which way the Hoak River flows:
- a. _____

- b. _____

- c. _____

10. What is the total length of Quarry Road shown on the map?_____
11. Does Quarry Road go uphill, downhill, or remain level from west to east?

PRACTICE TOPOGRAPHIC MAP EXERCISE 2
(questions based on map on following page)

1. What are the approximate longitude and latitude coordinates of Herrick **Center**? Your answer can be to the nearest 30”.

2. What are the approximate UTM coordinates of the mountain peak labeled A? Your answer can be to the nearest km.

3. What are the **exact** UTM coordinates of the crossroads at Belmont Corner?

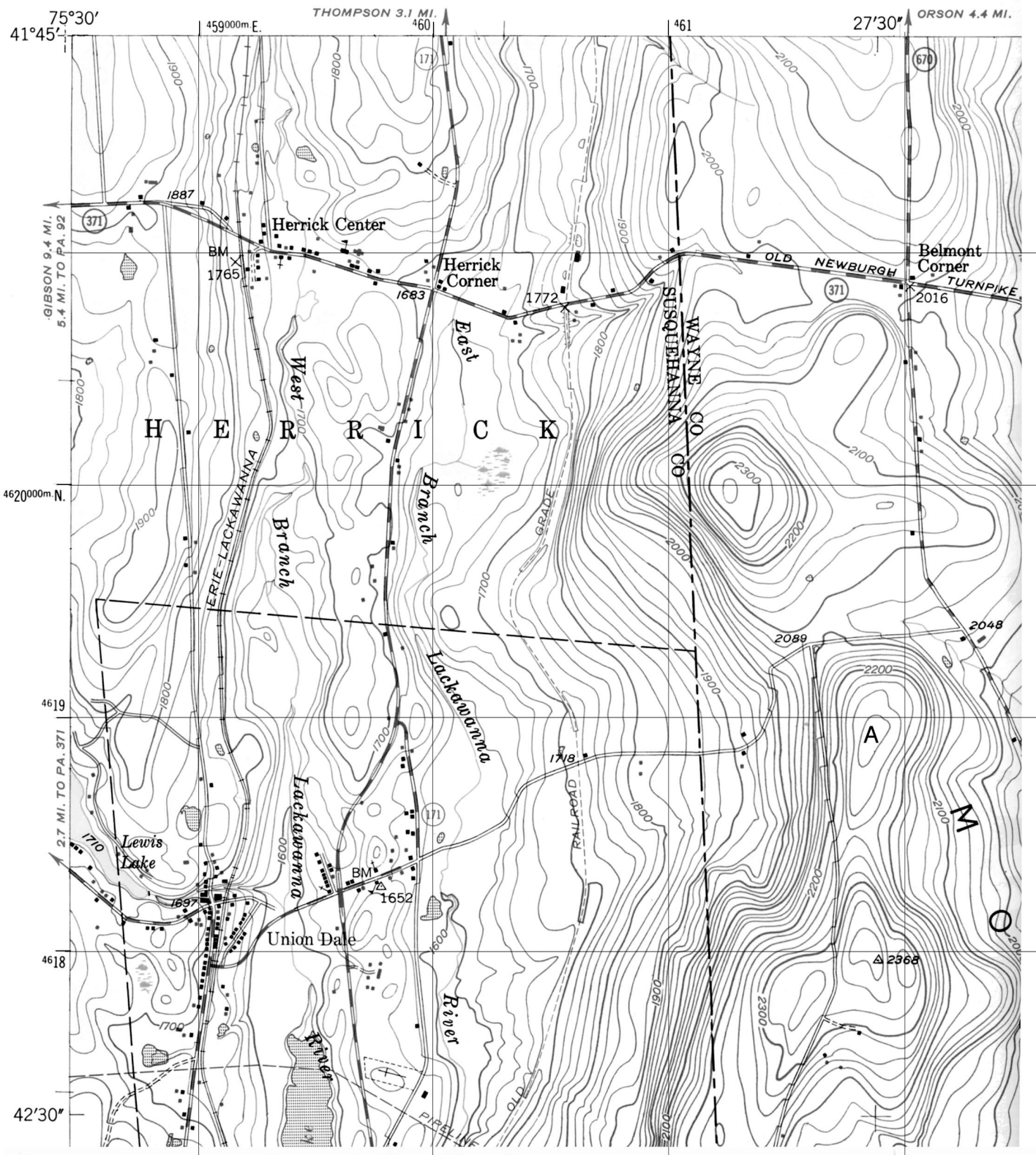
4. Use the bar scale to determine the approximate driving distance from Belmont Corner north to the edge of the map. Give your answer to the nearest 1/10 of a mile.

5. Use the ratio scale to determine the exact straight-line distance from Belmont Corner to Herrick Corner. Show all of your calculations and measurements below. Give your answer in **kilometers**.

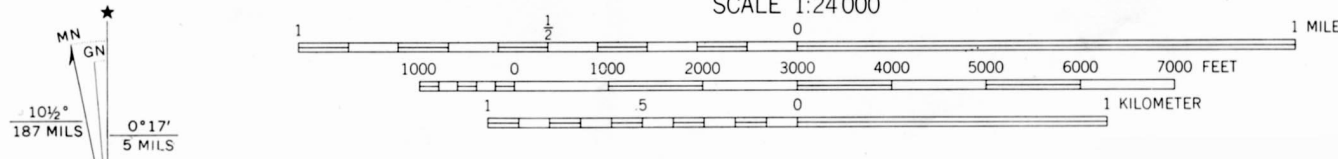
6. What is the elevation of the hilltop located at UTM 461^{800} E and 4620^{650} N?

7. What is the elevation of the top of the mountain peak labeled A?

8. What is the approximate height of the hilltop in question 6 above the crossroads at Belmont Corner? (Imagine that you start from Belmont Corner and hike to the top of the hill. How much vertical distance did you have to climb to get to the top?)



SCALE 1:24 000



CONTOUR INTERVAL 20 FEET
 NATIONAL GEODETIC VERTICAL DATUM OF 1929

UTM GRID AND 1969 MAGNETIC NORTH
 DECLINATION AT CENTER OF SHEET

Lab 3 - Physical Properties of Minerals

PURPOSE

The purpose of today's laboratory is to introduce students to the techniques of mineral identification. However, we will not identify minerals this week. Rather, we will define what a mineral is and illustrate the basic physical properties of minerals. By the end of today's lab you will have learned both how to **observe** and **record** the basic physical properties of minerals. Next week, you will observe physical properties and identify twenty important rock-forming minerals.

INTRODUCTION

Are minerals and rocks the same? If we visualize rocks as being the "words" of the geologic "language," then minerals would be the "letters" of the geologic "alphabet." **Rocks are composed of minerals!** That is, rocks are aggregates or mixtures of one or more minerals. Therefore, of the two, minerals are the more-fundamental basic building blocks. Minerals are composed of submicroscopic particles called **atoms** or **elements** (uncharged) and **ions** (charged) and these particles consist of even smaller units of mass called **electrons, neutrons, protons**, and a host of **subatomic particles** too numerous to mention here. In subsequent laboratory sessions, we will take up the various kinds of rocks. But first, we must study their component minerals.

MINERALS

Definition:

A **mineral** is a naturally occurring, inorganic, crystalline solid (not amorphous), with a chemical composition that lies within fixed definable limits, that possesses a characteristic set of diagnostic physical properties. Nearly 3,000 different minerals are now recognized yet the average geologist can work with the ability to identify a handful of common rock-forming minerals. The essential characteristic of a mineral is that it is **a solid whose ions are arranged in a definite lattice**—no lattice, no mineral. Some naturally occurring substances such as volcanic glass are inorganic and solid, but not crystalline. Other substances found in rock, such as coal and amber, are organic and non-crystalline. These substances which are commonly thought of as minerals although technically they are not are called **mineraloids**.

To summarize: for a substance to be termed a mineral, it must be:

1. Crystalline - The term "crystalline" means that a distinctive, orderly lattice exists. This orderly arrangement of the particles (ions and atoms) composing the mineral follows laws of geometric symmetry and may involve single atoms or a combination of atoms (molecules).

2. Inorganic - This term excludes from the definition of minerals all materials that are organic substances that are not **biocrystals** (minerals manufactured by living things). The exclusion is particularly aimed at carbon-hydrogen-oxygen compounds, the compounds of

organic chemistry. A substance such as amber, which is commonly used in jewelry, is not considered to be a mineral. For the same reason, coal is not a mineral, yet, carbon in the form of graphite and diamond are minerals because each possesses an important and distinctive characteristic – a crystal lattice.

3. Distinctive chemical composition - Minerals may be composed of a single element (carbon, as in graphite and diamond; gold, silver, copper, or sulfur, for example) or combinations of elements. Such combinations range from simple to highly complex. Among combinations, the composition may vary, but the variation is within specific limits.

4. Occurring in Nature - This is another way of saying "a naturally occurring solid." Substances that have been manufactured and are not found in nature are generally excluded from consideration as minerals.

PHYSICAL PROPERTIES

We will concentrate on those mineral properties that can be identified by visual inspection and by making diagnostic tests using the simple "tools" (available in your Geology Kits) on small specimens. (If it is possible to pick up a specimen and hold it in one's hand, geologists call it a "hand specimen.") Most geologists routinely use these same tests and tools both in the laboratory and in the field to identify the common minerals that form most rocks.

Below is a list of the important lattice-controlled properties that we discuss with the most-useful properties written in **CAPITAL LETTERS**. The others are of lesser importance, and some can be considered "exotic physical properties." Keep in mind that you should always proceed on the basis that you are dealing with an unknown.

LUSTER	Crystal form	Flexibility / Elasticity
COLOR	Twinning	Brittleness / Tenacity
HARDNESS	Play of colors	Odor
STREAK	Specific Gravity	Taste
CLEAVAGE	Magnetism	Feel
	Diaphaneity	

LUSTER

The property known as luster refers to the way a mineral reflects light. Luster is a property that can be determined in a general way simply by looking at a specimen. Usually, luster is described in relation to the appearance of a familiar substance. Luster can be treated on two levels: (1) quantitative, and (2) qualitative. Quantitatively, luster is essentially the measured intensity of the reflection of light from a fresh surface of the mineral. Special instruments, known as reflected light microscopes, are available for measuring light reflected from minerals. For our purposes, however, we can use the qualitative method by noting general categories. The degrees of intensity of reflected light can range from high to low or from splendid to shining, glistening, and glimmering through dull or dead (non-reflective). We will compare the way the mineral reflects light with the qualitative reflectivity of substances known to **most** people. Some examples are:

Qualitative Categories of Luster

Metallic: the luster of metal

Non-metallic:

adamantine: the luster of diamond

vitreous: the luster of broken glass

shiny: just what it sounds like

porcellanous: the luster of glazed porcelain

resinous: the luster of yellow resin

greasy: the luster of oil or grease

pearly: the luster of pearl

silky: like silk

earthy: like a lump of broken sod

dull: the opposite of shiny

Sub-metallic: between metallic and non-metallic lusters

COLOR

The color is generally the first thing one notices about a mineral. Color is an obvious feature that can be determined even without touching the specimen. In some cases, color is a reliable property for identifying minerals. For example, the minerals in the feldspar family can be sorted into categories by color. **Potassium feldspar** (or **orthoclase**) is cream colored, greenish, pink, even reddish. The members of the **plagioclase group** tend to be white, gray, bluish or even transparent and glassy (vitreous luster).

Likewise, minerals in the mica family can be identified by color. Whitish mica is **muscovite**; black - **biotite**; brown - **phlogopite**; green - **chlorite**; etc. However, even here, caution is required because slight weathering or tarnish can alter the color. Biotite can take on a brown or golden hue; chlorite can lighten to be confused with muscovite.

By contrast, **quartz** is an example of a single mineral that boasts numerous colors and hues that are not significant lattice-related properties but functions of small amounts of impurities. Milky quartz is white; smoky- or cairngorn quartz is black; amethyst is purple; citrine is lemon-yellow; rose quartz is pink to light red; jasper is dark red; and just plain old garden-variety quartz is clear, transparent, and colorless. As this list shows, quartz comes in so many colors that color alone is an almost-worthless property for identifying quartz. Calcite is an example of another mineral displaying many colors (white, pink, green, black, blue, and clear and transparent, for example).

Although color is an important physical property that should be recorded, be aware of the minerals in which it is a reliable diagnostic property and of those in which color is not diagnostic but more likely to be a trap for the unwary. The diagnostic mineral charts in Lab 4 deemphasize the importance of color in non-metallic minerals by designating dark- from light-colored mineral categories. As such dark-colored minerals are black, gray, dark green, dark blue, and dark red. Light-colored minerals are white, off-white, yellow, light green, light blue, pink, and translucent. All metallic minerals are considered dark colored. In general, the dark-colored minerals fall into a chemical class called **mafic** (rich in iron and magnesium) and the light-colored minerals form

the **felsic** chemical class (rich in silica and aluminum). Rocks are subdivided into these two basic chemical schemes as well.

HARDNESS

The hardness of a mineral is its **resistance to scratching or abrasion**. Hardness is determined by testing if one substance can scratch another. Hardness is not the ability to withstand shock such as the blow of a hammer (A mineral's shock resistance is its tenacity, to be discussed later.) The hardness test is done by scratching the point or edge of the testing item (usually a glass plate, nail, or knife blade) against a flat surface of the mineral. Exert enough pressure to try to scratch the mineral being tested.

Hardness in a numerical (but relative) form is based on a scale devised by the German-born mineralogist, **Friedrich Mohs** (1773-1839). His scheme, now known as the Mohs (not Moh's) Scale of Hardness, starts with a soft mineral (talc) as No. 1 and extends to the hardest mineral (diamond) as No. 10. (The true hardness gap between No. 10 and No. 9 is greater than the gap between No. 9 and No. 1). The numbered minerals in this scale are known as the **scale-of-hardness minerals**. The numbers have been assigned in such a way that a mineral having a higher numerical value can scratch any mineral having a smaller numerical value (No. 10 will scratch Nos. 9 through 1, etc., but not vice versa). Mohs selected these scale-of-hardness minerals because they represent the most-common minerals displaying the specific hardness numbers indicated. In terms of absolute hardness, the differences between successive numbered scale-of-hardness minerals is not uniform, but increases rapidly above hardness 7 because of the compactness and internal bonding of the lattice. Most precious and semi-precious gems exhibit hardness 8, 9, and 10 and are relatively scarce.

The **Mohs Scale of Hardness** is as follows:

- | | | |
|-------------------|------------------------|-----------------------|
| 1. Talc (softest) | 5. Apatite | 8. Topaz |
| 2. Gypsum | 6. Orthoclase feldspar | 9. Corundum |
| 3. Calcite | 7. Quartz | 10. Diamond (hardest) |
| 4. Fluorite | | |

It is useful to memorize the names of these minerals and their Mohs hardness numbers. We will be using over and over again the minerals numbered 1 through 7. One can purchase hardness-testing sets in which numbered scribes have been made with each of the scale-of-hardness minerals. Lacking such a set of scale-of-hardness scribes, for most purposes, including field identification, it is possible to fall back to a practical hardness scale as is listed below. This simple scale is based on common items normally available at all times. The hardness numbers are expressed in terms of Mohs' Scale. Once you have determined their hardness against materials of known Mohs numbers, you can add other items (keys, pens, plasticware, etc.) to your list of testing implements.

Mohs Practical Hardness Scale

- 6.0 = Most hard steel
- 6.0 = Unglazed porcelain
- 5.0 - 5.5 = Glass plate
- 3.0 = Copper Coin (pre-1982 cent)
- 2.5 = Fingernail

The practical scale is very useful for making hardness tests. In this lab we will use the Practical Hardness Scale to subdivide minerals into three general groups:

- Hard** - minerals harder than 5.0 (these will scratch glass).
- Soft** - minerals softer than 2.5 (these you can scratch with a fingernail).
- Medium** - minerals between 2.5 and 5.0 (you can't scratch with a fingernail but will not scratch glass).

One of the columns to be filled in on the exercise sheets for Labs 3 and 4 and on the answer sheet in the Mineral Practicum is hardness. In that column you will write down the results of your hardness tests using the Practical Hardness Scale listed above.

STREAK

Whereas color refers to the bulk property of a mineral, **streak** is the color of a powder made from the mineral. (The property of "streak" in minerals is not to be confused with the definition of "streak" invented a few years ago by college students running around college campuses "in the altogether.") The ideal way to determine a mineral's streak is to grind a specimen into a powder using a mortar and pestle. If we all did this every time we wanted to check on the streak of a mineral, our nice collection would very rapidly disappear. Fortunately, we can obtain the streak of a mineral by rubbing one specimen at a time firmly against a piece of nonglazed porcelain known as a "streak plate."

The friction between the mineral and streak plate leaves a tiny trail of colored powder – the streak of the mineral. After many tests, its original white surface may be obscured with the powder of many minerals. It is possible to wash streak plates and reuse them many times. (Rub a little scouring powder on the wet surface of a used streak plate and it will become like new.) Incidentally, the use of a streak plate serves a dual purpose. Because unglazed porcelain is made from feldspar, if a mineral leaves a streak it is also softer than feldspar (= 6 on the Mohs Scale of Hardness). Naturally, minerals that scratch the streak plate are harder than 6.

One caution about streak: hard non-metallic minerals may give what looks like a white streak. In reality what is happening is that these minerals are scratching the streak plate; the white powder is not from the mineral but from the streak plate itself. As such, learn to distinguish between a white streak (unknown softer than streak plate), a colorless streak (unknown softer than streak plate), and no streak (unknown harder than streak plate). As a matter of standard procedure, test all metallic minerals with your streak plate, as streak is very diagnostic in metallic minerals.

In most cases, the bulk color of the mineral in hand specimen will be the same as the color of the streak. However, divergences between bulk color and the streak may be so startling as to be a "dead give-away" for identifying that mineral. For example, some varieties of **hematite** display a glistening black metallic luster but the red-brown streak will always enable you to distinguish hematite from shiny black **limonite** whose streak is yellowish brown. The streak of **magnetite** is black. In these cases, streak is much more diagnostic than the outward color of a mineral.

THE WAYS MINERALS BREAK: FRACTURE VS. CLEAVAGE

The way a mineral breaks is a first-order property of the crystal lattice and thus is extremely useful, if not of paramount importance, in mineral identification. The broken surface may be irregular (defined as "**fracture**") or along one or more planes that are parallel to a zone of weakness in the mineral lattice (defined as "**cleavage**").

Fracture surfaces may be even, uneven, or irregular, including fibrous, splintery, and earthy fractures. (One would describe the way wood breaks as splintery fracture.) A distinctive kind of fracture is along a smooth, curved surface that resembles the inside of a smooth clam shells. Such curved fracture surfaces are referred to as **conchoidal** (glass, when chipped, displays a conchoidal fracture).

Cleavage can be a confusing concept to master. Keep in mind that a cleavage is not just a particular plane surface but rather is a family of plane surfaces all oriented in the same direction. In other words, the concept of cleavage includes not only a single plane surface, but all the plane surfaces that are parallel to it. For example, the top and bottom of a cube form two parallel surfaces. Because these surfaces are parallel, they can be defined by specifying the orientation of one single plane.

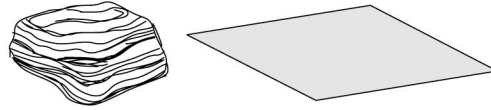
If a mineral cleaves rather than fractures, then the result is two relatively flat smooth surfaces, one on each half of the split mineral. Further, the two surfaces will be mirror images of each other (symmetrical). Because these surfaces (and all other segments of surfaces parallel to them) are smooth, they will reflect light and often do so more strongly than the rest of the specimen.

We repeat again the fundamental point that a cleavage direction is the physical manifestation of a plane of weakness within the mineral lattice. This weakness results from a planar alignment of weak bonds in the lattice. The strength or weakness of these aligned bonds affects the various degrees of perfection or imperfection of the cleavage (degree of smoothness/flatness of the surfaces).

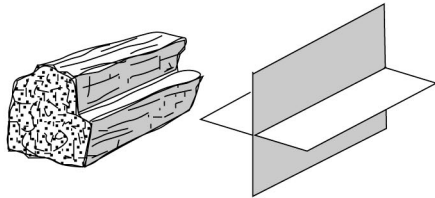
After you have learned to recognize cleavage surfaces, you must deal with two final points of difficulty about cleavage. These difficulties can be expressed by two questions: (1) How many directions of cleavage are present?, and, (2) How are the cleavage directions oriented with respect to one another?

Some minerals, notably those in the mica and clay families having sheet-structure lattices, display only one direction of cleavage and it is likely to be perfect. Such cleavage is commonly termed **basal cleavage**. Other minerals possess two, three, four or six cleavage directions. No mineral exists that displays five directions of cleavage.

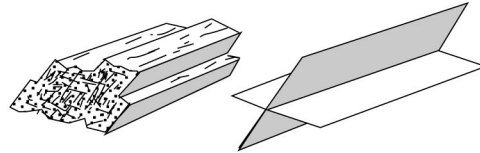
Minerals having three or more cleavage directions break into cleavage fragments that produce distinct, repetitive geometric shapes. Breakage along three cleavages at right angles, as in halite or galena, yields cubes. Not surprisingly, such cleavage is described as being **cubic**. If the three cleavage directions are not at right angles, the cleavage fragments may be tiny rhombs, as in the **rhombohedral cleavage** of the carbonate minerals, calcite and dolomite.



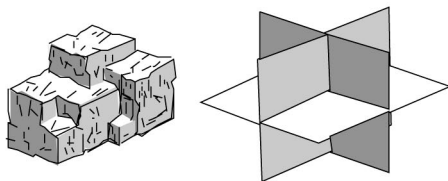
A. **Basal** - One direction of cleavage. Mica, graphite, and talc are examples.



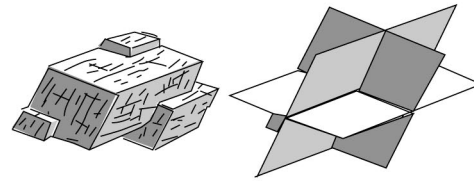
B. **Rectangular** - Two directions of cleavage that intersect at 90° angles. Plagioclase is an example.



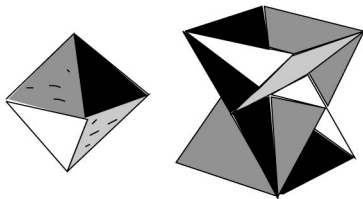
C. **Prismatic** - Two directions of cleavage that do not intersect at 90° angles. Hornblende is an example.



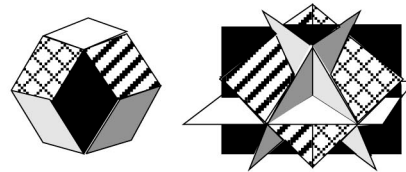
D. **Cubic** - Three directions of cleavage that intersect at 90° angles. Halite and galena are examples.



E. **Rhombic** - Three directions of cleavage that do not intersect at 90° angles. Calcite is an example.



F. **Octahedral** - Four directions of cleavage. Fluorite is an example.



G. **Dodecahedral** - Six directions of cleavage. Sphalerite is an example.

Figure 3.1 - Examples of cleavage-direction geometries observed in the common rock-forming minerals.

Crystal Form

The external form of a mineral is a function of several factors. In the simplest, ideal case, the external form is a direct outward expression of the internal mineral lattice. In this case, the mineral displays beautiful **crystal faces** that are planes and form regular sharp boundaries with adjoining planes that are arranged in clearly defined geometric solids (and we refer to such an object simply as "a crystal"). True crystal forms can develop only where (1) the mineral lattice was able to grow uninhibited in all directions, as is the case where the growing lattice is surrounded by empty space or by a liquid; or (2) the power of crystallization of the growing lattice is so great that despite all obstacles, the mineral develops its own crystal faces (and in the process may prevent adjacent growing mineral lattices from developing their crystal faces).

Crystal form can be extremely important in identifying minerals. However, minerals displaying well-developed crystal forms are not very common. In most cases this will not be a useful property for mineral identification.

Twinning

When two or more parts of the same mineral lattice become intergrown, the phenomenon is referred to as "**twinning**." Parts of a twinned crystal may penetrate into another part; such cases are referred to as "penetration twinning" (as in **staurolite**, an important metamorphic mineral). The crystal lattices of one part of a twin can be parallel to the lattice of the other part. Or lattice parts can be rotated through 180° with respect to the lattice of the other part. Such parallel twinning can result in twin zones or polysynthetic twin planes that may be visible as planar patterns on the external surfaces of the crystal (crystal faces or cleavage planes). Parallel-type internal twinning is diagnostic of the plagioclase group of feldspars. The expression of this kind of internal twinning is a series of closely spaced parallel lines known as **twinning striae** that can be seen on cleavage planes when they are reflecting light. Other twinning striae appear as lines on crystal faces of pyrite.

Play of Colors

The property known as "**play of colors**" is an expression of internal iridescence. To see if a mineral displays this property, rotate the specimen into different orientations under strong light. The "play" is the internal display of some colors of the spectrum. A striking blue iridescence is most peculiar to the varieties of plagioclase named albite (also known as moonstone) and in labradorite (referred to in that mineral as "labradorescence"). Such "play of colors" can be seen in other minerals and may result from various causes. Numerous closely spaced incipient internal cracks (cleavages) or included foreign materials can cause light to be multiply reflected and refracted inside the mineral and thus enable the colors to "play."

Specific Gravity

As you already know from your work in the first week's lab session, the property of specific gravity is a number expressing the ratio between the weight of mineral compared to the weight of an equal volume of water. Practically speaking, specific gravity is a result of whether the specimen that is held in your hand feels inordinately heavy or light. Such "feeling" needs to be used with caution because one must evaluate the "heaviness" of "lightness" against the size or total mass of the specimen being held. Obviously, the larger the specimen, the heavier it will be. The key point is whether the specimen is inordinately heavy or light with respect to its size (volume).

Magnetism

The property of magnetism refers to what is known technically as **magnetic susceptibility**. This is the ability of a mineral to attract or be attracted by a magnet. Many minerals display such magnetic attraction but not all of them contain iron as one might suppose. To make a valid magnetic test, use a small magnet and see if it sticks to the unknown mineral. For our purposes, the only common magnetic mineral is magnetite.

Flexibility/Elasticity

The two properties of flexibility and elasticity relate to the outcome of a simple bending test of thin plates of flaky minerals. Only a flexible mineral can be bent. The elasticity factor refers to what happens after you bend a mineral flake and then let go of it. If the specimen remains bent, then we say that the mineral is **flexible but inelastic**. By contrast, if you can bend a mineral and after you have let go, it returns to its original position or shape, then that mineral is **not only flexible but is also "elastic."** The clear, transparent, variety of gypsum known as selenite or the green mica chlorite are examples of flexible minerals that are inelastic. The light-colored mica muscovite is a flexible mineral that is elastic.

Brittleness/Tenacity

These two properties are at opposite ends of the spectrum describing how a mineral behaves when it is subjected to stress (hammer blow, applied pressure). A brittle mineral disintegrates with relative ease. A mineral that resists shattering is referred to as being tenacious.

Odor

A few rocks and minerals have distinctive odors. Some freshly broken rocks emit such a distinctive "gassy" odor that German geologists coined the name "Stinkstein" for them. Among minerals, the earthy-musty odor of kaolinite can be enhanced by breathing on the specimen before smelling it. A distinctive "rotten-egg" odor can be detected from a fresh streak of some sulfide minerals. The odor arises because during the streak test, sulfur from the mineral, such as galena (a lead sulfide with formula PbS) or pyrite (iron sulfide with the formula FeS₂), is dispersed into the air.

Taste

Who would think of tasting a mineral? Among minerals that are easily soluble in water, taste can be useful. The classic example is the salty taste of halite (the mineral name of common table salt). Caution must be exercised because some minerals are toxic and certainly unpleasant to the palate. We do not advise tasting unknown minerals (in fact, to do so in lab would be a violation of health and safety regulations).

Feel

Some minerals feel distinctive against your fingertips. Words useful for describing feel are smooth, soapy or greasy. Common minerals that feel distinctive are kaolinite, talc, and graphite.

Diaphaneity

The relative ability of a mineral to allow light to pass through it is named **diaphaneity**. Three possibilities exist:

Transparent - light passes through and one can see through the mineral

Translucent - light passes through but one cannot see through the mineral

Opaque - light does not pass through the mineral

LABORATORY REPORT
LAB 3 – Physical Properties of Minerals

Using the Mineral Physical Property Kit, identify the physical property requested for each lettered specimen in the table below.

Specimen	Property	Property Identification	Additional Property
A	Luster		Streak
B	Luster		Fracture
C	Luster		Streak
D	Color		Cleavage
E	Color		Hardness
F	Color		Streak
G	Hardness		Cleavage
H	Hardness		Cleavage
I	Hardness		Feel
J	Streak		Hardness
K	Streak		Hardness
L	Streak		Cleavage

LABORATORY REPORT
LAB 3 – Mineral Cleavage

Using the Mineral Cleavage Kit, identify the type of cleavage for each numbered specimen in the table below. Consult Figure 3.1 for illustrations of different types of cleavage.

Specimen	# and Angle of Cleavage Planes	Name of Cleavage Type
21		
22		
23		
24		
25		
26		

Lab 4 - Mineral Identification

What to do:

Having learned the physical properties displayed by minerals, in today's laboratory exercise you will identify twenty common mineral specimens. Review the concepts learned last week and try to logically and systematically identify the twenty minerals. Use the **mineral tests** you learned last week to make the observations of luster, hardness, streak, cleavage, and other properties that will lead you to the correct identifications. Record your observations on the Lab 3 Data Sheet. Provided on the following pages are a series of tables and charts of mineral properties to help you. Particularly useful are Tables 4.1 and 4.2 which allow you to key out minerals starting from general and working to more specific properties. Remember, next week you will be tested on your ability to identify these twenty common minerals.



Table 4.1 - Mineral identification flow chart for non-metallic, light-colored minerals.

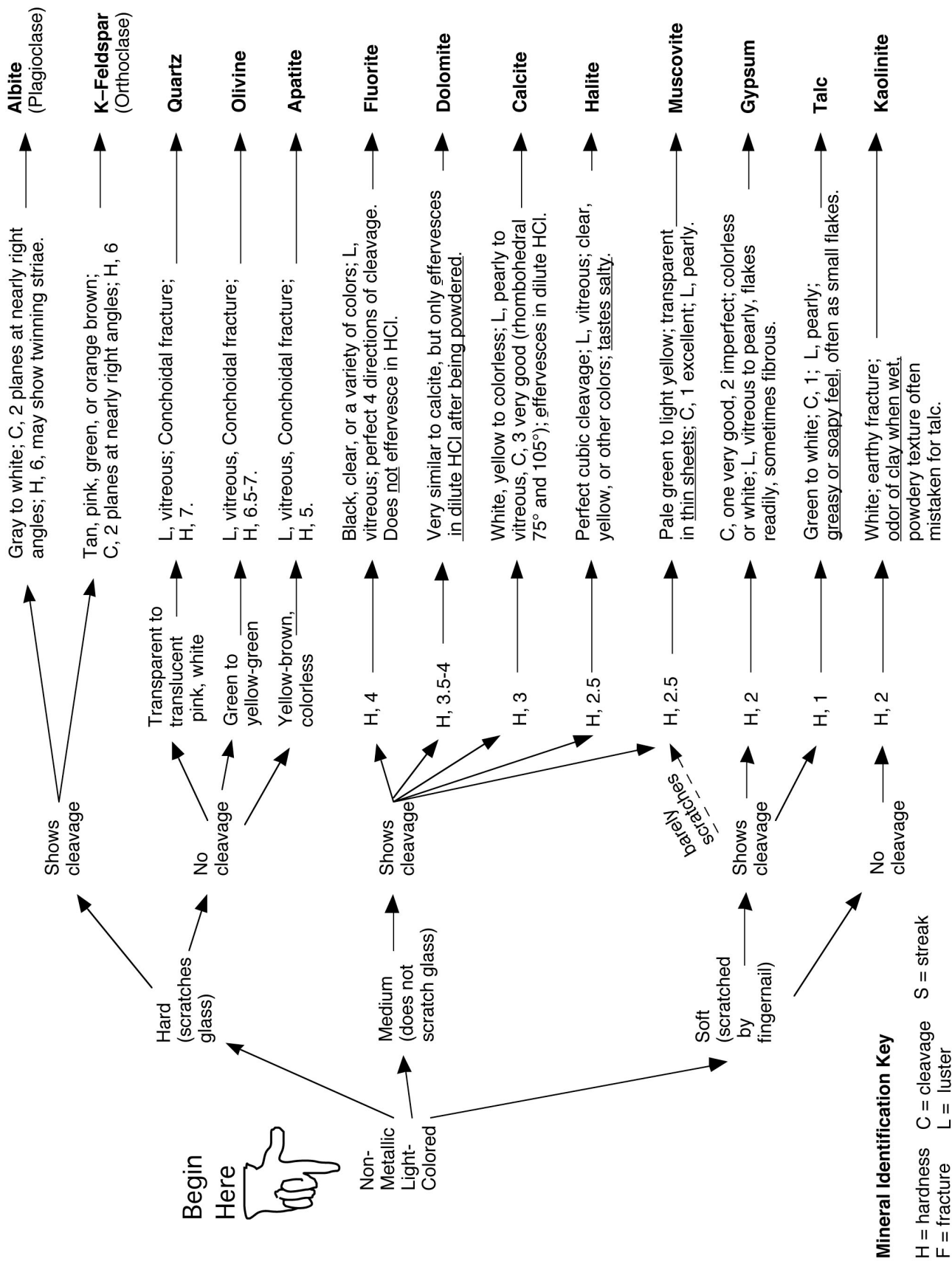


Table 4.2 - Mineral identification flow chart for non-metallic, dark-colored minerals and metallic minerals.

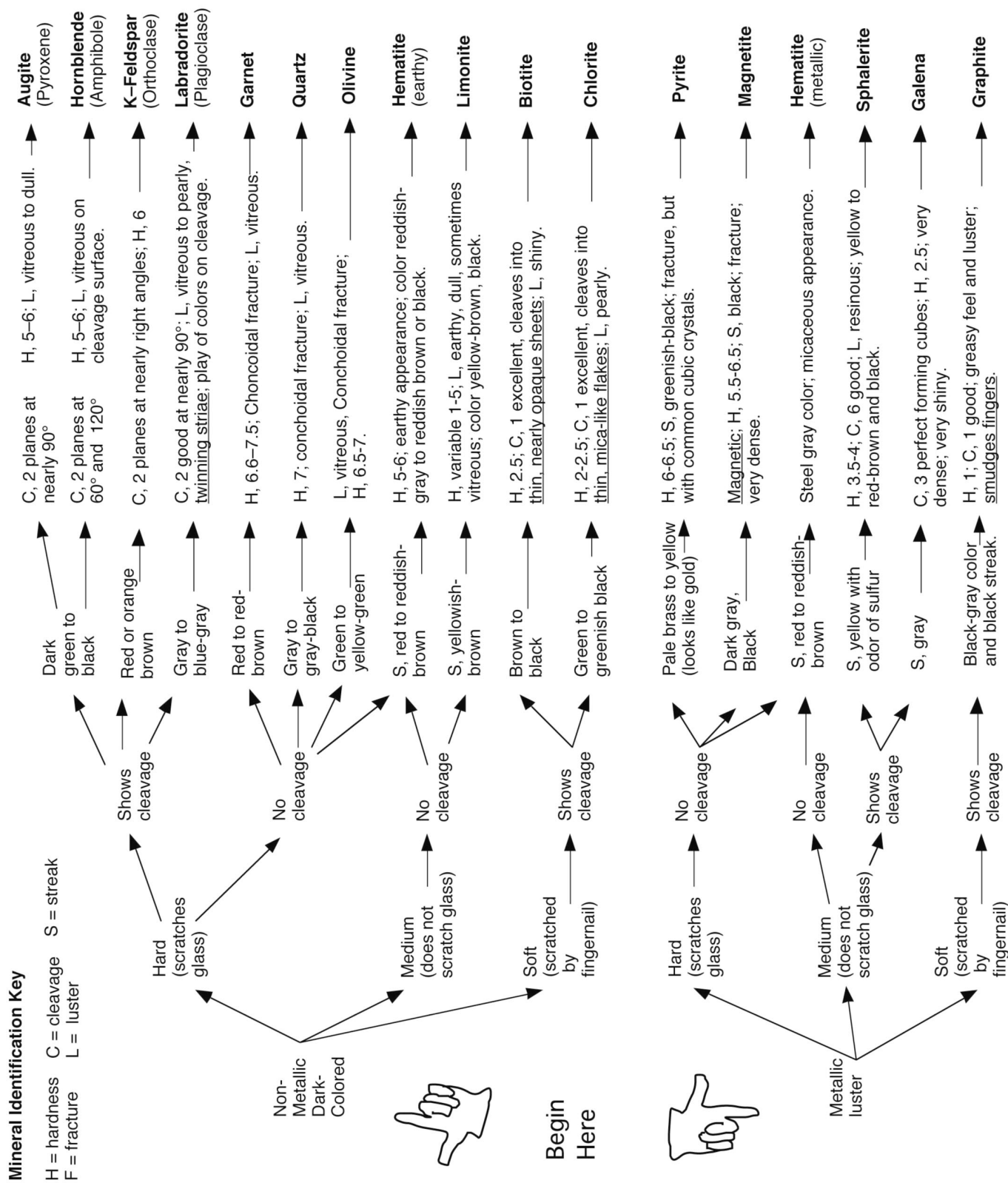


Table 4.3 (three pages) – Mineral tables with detailed properties and descriptions.

Fracture or Cleavage	Color	Streak	Luster	Hardness (Mohs scale)	Remarks	Name and Chemical Composition
two cleavages, almost at right angles	white, green or other light colors; usually opaque	white (colorless)	vitreous	6.0	cleavage surfaces sometimes show fine, parallel "twinning" striae	Albite (light plagioclase feldspar) Al, Ca, Na silicate
conchoidal fracture	amber, green, white, or colorless	white (colorless)	vitreous	5.0	primary mineral found in bones and teeth	Apatite Calcium (Cl, F) phosphate
two cleavages, almost at right angles	black, dark green or brown; opaque	greenish-grey	vitreous	5.0 to 6.0	cleavage with color is distinctive; cleavages often small, stepped	Augite (pyroxene) Ca, Na, Mg, Fe, Al silicate
one excellent; splits into very thin sheets	black or bronze; thin sheets clear but "smoky"	greenish-white	very shiny	2.5 to 3.0	dark color and cleavage are distinctive; folia are elastic	Biotite (black mica) Mg, Fe silicate
rhombohedral – 3 good cleavages not at right angles	colorless, white, pastels, etc.; clear to opaque	white (colorless)	vitreous to pearly	3.0	effervesces vigorously in dilute HCl	Calcite $CaCO_3$
one very good cleavage direction	various shades of green; transparent to translucent	white (colorless)	vitreous to pearly	2.0 to 2.5	looks like green mica; folia flexible but not elastic	Chlorite hydrous magnesium aluminosilicate
rhombohedral – 3 good cleavages not at right angles	white, brownish, pink	white (colorless)	vitreous to pearly	3.5 to 4.0	very similar to calcite, but effervesces slowly in HCl only after being powdered	Dolomite $CaMg(CO_3)_2$
octahedral – 4 good cleavages	colorless, black, purple, green, yellow, etc.	white (colorless)	vitreous	4.0	often fluorescent in UV light, forms both cubic and octahedral crystals	Fluorite CaF_2
cubic – 3 good cleavages at right angles	lead-grey, silver; opaque	lead-grey	bright metallic	2.5	looks like shiny lead, feels very heavy (high specific gravity)	Galena PbS
one excellent - expressed as tiny flakes	lead-grey, black; opaque	black	dull metallic	1.0 to 2.0	greasy feeling, marks fingers and paper like pencil lead	Graphite carbon

Table 4.3 (2 of 3 pages) – Mineral tables with detailed properties and descriptions.

Fracture or Cleavage	Color	Streak	Luster	Hardness (Mohs scale)	Remarks	Name and Chemical Composition
fracture	red to reddish-brown; translucent to opaque	none	vitreous to resinous	6.5 to 7.5	commonly seen as 12-sided crystals in metamorphic rocks	Garnet silicate group of variable composition
one good cleavage direction	colorless or white also brown, etc.; transparent to translucent	white (colorless)	vitreous, also pearly	2.0	can be fibrous or crystalline; folia are flexible but not elastic; powder feels coarse on fingertips	Gypsum $CaSO_4 \cdot 2H_2O$
cubic – 3 good cleavage directions	clear, white, brownish; can be any color	white (colorless)	vitreous	2.5	rock salt; has a salty taste	Halite $NaCl$
fracture irregular or basal cleavage in micaceous, metallic variety	red to steel grey; opaque	deep red to reddish-brown	dull and earthy or metallic	5.5 to 6.5	to very different looking forms occur, one earthy the other metallic, often micaceous; streak is characteristic	Hematite Fe_2O_3
two cleavages, intersecting at 56° and 124°	black, dark green or brown; opaque	light green to white (colorless)	vitreous	5.0 to 6.0	cleavage angles and color are distinctive	Hornblende (amphibole) Ca, Na, Mg, Fe, Al, Ti silicate
fracture	white, may be stained red, brown or black	white (colorless)	dull	2.0 to 2.5	often mistaken for chalk; when wet has an earthy or clay odor	Kaolinite aluminous silicate
two cleavages, almost at right angles	grey-black to bluish grey	white (colorless)	vitreous	6.0	cleavage surfaces often show fine, parallel striae called 'twinning'	Labradorite (dark plagioclase feldspar) Al, Ca, Na silicate
fracture unusually irregular, can be conchoidal	yellow, rusty brown to dark brown; opaque	rusty brown	dull and earthy to vitreous	5.0 to 5.5	crumbly, often appears softer than it is; streak is very characteristic	Limonite $FeO(OH) \cdot nH_2O$

Table 4.3 (3 of 3 pages) – Mineral tables with detailed properties and descriptions.

Fracture or Cleavage	Color	Streak	Luster	Hardness (Mohs scale)	Remarks	Name and Chemical Composition
irregular fracture	black; opaque	black	dull to metallic	6.0	magnetic; feels heavy (high specific gravity)	Magnetite Fe_3O_4
one excellent; splits into very thin sheets	silvery, white; transparent in thin sheets	white (colorless)	vitreous to pearly	2.0 to 2.5	light color and cleavage are distinctive; folia are elastic	Muscovite (white mica) K, Al silicate
conchoidal fracture	greyish-green; transparent to translucent	pale green, white	vitreous	6.5 to 7.5	massive olivine may be opaque; commonly occurs in granular aggregates	Olivine $(MgFe)_2SiO_4$
two cleavages at right angles	white, pink, green; generally opaque	white (colorless)	vitreous	6.0	differs from the plagioclase feldspars in its lack of twinning striae	Orthoclase (K-feldspar) Al, K silicate
irregular fracture, brittle	brassy yellow; opaque	greenish or brownish black	shiny metallic	6.0 to 6.5	often found with striated cubic crystals; commonly known as 'fools gold'	Pyrite FeS_2
irregular or conchoidal fracture	clear, white, pink, black, etc.; transparent to opaque	none	vitreous	7.0	many varieties, some are semi-precious gemstones; hardness and luster are characteristic	Quartz SiO_2
eight perfect cleavage directions (dodecahedral)	yellow to red-brown and black	yellow	resinous	3.5 to 4.0	fresh streak has odor of sulfur (rotten eggs); reacts with HCl to give off hydrogen sulfide gas	Sphalerite ZnS
one good cleavage direction, seen as small flakes	white to green, translucent	white (colorless)	pearly or greasy	1.0	feels greasy or soapy; fine powder feels smooth on fingertips	Talc hydrous magnesium silicate

Table 4.4 (two pages) – Mineral Properties Chart

Minerals Arranged by <u>Hardness</u>																																										
soft Scratched by fingernail <2.5	medium 2.5 – 5.5		hard Scratches glass >5.5																																							
Talc Gypsum Graphite Kaolinite Chlorite Muscovite	Calcite Galena Fluorite Halite Dolomite Biotite Hematite Sphalerite Apatite Limonite	Quartz Augite * Olivine Hornblende * Magnetite Hematite * Pyrite Albite Garnet Labradorite K-feldspar																																								
* indicates that some varieties may be softer than glass.																																										
Minerals Arranged by <u>Luster</u>																																										
<u>Metallic</u> Galena Graphite Hematite (metallic) Magnetite Pyrite Sphalerite #	<table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="3" style="text-align: center;"><u>Nonmetallic</u></th> </tr> <tr> <th style="text-align: left;">Vitreous</th> <th style="text-align: left;">Pearly</th> <th style="text-align: left;">Earthy</th> </tr> </thead> <tbody> <tr> <td>Quartz</td> <td>Labradorite #</td> <td>Hematite (earthy)</td> </tr> <tr> <td>K-feldspar #</td> <td>Albite #</td> <td>Limonite #</td> </tr> <tr> <td>Garnet</td> <td>K-feldspar #</td> <td>Kaolinite</td> </tr> <tr> <td>Calcite #</td> <td>Calcite #</td> <td></td> </tr> <tr> <td>Gypsum #</td> <td>Dolomite #</td> <td></td> </tr> <tr> <td>Olivine</td> <td>Chlorite</td> <td></td> </tr> <tr> <td>Halite</td> <td>Talc</td> <td></td> </tr> <tr> <td>Fluorite</td> <td>Muscovite</td> <td></td> </tr> <tr> <td>Augite #</td> <td></td> <td></td> </tr> <tr> <td>Hornblende</td> <td>Albite #</td> <td>Labradorite #</td> </tr> <tr> <td></td> <td></td> <td>Apatite</td> </tr> </tbody> </table>			<u>Nonmetallic</u>			Vitreous	Pearly	Earthy	Quartz	Labradorite #	Hematite (earthy)	K-feldspar #	Albite #	Limonite #	Garnet	K-feldspar #	Kaolinite	Calcite #	Calcite #		Gypsum #	Dolomite #		Olivine	Chlorite		Halite	Talc		Fluorite	Muscovite		Augite #			Hornblende	Albite #	Labradorite #			Apatite
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# indicates that some varieties can have a different luster.																																										
Minerals Arranged by <u>Streak</u>																																										
(Always use the streak test for minerals having a metallic, shiny, or earthy luster.)																																										
<u>Gray to Black</u>	<u>Reddish–Brown</u>	<u>Yellowish–Brown</u>	<u>Yellow</u>																																							
Galena Magnetite Pyrite	Hematite	Limonite	Sphalerite (when streak is fresh it gives off an odor of sulfur)																																							

Table 4.4 (cont'd) – Mineral Properties Chart

Minerals Arranged by <u>Method of Breaking</u>								
<p style="text-align: center;">Fracture (no cleavage)</p> <p style="text-align: center;">Quartz Garnet Olivine Pyrite Kaolinite Hematite Limonite Apatite*</p> <p style="font-size: small;">*apatite has one cleavage direction but it is not usually visible.</p>	<p style="text-align: center;">Cleavage</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; text-align: center; padding: 5px;"> <p>One (well expressed)</p> <p>Muscovite Biotite Chlorite</p> <p>One (poorly expressed)</p> <p>Talc Graphite Hematite (specular)</p> </td> <td style="width: 50%; text-align: center; padding: 5px;"> <table style="width: 100%;"> <tr> <td style="width: 50%; text-align: center;"> <p>Two (right angles)</p> <p>Albite Labradorite K-feldspar Augite</p> </td> <td style="width: 50%; text-align: center;"> <p>Two (not at right angles)</p> <p>Hornblende Gypsum *</p> <p style="font-size: x-small;">* gypsum's cleavage is often poorly expressed.</p> </td> </tr> <tr> <td colspan="2" style="text-align: center; padding: 5px;"> <p>Three or more</p> <p>Galena Dolomite Halite Fluorite Calcite Sphalerite</p> </td> </tr> </table> </td> </tr> </table>		<p>One (well expressed)</p> <p>Muscovite Biotite Chlorite</p> <p>One (poorly expressed)</p> <p>Talc Graphite Hematite (specular)</p>	<table style="width: 100%;"> <tr> <td style="width: 50%; text-align: center;"> <p>Two (right angles)</p> <p>Albite Labradorite K-feldspar Augite</p> </td> <td style="width: 50%; text-align: center;"> <p>Two (not at right angles)</p> <p>Hornblende Gypsum *</p> <p style="font-size: x-small;">* gypsum's cleavage is often poorly expressed.</p> </td> </tr> <tr> <td colspan="2" style="text-align: center; padding: 5px;"> <p>Three or more</p> <p>Galena Dolomite Halite Fluorite Calcite Sphalerite</p> </td> </tr> </table>	<p>Two (right angles)</p> <p>Albite Labradorite K-feldspar Augite</p>	<p>Two (not at right angles)</p> <p>Hornblende Gypsum *</p> <p style="font-size: x-small;">* gypsum's cleavage is often poorly expressed.</p>	<p>Three or more</p> <p>Galena Dolomite Halite Fluorite Calcite Sphalerite</p>	
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<p>Two (right angles)</p> <p>Albite Labradorite K-feldspar Augite</p>	<p>Two (not at right angles)</p> <p>Hornblende Gypsum *</p> <p style="font-size: x-small;">* gypsum's cleavage is often poorly expressed.</p>							
<p>Three or more</p> <p>Galena Dolomite Halite Fluorite Calcite Sphalerite</p>								
Minerals Arranged by <u>Special Features</u>								
<p style="text-align: center;"><u>Striae</u></p> <p>On cleavage faces</p> <p>Albite Labradorite</p> <p>On crystal faces</p> <p>Pyrite Hornblende</p>	<p style="text-align: center;"><u>Taste</u></p> <p>Halite (salty)</p>	<p style="text-align: center;"><u>Smell</u></p> <p>Kaolinite (smells like clay when wet)</p>						
<p style="text-align: center;"><u>Reaction to Dilute Acid</u></p> <p>Calcite (effervesces readily) Dolomite (effervesces only weakly when first scratched or powdered)</p>	<p style="text-align: center;"><u>Magnetism</u></p> <p>Magnetite</p>							
	<p style="text-align: center;"><u>High Specific Gravity</u> (minerals that "feel heavy")</p> <p>Galena Pyrite Magnetite Sphalerite Hematite</p>							

Laboratory Data Sheet 4.1
Mineral Identification

#	Luster / Color	Hardness	Cleavage	Streak	Other Property	Mineral ID
1						
2						
3						
4						
5						
10						
6						
11						
8						
9						

Laboratory Data Sheet 4.1
Mineral Identification

#	Luster / Color	Hardness	Cleavage	Streak	Other Property	Mineral ID
7						
15						
19						
20						
12						
13						
14						
18						
16						
17						

Lab 5 – Rock Groups and Rock Properties

Minerals and Rocks

Minerals are the fundamental solids that compose the crust and mantle of the Earth. In the previous lab we saw that of the thousands of different minerals that have been identified, only about twenty are common in the crust of the Earth. Rarely are these common minerals found separately in great abundance. Instead, minerals tend to form and associate together in aggregates called **rocks**. Most rocks are comprised of a mix of two or more minerals. Of the twenty common minerals, ten compose the bulk of almost all rock on Earth. These ten “rock-forming” minerals are quartz, k-feldspar, albite, labradorite, hornblende, augite, olivine, calcite, clay, and mica (biotite and muscovite).

How many different kinds of rocks are there? This is difficult to define precisely. In detail, any rock that forms at a particular place and time is unique and no two rocks are exactly alike. However, similar geologic environments and conditions produce similar rocks that are given the same name. Geologists who specialize in **petrology** (the study of rocks and rock formation) recognize hundreds of different kinds of rock. Fortunately, many kinds of rock are similar enough to share a general name and some kinds of rock are more common than others. Therefore, as with minerals, to understand and appreciate the basic concepts of geology, we only need to be able to identify about twenty different kinds of rock.

Why is it so important for geologists to be able to identify rocks? The answer to this question is found in the fact that all rocks have a history of formation. The types and associations of minerals found in a rock (**mineral composition**) and the size, shape, and arrangements of the individual mineral grains and crystals of a rock (**texture**) are caused by how and where the rock formed. In other words, particular geologic processes (for example, erosion, volcanism, or burial) and conditions (such as temperature and pressure) combine to produce a particular kind of rock. When a geologist identifies a rock, he or she is also identifying the processes and conditions that created the rock. This is how we come to learn how the Earth functions and evolves – by reading from the rocks the story of their formation. The great importance that geologists attach to rock formation is revealed in the fact that the first question any geologist asks about a rock is not “what is its name?” but rather, “what group of rock does it belong to?”

Introduction to the Three Rock Groups

Geologists classify rocks into three major groups: (1) **igneous**; (2) **sedimentary**; and (3) **metamorphic**. This classification reflects the fact that rocks form by three fundamentally different processes. Igneous rocks form from the cooling and crystallization of minerals from a molten state. Sedimentary rocks form from the accumulation of mineral grains or mineral precipitates in layers at the surface of the Earth. Metamorphic rocks form when a pre-existing rock is changed by exposure to high temperatures and / or pressures. Each of these processes takes place in different places on and within the Earth and each records different kinds of information within the rock. For example, igneous rock forms wherever there is enough heat in the Earth to melt rock. Usually this occurs where tectonic plates are either moving apart or

colliding, but also where excess heat is escaping from the mantle. By identifying and studying igneous rock we learn about how the Earth's interior functions. Sedimentary rock forms as sediments (gravel, sand, mud, shell, and salts) accumulate on the Earth's surface. Different environments produce different mixtures of sediment, which often preserve the remains of plants and animals as **fossils**. Geologists can reconstruct the environments and life that existed in the Earth's past from layers of sedimentary rock. Most metamorphic rock forms when tectonic plates collide and mountains are pushed up as wrinkles in the Earth's crust. Many geologists study metamorphic rock to understand the process and history of mountain building on the Earth.

The objective of this two-week lab is to become proficient at rock identification and to learn to distinguish among the three groups of rock - igneous, sedimentary, and metamorphic. Your main task is to examine each of 20 unknown specimens and attempt to determine rock type from the texture and mineral composition. For many people, the most challenging aspect of rock identification is determining rock group. For example, it is easy to identify a dull, black rock as a basalt if you already know you are dealing with an igneous rock. But there are also dull, black sedimentary rocks (mudstones) and metamorphic rocks (slate). How do you determine to which group a rock belongs before you have identified it? Although it may seem backward, we will first examine the properties of each rock group individually before we attempt to distinguish one group from another. After all, how can you hope to distinguish an igneous from a metamorphic rock without first understanding the characteristics of each group?

Characteristics of the Different Rock Groups

Although there are fundamental differences between igneous, sedimentary, and metamorphic rocks, all rocks share two basic properties – they have a well-defined **mineral composition** and **texture**. Mineral composition describes the mix of minerals present in the rock and their relative proportions. Most rocks are composed mainly of one or two **primary minerals**, others may contain roughly equal amounts of several minerals. Additional minerals that occur in a rock in small amounts are called **accessory minerals**. Texture describes how the minerals appear in the rock in terms of the size, shape, and arrangement of the mineral crystals or grains. Each group of rocks has its own characteristic suite of textures that develop because of the different processes of rock formation.

IGNEOUS ROCKS

Igneous rocks form whenever molten rock cools enough that it freezes into solid crystals of mineral. Molten rock beneath the surface of the Earth is called **magma**, which cools slowly to form **intrusive** (“within other rock”) or **plutonic** (“deep in the Earth”) igneous rock. Magma can also be erupted onto the surface of the Earth as **lava**, which freezes rapidly to form **extrusive** (surface) igneous rock. Solid masses of igneous rock are found in a variety of distinctive shapes and sizes (see Optional Exercise 5.1 at the end of Lab 5).

Mineral Composition

In igneous rocks, mineral composition is determined primarily by the location within the Earth of the source of the magma. Magma derived from the upper mantle tends to produce rocks that are rich in dark-colored, dense minerals such as olivine, pyroxene, and amphibole. These

minerals form dark, dense **mafic** igneous rocks. Mafic magmas are usually erupted where plates are diverging such as at the mid-ocean ridges or in East Africa where the continent is rifting. Mafic magma is also produced when the upper mantle melts over a hot spot, such as beneath the island of Hawaii. Magma derived from the melting of continental crust tends to produce silica-rich minerals such as quartz, K-feldspar, and albite. These minerals form light-colored, less dense **felsic** igneous rocks. Magma that forms at subduction zones where plates are in collision derives from the partial melting of upper mantle in the presence of water. This process produces a magma that is **intermediate** in composition that freezes to form rock comprised of a mix of both light minerals (e.g. albite) and dark minerals (e.g. amphibole, pyroxene). Intermediate magma feeds the volcanoes of the Andes Mountains in South America where plates beneath the Pacific Ocean are colliding with the western margin of the continent.

Igneous rocks include most of the common rock-forming minerals - quartz, feldspars, pyroxene, amphibole, and olivine. Accessory minerals include mica and magnetite. Igneous rocks are always harder than glass due to their mineral composition. Table 4.1 illustrates the mineral composition of common igneous rocks.

Texture

Igneous rock is almost always crystalline because it cools and solidifies from a melt. One of the important parts of the cooling history of an igneous rock is the rate of cooling. Was cooling fast (days to weeks) or slow (thousands to millions of years)? Cooling rate is directly related to where the magma or lava is located in the Earth. Lava cools very rapidly at the surface of the Earth, but magma located deep within the Earth cools very slowly. During slow cooling, scattered large crystals can grow. During rapid cooling, many small crystals will grow. During extreme chilling (such as occurs when lava is quenched in water or under glacial ice) no crystals form at all and the result is a non-crystalline solid known as **natural glass**. Note that glass does not have a mineral composition because all minerals are crystalline by definition. The molecular structure of glass is more like a liquid than a solid and physicists often refer to glass as a “rigid liquid”.

In addition to the rate of cooling, whether the cooling was uniform or non-uniform affects the texture of the rock. If the cooling history was uniform, then the crystals in the rock will all be of about the same size and the texture will be **equigranular**. If the cooling history was not uniform, then the different crystals within the rock will have cooled at different rates and the rock will have two populations of crystals of very different sizes. Such non-uniform textures in igneous rocks are named **porphyritic textures**. In an igneous rock having a porphyritic texture, the distinctly larger crystals are named **phenocrysts** and the smaller crystals are collectively designated as the **groundmass**.

More than in any other group of rocks, texture in igneous rocks provides easily interpretable information about how a particular rock has formed. To summarize: Phaneritic rocks such as granite form from the slow cooling of magma deep within the Earth forming large, visible crystals. Igneous rock that cools more rapidly at shallower depths within the Earth tends to be composed of smaller crystals. Magma that erupts as lava and cools on the surface of the Earth will have an aphanitic texture consisting of microscopic crystals. A porphyritic texture indicates a magma that initially began cooling slowly, but that later was erupted and cooled

rapidly. Glassy igneous rocks form from silica-rich lavas that are rapidly chilled at the surface. Gas-rich lavas result in a vesicular aphanitic texture.

Textures in Igneous Rocks:

- 1 - **glassy** (No crystals – rock looks like massive glass or may be extremely frothy and light).
- 2 - **aphanitic** (Crystals are microscopic – rock appears dull and uniform in color with a few small, scattered visible crystals).
- 3 - **porphyritic** (Two different crystals sizes are present – in many cases visible, angular crystals are floating in a dull, aphanitic groundmass).
- 4 - **phaneritic** (Crystals are large enough to see in hand specimens – cleavage planes of individual crystals shine in reflected light and different minerals may be apparent).
- 5 - **pegmatitic** (Individual mineral crystals are larger than 10 mm – this texture is best seen in large specimens).

Special Volcanic Textures

While cooling is in progress, gases dissolved in a lava are rapidly escaping. The rapid escape of gases from lava creates a spongy-looking rock full of small more-or-less spherical cavities named **vesicles**. The resulting igneous rock is referred to as a **vesicular igneous rock**. Many vesicles remain as empty spaces but others become filled with minerals to form tiny cavity-filling mineral deposits named **amygdules**.

CLASSIFYING IGNEOUS ROCKS

Igneous rocks are classified by both their mineral composition and texture (Table 5.1). A magma with a particular composition can solidify to form several different kinds of igneous rocks, depending on where and how fast the magma cooled and the different textures that result. For example, a felsic magma will produce a rock rich in quartz, K-feldspar, and albite. If this magma cools slowly, deep in the Earth, it will form a phaneritic rock called **granite**. If erupted as a lava and rapidly cooled, the same magma will form an aphanitic rock called **rhyolite**. Likewise, a mafic magma will freeze to form crystals of olivine, labradorite, hornblende, and augite. When cooled slowly deep in the Earth, the phaneritic rock that forms is a **gabbro**. When cooled rapidly near the surface of the Earth, the same magma forms an aphanitic rock called **basalt**. Intermediate magmas produce **diorite** (phaneritic) and **andesite** (aphanitic). Commonly, an intermediate magma may begin to cool slowly, producing large crystals of albite and hornblende. Before all of the magma freezes, it may be erupted on to or near the surface, resulting in rapid cooling for the remaining melt. This forms an **andesite porphyry** – a rock combining both phaneritic and aphanitic crystals. Massive volcanic glass is called **obsidian**. A frothy glass having tiny (<1 mm) cavities is **pumice**. A vesicular mafic rock having large (>1 mm) cavities is **scoria**.

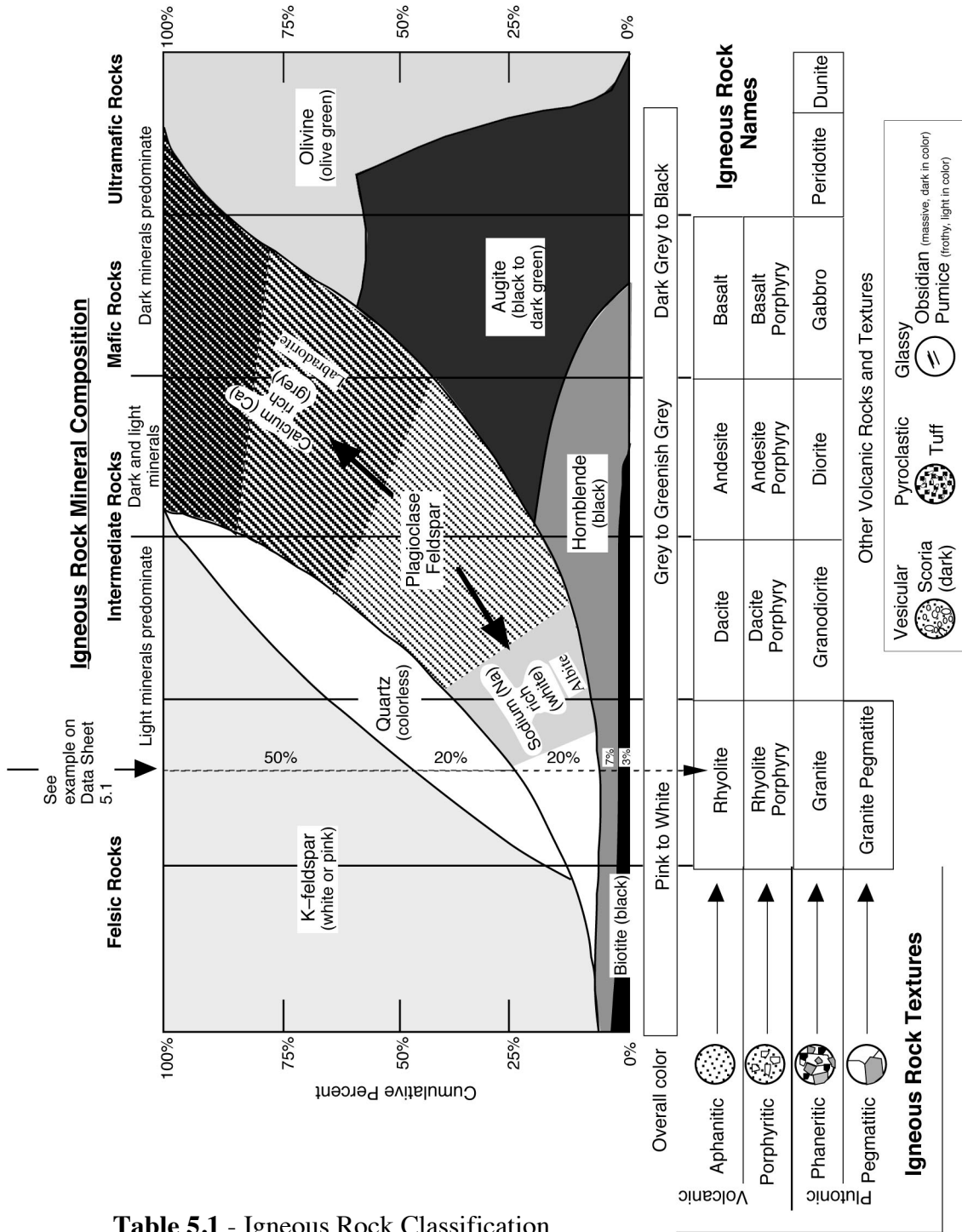


Table 5.1 - Igneous Rock Classification

Table 5.1 lists the names of common igneous rocks based on their texture (vertical axis) and mineral composition (horizontal axis). By estimating the overall mineral composition of an igneous rock sample one chooses a family of igneous rock types. Identifying the texture of the sample then allows one specific type of rock to be chosen from the family. Example A on Table 5.1 illustrates how to use this chart. In this case, felsic minerals predominate (50% K-feldspar, 20% quartz, 20% albite), the mafic minerals (hornblende and biotite) constitute only 10% of the rock. This identifies the specimen as belonging to the rhyolite - granite family. Because the texture is one of large, visible crystals (phaneritic) the specimen is identified as granite.

SEDIMENTARY ROCK

Most of the rock exposed at the Earth's surface is sedimentary rock that formed by the deposition of layers of loose mineral material called **sediment** (e.g. gravel, sand, mud, shells). After deposition, the loose sediment grains become cemented together to form rock. Four important attributes of sedimentary rocks are: (1) they form in horizontal layers; (2) they contain the remains of extinct organisms (fossils); (3) they contain evidence of the environment in which they were deposited (lagoons, deltas, rivers, dunes, shallow marine coasts, coral reefs, deep-sea floor, etc.); and (4) they contain all of the world's fossil fuels such as coal, oil, and natural gas.

Mineral Composition

Sediments, the raw materials of sedimentary rock formation, are formed by several different processes. **Clastic sediments** are produced by the erosion and weathering of existing rock. Weathering chemically degrades most rock-forming minerals into dissolved ions, iron oxides, and clay. Quartz is not chemically degraded by weathering. Therefore, most clastic sediment is composed of quartz and or clay. The dissolved ions released by weathering are washed by rivers into the ocean where they may be precipitated as **chemical sediment**. The most abundant chemical sediment is calcium carbonate (calcite), which is produced by a variety of marine organisms such as algae and corals, as well as by inorganic precipitation. Once deposited, calcite sediments may be chemically recrystallized into dolomite mineral. Calcite and dolomite sediments are often grouped as **carbonate sediments**. Chemical sediment can also be produced by the evaporation of seawater, which leads to the crystallization of halite (rock salt) and gypsum. Silica can be crystallized by tiny marine plankton (diatoms and radiolarians) or it can be precipitated as layers or nodules within other types of sediment. **Carbonaceous sediment** is formed from the partially decayed remains of plants and consists mostly of the element carbon.

Texture

Most sedimentary rocks do not appear crystalline, rather, are composed of mineral grains that were deposited and then cemented together. Texture in clastic and carbonate sedimentary rocks is distinguished by the size of the sediment grains in the rock. **Pebble** size sediments are larger than 2 mm. **Sand** size sediments are smaller than pebbles, but large enough to see with the naked eye or low-power magnifying lens. **Mud** size sediments are microscopic and may consist of both quartz silt and clay particles. Rock that contains a large portion of clay will often be **fissile**, which is a tendency to split into thin slabs. Crystalline textures are hard to distinguish from aphanitic igneous textures except for the fact that igneous rocks tend to be hard.

Because most sediments are transported by ice, wind, water, or gravity before being deposited, they may be altered in a variety of ways. Most sediment particles start out **angular** in shape but become **rounded** as they are transported. Water and wind are very effective at **sorting** sediment particles based on size. Sediment that has not been transported very far will contain a mix of gravel, sand, and mud and is **poorly sorted**. Sediment that has been transported a great distance or washed by waves and currents will tend to only have a limited range of grain sizes and is **well sorted**. Sorting is also related to **sediment maturity**. Sediments that are mature have been significantly transported and subjected to extensive rounding, chemical weathering, and sorting. Immature sediments tend to be angular, poorly sorted, and to contain minerals such as K-feldspar that are normally degraded by chemical weathering.

CLASSIFYING SEDIMENTARY ROCKS

Sedimentary rock is classified primarily on the sediment type composing the rock and the grain size present in the rock (Table 4.2). Other factors include the accessory minerals present, the degree of sorting in the rock, and the roundness of the sedimentary particles. A clastic rock composed of large, pebble size grains is called a **conglomerate** if the pebbles are rounded and a **breccia** if the particles are angular and poorly sorted. A clastic rock composed of sand is called a **quartz sandstone** if composed mostly of quartz sand. If, however, there is a notable quantity of feldspar, mica, and iron oxide mixed with the quartz sand, then the rock is called an **arkose**. If there are grains of rock fragments and mud mixed with the sand, then the rock is known as a **greywacke**. Rocks composed of mud are called **mudstone** if they are massive and **shale** if they are fissile and easily split. Carbonate rocks are referred to as **limestone** when composed of calcite and **dolostone** when composed of dolomite. Limestones composed of large shell fragments are called **coquina** and a white limestone composed of the microscopic shells of marine algae is called **chalk**. All carbonate rocks will react with dilute hydrochloric acid to produce bubbles of carbon dioxide, which makes them easy to identify. The few crystalline sedimentary rocks are the evaporites, which can be identified by their distinctive mineral composition (**rock salt** and **rock gypsum**). Siliceous rocks (**chert** or **flint**) have a distinctive conchoidal fracture and waxy luster. Carbonaceous rock (**coal**) is notably less dense than almost all other rocks and usually dusty black in appearance.

Sedimentary Rock Textures and Grain Types

Clastic texture: The clastic texture is characterized by particles that were broken by the process of mechanical weathering and erosion. Such broken particles include rock fragments, mineral grains, and clay particles.

Bioclastic texture: Many limestones are composed almost exclusively of broken shell material derived from a wide variety of marine organisms (corals, algae, plankton, shellfish, etc.). Shell material is also referred to as **skeletal grains**.

Oolitic texture: Calcium carbonate is sometimes precipitated out of the waters of the basin of deposition in such a way that it accretes concentrically to form a coating around a nucleus particle (quartz, skeletal particle, clay particle etc.). Such coated particles are named **ooids** because they look like tiny eggs. A sediment or sedimentary rocks composed of ooids is said to possess **oolitic texture**.

Pyroclastic texture: Volcanic eruptions (particularly explosive eruptions) often produce **tephra** consisting of a range of grain sizes (from large “bombs” to tiny ash particles) that settle out to form layers of volcanic sediment. These sediments are referred to as **pyroclasts**.

Detrital	<u>Clastic</u> Quartz and / or rock fragments and / or clay		Environments of Deposition	
	Pebble (>2mm)	Rounded rock- or mineral fragments, some quartz sand	Conglomerate	High-energy areas: streams, river beds, shorelines.
		Angular rock- or mineral fragments, some sand	Breccia	Arid regions: flash floods, landslides, cave collapse
	Sand (2mm to .06mm)	Mostly quartz sand, usually light in color	Quartz sandstone	Sand dunes, beaches, offshore sand bars, river beds.
		Mixture of feldspar, mica, quartz sand, some rock fragments, red-brown in color	Arkose	Arid regions where granite is weathering.
		Dark rock fragments and quartz, matrix of clay and silt, dark in color	Graywacke (Lithic sandstone)	Rapid deposition in off-shore deep water near areas of active tectonism.
	Mud (<.06mm) (invisible)	Dull, fine-grained rock, breaks into irregular blocks, may be composed of quartz silt (siltstone) and / or clay (claystone).	Mudstone	Low energy environments such as lake bottoms, floodplains, lagoons, or in deep water.
		Mudstone that splits into thin, flat pieces (fissile)	Shale	
	Chemical and Biogenic	<u>Carbonate</u> Calcium carbonate (effervesces freely on contact with dilute acid)		Generally the result of organic production of calcium carbonate by marine organisms in tropical- to subtropical climates.
		reacts with acid	Gray to white, granular to smooth	
White, chalky			Chalk	
		Shell fragments	Coquina	
Dolomite (effervesces slowly when powdered)		Dolostone	Reaction of limestone with Mg-rich fluids.	
<u>Evaporite</u>		Rock Salt Rock Gypsum	Produced by evaporation in arid environments - desert basins or coastal tidal flats.	
	Crystalline texture			
<u>Other</u>		Chert, Flint	Deep-sea 'oozes' or precipitated in cavities.	
	Smooth, waxy-looking, conchoidal fracture, siliceous (quartz)			
	Black, dusty to vitreous, low density (composed of organic carbon)	Coal	Buried plant remains deposited in swamps and bogs.	

Table 5.2 – Sedimentary Rock Classification

METAMORPHIC ROCKS

Metamorphic rock is formed when pre-existing rock (the **parent rock** or **protolith**) is subjected to major changes in temperature and pressure. Most metamorphic rock is created when large regions of bedrock become buried beneath rising mountains during the collision between tectonic plates (**regional metamorphism**). Some metamorphic rock is also produced when bedrock is heated by contact with magma (**contact metamorphism**). Small quantities of metamorphic rock are formed by the pressure produced when rock moves along faults in the Earth's crust and with the extreme high pressure of impacting meteorites and asteroids. The metamorphic changes that occur in the parent rock alter both the mineral composition and the texture of the rock. Geologists refer to the “**3 R's**” of metamorphism to describe the changes that occur in metamorphic rock. **Recrystallization** is the transformation of one mineral into a different mineral by rearrangement of the atoms within the crystal lattice. For example, clay minerals will recrystallize into mica minerals at high temperature and pressure. **Regrowth** is the tendency for mineral crystals to amalgamate and become larger during metamorphism. **Reorientation** of mineral crystals results from directional pressure, which causes the crystals to regrow in a preferred direction. All of these metamorphic changes occur while the rock remains in a solid state. If the rock becomes hot enough to melt, it will become magma and eventually cool into igneous rock.

Mineral Composition

Metamorphic rocks include most of the common rock-forming minerals: quartz, feldspars, hornblende, mica, and calcite / dolomite. Clay minerals are recrystallized by metamorphism into mica and many metamorphic rocks are rich in glittery flakes of mica. Recrystallization also produces large crystals of accessory minerals such as garnet, staurolite, kyanite, and andalusite.

Texture

Because of the processes of regrowth and recrystallization, most metamorphic rocks are crystalline and many have large, visible crystals. Geologists divide metamorphic rocks into two broad textural categories based on whether or not they show the influence of pressure on their texture. **Foliated** metamorphic rocks have a non-random texture, meaning that their mineral crystals are oriented in some way. Foliation may be expressed as a rock cleavage, mineral layering or banding, and crystal or grain elongation and orientation. Often, foliated metamorphic rocks contain distinctive crystals of garnet that can be seen to have grown within the rock, disrupting the surrounding mineral crystals. **Non-foliated** metamorphic rocks are randomly crystalline and are usually composed of either quartz or carbonate minerals (calcite / dolomite). Large crystals of accessory minerals such as garnet that grow within the fabric of a rock during metamorphism are called **porphyroblasts** and impart to the rock a **porphyroblastic texture**.

Examples of common metamorphic textures should be examined in lab with your professor with the use of the Rock Texture Kits. For now don't concern yourself with the rock names (in parentheses below). Just focus on the textural varieties of metamorphic rocks.

CLASSIFYING METAMORPHIC ROCKS

Metamorphic rocks are classified primarily based on their texture, which reflects the intensity of heat and pressure that the rock was exposed to during metamorphism (Table 4.3). Mineral composition is largely inherited from the parent rock, although recrystallization can transform the parent minerals within limits. Metamorphism is also progressive, meaning that rock will undergo continuous metamorphic change as it becomes buried deeper and deeper within the Earth. For example, the parent sedimentary rock mudstone or shale is one of the more common rocks to form on the surface of the Earth. During the early stages of metamorphism (**low-grade**), the clay minerals in mudstone begin to recrystallize into mica and reorient to form layers, giving the resulting metamorphic rock **slate** a slaty cleavage. With deeper burial, the microscopic crystals of mica in the rock regrow, becoming larger. This results in **phyllite**, a rock that is similar to slate but one that has a distinct shine on its foliation surfaces because the larger mica crystals better reflect light. Under **high-grade** metamorphic conditions deep in the Earth, the mica crystals regrow to become visible to the eye, resulting in a **schist**. Most schists contain layers (folia) of large, glittery mica crystals. Eventually, mica will recrystallize into feldspar as quartz grains present as silt in the parent rock regrow to become visible. Pressure and shearing within the rock will cause the quartz and feldspar to segregate into distinct layers and stripes, forming a rock with banded foliation called **gneiss**. If the parent rock is a mafic igneous rock such as basalt, the same sequence of rock textures will form, but with different mineral compositions. Under high-grade metamorphic conditions a basalt will metamorphose into a hornblende gneiss, which is also called **amphibolite**. Most non-foliated rocks lack foliation because the mineral in the parent rock does not segregate or reorient during metamorphism. For example, the parent rock sandstone is composed primarily of quartz. During metamorphism the quartz grains in the sandstone regrow to form larger, more uniform crystals of quartz, but without a particular orientation. This produces the metamorphic rock **quartzite**. Likewise, carbonate sedimentary rocks metamorphose into **marble**, a rock composed of large, intergrown crystals of calcite or dolomite.

Hints for Distinguishing Parent Rocks from Their Metamorphic Products

Quartzite vs. sandstone: In quartzite, the rock breaks **across** the individual quartz grains. In the sandstone parent rock, a broken surface feels "rough" (like sandpaper) because the rock breaks **around** the quartz particles, between the clasts and the cement.

Calcite marble vs. limestone: Both rocks consist of calcite and can be scratched with a knife blade and will effervesce immediately with dilute hydrochloric acid. The limestone parent rock may display fossils and be gray to dark gray. Marble will show glittering cleavage faces and be crystalline, with no fossils.

Dolomite marble vs. dolostone: The texture of both rocks is crystalline and they both consist of the mineral dolomite. Both will effervesce in dilute hydrochloric acid only after first being scratched. If the rock shows cleavage faces, it is dolomitic marble.

Granite-gneiss vs. granite: The fabric of the parent rock granite is random. The fabric of the granite-gneiss is oriented. This oriented fabric is expressed by a well-developed gneissic layering or foliation. The mineral layers may appear streaky, but are clearly visible by the

FOLIATED (minerals oriented or layered)

		FELSIC ← Parent Rock → MAFIC	
		e.g. mudstone, granite e.g. basalt	
Texture (mineral appearance)	INVISIBLE	<p>Slate: Dull, brittle, with good cleavage due to recrystallization of clay to mica; can be gray, black, red, or green</p>	<p>Chlorite slate Similar to slate but with abundant green chlorite.</p>
	BARELY VISIBLE	<p>Phyllite: Similar to slate, but with sheen on cleavage surface due to growth of mica minerals and chlorite.</p>	<p>Chlorite phyllite: Similar to phyllite but with abundant green chlorite.</p>
	OBVIOUS (LARGE)	<p>Mica Schist: Well-foliated rock with abundant large, platy micas in parallel orientation. Crystals of garnet (porphyroblasts) are often present.</p> <p>Gneiss: Well-foliated rock with distinct bands of compositionally segregated mineral grains. Granite Gneiss - similar to granite but foliated.</p>	<p>Chlorite schist: Similar to felsic schist, but with abundant chlorite mineral. Because of its common green color is it often called 'Greenschist'.</p> <p>Amphibolite: Dark, well-foliated rock consisting principally of oriented, needle-like amphibole crystals. Grain size is variable.</p>

NON - FOLIATED

Carbonate	
Mineral Composition	<p>REACTS WITH ACID</p> <p>Marble (calcite or dolomite): Large, interlocking crystals of calcite or dolomite. Sometimes white in color, often with bands or streaks of color resulting from impurities in the composition of the parent limestone or dolostone.</p>
	<p>Quartz</p> <p>Quartzite: Large, interlocking crystals of quartz resulting from the regrowth of original detrital quartz grains in the parent sandstone.</p> <p>Metaconglomerate: pebbles regrown and indistinct, rock breaks across pebbles. Pebbles may also be stretched and elongated in the direction of least metamorphic stress.</p>
	<p>Misc.</p> <p>Hornfels: Dull-looking, brittle rock of variable composition resulting from contact metamorphism of a variety of parent shales and mudstones.</p> <p>Serpentinite: Greenish, hard, greasy- or soapy feeling rock formed from the hydrothermal alteration of ultramafic parent rocks.</p> <p>Talc Schist: A metamorphic rock composed entirely of soft talc derived from hydrothermal alteration of magnesium-rich parent rocks.</p> <p>Anthracite: Metamorphic coal; black, shiny, low density, conchoidal fracture.</p>

Table 5.3 Metamorphic Rock Classification

Table 5.4 - Rock Texture Reference Collection

Use these small hand samples as references to identify textures in the three different rock types.

Specimen	Rock Type	Texture
1	Igneous	Glassy (massive)
2	Igneous	Aphanitic
3	Igneous	Phaneritic
4	Igneous	Vesicular (glassy)
5	Igneous	Porphyritic
6	Sedimentary	Sand (clastic)
7	Sedimentary	Clay / Mud (clastic)
8	Sedimentary	Pebble (clastic)
9	Sedimentary	Crystalline
10	Metamorphic	Non-foliated
11	Metamorphic	Foliated (slaty cleavage)
12	Metamorphic	Non-foliated
13	Metamorphic	Foliated (banded)
14	Metamorphic	Porphyroblastic
15	Metamorphic	Foliated (schistose)

Lab 5 Exercises – Rock Groups and Rock Properties

LAB EXERCISES

Instructions: This laboratory has three stations, each with a group of specimens for you to examine using hand samples and the Rock Texture Reference Collection (see Table 5.4). The objective of these activities is for you to familiarize yourself with the different rock textures and minerals in rocks and how texture and mineral composition are combined to classify rocks. Next week you will apply what you learn today to identify twenty common rock types.

Station 1: Igneous Rocks and Textures

Key Words:

Igneous Textures: aphanitic, phaneritic, porphyritic, glassy, vesicular

Minerals: quartz, K-feldspar, albite, labradorite, hornblende, augite, olivine

Igneous rock categories: felsic, mafic, volcanic, intrusive, extrusive

1. Identify which sample(s) of igneous rock have the following textures:

<u>Texture</u>	<u>Sample #s</u>
Aphanitic	_____
Porphyritic	_____
Phaneritic	_____
Glassy	_____
Vesicular	_____

2. Identify which sample(s) of igneous rock have the following mineral compositions:

<u>Mineral Composition</u>	<u>Sample #s</u>
Felsic (quartz, K-feldspar, albite)	_____
Intermediate (hornblende, feldspar)	_____
Mafic (hornblende, augite, olivine)	_____
Glass (silica mineraloid)	_____

3. Using Table 5.1 – Igneous Rock Classification - combine texture and mineral composition to identify which sample represents each of the following rock types:

Rhyolite	_____	Granite	_____	Gabbro	_____
Andesite Porphyry	_____	Scoria	_____	Diorite	_____
Basalt	_____	Obsidian	_____		

Station 2: Sedimentary Rocks and Textures

Key Words:

Sedimentary Textures: grain size – pebble, sand, mud, fossils

Minerals: quartz, K-feldspar, clay, calcite, dolomite, halite, gypsum

Sedimentary rock categories: clastic, carbonate, evaporite, carbonaceous

1. Identify which sample(s) of sedimentary rock have the following textures:

<u>Texture</u>	<u>Sample #s</u>
Pebble	_____
Sand	_____
Mud	_____
Crystalline	_____
Bioclastic (composed of fossil grains)	_____
Other	_____

2. Identify which sample(s) of sedimentary rock have the following mineral compositions:

<u>Mineral Composition</u>	<u>Sample #s</u>
Quartz (glassy, light in color)	_____
Clay (dull, dark in color)	_____
Calcite (reacts with dilute HCl)	_____
Halite (crystalline rock salt)	_____
Carbon (low density, black, dusty)	_____

3. Which specimen(s) of sedimentary rocks contain fossils? _____

4. Using Table 5.2 – Sedimentary Rock Classification - combine texture and mineral composition to identify which sample represents each of the following rock types:

Coal	_____	Arkose	_____	Sandstone	_____
Conglomerate	_____	Halite	_____	Greywacke	_____
Shale	_____	Limestone	_____		

Station 3: Metamorphic Rocks and Textures

Key Words:

Metamorphic Textures: foliated, non-foliated, cleavage, schistose, banded, porphyroblastic

Minerals: quartz, feldspar, mica, hornblende, calcite, dolomite, garnet

Metamorphic rock categories: low grade, high grade

1. Identify which sample(s) of metamorphic rock have the following textures:

<u>Texture</u>	<u>Sample #s</u>
Slaty cleavage (weak foliation)	_____
Schistose foliation	_____
Banded foliation	_____
Non-foliated texture	_____
Porphyroblastic texture	_____

2. Identify which sample(s) of metamorphic rock have the following mineral compositions:

<u>Mineral Composition</u>	<u>Sample #s</u>
Mica + Quartz (glittery flakes + glassy grains)	_____
Calcite (shiny cleavage faces, reacts with HCl)	_____
Garnet (deep red, well-formed crystals)	_____
Quartz (hard, sugary appearance)	_____
Hornblende (black, shiny cleavage faces)	_____
Mica + Clay (dull to moderately shiny)	_____

3. Using Table 5.3 – Metamorphic Rock Classification - combine texture and mineral composition to identify which sample represents each of the following rock types:

Marble	_____	Slate	_____
Phyllite	_____	Gneiss	_____
Schist	_____	Quartzite	_____
Porphyroblastic Schist	_____	Amphibolite	_____

Lab 6 – Rock Identification

What to do:

Using your observations of mineral composition and rock texture, you will identify twenty unknown rock specimens. Observe each specimen carefully and record your observations on the Lab 6 Data Sheet. Use Table 6.1 to determine which of the three rock groups each specimen belongs in. Tables 6.2, 6.3, and 6.4 will assist you in identifying specific rock names. You may also wish to consult the classification charts found in Laboratory 5.

THREE IMPORTANT QUESTIONS TO ASK WHEN TRYING TO IDENTIFY AN UNKNOWN ROCK

1. Is the rock **IGNEOUS**, **SEDIMENTARY**, or **METAMORPHIC**? Observing whether a rock is layered, whether it is grainy or crystalline, and whether it has fossils or vesicles, will help determine the formational origin of the rock. Once this determination is made, you can focus on identifying the textures and minerals relevant to classifying rocks within each formational category. Unfortunately, there is no one simple test for determining if a rock is igneous, sedimentary, or metamorphic. Instead, a variety of observations of mineral composition and texture must be combined to make the correct determination. These observations are summarized in the flow chart in Table 6.1
2. What is the **MINERAL COMPOSITION**? Is the rock composed of several types of minerals or just one? Are the minerals hard silicate minerals, soft silicate minerals, or carbonates? A simple hardness scratch test will distinguish soft from hard minerals. A test with dilute acid will identify carbonate minerals. Quartz appears glassy and grey in crystalline rocks and shows no cleavage planes. In sedimentary rocks, quartz occurs as light-colored pebbles and sand grains. K-feldspar shows cleavage planes and is usually pink to orange in color. Albite is similar, but white in color. A grey mineral with cleavage is likely to be dark plagioclase feldspar. A light-colored, flakey mineral is muscovite mica. A shiny, dark, flakey mineral is biotite mica. Black minerals with cleavage faces may be hornblende or augite. Hornblende crystals are often elongate and needle-like, whereas augite crystals tend to be blocky. Calcite will react immediately and vigorously with dilute acid. Dolomite will react slowly after first being powdered.
3. What is the **TEXTURE**? Texture is an important clue to determining both the rock group in which a sample belongs and the name of the rock itself. Is the rock heterogeneous in appearance – can you see individual crystals or grains? Large crystals are found in phaneritic igneous rock and in high grade metamorphic rock. Grains are characteristic of sedimentary rock. Is the rock layered? Layered rocks may be sedimentary or metamorphic. Rocks that are homogeneous in appearance may be fine-grained sedimentary rocks or aphanitic igneous rocks (a scratch test, described above, with distinguish between the two possibilities). Fossils are indicative of sedimentary rock. Vesicles form in volcanic igneous rock.

FIVE SIMPLE TESTS TO PERFORM ON ROCKS

HARDNESS: Try to scratch the rock with a knife blade or a nail. If you can't scratch the rock, then it probably consists of silicate minerals (the hardness of most silicates falls in the range of 5 to 7; exceptions are minerals of the mica group and talc). Apart from these flaky "soft" silicates, the other soft minerals (hardness <5) are abundant only in some sedimentary rocks (such as limestone, dolostone, gypsum rock, halite rock, and shale) or metamorphic rocks derived from these (calcite marble, dolomite marble, slate, phyllite, schist).

REACTION WITH DILUTE ACID: If you detect a "soft" rock, then apply a drop of dilute hydrochloric acid. Vigorous bubbling indicates calcite (the chief mineral in limestone and calcite marble. If no bubbling takes place, powder a portion of the rock with a knife or nail and check to see if the powdered rock effervesces. If the powder reacts faintly, then the rock may be a dolostone or a dolomitic marble. Silicate minerals do not react with dilute acid, although some sandstone and shale may effervesce because of calcite cement between the silicate grains.

DENSITY: The density of a rock is a function of the density average of the constituent minerals and of how much air-filled pore space is present. Dense rocks are composed of dense minerals closely arranged with minimum pore space. Many rocks have similar densities because they are composed mainly of quartz and feldspars. However some rocks are distinctive for having unusually high or low density. Heavy, high density rocks include igneous rocks such as basalt and gabbro that are composed of the iron-rich minerals olivine, augite, and hornblende. Light, low density rocks include coal, composed of the light element carbon, and pumice, which is a frothy glass with many small vesicles.

VISUAL OBSERVATION – THE EYEBALL TEST: For crystalline rocks (mostly igneous and metamorphic), one of the most important observations you can make is to see if the rock is composed of visible crystals or not. Most of the rock-forming minerals have cleavage. On a broken surface of the rock large, cleavage faces of visible minerals will flash and wink as the rock is slowly rotated in light. In contrast, microscopic crystals are invisible to the eye and appear dull. Large crystals are easy to see in rocks composed of a mix of different colored minerals (e.g. granite) but are more difficult to spot in rocks composed of dark minerals (e.g. gabbro) or a single mineral only (e.g. marble). Look carefully. If you see cleavage faces shining in the light you are looking at large, phaneritic crystals. Careful observation of a specimen can also reveal other important clues to the identity of a rock. Does the rock contain vesicles? Vesicular rocks are usually volcanic (igneous). Can you see any pieces of shell or other fossils in the rock? Fossils are only found in sedimentary rock (with a few, very rare, exceptions). What is the color of the rock? Light colored rocks are usually rich in felsic minerals such as quartz and feldspars, while dark colored rocks tend to be rich in mafic minerals such as hornblende, augite, and olivine.

TACTILE OBSERVATION – THE TOUCH TEST: Clastic sedimentary rocks are composed of grains of mineral material. Sand size grains are visible, but often difficult to distinguish because they are small and uniform in color. However, on a freshly broken rock surface, sand grains protrude and will feel rough on your fingertips. Rub the surface of the rock. If it feels abrasive the rock is probably composed of sand size grains. Rocks that feel smooth are either crystalline (e.g. rock salt) or composed of microscopic grains (e.g. mudstone).

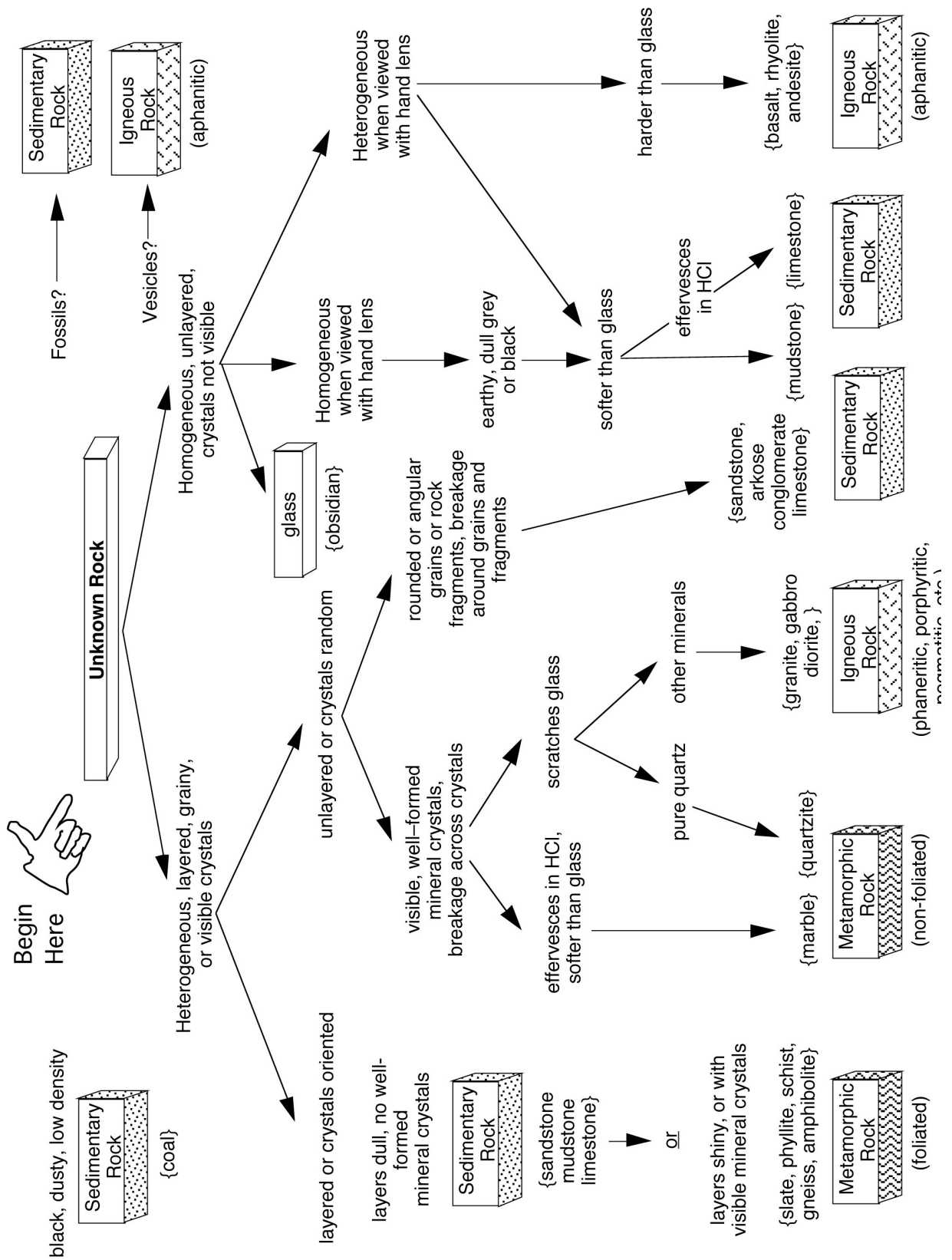


Table 6.1 – Rock Group Flow Chart

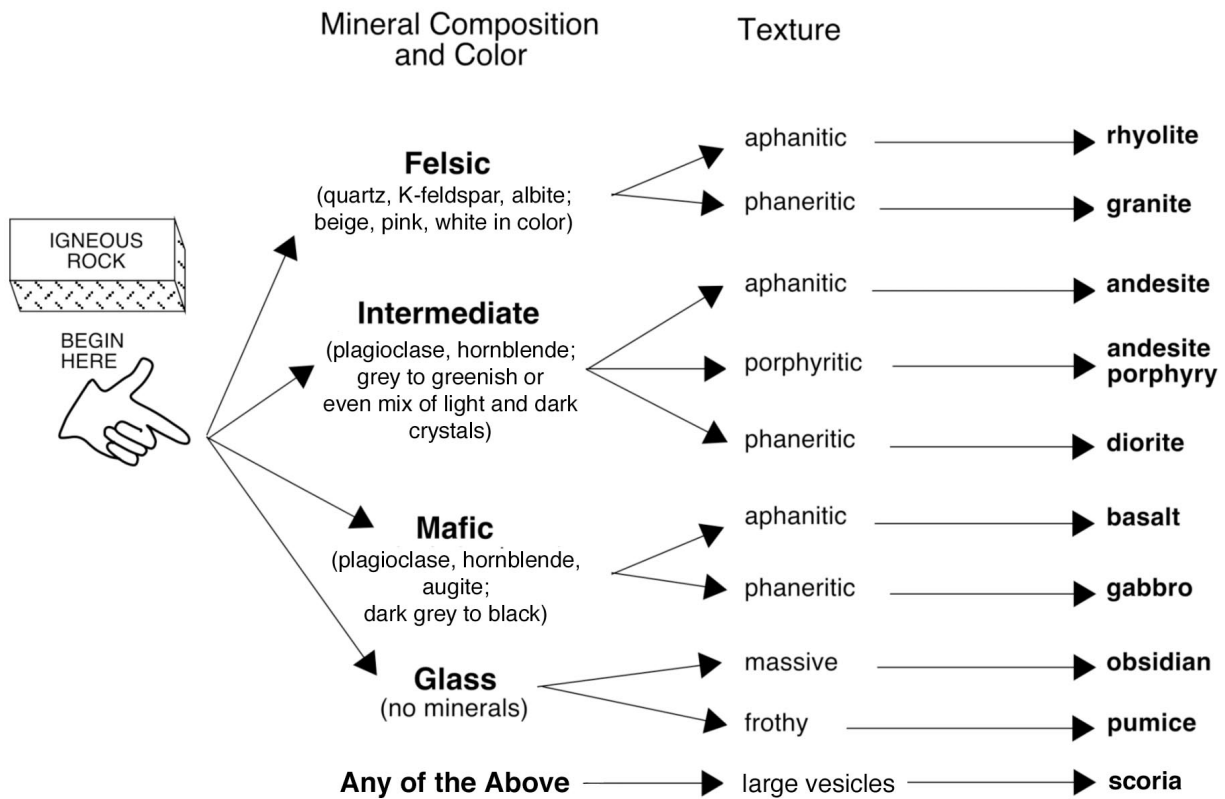


Table 6.2. Flow Chart for Identifying Igneous Rock

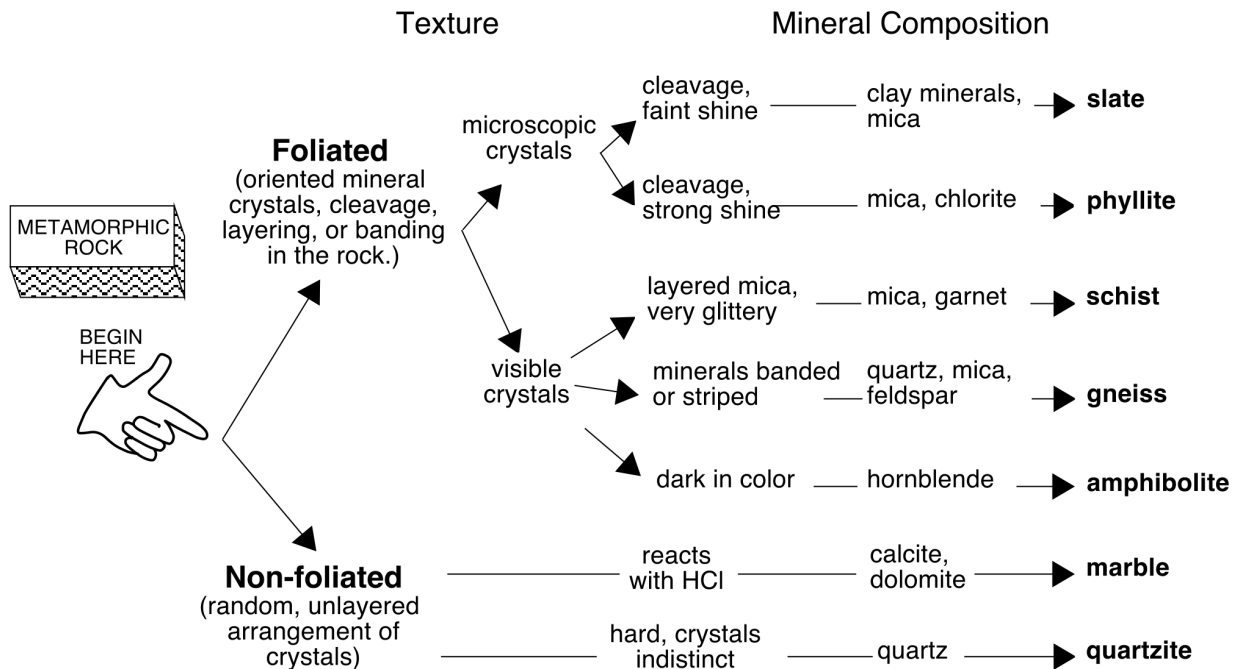


Table 6.3. Flow Chart for Identifying Metamorphic Rock

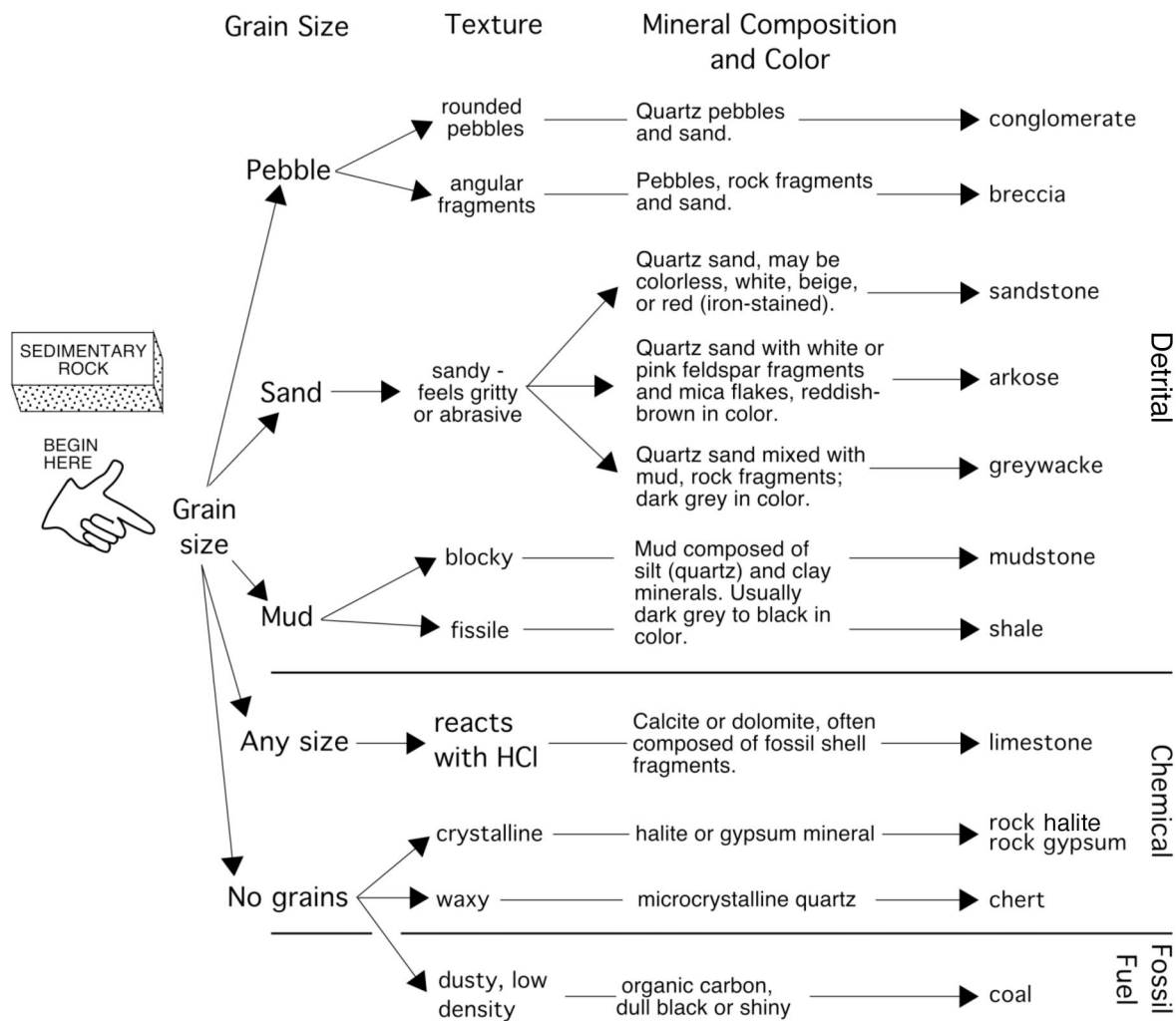


Table 6.4. Flow Chart for Identifying Sedimentary Rock

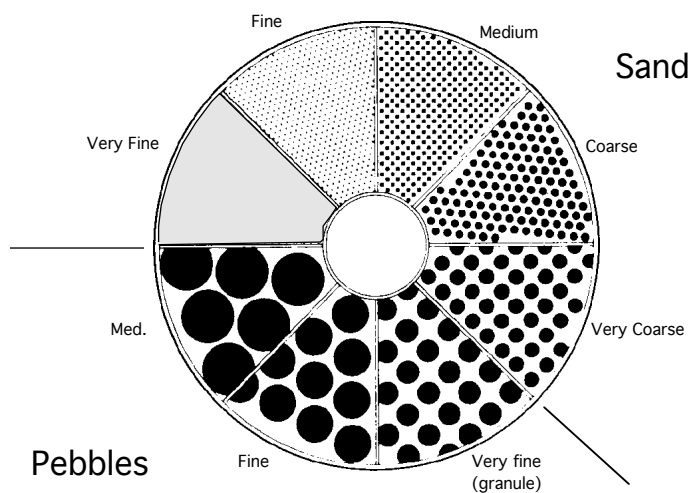


Figure 6.1. Diagram for Estimating Sediment Grain Size

Laboratory Data Sheet 6.1
Rock Identification

#	Rock Group	Texture	Distinctive Features	Mineral Composition	Rock Name	Notes
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Laboratory Data Sheet 6.1
Rock Identification

#	Rock Group	Texture	Distinctive Features	Mineral Composition	Rock Name	Notes
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

Guide to Final Oral Presentation and Research Paper

All students taking introductory geology courses are required to present a 10-minute oral presentation using digital media during the final sessions of the lab component of the course. In addition, a written report based on your presentation will also be graded. Below are the instructions and guidelines to follow for a successful presentation and paper.

Choosing a Topic

Your presentation and paper should explain a set of related facts and ideas in a way that is both interesting and understandable to your audience. Remember, your job here is to teach us all something. Assume that your audience knows little to nothing about your topic and it is your job to explain it to us in a clear and logical sequence. You may also want to include in your presentation some discussion of the civic or personal dimensions of your topic. In other words, how does your topic impact or involve human society in political, economic, medical, religious, moral, or cultural ways, or why is the topic important to you? Another good way to approach building a talk is to begin with a question, and then use your talk to answer that question. You should choose a topic that interests you. Try to avoid broad topics in favor of narrow, more focused topics. “Coral Reefs” is an interesting topic, but much too broad to discuss in a short presentation. A better topic would be “Coral Reefs of the Bahamas” or “Threats to Coral Reefs”. Another good approach is to find an article in the news or online and report on that, using additional sources to help explain the content and significance of the article. For example, “Viruses May Be Causing Coral Bleaching and Decline Around the World”, ScienceDaily (July 12, 2012) would be a good basis for a talk and paper on threats to coral reefs.

Oral Presentation

Your presentation must incorporate some elements of digital multimedia (images, charts, graphs, diagrams, video, audio) to accompany and illustrate your spoken text. Traditionally, most students have used PowerPoint to compose their presentations, but if you would like to use a different platform you should first discuss it with your lab instructor to make certain it will work on the classroom presentation equipment. Each presentation should include a minimum of 10 slides and you should compose about a half page to a full page of notes for each slide (this can usually be done within the notes section of your presentation file which is not visible onscreen). As addressed below, such notes will facilitate writing the accompanying research paper that is due in lab at the end of the semester. **Your first slide must be a title slide with your name on it.** The remaining slides should be a combination of photos and diagrams. All images should be referenced in your presentation. List the source (book or web site) in small type below the image. You may include text in your slides to outline your main talking points or to list important facts (use at least 16 pt font so your audience can read the text), but avoid placing too much text on a single slide and DO NOT put your notes on each slide and read from them during your presentation (this is known as “Death by PowerPoint”). Try not to include slides that are all text. Proofread your slides carefully to catch spelling and grammatical errors. To deliver an effective presentation, you should prepare note cards with what you want to say outlined on the cards or use the notes feature in your presentation software.

When giving your presentation, face your audience and speak loudly and clearly, making eye contact with people around the room. Use your note cards to remind yourself of what you want to say, but avoid reading too much directly from the cards. If you are using technical

terms, local place names, or other unfamiliar vocabulary, find out the correct pronunciations ahead of time. It is always a good idea to practice your presentation ahead of time in front of a live audience composed of family or friends.

Written Report You must also hand in a written report, based on your oral presentation, in fulfillment of the writing requirement for distribution courses at Hofstra. You should research your topics carefully, compile facts and ideas, and derive some real information to transfer to your student colleagues. By including factual notes with your slides, as suggested above, you will easily be able to extract and edit your notes to produce a paper. A list of references, including web site references, must be included in your paper as well as in your presentation. Hofstra University requires that all graded written assignments include a bibliography that follows an established format such as MLA or APA. For guidance on how to cite sources and format a bibliography, go to the Online Writing Lab (OWL) Research and Citation Sources guide at: <http://owl.english.purdue.edu/owl/section/2/>.

Checklists for a Successful Presentation and Written Report

Presentation file delivery

1. Email file or deliver on a USB drive to your lab instructor **at least one day** prior to your presentation.
2. Make sure any movie files or sound files in your presentation are included in a folder with your presentation file or they will not work.
3. DO NOT bring your presentation to class expecting to present it using your own laptop.

Oral Presentations Using Digital Media

1. Presentation logically organized, accurate, and complete
2. Images / slides relevant and helpful in successfully teaching about your topic
3. Minimum 10 images / slides, including title image / slide
4. Images / slides include a combination of text, images, and diagrams – no slides with only text
5. Images taken from online or print sources referenced on the slide
6. DO NOT read directly from your presentation on screen (we can all read for ourselves)
7. Speak clearly and project your voice
8. Make eye contact with your audience
9. Correct pronunciation of technical terms, place names, and unfamiliar vocabulary

Written Report

1. **Report MUST be typed, double-spaced, 12 pt. Times or similar font, 1 inch margins**
2. Report must include a reference list (bibliography) including web site citations in correct format (see above). References listed in your bibliography should be cited where appropriate in the body of your paper.
3. Minimum 5 pages in length.
4. Text must be your own wording. Do not copy and paste from web sites or other sources! This is plagiarism! Your report may be checked for plagiarism using web-based search engines. All students are expected to follow Hofstra's policy on Academic Honesty, as outlined in *The Guide to Pride*. If you are uncertain if your work is in violation of this policy, don't hesitate to ask your professor for advice and guidance.

Introductory Geology Suggested Topics

The Geology faculty suggests that you chose a topic that you are interested in – for example the geology of a place you have visited or a geological or meteorological event that you have personal experience with. Other possible suggestions are listed below:

Famous Hurricanes

1938 “Long Island Express”; 2004 season: Charley, Frances, Ivan (magically reappearing as a hurricane *after* devolving to a tropical depression); Andrew, Gloria; Pacific Ocean Typhoons; Indian Ocean Cyclones; How Hurricanes Form; Hurricanes and the North Atlantic Oscillation; Hurricanes and El Nino; Hurricane/Earthquake Prediction and Preparedness; etc.

Famous Earthquakes

1906 San Francisco; 1811-12 New Madrid; 1964 Alaska; 1884 New York, NY; 1999 Northridge, CA; 1995 Kobe, Japan; 1999 Izmit, Turkey, 1886 Charleston, SC; 1960 Chile; 1986 Loma Prieta, CA; 1976 Tangshan, China; 1997 Iran; 1990 Philippines; San Andreas fault; Ramapo fault; Earthquake Prediction and Preparedness; etc.

Igneous Geology - Some Famous Volcanic Eruptions

1886 Krakatoa; 1960 Surtsey, Iceland; 1980 Mt. St. Helens; 1981 El Chichon, Mexico; 1942-43 Paricutin, Mexico; 1993 Pinatubo; 1991 Mt. Unzen, Japan; 1912 Mt. Lassen, CA; 1968 Cerro Negro, Nicaragua; 1985 Nevado del Ruiz, Colombia, etc.

Igneous Forms and Features

Palisades Intrusive Sheet, NJ; Columbia River Basalts, WA and OR; Deccan Traps, India; Iceland; Hawaii; Mt. Fuji, Japan; Shiprock, NM; Sierra Nevada batholith; Henry Mountains, UT; Crater Lake, OR (Mt. Mazama); Yellowstone Caldera, WY; Mono Craters, CA; etc.

Regional Geology - Geology of Long Island

Coastal features; LI beach formation; Montauk Point; Fire Island; Hither Hills State Park; LI hydrology; LI glaciation; etc.

Geology of NYC and Vicinity

Bear Mountain; Bedrock Geology of NYC; Central Park; Prospect Park; Riverside Park; Glacial Geology; NYC Water Tunnels; Hudson River; Palisades; Influence of Geology on Engineering Construction; Hudson Submarine Canyon; 125th Street “Manhattanville” fault; etc.

Climate and Oceanography

Longshore drift on Long Island’s Barrier Beaches; Impact of Hurricanes on Long Island (or any other geographical location of interest); Why Glacial Periods Happen; How El Nino works; Trends in Hurricane Intensity and Frequency Over the Last 50 Years; Black Smokers and Sulphur-based Life Forms; Location of the World’s Deserts; The Greenhouse Effect and Global Warming; The Dust Bowl; Recent Droughts in the NY area; Drought and Decline of Ancient Civilizations; Climate Change and Human Evolution

Planetary Geology

Comparative Planetology (Mars vs. Earth; Earth's Moon vs. Mercury, etc.); Crater Morphology; History of Space Travel; Lunar Missions; Lunar vs. Martian, vs. Venusian vs. Mercurian Impact Craters; Mercury, Gemini, and Apollo Missions; Mineralogy and Origin of Meteorites; Mineralogy of the Moon; Multi-ringed Basins; Planetary Orbits; Planetary Ring Systems; Post-WWII Rocketry; Russian Space Missions; Space Exploration - Mariner, Pioneer, Voyager, Mars Global Surveyor, Galileo, Deep Impact, Mars Express, Future Missions, etc.; Terrestrial Impact Craters (Panther Mtn., Meteor Crater, etc.); WW-II Rocketry.

Places

Geology of your hometown, favorite vacation spot, National Park, any Caribbean Island, etc.

Sources for Articles on Current Research / News in the Geosciences

Nature (Journal - access through the Hofstra Library Research Databases (Math / Science) link)

Science News (<http://www.sciencenews.org/>)

Science Daily (<http://www.sciencedaily.com/news/>)

Geology.com (<http://geology.com/news/>)

Earth Magazine (<http://www.earthmagazine.org/>)

Phys.org (<http://phys.org/space-news/earth-sciences/>)

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#	Luster	Hardness	Cleavage <small>yes / no, number?</small>	Other <u>useful</u> character <small>streak, color, etc.</small>	Mineral Name
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					

#	Igneous Sedimentary Metamorphic	Textures and / or other features	Minerals Present	Rock Name
1				
2				
3				
4				
5				
6				
7				
8				
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Peer Review Sheet - Student Reviewer Name _____

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