

# PLANET EARTH LABORATORY MANUAL

Fourteenth Edition

Geology 001



J Bret Bennington, Charles Merguerian, and E. Christa Farmer

Department of Geology, Environment, and Sustainability

Hofstra University

**Planet Earth Laboratory Manual, Fourteenth Edition – Geology 001**

Copyright © 2020 by J Bret Bennington, Charles Merguerian, and E. Christa Farmer, Department of Geology, Environment, and Sustainability, Hofstra University

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without the written permission of the publisher.

Requests for permission to make copies of any part of the work should be mailed to:

Permissions Department  
Academx Publishing Services, Inc.  
P.O. Box 208  
Sagamore Beach, MA 02562  
<http://www.academx.com>

Printed in the United States of America

ISBN-13: 978-1-68284-744-2

ISBN-10: 1-68284-744-6

# TABLE OF CONTENTS

---

How to Get Help and Find out More about Geology at Hofstra.....	v
Lab 1: Physical Properties of Minerals.....	1
Lab 2: Mineral Identification.....	13
Lab 3: Rock Groups and Rock Properties.....	25
Lab 4: Rock Identification.....	45
Lab 5: Navigating Planet Earth.....	53
Lab 6: Three-Dimensional Planet Earth: Topographic Maps.....	69
Lab 7: Topographic Profiles, Vertical Exaggeration, and Slopes.....	83
Guide to Final Oral Presentation and Research Paper.....	95
Introductory Geology Suggested Topics.....	97
Mineral Practicum.....	99
Rock Practicum.....	101
Peer Review Sheets.....	103





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

**Email:** Geology professors can be contacted via Email:

### **Full-time Faculty:**

Dr. J Bret Bennington ([geojbb@hofstra.edu](mailto:geojbb@hofstra.edu)),  
Dr. Jase Bernhardt ([jase.e.bernhardt@hofstra.edu](mailto:jase.e.bernhardt@hofstra.edu)),  
Dr. Christa Farmer ([geoecf@hofstra.edu](mailto:geoecf@hofstra.edu))  
Dr. Antonios Marsellos ([antonios.e.marsellos@hofstra.edu](mailto:antonios.e.marsellos@hofstra.edu)).

### **Adjunct Faculty:**

Dr. Nehru E. Cherukupalli ([geonec@hofstra.edu](mailto:geonec@hofstra.edu))  
Dr. Lillian Hess Tanguay ([geolht@hofstra.edu](mailto:geolht@hofstra.edu))  
Dr. Richard S. Liebling ([georsl@hofstra.edu](mailto:georsl@hofstra.edu))  
Dr. Dennis Radcliffe ([geodzr@hofstra.edu](mailto:geodzr@hofstra.edu)),  
Prof. Adina Hakimian ([Adina.L.Hakimian@hofstra.edu](mailto:Adina.L.Hakimian@hofstra.edu))  
Prof. Steven Okulewicz ([geosco@hofstra.edu](mailto:geosco@hofstra.edu)).

### **Geology Department: Pay us a visit!**

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

Our administrative assistant 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 **Gittleston 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 - 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.

<b>LUSTER</b>	Crystal form	Flexibility / Elasticity
<b>COLOR</b>	Twinning	Brittleness / Tenacity
<b>HARDNESS</b>	Play of colors	Odor
<b>STREAK</b>	Specific Gravity	Taste
<b>CLEAVAGE</b>	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 splendent 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.

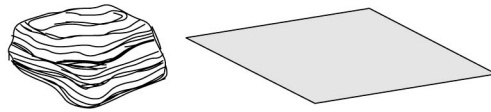
We repeat again the fundamental point that a cleavage direction is the physical manifestation of a plane of weakness within the mineral lattice. This weakness results from a planar alignment of weak bonds in the lattice. The strength or weakness of these aligned bonds affects the various degrees of perfection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

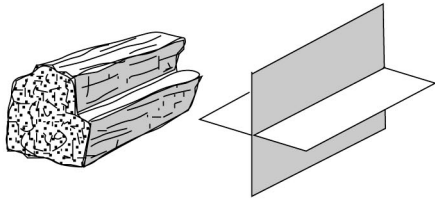
Some minerals, notably those in the mica and clay families having sheet-structure lattices, display only one direction of cleavage and it is likely to be perfect. Such cleavage is commonly termed **basal cleavage**. Other minerals possess two, three, four or six cleavage directions. No mineral exists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

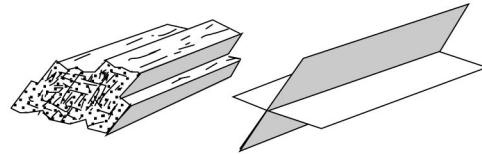




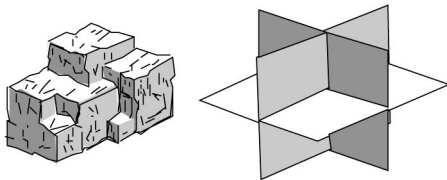
A. **Basal** - One direction of cleavage. Mica, graphite, and talc are examples.



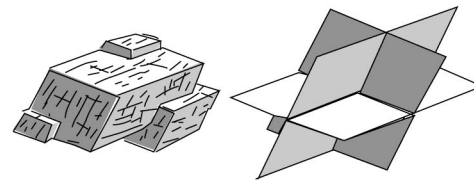
B. **Rectangular** - Two directions of cleavage that intersect at 90° angles. Plagioclase is an example.



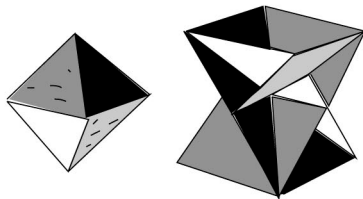
C. **Prismatic** - Two directions of cleavage that do not intersect at 90° angles. Hornblende is an example.



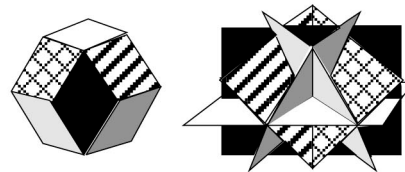
D. **Cubic** - Three directions of cleavage that intersect at 90° angles. Halite and galena are examples.



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 1.1** - 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  $FeS_2$ ), 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

## LAB Exercise 1.1 – Physical Properties of Minerals

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

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

## LAB Exercise 1.2 – 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.

<b>Specimen</b>	<b># and Angle of Cleavage Planes</b>	<b>Name of Cleavage Type</b>
<b>21</b>		
<b>22</b>		
<b>23</b>		
<b>24</b>		
<b>25</b>		
<b>26</b>		

## Lab 2 - Mineral Identification

### What to do:

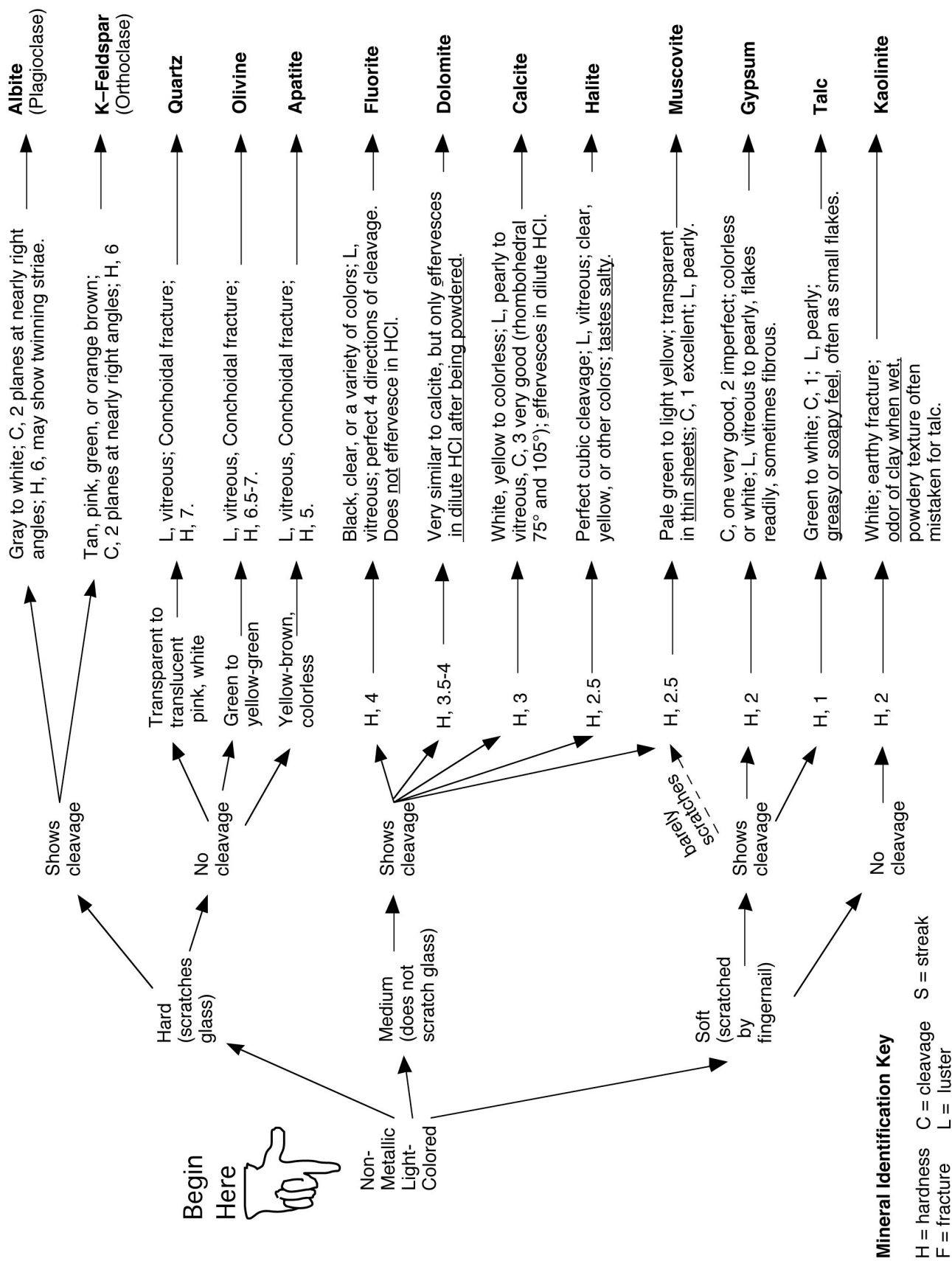
Having learned the physical properties displayed by minerals, in today's laboratory exercise you will identify twenty common mineral specimens. Review the concepts learned last week and try to logically and systematically identify the twenty minerals. Use the **mineral tests** you learned last week to 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 2.1 and 2.2 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.



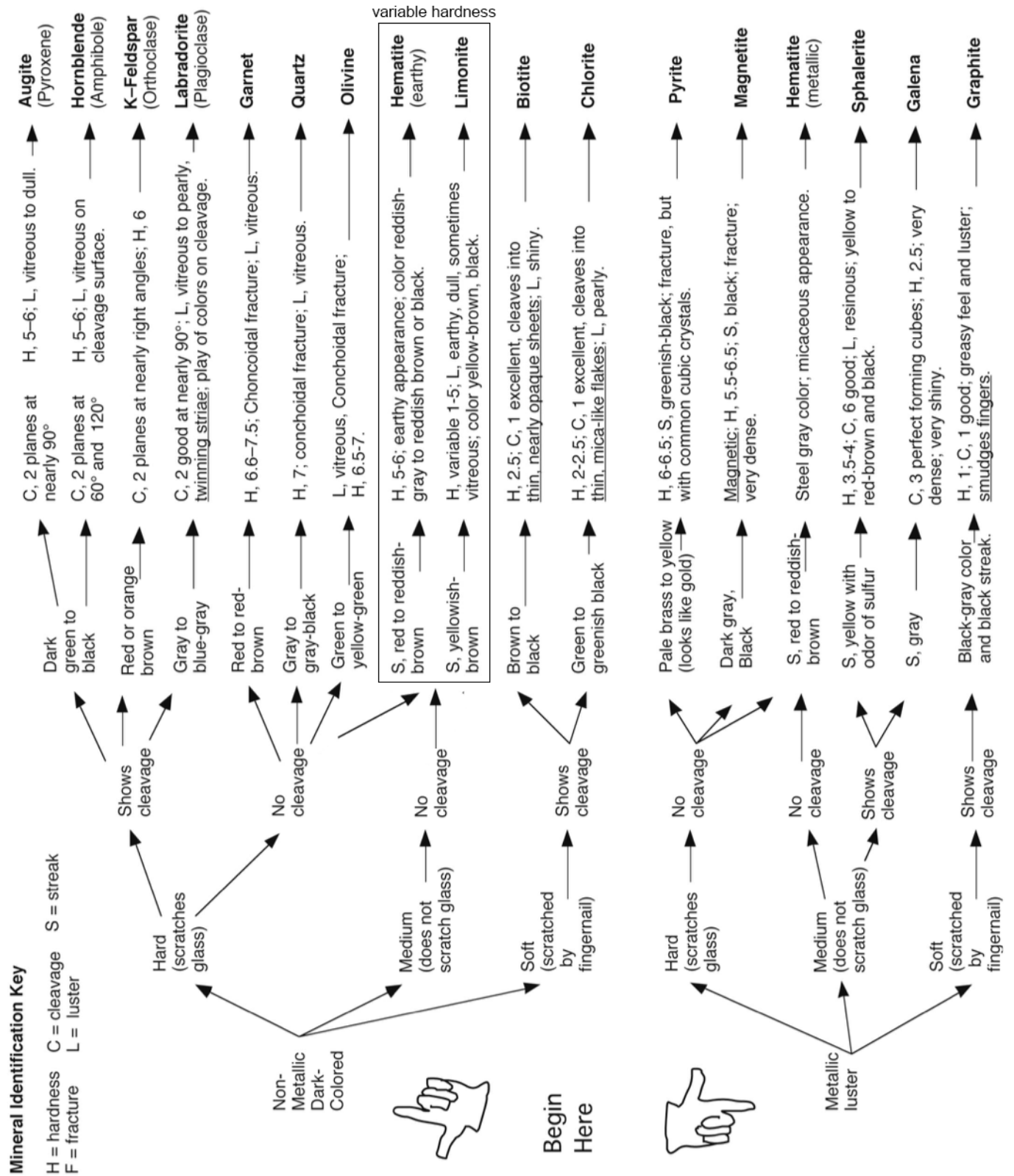




**Table 2.1** - Mineral identification flow chart for non-metallic, light-colored minerals.



**Table 2.2** - Mineral identification flow chart for non-metallic, dark-colored minerals and metallic minerals.



**Table 2.3 (three pages)** – Mineral tables with detailed properties and descriptions.

<b>Fracture or Cleavage</b>	<b>Color</b>	<b>Streak</b>	<b>Luster</b>	<b>Hardness (Mohs scale)</b>	<b>Remarks</b>	<b>Name and Chemical Composition</b>
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	<b>Albite</b> (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	<b>Apatite</b> 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	<b>Augite</b> (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	<b>Biotite</b> (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	<b>Calcite</b> $CaCO_3$
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	<b>Chlorite</b> 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	<b>Dolomite</b> $CaMg(CO_3)_2$
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	<b>Fluorite</b> $CaF_2$
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)	<b>Galena</b> $PbS$
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	<b>Graphite</b> carbon

Table 2.3 (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	<b>Garnet</b> 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	<b>Gypsum</b> $CaSO_4 \cdot 2H_2O$
cubic – 3 good cleavage directions	clear, white, brownish; can be any color	white (colorless)	vitreous	2.5	rock salt; has a salty taste	<b>Halite</b> $NaCl$
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	<b>Hematite</b> $Fe_2O_3$
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	<b>Hornblende</b> (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	<b>Kaolinite</b> 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'	<b>Labradorite</b> (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	<b>Limonite</b> $FeO(OH) \cdot nH_2O$

**Table 2.3 (3 of 3 pages) – Mineral tables with detailed properties and descriptions.**

<b>Fracture or Cleavage</b>	<b>Color</b>	<b>Streak</b>	<b>Luster</b>	<b>Hardness (Mohs scale)</b>	<b>Remarks</b>	<b>Name and Chemical Composition</b>
irregular fracture	black; opaque	black	dull to metallic	6.0	magnetic; feels heavy (high specific gravity)	<b>Magnetite</b> $Fe_3O_4$
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	<b>Muscovite</b> (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	<b>Olivine</b> $(MgFe)_2SiO_4$
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	<b>Orthoclase</b> (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'	<b>Pyrite</b> $FeS_2$
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	<b>Quartz</b> $SiO_2$
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	<b>Sphalerite</b> $ZnS$
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	<b>Talc</b> hydrous magnesium silicate



**Table 2.4 (two pages) – Mineral Properties Chart**

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

**Table 2.4 (cont'd) – Mineral Properties Chart**

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



**Laboratory Data Sheet 2.1**  
**Mineral Identification**

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

**Laboratory Data Sheet 2.1**  
**Mineral Identification**

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

## Lab 3 – 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 record 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 multi-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).

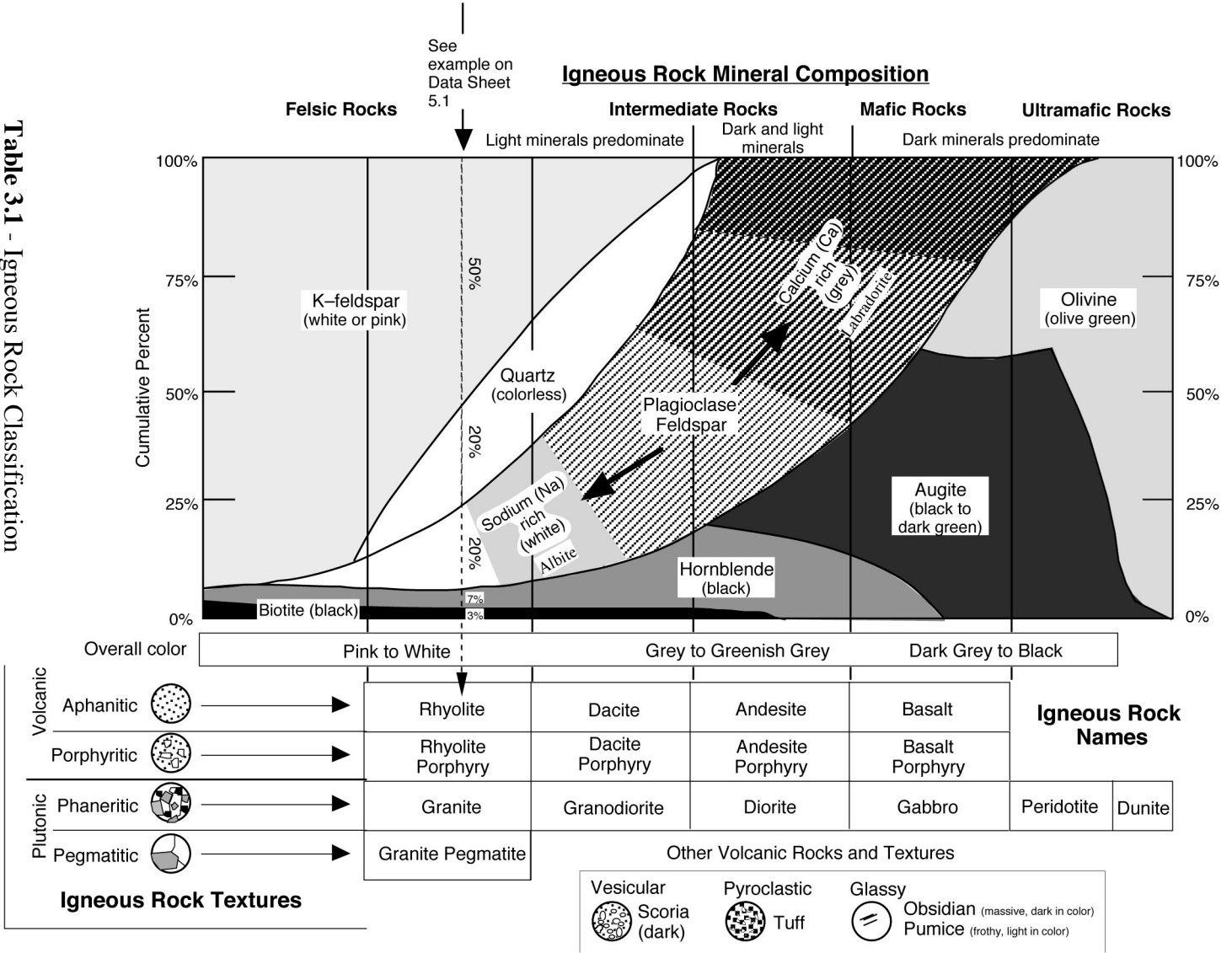
## Special Volcanic Textures

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**.

### Igneous Rock Mineral Composition



**Table 3.1 - Igneous Rock Classification**

Table 3.1 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 physical weathering of existing rock (these sediments are also called **detrital**). Weathering also 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 can be precipitated as **chemical sediment**. Marine organisms such as corals, mollusks, plankton, and algae precipitate calcium carbonate and silica minerals in their tissues and shells to form **biogenic sediment**. Calcium carbonate grains are also produced by inorganic precipitation. Once deposited, calcium carbonate sediments may be chemically recrystallized into calcium-magnesium carbonate (dolomite) mineral. Calcium carbonate and dolomite sediments are often grouped as **carbonate sediments**. Chemical sediment is also 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** sedimentary rock 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 3.2). 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 (HCL) 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**.



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

**Table 3.2** – 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 3.3).

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 alternation of light-colored minerals (feldspars and quartz) with dark-colored biotite or amphibole.

FOLIATED (minerals oriented or layered)

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

NON - FOLIATED

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

Table 3.3 Metamorphic Rock Classification

Table 3.4 - Rock Texture Reference Collection

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

<b>Specimen</b>	<b>Rock Type</b>	<b>Texture</b>
1	Igneous	Glassy (massive)
2	Igneous	Aphanitic
3	Igneous	Phaneritic
4	Igneous	Vesicular (glassy)
5	Igneous	Porphyritic
<b>6</b>	<b>Sedimentary</b>	<b>Sand (clastic)</b>
7	<b>Sedimentary</b>	<b>Clay / Mud (clastic)</b>
8	<b>Sedimentary</b>	<b>Pebble (clastic)</b>
9	<b>Sedimentary</b>	<b>Crystalline</b>
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 3 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 3.4). 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>
<b>Aphanitic</b>	_____
<b>Porphyritic</b>	_____
<b>Phaneritic</b>	_____
<b>Glassy</b>	_____
<b>Vesicular</b>	_____

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

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

3. Using Table 3.1 – 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, carbonate (calcite, dolomite), halite, gypsum

Sedimentary rock categories: clastic, chemical (evaporite, bioclastic), carbonaceous

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

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

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

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

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

4. Using Table 3.2 – 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>
<b>Slaty cleavage (weak foliation)</b>	_____
<b>Schistose foliation</b>	_____
<b>Banded foliation</b>	_____
<b>Non-foliated texture</b>	_____
<b>Porphyroblastic texture</b>	_____

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

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

3. Using Table 3.3 – 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 4 – 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 4 Data Sheet. Use Table 4.1 to determine which of the three rock groups each specimen belongs in. Tables 4.2, 4.3, and 4.4 will assist you in identifying specific rock names. You may also wish to consult the classification charts found in Laboratory 3.

### 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, will 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.

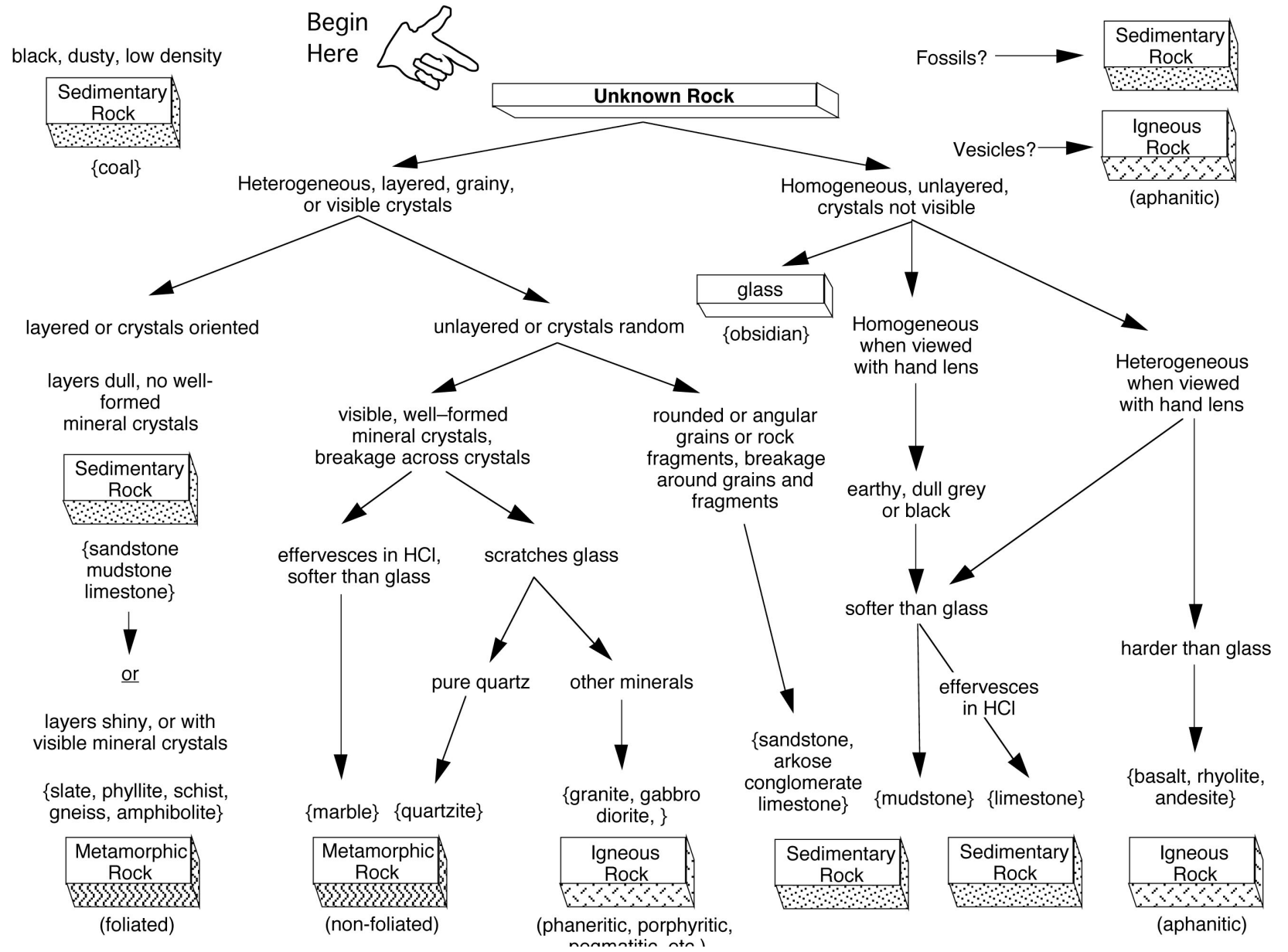
**DENSITY:** The density of a rock is a function of the density average of the constituent minerals and of how much air-filled pore space is present. Dense rocks are composed of dense minerals closely arranged with minimum pore space. Many rocks have similar densities because they are composed mainly 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.

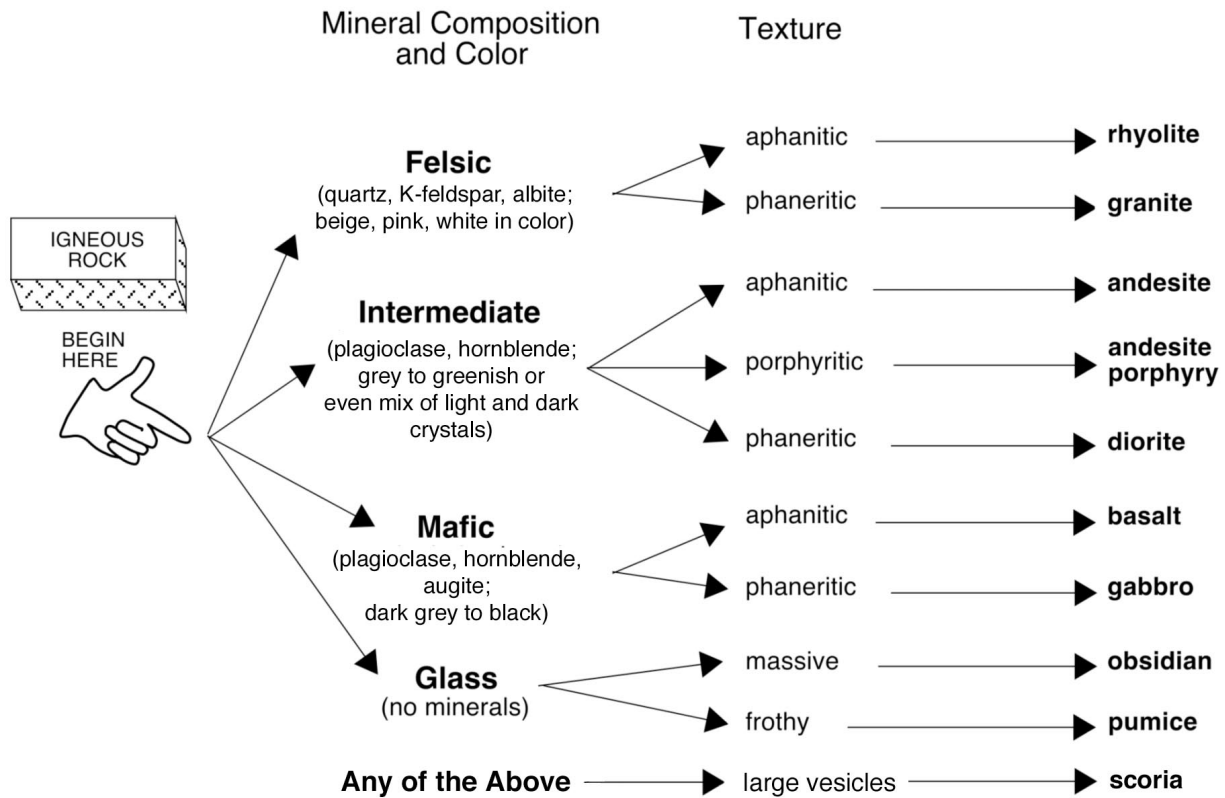
**TACTILE OBSERVATION – THE TOUCH TEST:** Clastic sedimentary rocks are composed of grains of mineral material. Sand size grains are visible, but often difficult to distinguish because they are small and uniform in color. However, on a freshly broken rock surface, sand grains protrude and will feel rough 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).



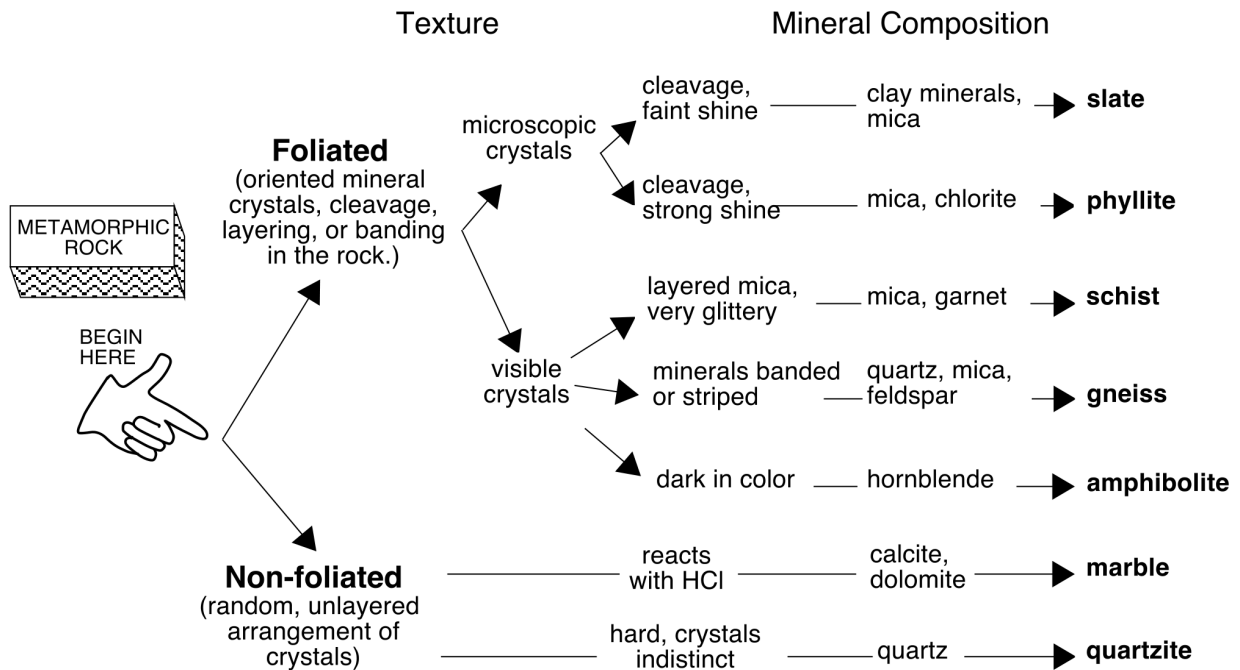
Table 4.1 – Rock Group Flow Chart



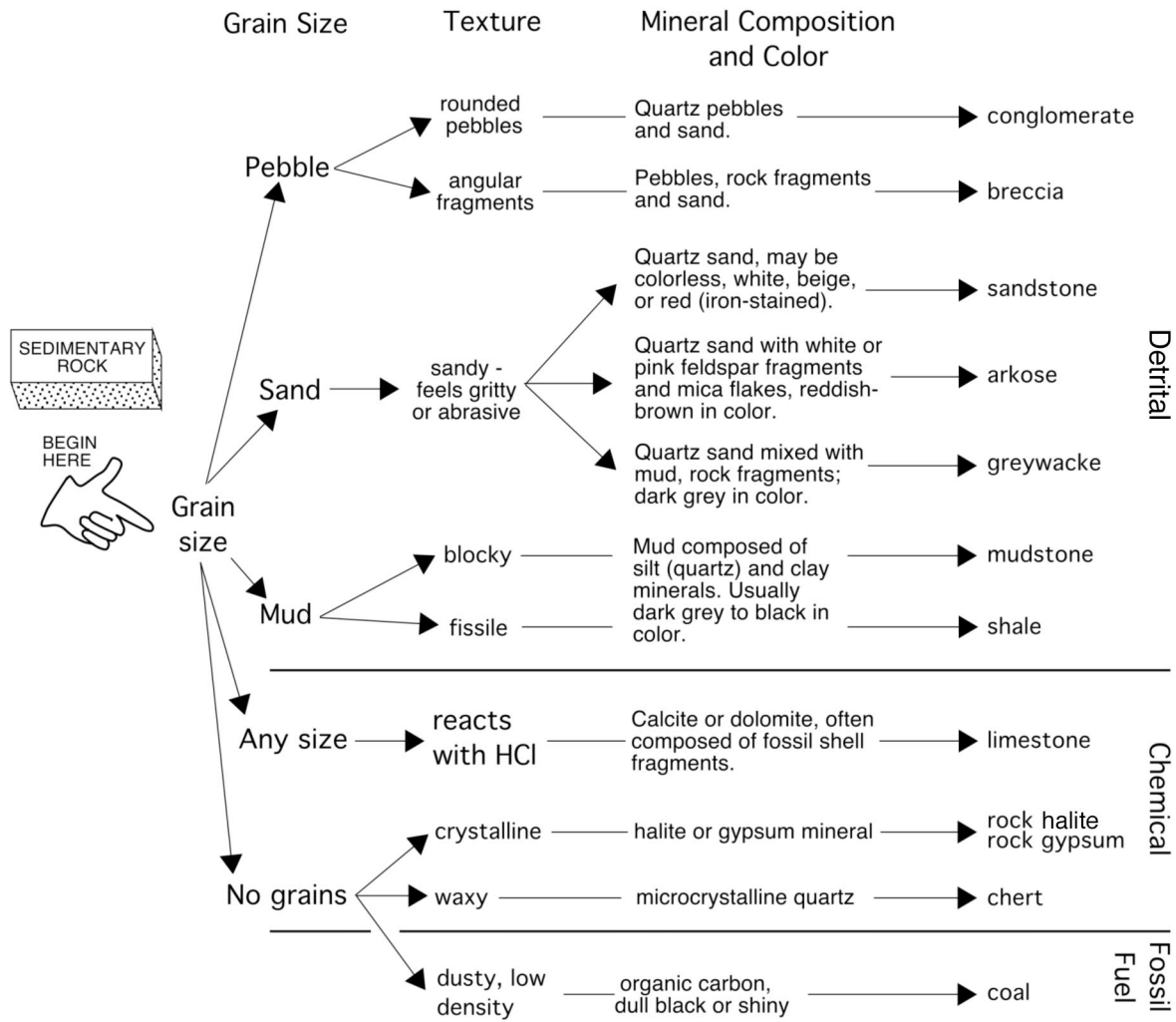




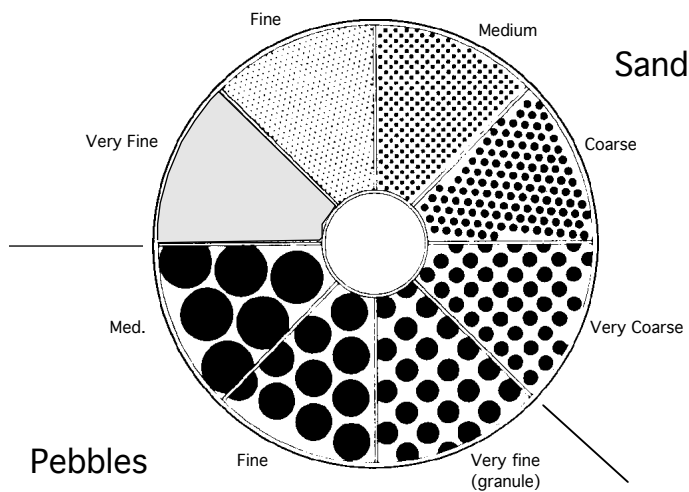
**Table 4.2.** Flow Chart for Identifying Igneous Rock



**Table 4.3.** Flow Chart for Identifying Metamorphic Rock



**Table 4.4.** Flow Chart for Identifying Sedimentary Rock



**Figure 4.1.** Diagram for Estimating Sediment Grain Size

**Laboratory Data Sheet 4.1**  
**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 4.1**  
**Rock Identification**

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

## **Lab 5 – Navigating Planet Earth**

### Finding Location, Direction, and Distance Using GPS, a Compass, and Google Earth

#### **PURPOSE**

The objective of this lab is to use the Global Positioning System (GPS), a magnetic compass, and Google Earth, a free computer program, to gain some experience with finding your **location** on the Earth, measuring **bearings** and **distances**, and calculating **map scale**, a parameter that is useful in quickly understanding the size of the area represented on a map. We will accomplish this by doing four sets of activities: 1) using a handheld GPS unit to find the latitude / longitude and UTM coordinates of your position; 2) using paces to measure distance; 3) using a compass to measure direction; 4) measuring distance and finding location on maps using Google Earth; and 5) working with map scale. These activities will help you understand how we use maps and navigate around planet Earth in the 21<sup>st</sup> Century.

#### **LOCATING A POINT ON THE SURFACE OF THE EARTH**

The location of a point on the surface of the Earth can be specified using two coordinates on a grid. For example, longitude and latitude lines form a grid system that can be used to specify any unique location on the globe. In the United States, four kinds of grid system are used: (a) latitude and longitude; (b) the universal metric grid system or UTM; (c) the United States Land Survey; and (d) the 10,000-foot grid system. Lat. / Long. and UTM are most commonly used and we will learn how to specify location using them in this lab. Land-survey maps (c) are used mostly in the western states and the 10,000-foot grid system (d) is used by the New York State Department of Transportation.

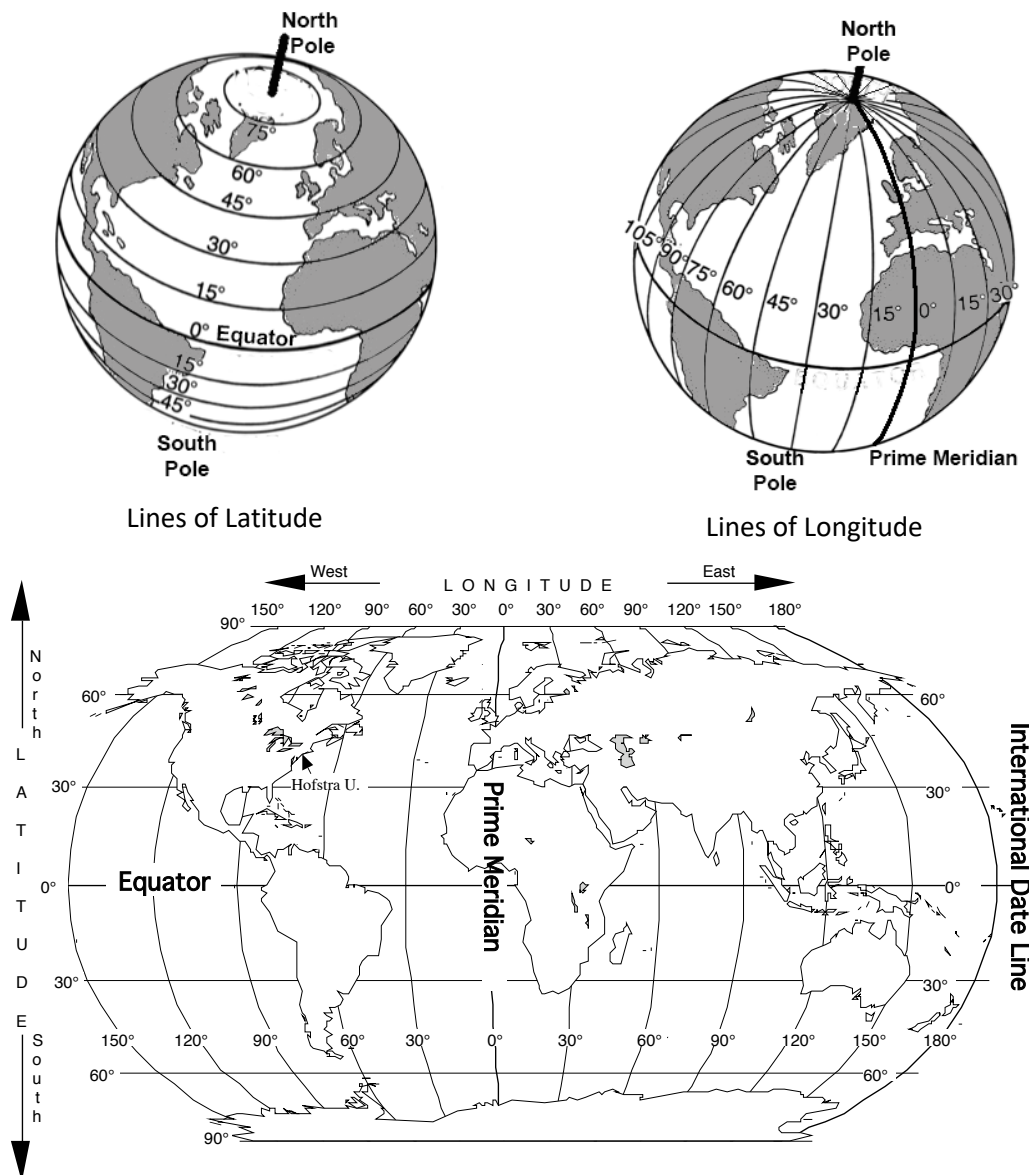
#### **LONGITUDE AND LATITUDE**

The Earth is a sphere rotating around an axis defined by two poles. The location of points or areas on the surface of the Earth can be designated by means of two groups of intersecting circles known as **latitude** and **longitude** (Figure 5.1). Both latitude and longitude lines represent angular subdivisions of a circle and are therefore measured in **degrees**, **minutes**, and **seconds**. Remember that there are 360 degrees in a circle, 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 5.1). 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. Latitude is the measure of angular distance along an arc that extends 90° from the equator to a pole (1/4 the distance around a 360° circle).

**Longitude** lines are lines that encircle the Earth from pole to pole in north-south 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**. Longitude is the

measure of angular distance along an arc that extends 180° from the Prime Meridian to the International Dateline in either the east or west direction (1/2 the distance around a 360° circle).



**Figure 5.1** - 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. If you know what time it is in Greenwich and you know the local time, you can calculate your longitude.

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

## UNIVERSAL TRANSVERSE MERCATOR GRID (UTM)

A commonly used grid system that is based on linear distance rather than angular distance is the **Universal Transverse Mercator Grid** or **UTM**. The UTM grid system is based on the Universal Transverse Mercator map projection (hence the name ‘UTM’). This grid system subdivides the globe into rectangular **zones** whose boundaries are defined by longitude and latitude (Figure 5.2), but within each zone the UTM grid is defined by one-kilometer squares. Each UTM line on the grid is exactly 1000 meters (1 kilometer) to the north or east of the previous 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 grid zone and the UTM coordinates read from a GPS unit or a map to locate a particular point. On a map, points between the marked UTM grid lines can be accurately located by using the 1000-meter scale bar found at the bottom of the map (Figure 5.3).

Note: unlike longitude and latitude coordinates, UTM coordinates always increase from west to east and from south to north. In each rectangular grid zone, the (0,0) coordinate is found in the lower left corner of the rectangle.

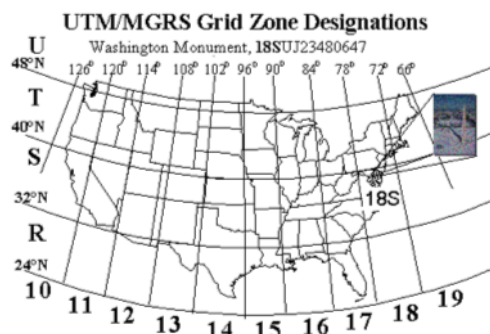


Figure 5.2 – UTM Grid Zones

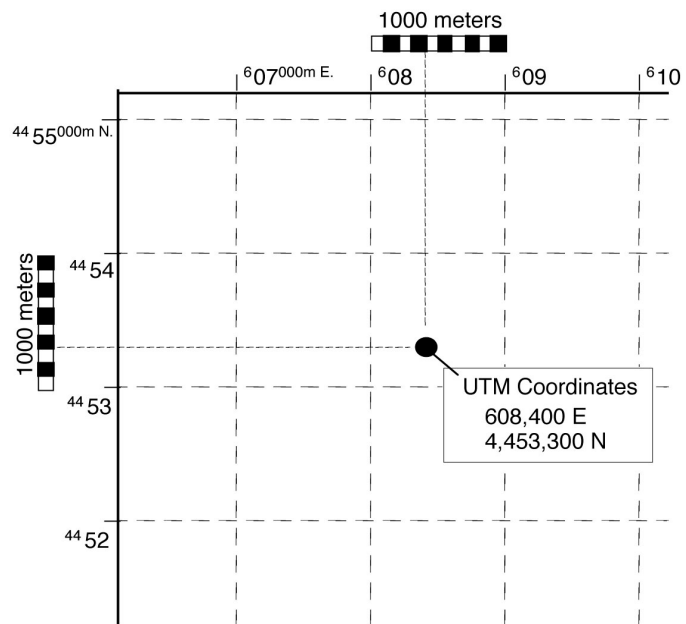


Figure 5.3 – example of a UTM grid from a map

## MEASURING A MAGNETIC COMPASS BEARING

A **magnetic compass** is a device that uses a small magnetized needle on a pivot to measure the direction to north based on the orientation of the Earth's magnetic field. 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. The Earth's magnetic poles do not perfectly overlap with its geographic poles, so that there are two ways to define north. **Geographic (True) North** is the direction to the north pole. **Magnetic North** is the direction toward which a compass needle points. The angle between Magnetic North and True North is known as the **magnetic declination** (Figure 5.4). Because the magnetic pole shifts with time, the declination needs to be monitored and updated for accurate navigation using a compass. Professional compasses can be adjusted to compensate for the difference so that the compass always reads the true north value.

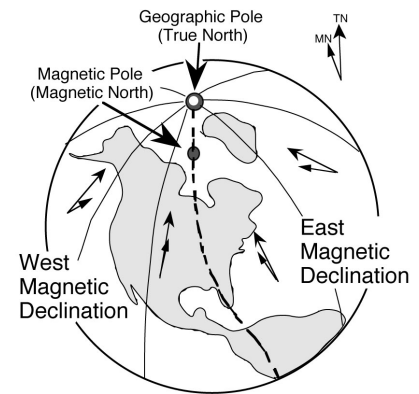


Figure 5.4

## The Compass Rose

The compass rose is the familiar north, east, south, west cross used to show direction on a map (Figure 5.5). 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° north, 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].)

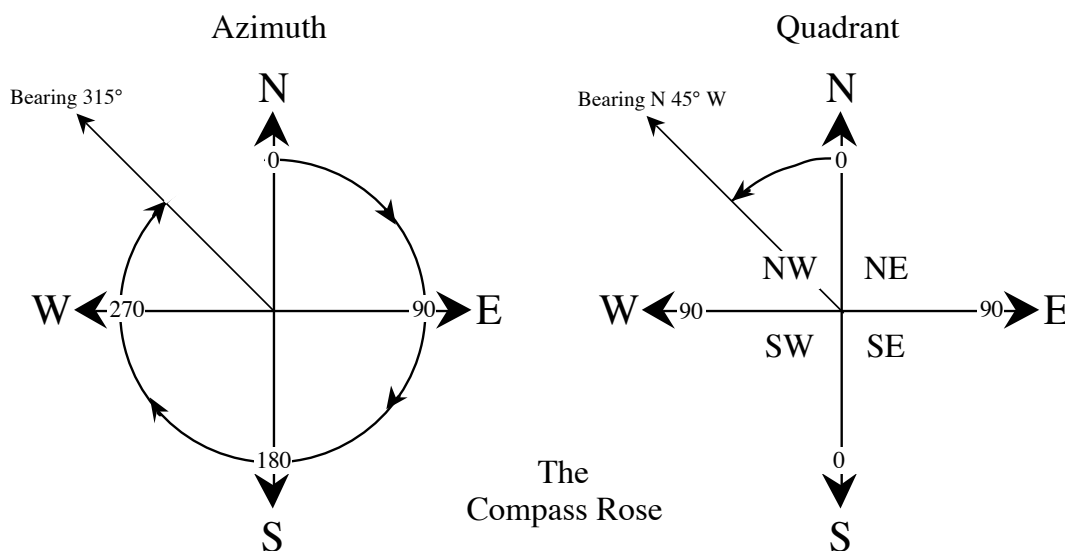


Figure 5.5 The Compass Rose showing both azimuth and quadrant bearings.

## 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 also called the **representative fraction** (abbreviated as **RF**).

<b>U. S. Topographic map series</b>	<b>RF</b>
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.

## EXERCISE 1: Measuring the Length of Your Pace

A quick way to measure distances is to count your footsteps and multiply by the average length of a footstep, which is called your **pace**. Your instructor will lay out a 50 meter runway on the walkway outside of the classroom. Starting with one foot positioned at the starting line, walk runway at a normal walking pace until you get to the 50 meter mark. Count every step you take. This counts **paces**. Record here how many paces you took in 50 meters:

a) # of paces in 50 meters: \_\_\_\_\_

b) Divide 50 meters by the # of paces to get the length of your pace in meters:

\_\_\_\_\_ meters / pace

## EXERCISE 2: Using a Magnetic Compass

A professional magnetic compass (Figure 5.6) will have a dial that can be rotated around the face of the compass and a mirrored lid with a sight. The red needle on the compass orients to the Earth's magnetic field. If you turn the dial so that the red box on the dial overlaps with the needle the directional bearings on the dial will be oriented correctly. To read a bearing, hold the compass up to your eye and sight to a distant point. While you have the compass pointing in the direction of the bearing, use the mirror to turn the dial to align it ("put the red needle in the red house") and read the number on the dial that is aligned with the compass sight. This is the bearing.



Figure 5.6

Take the compass and go outside and practice sighting and reading bearings from a position in front of the statue of Frederick Douglas in front of Monroe Hall.

### To Do:

- Use the compass to find the direction to **north**. Draw an arrow in the box labeled "Compass Rose" that points to north on the map in Figure 5.7. Draw arrow to show South, East, and West, connected to form a cross. This is called a **compass rose**.
- What is the compass bearing from the statue of Frederick Douglas in front of Monroe Hall to the Axinn Library? (record your answer in data Table 1 below)
- What is the compass bearing from the statue of Frederick Douglas in front of Monroe Hall to the deli on the opposite side of California Ave (ABP – Au Bon Pain)? (record your answer in data Table 1 below)

### **EXERCISE 3: Using GPS to Find Longitude and Latitude and UTM Coordinates**

The Global Positioning System (GPS) is a network of satellites that can be used by GPS receivers on the ground to pinpoint their location. The satellites send out signals that are received by the GPS receiver. From these signals the GPS can determine the location and distance of each satellite. If three satellites can be read, then the GPS can triangulate to find its location. GPS is used for navigation by just about any modern electronic device that needs to know where it is – smart phones, car / boat / plane navigation systems, drones, cameras, etc. The small, handheld GPS units we will be using today can translate their position into both latitude / longitude and UTM coordinates displayed on the screen.

#### **To Do:**

Take the map in Figure 1.5 and head outside with a GPS unit. Team up with your lab table. When you get outside make sure you are away from the building and turn on your GPS unit if it is off. You may need to give it a minute to locate satellites and fix its position.

1. Find the intersection of the sidewalk from Gittleson with the sidewalk along California Avenue, and use the GPS to find the exact lat. / long. and UTM coordinates of this point (labeled point “A” on the map). Record this information in the box by point A on your map and in data Table 2 below.
2. Now, walk the distance from the Gittleson point along the California Avenue sidewalk to the front of Berliner Hall (point “B” on the map). Count how many paces (steps) you take to get to point B. Record the # of paces from Point A to Point B in data Table 3 below.
3. At Point B use your GPS to find the lat. / long. and UTM coordinates of where you are standing, and record this information in the box by point B on your map and in data Table 2 below.

Walk back to Point A.

4. Now, walk the distance from the west end of Gittleson (point A) along the sidewalk past the New Business School building to the side of the Career Center (point “C”). Count how many paces you take to get to point C and record this in data Table 3 below.
5. While you are at point C, use your GPS again to find the lat. / long. and UTM coordinates of where you are standing, and record this information in the box by point C on your map and in data Table 2 below.

**Now head back into the classroom.**

## Calculations and Questions:

1. Compare the latitude and longitude and UTM coordinates between Point A (Gittleston) and Point B (Berliner).
  - a. Calculate the difference in latitude and in longitude observed moving from point to point and record in data Table 2.
  - b. Calculate the different in UTM E and UTM N observed moving from point to point and record in data Table 2.
  - c. In which direction were you were walking as you went from A to B?  
\_\_\_\_\_
  - d. Estimate the distance from point A to point B by multiplying the number of paces you counted by the average length of your pace (from above) and record in data Table 3.

How does this distance compare to the change in the UTM north coordinate?

2. Compare the latitude and longitude and UTM coordinates between Point A (Gittleston) and Point C (Career Center).
  - a. Calculate the difference in latitude and in longitude observed moving from point to point and record in data Table 2.
  - b. Calculate the different in UTM E and UTM N observed moving from point to point and record in data Table 2.
  - c. In which direction were you were walking as you went from A to C?  
\_\_\_\_\_
  - d. Estimate the distance from point A to point C by multiplying the number of paces you counted by the average length of your pace (from above) and record in data Table 3.

How does this distance compare to the change in the UTM east coordinate?

## EXERCISE 4: Longitude / Latitude and Distance Measurements in Google Earth

### To Do:

Back in the lab room, find a computer and open Google Earth. If you want to install GE on your own computer, go to [www.google.com/earth](http://www.google.com/earth) and click on “Earth Versions” and download Google Earth Pro (or the regular version, but Pro has more features and it’s still free). If you don’t have your own computer to use for this, borrow one in the computer lab next door to the classroom. Speak to your instructor if you have any questions about this step.

### Google Earth Basics

Search for “Hofstra University” in the search bar at the upper left of the Google Earth window. This will zoom in on our campus. Can you find Gittleson Hall? Note that the latitude and longitude coordinates of the cursor are shown at the bottom of the map window.

If the format of the long / lat coordinates on the Google Earth screen is different than those on your GPS, click the “Tools” menu at the top of the Google Earth window (“Preferences” on a Mac), and you can choose among several formats to display. You can also display UTM coordinates.

Click the “Add Placemark” button on the top tool bar (it looks like a little yellow pushpin). Name this first one “Point A” and enter the latitude and longitude that you measured with your GPS earlier. Does the placement of this pin match the location of point A on your map? Note that while the Placemark window is open you can move the pushpin icon and the coordinates will update automatically in the window.

Add two more placemarks for point B and point C following the same directions in the preceding paragraph.

Zoom in on the map, using the “+” button at the top right, until point A, point B, and point C are visible near the edges of the map. You may want to use the “View” -> “Reset” -> “Tilt and Compass” function (for which the keyboard shortcut is clicking “n” and then “u”) to keep the map oriented with North at the top of the page, and the view angle straight down.

### Distance in Google Earth

Now measure the distance between point A and point B using Google Earth. Click on the “Show Ruler” button in the middle of the top menu, and make sure “map length” shows “meters” in the drop-down box. Click on point A (you will notice that the pointer now looks like a cross-hair: line up the tip of the pin with the center of the cross-hair) and then click on point B. Note that you can change the units in the measurement box to “centimeters” and the value updates.

d) Measure distance in (m) and (cm) between Point A and Point B? Record in data Table 3.

e) Measure distance in (m) and (cm) between Point A and Point C? Record in data Table 3.

Compare this answer to the distance you paced between point A and point B: are they the same? Are they at least similar? What are some of the possible sources of discrepancy between these two measurements

## EXERCISE 5: MAP SCALE

All maps need to have some way of indicating the **scale** of the map. For example, notice that there is a little bar with tick marks on it in the lower left of the Google Earth Pro window that gives a distance at the end of the bar. (If there is no such bar, click on the “View” menu and check the “Scale Legend” box. If the scale is in feet, click “Tools” -or “Google Earth” on a Mac- and then “Options” to change the units of measurement.) This is called a **scale bar**, and it helps you determine the distance between various points on the map. The distance written next to the bar is the length of this bar in reality. In Google Earth, as you zoom in or out the scale bar changes to match the changing scale of the map. Scale can also be expressed as a numerical ratio that shows how much larger the real world is compared to the map. For example, a numerical scale of 1:4000 means that if you enlarged the map 4000 times in both width and length it would be the same size as the area it represents. Think of scale as a magnification factor.

### Calculating the Scale of Your Map

We can calculate a numerical scale for the map of the southeastern quadrant of the campus that we have been working with. To do this, we just need to measure the **actual distance** between two points on the map and the equivalent **map distance** measured directly from the map.

- a) Look up the **actual distances** in cm you measured in Google Earth between the pairs of points in on data Table 3.
- b) Use a ruler to measure the **map distance** in cm between points A and B on your map: record this in data Table 3.
- c) Divide the **actual distance** in cm by the **map distance** in cm.
- d) Record this number in data Table 3 in the format “1:X” where X is your answer in “d” above, rounded to the nearest whole number. This value is the **numerical or ratio scale** and can be read as “1 unit on the map = X units in reality”.

Add the scale you just calculated to your map. You can use this **numerical (ratio) scale** (the number in part e) as a conversion factor to calculate how far a map distance is in reality, and vice versa.



**Procedure for estimating distances on a map using a numerical scale:**

**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**.

**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.

**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.

**Use the method above to solve these two problems:**

a. 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?

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



TABLES for Recording Data

Table 1: Compass Bearings

	<b>Azimuth</b>	<b>Quadrant</b>
<b>FD Statue – Axinn Library</b>		
<b>FD Statue – Hofstra Deli (ABP)</b>		

Table 2: Location Coordinates

	<b>Latitude</b>	<b>Longitude</b>	<b>UTM E</b>	<b>UTM N</b>
<b>Point A</b>				
<b>Point B</b>				
<b>Point C</b>				
<b>B – A =</b>				
<b>C – A =</b>				

Table 3: Distances and Scale

	<b>A to B</b>	<b>A to C</b>
<b># of paces</b>		
<b>Estimated Distance (m)</b> <b>(# paces x meters/pace)</b>		
<b>UTM Distance (m) from Table 2</b>		
<b>Google Earth Distance (m)</b>		
<b>Google Earth Distance (cm)</b>		
<b>Map Distance (cm)</b>		
<b>Estimated Map Scale</b> <b>(Google Earth Distance / Map Distance)</b>		



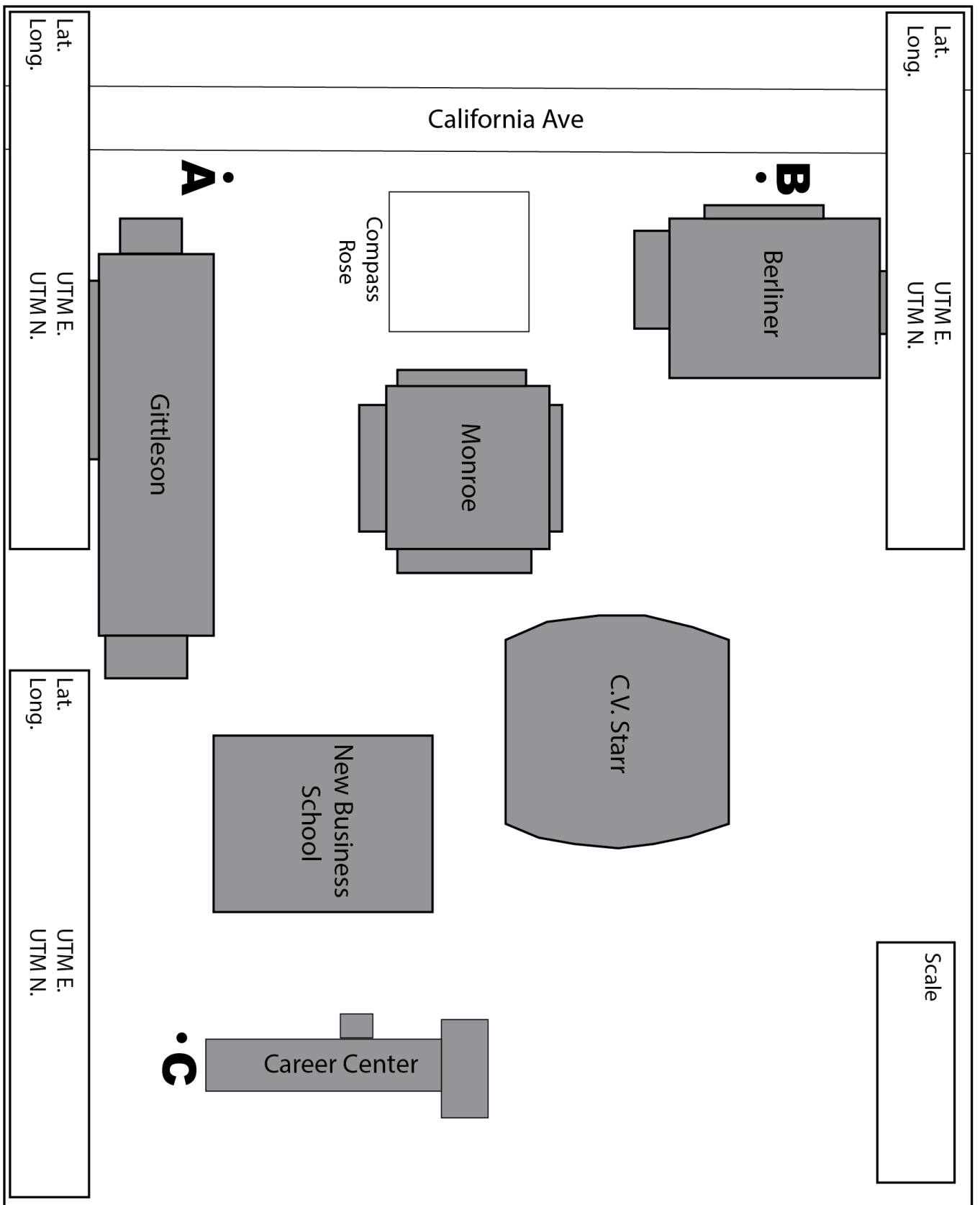


Figure 5.7. Map of the southeast quadrant of the Hofstra University Campus.



## Lab 6 – Three-Dimensional Planet Earth: Topographic Maps

### PURPOSE

You may have noticed that Planet Earth is not flat! Our planet has **topography**, or three-dimensional relief, and we need special maps to show topographic features on flat two-dimensional surfaces like paper and computer screens. This geology lab is designed to teach you the basic skills needed to read, construct, and interpret topographic maps. The goal of this lab is to help you understand how **elevation** (the vertical distance a point on Earth is relative to sea level) is represented on **topographic contour maps**.

Contour lines are lines on a map that represent points of equal elevation on the landscape. For example, imagine you traversed around a hill while maintaining the same elevation and dragging a paint brush behind you, you would be drawing one contour line of the hill. Then if you climbed a certain height to a higher elevation and then did it again, you would draw another contour line. If you climbed the same height to a higher elevation and repeated the process until you reached the top of the hill you would have contoured the hill. Looking directly down on the hill from above, the contours you painted would appear as you see them on a topographic map (Figure 6.1). The change in elevation from one contour line to the next is called the **contour interval**.

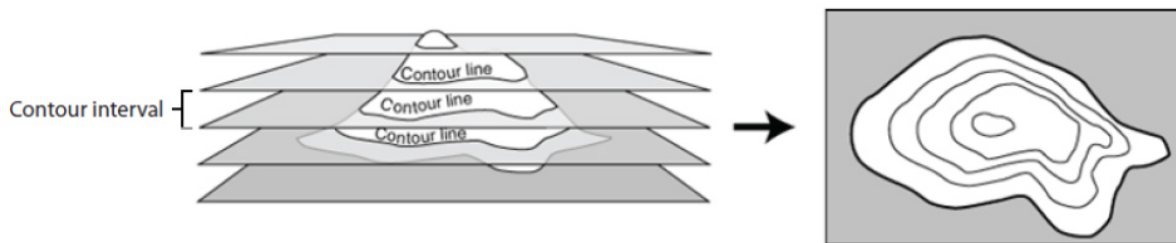


Figure 6.1: Construction of contour lines from topography.

### PART 1: MAKING A SIMPLE TOPOGRAPHIC MAP OF A “VOLCANO”

On your lab table you will see a clear plastic bowl which, when inverted, will serve as a model of a volcano. Follow the steps below to construct a **topographic map** of this object, using the graph paper on the next page. A topographic map represents three-dimensional space on a two-dimensional map, using **contour lines**, which are lines of equal elevation, to show the third dimension (height / depth).

1. First, determine the dimensions of the bowl by measuring the following in centimeters:

- a) Diameter of the base of the volcano (rim of the bowl):

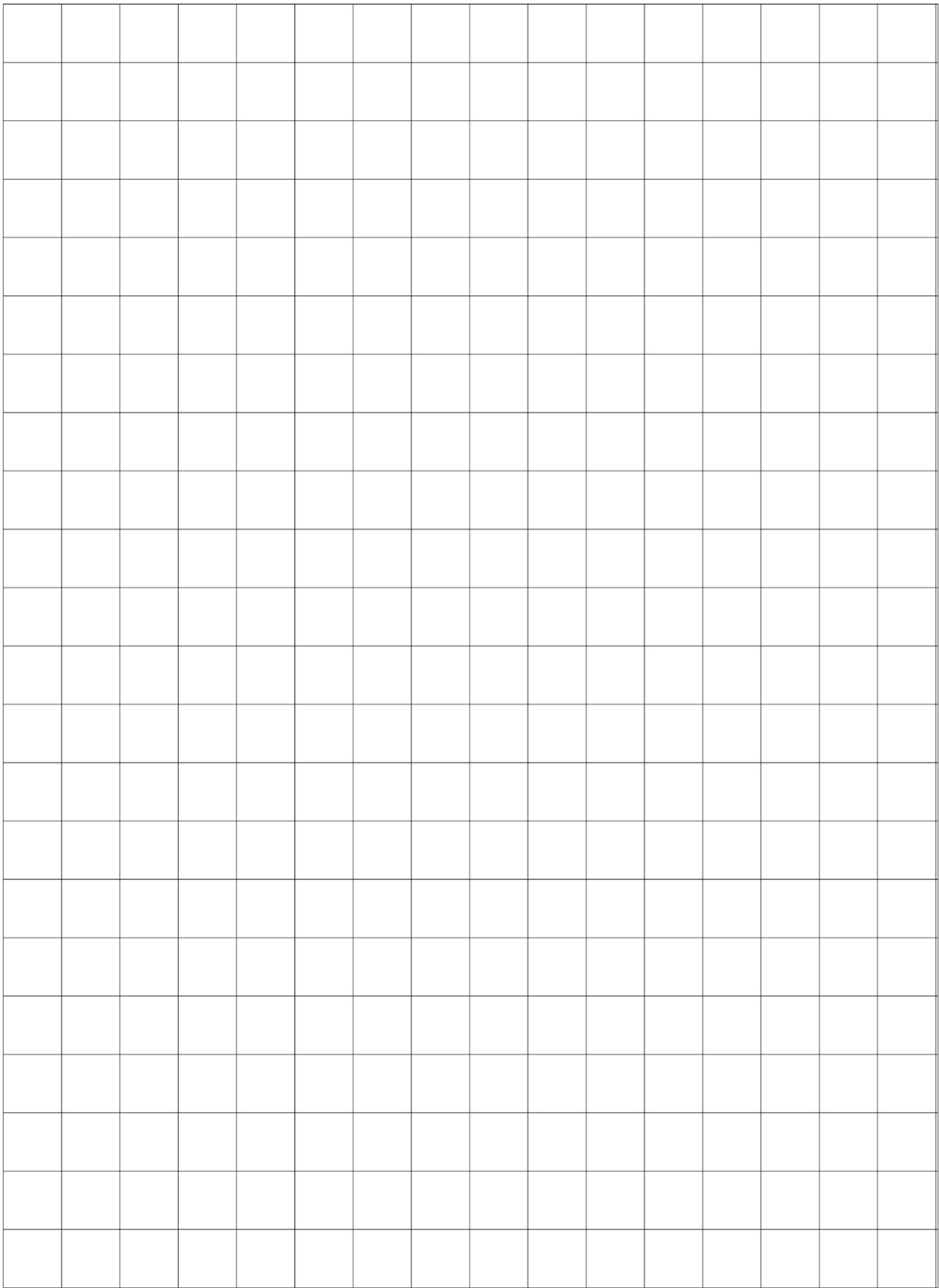
\_\_\_\_\_ cm

- b) Diameter of the top of the volcano (base of the bowl):

\_\_\_\_\_ cm

2. Next, we need to decide the **scale** (remember the definition of this from last class?) of the map you are creating. To make it easier to fit on the piece of paper, use a scale of **1:2** (1 cm on the map = 2 cm in the real world). Draw a scale bar on your map.
3. Set a point in the middle of the graph paper page as the center of the volcano and mark it with a dot. Draw the circumference of the base of the volcano around your center point – use a drafting compass if you want to make a neat circle. Remember to draw it **to scale** (divide your actual measurement by 2 to get the map measurement). Label this circle “0” to represent the zero contour line at sea level.
4. Use a ruler and an erasable marker to measure and mark opposite sides of the volcano every 3 cm in elevation above the base (3 cm is the contour interval).
5. At each 3 cm vertical interval measure the diameter of the volcano at that elevation and draw a circle to scale centered on your map. Label each circle with its elevation value in cm. Note that the vertical dimension does **not** have a scale on a flat map – simply label the contours with their actual values as you measured.
6. There are two circles with **hatchure marks** drawn on the flat top of the volcano. These represent elevation contours showing a crater at the top of the volcano. Draw these to scale on your map and also draw in the hatchure marks, which show that the contour lines enclose a depression. Label the first hatchured contour with the same value of the last outside contour and the second (innermost) with a value that is one contour interval less.
7. All good maps have a title, North arrow, and scale. Make sure these things are on your map! The door in the Gittleson 162 lab room is on the North side of the room.







## **PART 2: UNDERSTANDING TOPOGRAPHIC MAPS USING THE AUGMENTED REALITY SANDBOX**

Now that you've constructed a simple topographic map, you have an idea of how contour lines work. When you read more complicated topographic maps, you must keep in mind several rules about more complex situations. To get an intuitive feel for some of these rules we can use a very clever piece of technology called an **augmented reality sandbox**. This is a combination of a video game camera and a projector mounted above a sandbox and controlled by a computer. You can create mountains, valleys, and craters in the sand and the video camera will scan the surface topography and the computer will create a colorized topographic map and project it directly onto your sandbox topography! You can visualize in real time what topographic contour lines look like for different landforms (you see them in 3D projected onto the sand and in 2D map view on the computer screen.)

### **To do:**

Using the augmented reality sandbox, model the following landforms and answer the questions below:

**1.** Create a large circular mountain with a crater at the top (think, volcano). As you climb up the mountain and then down into the crater, what is the **trend** of the contour lines (use the different colors as a proxy for contour elevation values – what is the color trend as you ascend the mountain and then start going down into the crater)?

**2.** Make a deep valley running down one side of your mountain (dig a deep furrow in the sand from the peak to the base). As the contour lines cross the valley, what pattern do they make on a map (this is best observed on the computer screen)?

How can you tell which way is the uphill direction on a contour map by looking at the contour lines crossing a valley?

**3.** Now reshape your mountain so that one side is very steep (like a cliff) and the other side has a very gentle slope (like a ramp). Describe how the contour lines on the steep slope differ from the contour lines on the shallow slope:

**4.** Now you are ready to review the rules of contour lines below and complete exercises 6.1 and 6.2 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 closed depression in the ground (crater, sink hole, etc.). Closed contours around a depression are marked by hachured lines to distinguish them from closed contours around a hill (Figure 6.2).

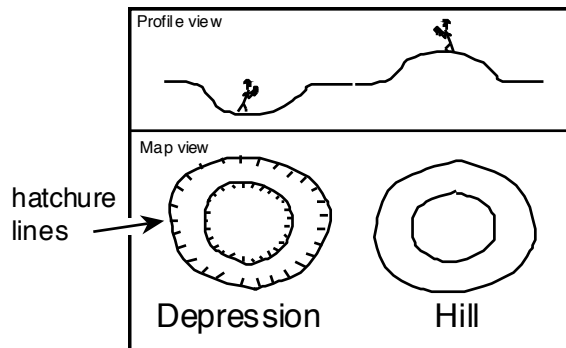


Figure 6.2

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 and do not change!
3. Contour lines **never** split, cross, or intersect, although at a vertical cliff they appear to come together and touch (Figure 6.3).

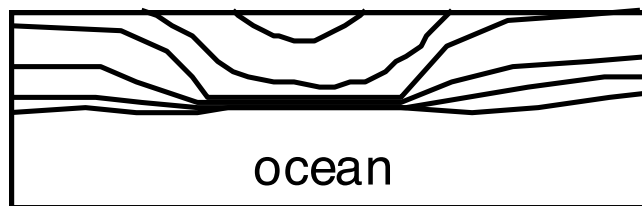
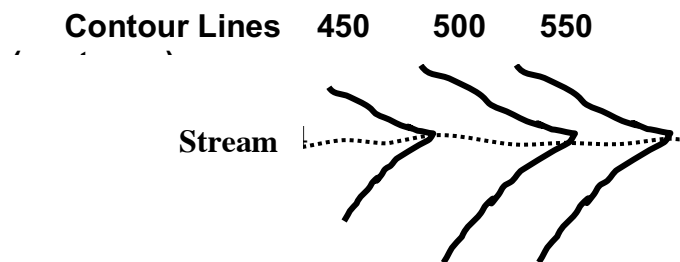


Figure 6.3

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 brown line than adjacent contours and also numbered somewhere along the trace of the contour line). Commonly used contour intervals are 5, 10, 20, 40, and 80 feet / meters.

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, similar to a dart board with the highest point at the “bullseye” in the center. 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 6.4).



8. Where two adjacent closed contours indicate opposite slopes (hachured contour next to a normal contour) both are the same elevation (Figure 6.5).

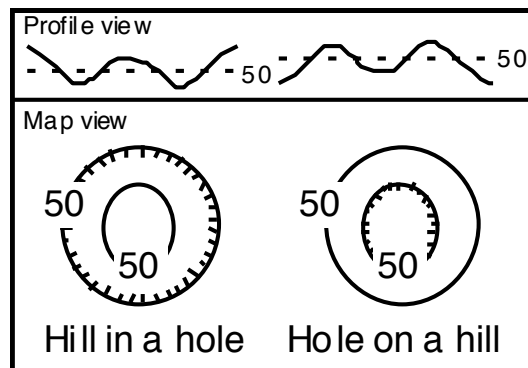


Figure 6.5

9. A hachured contour line, lying between two different contour lines, is the same elevation as the lower contour line (Figure 1.6).

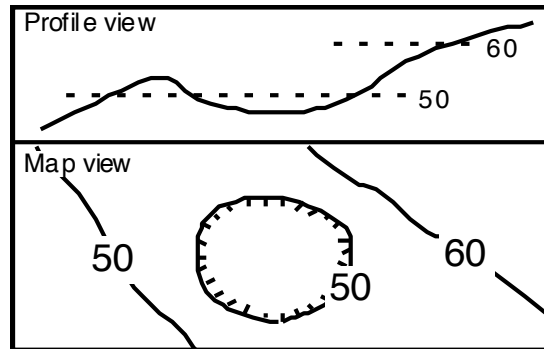


Figure 6.6

10. A closed contour line, lying between two different contour lines, is the same elevation as the higher contour line (Figure 1.7).

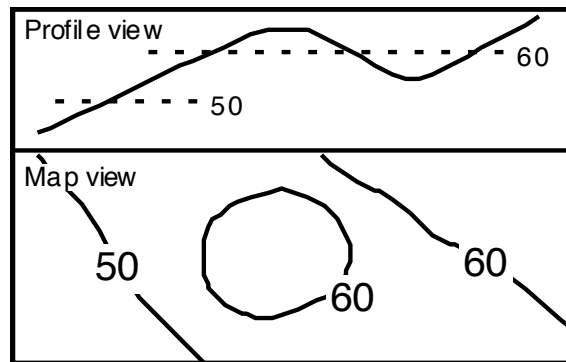


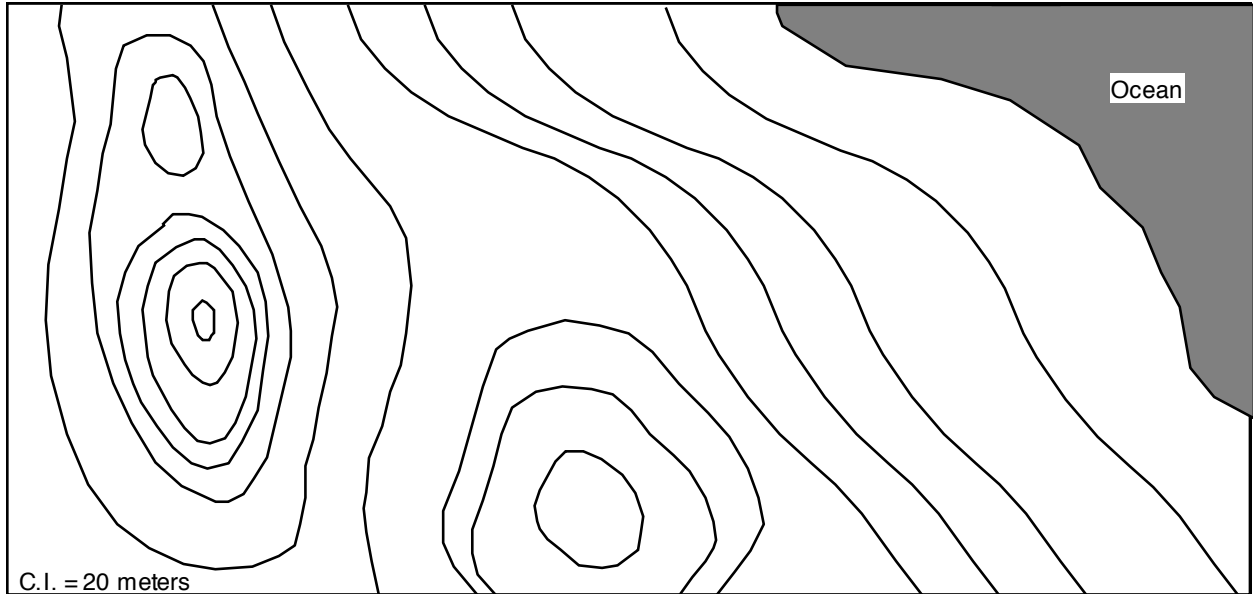
Figure 6.7

11. Finally, "**Obey all the rules**"!

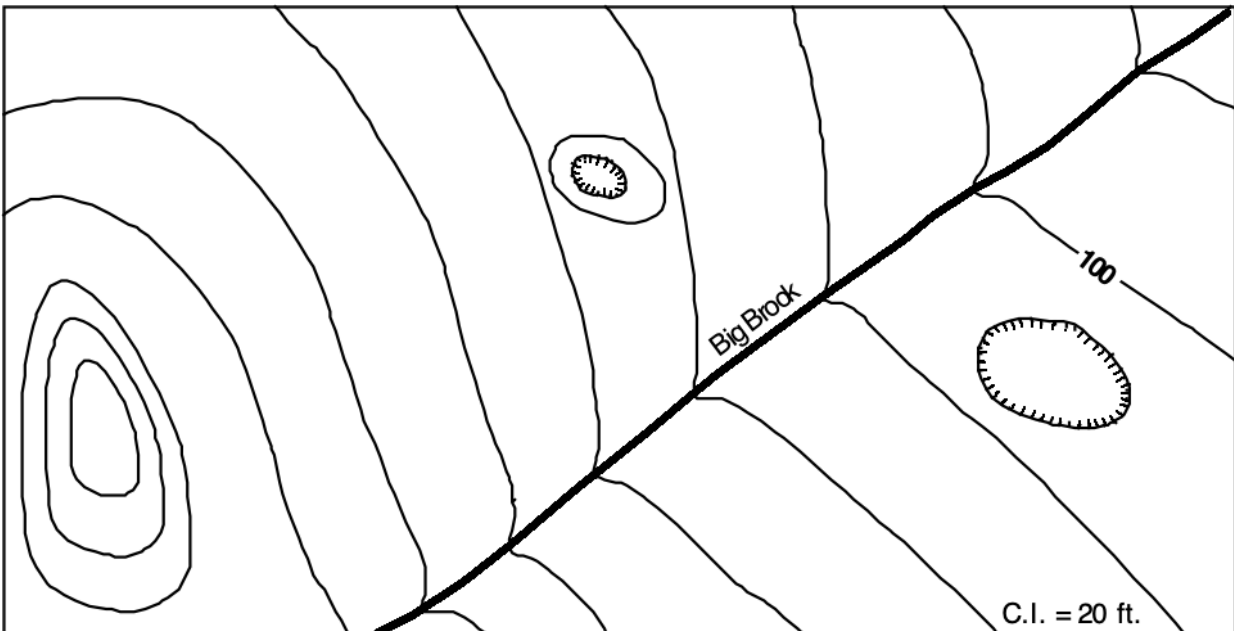
## LABORATORY EXERCISE 6.1

### Topographic Contour Maps

Using the rules of topographic contours, label all of the topographic contour lines in the following two maps with their correct elevations. Zero elevation is sea level (shoreline). Note the **contour interval (C.I.)** given on each map. Big Brook is a stream running across the second map.



Exercise 6.1a



Exercise 6.1b



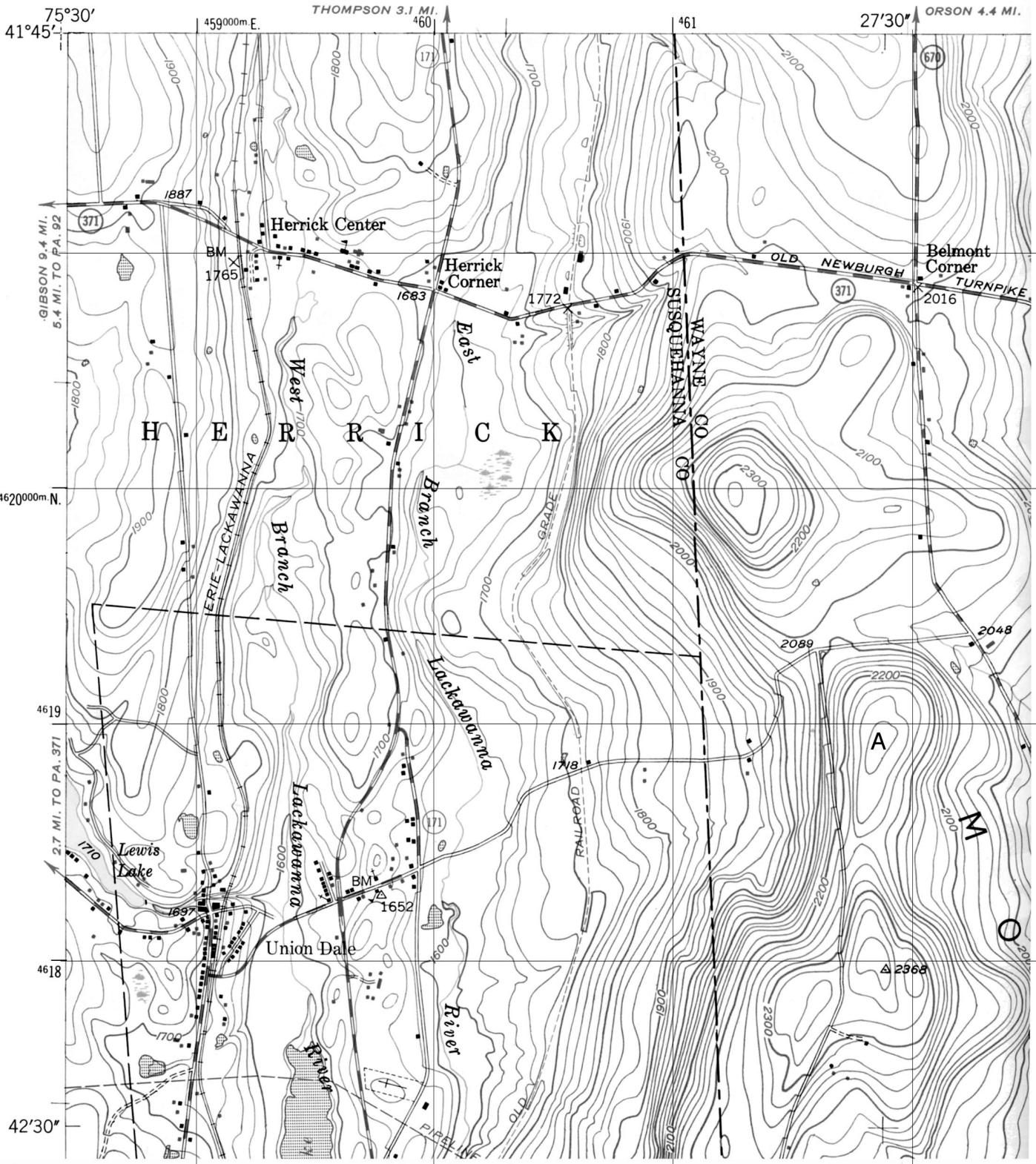


## **LABORATORY EXERCISE 6.2**

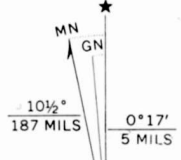
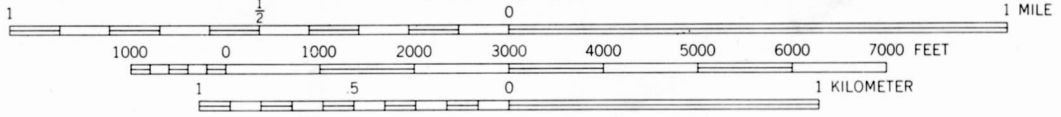
**(questions based on map on following page)**

1. What are the approximate longitude and latitude coordinates of the mountain peak located in the lower right quadrant of the map with an elevation of 2368'? 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 7 – Topographic Profiles, Vertical Exaggeration, and Slopes

In this activity, we will learn how to draw topographic profiles, or cross-sections of terrain, from topographic maps. From these profiles we will use scale to calculate vertical exaggeration and the slope values for different parts of the profiles. To apply these skills we will use some historical topographic maps of Mount St. Helens, a volcano in Washington State, to draw profiles so we can see how an eruption in 1980 dramatically altered its topography.

### 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 7.1).

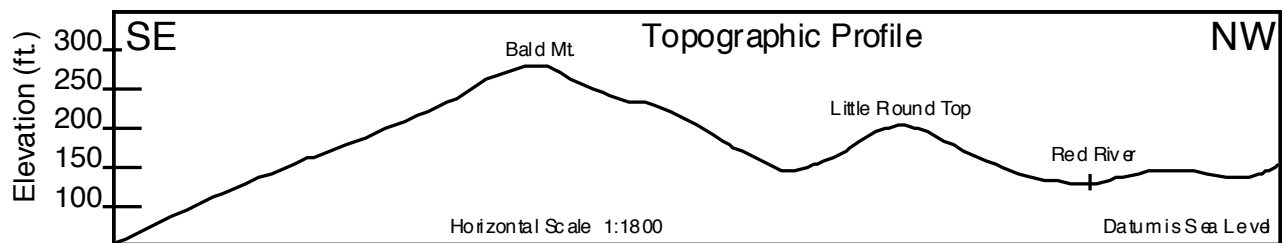


Figure 7.1 - Example of a topographic profile.

A well-constructed topographic profile should include the following information:

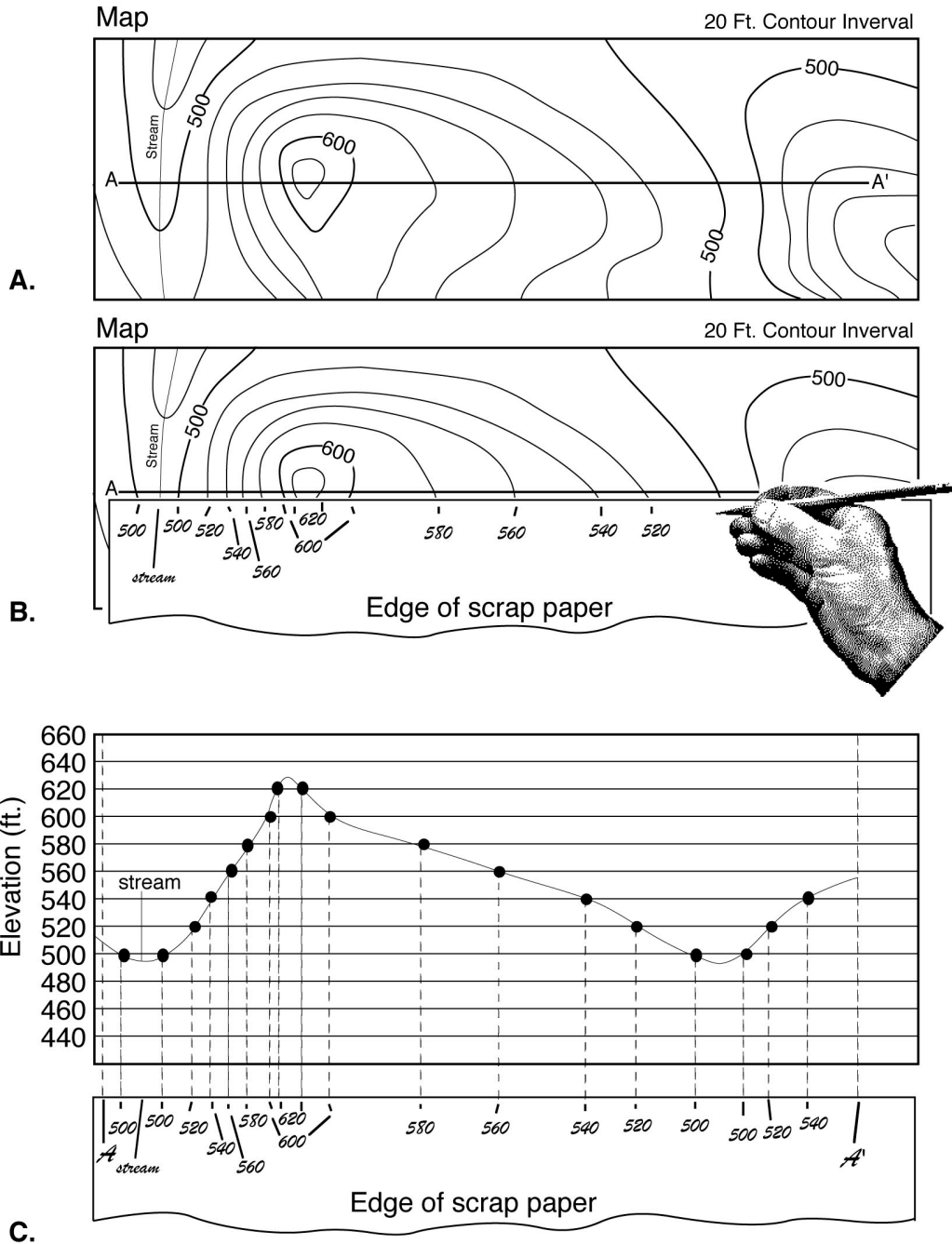
- A description of the line of the profile, including the name of the map quadrangle from which the profile was derived and the compass directions at each end of the profile (i.e., SE and NW).
- Above the profile, label the names of prominent geographic features, such as rivers or mountains.
- All profiles 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 7.2)

Step 1. Select the line of profile on the map.

Step 2. 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, make precise tick marks at places where contours intersect the edge of the paper strip. Label each tick mark with the elevation values of its contour.

Step 3. On a piece of graph paper, label the vertical scale to encompass a range of elevation values large enough to include the elevations of all the points (= contours) to be plotted (your vertical scale **does not** need to start from zero). 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 7.2** – Example showing how to draw a topographic profile.

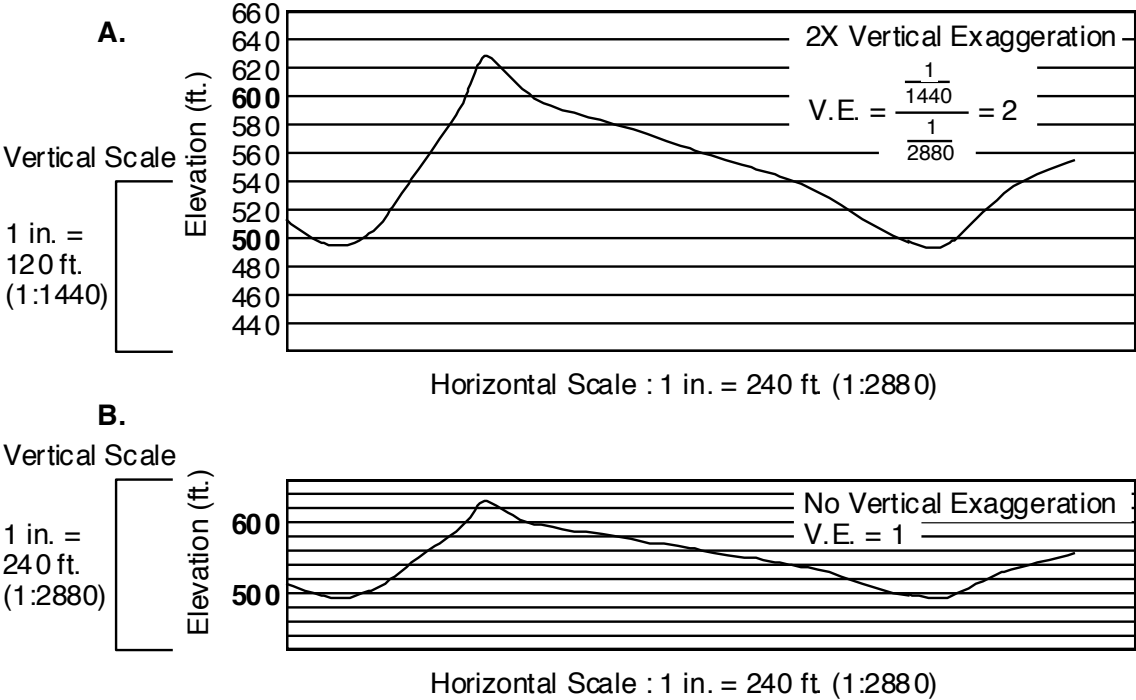
Step 4. Calculate vertical exaggeration. (See next section.)

### Calculating Vertical Exaggeration

**Vertical exaggeration (V.E.)** is the ratio of the vertical scale of a topographic profile to the horizontal scale of the profile. In effect, what V.E. does is to "stretch" the landscape according to the ratio (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. Most profiles have some amount of vertical exaggeration to make it easier to see the topographic relief. If the vertical scale is larger than the horizontal scale (as is usually the case), then the topographic profile will be 'stretched' in the vertical direction and steepness 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 or you can simply **invert the entire fraction** as: **2880/1440 = 2** and eliminate a calculation step (see also Figure 7.3 below.)



**Figure 7.3** Vertical Exaggeration.

- A. Vertical scale is twice as large as horizontal scale. V.E. = 2
- B. Vertical scale and horizontal scale are equal. V.E. = 1.

## Topographic Slopes (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?”

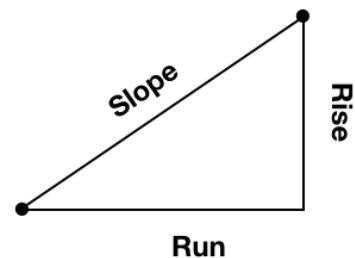
A simple way to remember gradient is the think **rise over run**. A gradient can be expressed in whatever units are of interest. Typically, gradients are expressed in feet per mile. If the units of vertical and horizontal distance are the same, then gradient becomes a **percent ratio**.

For example:

The maximum steepness of a railroad track bed over any length of track is traditionally given as .025 (= 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.  $2.5\% = .025 \times 5280$  feet/mile = 132 feet. Thus, a gradient of 132 feet per mile (= 2.5%) is the maximum gradient used for railroad lines.

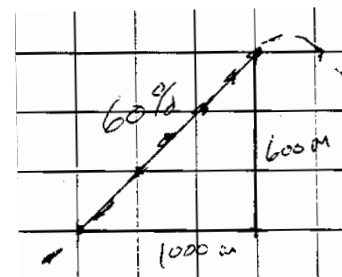
### Determining a gradient from a topographic profile

1. Pick two points along your profile between which you want to measure the gradient and connect them with a line. Draw a vertical line from the highest point down to the elevation of the lowest point (the **rise**). Draw a horizontal line from the lowest point across to the location of the highest point to form a right triangle (the **run**).



2. You use the vertical scale on your profile to measure the **rise** (change in elevation) from the first selected point on the profile to the last selected point.

3. You must use the **map scale** to measure the **run** (horizontal distance) between the two selected points. Use a ruler to measure the distance between the points, then multiply by the ratio scale to get the actual distance. Finally, you need to convert from the units you measured in (cm or in) to the units on your vertical scale (meters or feet).



4. Dividing the change in elevation (rise) by the horizontal distance (run) will give you **gradient** between these two points. If the horizontal distance and elevation units are different, they must be included in the gradient (as in feet per mile, feet per foot, or meters per kilometer). If the units are the same they can be reported as a percent if you multiply your answer by 100.

Note that a  $45^\circ$  slope has a gradient of 100% (the rise and the run are the same value). Slopes steeper than  $45^\circ$  will be greater than 100%.



## Making topographic profiles of Mount St. Helens

Mount Saint Helens is a large stratovolcano located in Washington State about 80 miles south of Seattle. In May of 1980, a landslide on the north slope of Mt. Saint Helens exposed the large magma chamber building up within the mountain resulting in a violently explosive eruption that blew the top off of the mountain, leaving a deep crater open to the north where the peak used to be (Figures 7.4 and 7.5). To visualize how the eruption changed the morphology of the mountain, we can draw two topographic profiles – one for the mountain before the eruption and one post-eruption.

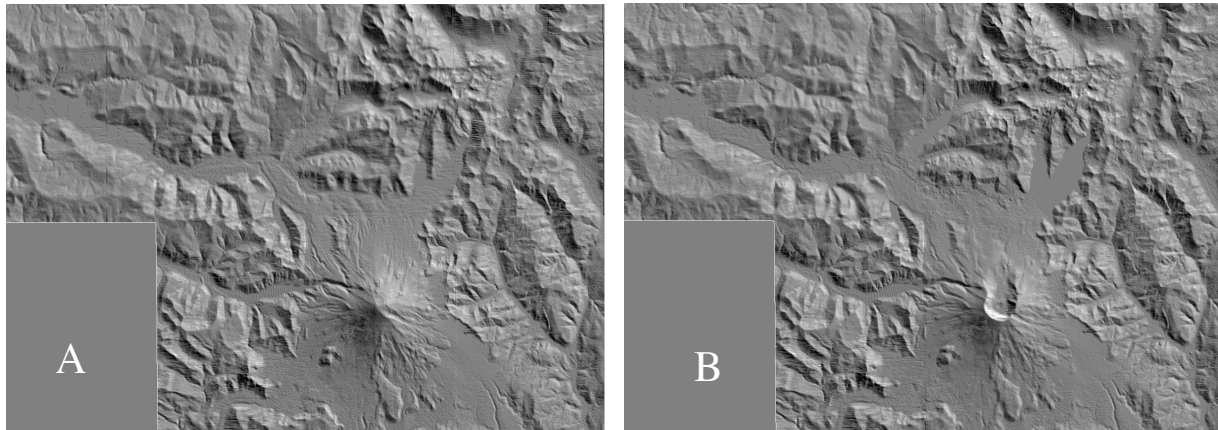


Fig. 7.4 Topographic shaded relief images of Mt. Saint Helens before (A) and after (B) the eruption. Images courtesy of U.S. Geological Survey (USGS).

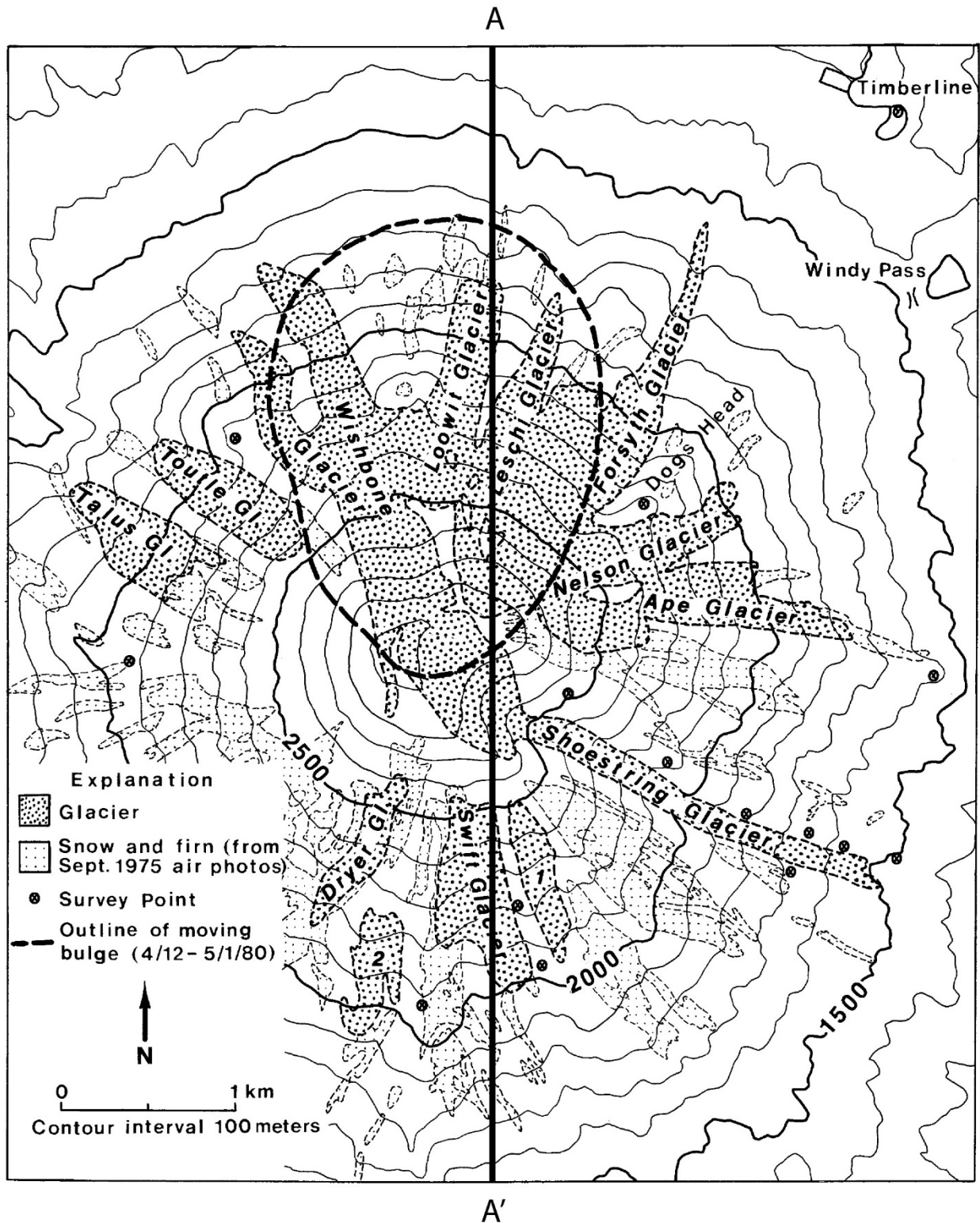


Fig. 7.5 Photographs of Mt. Saint Helens before and after the eruption (USGS).

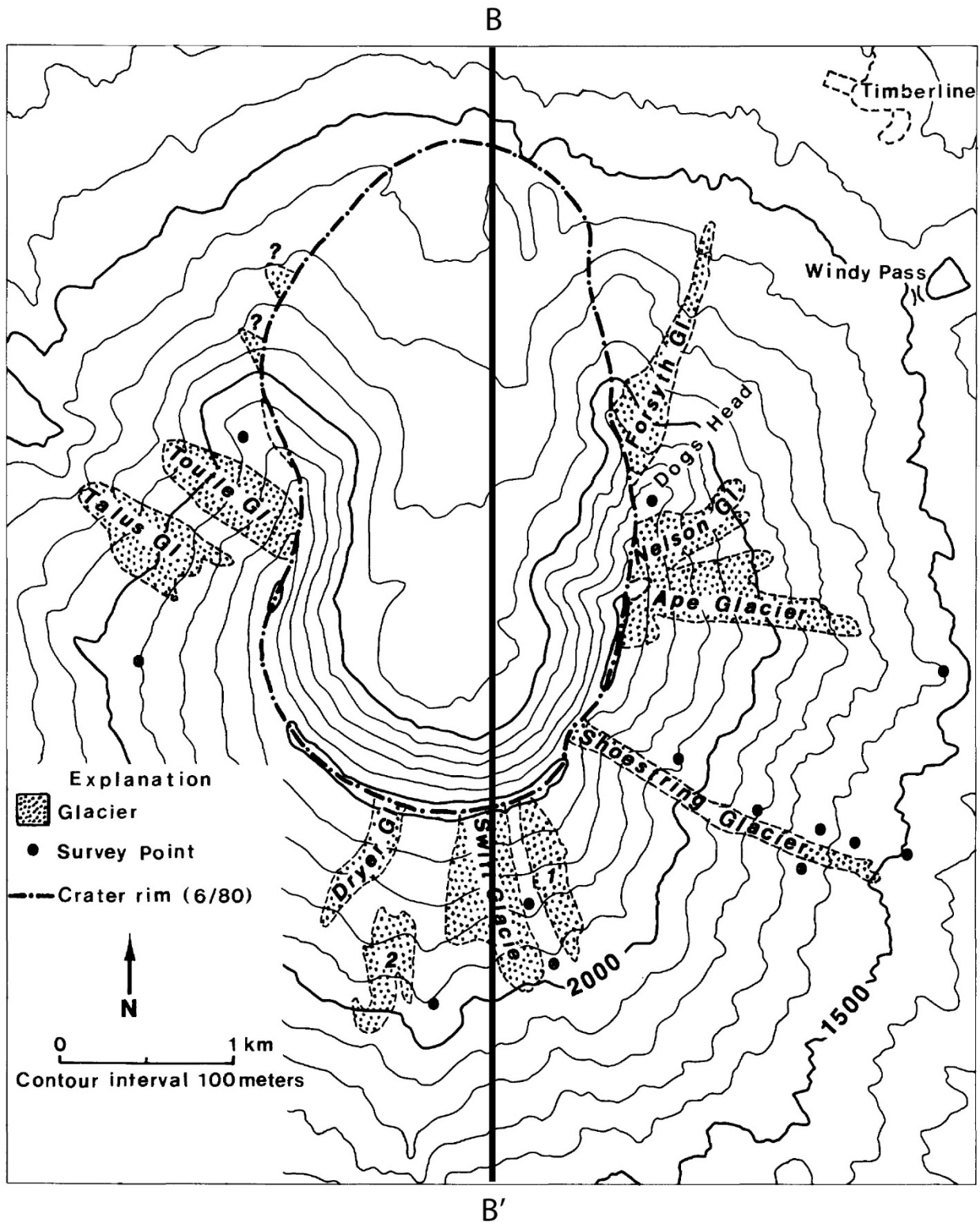
### To Do:

Using the maps and graph paper provided below, make overlapping topographic profiles of the A-A' and B-B' transects through the Mount St. Helens summit. Draw your profiles using a vertical scale of 1 cm on the map = 200 m of vertical relief. Use a dashed line for the pre-eruption profile, and a solid line for the post-eruption profile.





Topographic map of Mount St. Helens from before the 1980 eruption. Image from United States Geological Survey Circular 850-D, by Melinda Brugman and Austin Post.



Topographic map of Mount St. Helens from after the 1980 eruption. Image from United States Geological Survey Circular 850-D, by Melinda Brugman and Austin Post.





### Interpreting your profiles:

Your two profiles show the topography of Mount St. Helens before its 1980 eruption, and after the eruption.

1. Calculate the vertical exaggeration of your profiles (show all work):
  - a. Determine the horizontal scale (1 cm on the map = ? cm of actual distance):
  - b. Determine the vertical scale (1 cm on the profile = ? cm of elevation):
  - c. Divide the vertical scale fraction by the horizontal scale fraction:

Vertical Exaggeration = \_\_\_\_\_

Let's consider how the landscape changed because of the eruption:

2. What was the highest elevation of the mountain before the 1980 eruption?
3. What is the highest elevation of the mountain in the post-eruption profile?
4. What is the largest change of elevation due to the eruption at any single point along the profiles?
5. a. Calculate the steepest gradient, as a percentage, in the pre-eruption profile:
  - b. Calculate the steepest gradient, as a percentage, in the post-eruption profile:





## 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 / link 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; 125<sup>th</sup> 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/>)

## **REFERENCES**

Ellison, S. P., ed., 1958, General geology laboratory workbook. Physical geology and historical geology: New York, NY, Harper & Brothers, Publishers, 285 p.

Fairbridge, R. W., 1963, Earth--geology of the planet, p. 309-331 in Fairbridge, R. W., ed., The encyclopedia of atmospheric sciences and astrogeology. Encyclopedia of Earth Sciences, v. 2: New York, Reinhold Publishing Corp., 1200 p.

Friedman, G. M., Sanders, J. E., and Kopaska-Merkel, D. C., 1992, Principles of sedimentary deposits. Stratigraphy and sedimentology: New York, NY, Macmillan Publishing Company, 717 p.

Longwell, C. R., Flint, R. F., and Sanders, J. E., 1969, Physical geology: New York, NY, John Wiley and Sons, 685 p.

Sanders, J. E., 1981, Principles of physical geology: New York, John Wiley and Sons, 624 p.

Strahler, A. N., 1960, Physical geography, 2nd ed.: New York, NY, John Wiley and Sons, 534 p.

#	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					



#	Textures and / or other features	Minerals Present	Igneous Sedimentary Metamorphic	Rock Name
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				





**Peer Review Sheet - Student Reviewer Name** \_\_\_\_\_

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

- 1. Was the presentation clear and interesting?
  - 2. Did the photos and diagrams help you understand?
- \_\_\_\_\_

Worst					Best
1	2	3	4	5	
1	2	3	4	5	
Total:					

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

- 1. Was the presentation clear and interesting?
  - 2. Did the photos and diagrams help you understand?
- \_\_\_\_\_

Worst					Best
1	2	3	4	5	
1	2	3	4	5	
Total:					

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

- 1. Was the presentation clear and interesting?
  - 2. Did the photos and diagrams help you understand?
- \_\_\_\_\_

Worst					Best
1	2	3	4	5	
1	2	3	4	5	
Total:					

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

- 1. Was the presentation clear and interesting?
  - 2. Did the photos and diagrams help you understand?
- \_\_\_\_\_

Worst					Best
1	2	3	4	5	
1	2	3	4	5	
Total:					

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

- 1. Was the presentation clear and interesting?
  - 2. Did the photos and diagrams help you understand?
- \_\_\_\_\_

Worst					Best
1	2	3	4	5	
1	2	3	4	5	
Total:					

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

- 1. Was the presentation clear and interesting?
  - 2. Did the photos and diagrams help you understand?
- \_\_\_\_\_

Worst					Best
1	2	3	4	5	
1	2	3	4	5	
Total:					

**Peer Review Sheet - Student Reviewer Name** \_\_\_\_\_

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

Worst  Best

1. Was the presentation clear and interesting?

1 2 3 4 5

2. Did the photos and diagrams help you understand?

1 2 3 4 5

\_\_\_\_\_

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

Worst  Best

1. Was the presentation clear and interesting?

1 2 3 4 5

2. Did the photos and diagrams help you understand?

1 2 3 4 5

\_\_\_\_\_

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

Worst  Best

1. Was the presentation clear and interesting?

1 2 3 4 5

2. Did the photos and diagrams help you understand?

1 2 3 4 5

\_\_\_\_\_

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

Worst  Best

1. Was the presentation clear and interesting?

1 2 3 4 5

2. Did the photos and diagrams help you understand?

1 2 3 4 5

\_\_\_\_\_

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

Worst  Best

1. Was the presentation clear and interesting?

1 2 3 4 5

2. Did the photos and diagrams help you understand?

1 2 3 4 5

\_\_\_\_\_

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

Worst  Best

1. Was the presentation clear and interesting?

1 2 3 4 5

2. Did the photos and diagrams help you understand?

1 2 3 4 5

\_\_\_\_\_

Total:

**Peer Review Sheet - Student Reviewer Name** \_\_\_\_\_

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

Worst  Best

1. Was the presentation clear and interesting?

1 2 3 4 5

2. Did the photos and diagrams help you understand?

1 2 3 4 5

\_\_\_\_\_

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

Worst  Best

1. Was the presentation clear and interesting?

1 2 3 4 5

2. Did the photos and diagrams help you understand?

1 2 3 4 5

\_\_\_\_\_

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

Worst  Best

1. Was the presentation clear and interesting?

1 2 3 4 5

2. Did the photos and diagrams help you understand?

1 2 3 4 5

\_\_\_\_\_

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

Worst  Best

1. Was the presentation clear and interesting?

1 2 3 4 5

2. Did the photos and diagrams help you understand?

1 2 3 4 5

\_\_\_\_\_

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

Worst  Best

1. Was the presentation clear and interesting?

1 2 3 4 5

2. Did the photos and diagrams help you understand?

1 2 3 4 5

\_\_\_\_\_

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

Worst  Best

1. Was the presentation clear and interesting?

1 2 3 4 5

2. Did the photos and diagrams help you understand?

1 2 3 4 5

\_\_\_\_\_

Total:

**Peer Review Sheet - Student Reviewer Name** \_\_\_\_\_

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

- 1. Was the presentation clear and interesting?
  - 2. Did the photos and diagrams help you understand?
- \_\_\_\_\_

Worst					Best
1	2	3	4	5	
1	2	3	4	5	
Total:					

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

- 1. Was the presentation clear and interesting?
  - 2. Did the photos and diagrams help you understand?
- \_\_\_\_\_

Worst					Best
1	2	3	4	5	
1	2	3	4	5	
Total:					

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

- 1. Was the presentation clear and interesting?
  - 2. Did the photos and diagrams help you understand?
- \_\_\_\_\_

Worst					Best
1	2	3	4	5	
1	2	3	4	5	
Total:					

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

- 1. Was the presentation clear and interesting?
  - 2. Did the photos and diagrams help you understand?
- \_\_\_\_\_

Worst					Best
1	2	3	4	5	
1	2	3	4	5	
Total:					

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

- 1. Was the presentation clear and interesting?
  - 2. Did the photos and diagrams help you understand?
- \_\_\_\_\_

Worst					Best
1	2	3	4	5	
1	2	3	4	5	
Total:					

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

- 1. Was the presentation clear and interesting?
  - 2. Did the photos and diagrams help you understand?
- \_\_\_\_\_

Worst					Best
1	2	3	4	5	
1	2	3	4	5	
Total:					

**Peer Review Sheet - Student Reviewer Name** \_\_\_\_\_

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

- 1. Was the presentation clear and interesting?
- 2. Did the photos and diagrams help you understand?

Worst  Best

1 2 3 4 5

1 2 3 4 5

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

- 1. Was the presentation clear and interesting?
- 2. Did the photos and diagrams help you understand?

Worst  Best

1 2 3 4 5

1 2 3 4 5

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

- 1. Was the presentation clear and interesting?
- 2. Did the photos and diagrams help you understand?

Worst  Best

1 2 3 4 5

1 2 3 4 5

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

- 1. Was the presentation clear and interesting?
- 2. Did the photos and diagrams help you understand?

Worst  Best

1 2 3 4 5

1 2 3 4 5

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

- 1. Was the presentation clear and interesting?
- 2. Did the photos and diagrams help you understand?

Worst  Best

1 2 3 4 5

1 2 3 4 5

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

- 1. Was the presentation clear and interesting?
- 2. Did the photos and diagrams help you understand?

Worst  Best

1 2 3 4 5

1 2 3 4 5

Total:

**Peer Review Sheet - Student Reviewer Name** \_\_\_\_\_

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

Worst Best

1. Was the presentation clear and interesting?

1 2 3 4 5

2. Did the photos and diagrams help you understand?

1 2 3 4 5

\_\_\_\_\_

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

Worst Best

1. Was the presentation clear and interesting?

1 2 3 4 5

2. Did the photos and diagrams help you understand?

1 2 3 4 5

\_\_\_\_\_

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

Worst Best

1. Was the presentation clear and interesting?

1 2 3 4 5

2. Did the photos and diagrams help you understand?

1 2 3 4 5

\_\_\_\_\_

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

Worst Best

1. Was the presentation clear and interesting?

1 2 3 4 5

2. Did the photos and diagrams help you understand?

1 2 3 4 5

\_\_\_\_\_

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

Worst Best

1. Was the presentation clear and interesting?

1 2 3 4 5

2. Did the photos and diagrams help you understand?

1 2 3 4 5

\_\_\_\_\_

Total:

Presenter Name \_\_\_\_\_

Title \_\_\_\_\_

Worst Best

1. Was the presentation clear and interesting?

1 2 3 4 5

2. Did the photos and diagrams help you understand?

1 2 3 4 5

\_\_\_\_\_

Total: