EESC 1101

Introduction to Classification of Rocks Using the Building Stones of the Brooklyn College Campus

Rocks and Stones

Rocks and stones are not exactly the same thing: a **rock** is a natural material that is composed of an aggregate of one or more minerals, volcanic glass, or organic materials (e.g., coal, shells); a **stone** is a piece of rock that is used for a specified function (e.g., building stone, gravestone, gemstone, cobblestone streets, pumice stone).

Rocks are subdivided into three broad families based on the general processes and environments of formation:

- **Sedimentary Rocks** are materials composed of materials weathered from pre-existing rock. Sedimentary rocks commonly have a layered appearance due to grains of different composition, color, or size depositing at different times. This layering is called **bedding** (see Examples of Rock Fabrics plate).
- **Igneous Rocks** form from the solidification of molten rock. Intrusive igneous rocks are composed of crystals that are large enough to be seen with the naked eye because these rocks cooled slowly, deep within the Earth thereby allowing time for the crystals to grow. In contrast, extrusive (volcanic) igneous rocks cool very quickly after they erupt from a volcano, and so are composed of microscopic crystals. Most volcanic rocks make poor building stone because they may be weak, cracked, inconsistent in color, and/or contain large pores. Accordingly, volcanic rocks will not be discussed further in this lab.
- **Metamorphic Rocks** form from when pre-existing rocks are exposed to elevated heat and pressure. The directed pressure that is commonly associated with metamorphism reorients elongate or flat minerals to be parallel to each other, thereby defining layering in the rock that is referred to as a **foliation**. Under more extreme metamorphic conditions minerals may segregate into distinct light and dark colored layers forming a distinctly banded rock called **gneiss**. Metamorphism may also deform banding in rocks to form folded patterns (see Examples of Rock Fabrics plate for examples of foliation, gneissosity and folding).

The list of rocks that commonly have qualities that are suitable for building stone is relatively short, and is summarized in the table below:

Rock Family	Rock Name	Common Colors	Common Features
Sedimentary	Sandstone	Reddish Brown, Beige, White, Grey	Grainy; composed of rounded grains up to 2 mm in diameter. "Sandy" feel. Bedding is common.
	Limestone	Grey, Cream, Tan, Pink	Grainy. Fossils are common. Bedding is common. Stylolites are common.
Igneous	Granite	White, Pink, Speckled	Crystalline. Crystals large enough to see. Light colored
	Granodiorite	"Salt and Pepper"	Crystalline. Crystals large enough to see. Mix of light and dark crystals.
	Gabbro	Black, Green, Dark Grey	Crystalline. Crystals large enough to see. Dark colored
Metamorphic	Marble	White, Pink	Crystalline. Wispy, "marbled" textures are common. No fossils.
	Gneiss	Pink, Black and White	Crystalline. Bands of distinctly different color. Bands may be irregular and folded.

Components of Rocks: Crystals and Grains

Identifying and interpreting rocks can seem daunting at first; there are so many types and classes. However, systematically characterizing a couple of critical features can simplify the process significantly. If the components that comprise the rock are large enough to see, then the first step is to characterize the individual components of the rock. The fundamental subdivision is whether the rock is composted of crystals or grains:

- **CRYSTALS** are individual minerals that have grown in place to form a rock. In igneous rocks they are minerals that crystallize from the solidifying magma/lava. In metamorphic rocks, they are minerals that grow within the solid rock through chemical reactions between neighboring minerals. Thus identifying crystals in a rock means that the rock must be either **igneous or metamorphic**. Because crystals are individual minerals, they will display distinct mineral properties. Because minerals have a regular, ordered arrangement of atoms, crystals tend to have ***regular, polygonal shapes***. Adjectives such as blocky, bladed, needle-like, prismatic, rectangular, and hexagonal are commonly used to describe crystals. Many mineral also tend to display cleavage. On a broken surface of a rock, broken mineral crystals may exhibit cleavage which will be seen as ***flat, shiny faces***. (See Examples of Crystalline Textures on the following page.)
- **GRAINS** are pieces of pre-existing rock or organic material (e.g., shells) that have been cemented together to form a sedimentary rock. Thus identifying grains in a rock means that the rock must be **sedimentary**. Abrasion due to transport of sedimentary grains by wind or water tends to wear down any sharp edges, producing ***rounded*** grains (i.e., shapes like balls, jellybeans, etc.). Sandstone is a sedimentary rock that is composed of small (<2mm diameter) rounded grains, whereas conglomerate is a sedimentary rock composed of rounded pebbles. If a rock shatters/breaks but the fragments do not travel far (e.g., avalanche or rock slide) then the grains of rock will tend to be ***irregular, jagged, and angular***. Once cemented, these angular clasts (rock fragments) form a rock called **breccia**. Many animals forms shells/skeletons that are composed of mineral-like materials (calcium carbonates and phosphates) that can be incorporated into a rock once the animal dies. Such **fossil** grains can be recognized by ***complex and delicate shapes*** such as spirals, discs, arcs, radiating structures, and net-like structures. (See Examples of Grainy Textures on the following page.)

Examine the four jars of materials that contain examples of the types of non-organic components that may comprise a rock. For each material sketch the typical shapes, and provide several adjectives that best describe the materials.

G1: Rounded Grains (Pebbles) - fragments of mechanically weathered rock that have had their rough edges smoother by abrasion during transport in water (river or beach environment)

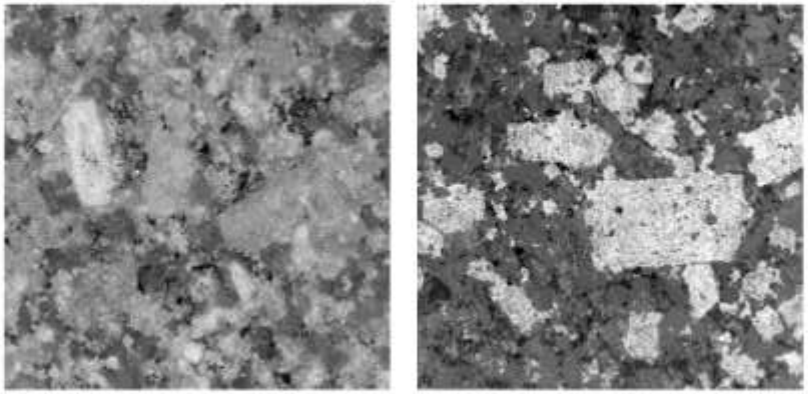
G2: Angular Grains – fragments of mechanically weathered rock that have not been abraded

G5: Ooids - a special form or spherical rounded grain of calcite that forms by accreting like a snowball as they roll around on the shallow seafloor due to wave energy)

C1: Crystals – cleavage fragments of minerals such as calcite, halite, and feldspar; growth crystals of minerals such as quartz

Rounded Grains	Angular Grains	Ooids	Crystals
Sketch:	Sketch:	Sketch:	Sketch:
Descriptive Adjectives:	Descriptive Adjectives:	Descriptive Adjectives:	Descriptive Adjectives:

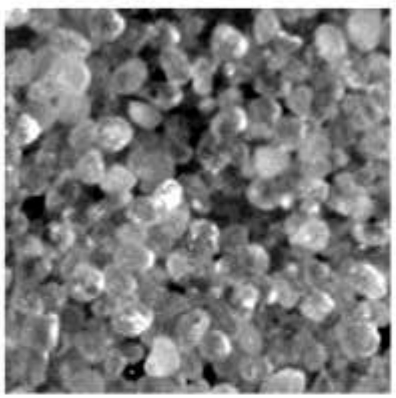
Examples of Crystalline Textures



Granites with plagioclase crystals that exhibit typical blocky polygonal forms

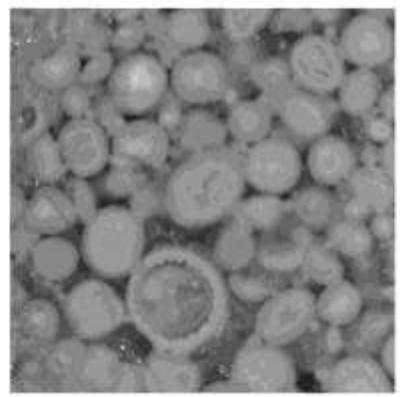
Metamorphic rocks with crystals that exhibit prismatic and bladed polygonal forms

Examples of Grainy Textures

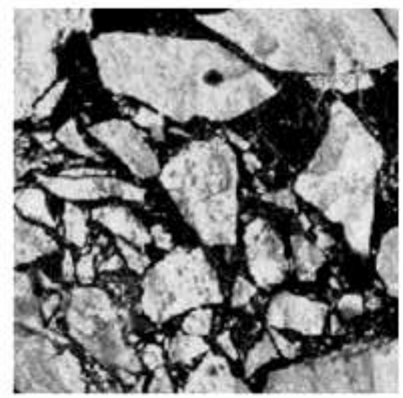


Sandstone composed of near-spherical sand grains of quartz and feldspar

Sandstone composed of rounded fragments of fossil material



Limestone containing ooids, which are round grains with concentric layers



Breccia containing angular fragments

Fossils are a common component in sedimentary rocks, and are particularly common in limestones (rocks composed of calcite and which form in shallow tropical marine environments). However, in many cases the animal shells/skeletons will have been broken into pieces by the energy of waves. In building stone, identifying fossils can be further complicated by the fact you are looking at a cut slice through the rock, and so you may be seeing a slice through the inside of the shell rather than the shape of the outer surface. To help you become familiar with the appearance of some common groups of fossils and how they can look when sliced, examine the seven fossil specimens listed below, and the photos in the "Examples of Fossils that Are Common in Limestones" plate on the following page.

F1	Modern coral	F1A	Slice through corals in limestone
F2	Modern gastropod (Snail)	F2A,B	Slices through modern gastropods
F3	Cut modern bivalve (Clam)		
F4	Fossilized crinoid stem		

Sketch the appearance of the four sliced samples and describe the general appearance of each.

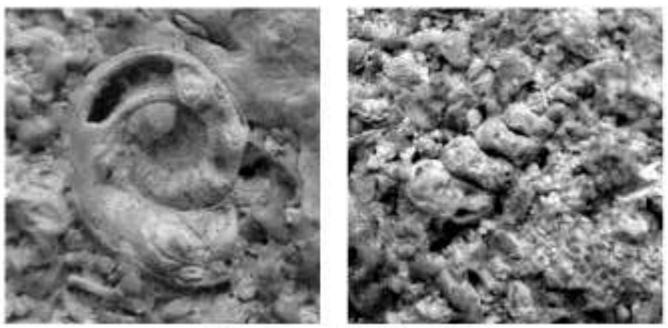
F1A: Coral	**F2A: Gastropod**	**F2B: Gastropod**	**F3: Bivalve**
Sketch	Sketch	Sketch	Sketch
Descriptive Adjectives	Descriptive Adjectives	Descriptive Adjectives	Descriptive Adjectives

Examine the six rocks listed in the table below. For each sample determine if the rock is composed of grains or crystals. If it is composed of grains, what kind of grains are most abundant (rounded grains, angular grains, ooids, fossils). Sketch the most diagnostic grain or crystal that you can see in the specimen. State whether each specimen is igneous or sedimentary.

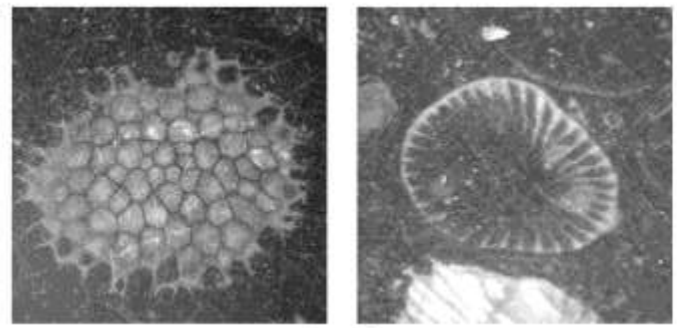
G3	**G4**	**G6**	**F5**	**C2**	**C3**
Crystal or Grain?	Crystal or Grain?	Crystal or Grain?	Crystal or Grain?	Crystal or Grain?	Crystal or Grain?
Type of Grain (If Applicable)	Type of Grain (If Applicable)	Type of Grain (If Applicable)	Type of Grain (If Applicable)	Type of Grain (If Applicable)	Type of Grain (If Applicable)
Diagnostic Sketch	Diagnostic Sketch	Diagnostic Sketch	Diagnostic Sketch	Diagnostic Sketch	Diagnostic Sketch
Sedimentary or Igneous?	Sedimentary or Igneous?	Sedimentary or Igneous?	Sedimentary or Igneous?	Sedimentary or Igneous?	Sedimentary or Igneous?

Examples of Fossils that Are Common in Limestone

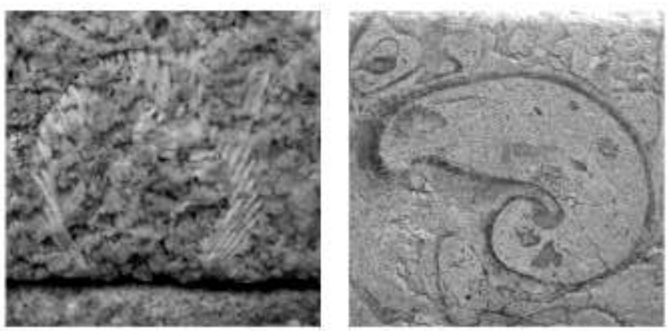
Bryozoans



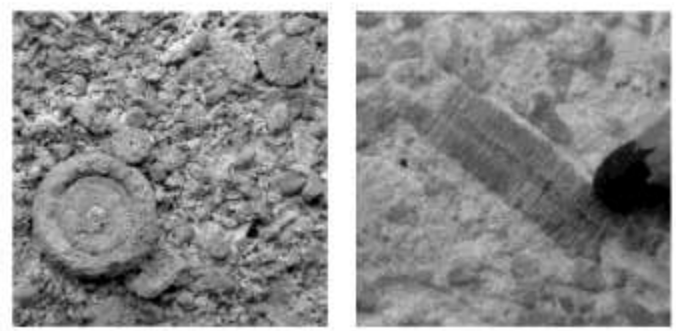
Gastropods (Snails)



Corals



Bivalves (Clams, Oysters)



Crinoids

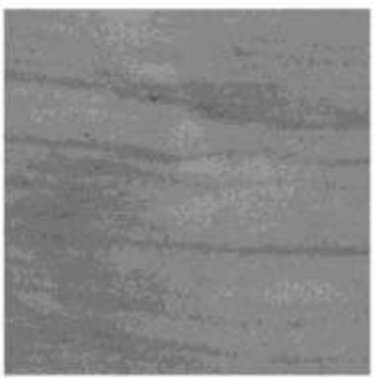
Layering: A Common Rock Fabric

Another easily definable attribute of rocks that will help you to classify rocks is the presence or absence of some form of layering in the rock. Sedimentary rocks very commonly exhibit layering that can be defined by changes in the color or size of the grains. This layering is called bedding. Changes in grain size occur due to changes in energy of the water (or wind) when the sediments were accumulating; faster moving water will carry away larger grains than will slow moving water. Changes in energy may be due to environmental factors such as storms of seasonal weather patterns (e.g., spring runoff). Changes in color of beds reflect changes in chemical or mineral composition.

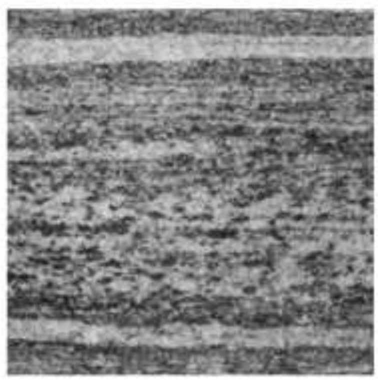
Metamorphic rocks commonly contain minerals such as micas and amphiboles that are aligned parallel to each other, producing a form of layering (foliation). Extreme metamorphism can lead to the development of a gneiss, a rock characterized by the segregation of minerals into distinct layers, typically bands of light minerals (quartz and feldspars) and dark minerals (biotite and amphibole). Deformation of the rock during metamorphism commonly results in the folding of metamorphic layering.

Since layering is very rare in igneous rocks, the presence of banding in a rock is evidence that the rock is likely a sedimentary or metamorphic rock. Examining a layered rock to determine whether it is composed of grains or crystals will allow you to classify it as a sedimentary or metamorphic rock, respectively.

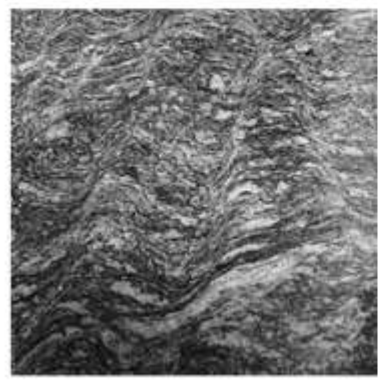
Examples of Rock Fabrics



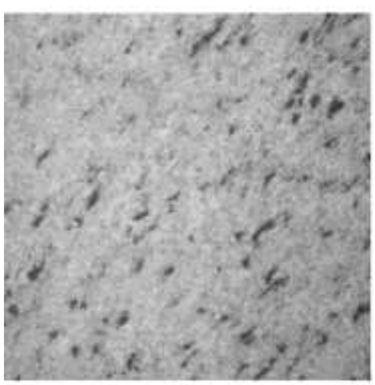
Bedding in sandstone



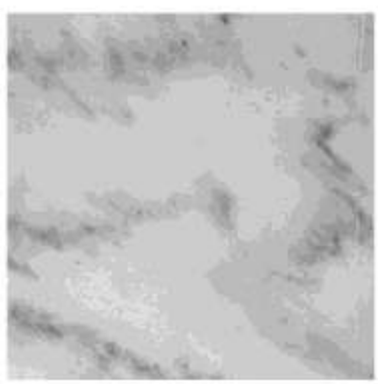
Banded gneiss



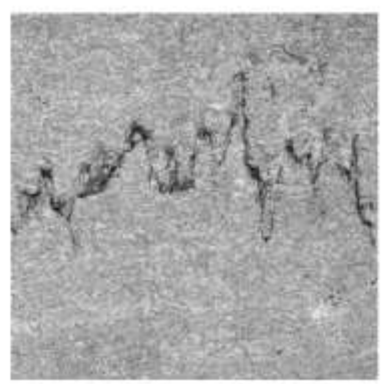
Folded Gneiss



Foliated granite with aligned amphibole crystals



Wispy, folded layers in marble



Stylolite in a grainy limestone

Examine the three layered samples (L1, L2 and L3), and determine if the rock is sedimentary (with bedding) or metamorphic (with gneissosity). State your evidence.

L1	L2	L3
Sedimentary or Metamorphic?	Sedimentary or Metamorphic?	Sedimentary or Metamorphic?
Evidence	Evidence	Evidence

Classification of Plutonic Igneous Rocks

Plutonic igneous rocks are classified based upon their chemical composition, which is reflected in their color. Rocks that are low in iron and calcium are light in color and are composed predominantly of white and/or pink feldspars and quartz. Rocks that are rich in iron and calcium are dark in color, and are composed predominantly of grey feldspars and black or green minerals such as amphibole, pyroxene or olivine. Based on this simple color-based scheme, three distinct plutonic rocks can be identified:

- **Granite**: a light-colored (felsic) intrusive rock with crystals of quartz, white feldspar, pink feldspar, and mica
- **Granodiorite**: an intermediately colored intrusive rock composed of light colored white to light grey feldspar and dark green to black amphibole and/or biotite. The mix of light and dark minerals gives the rock a coarse “salt-and-pepper” appearance.
- **Gabbro**: a dark-colored (mafic) intrusive rock that consists of dark grey feldspar and black to dark green Fe-rich minerals such as amphibole and pyroxene.

Stone-workers and sculptors apply a different definition of granite. To them granite is any hard rock that contains crystals. These dual definitions of “granite” explain why, for example, the Brooklyn Museum of Art labels ancient Egyptian sculptures that are carved from gabbro as being composed of “black granite”. To a geologist, the term “black granite” would be an oxymoron, since by definition granite must be light colored. A stone mason’s definition of granite would also include the banded metamorphic rock called gneiss.

Sample C3 is: Granite Diorite Gabbro (circle one)

Limestone and Marble

Limestone is a sedimentary rock that is composed predominantly of the mineral **calcite** (calcium carbonate; $CaCO_3$). Most limestone forms in shallow, tropical, marine environments, and a common component of limestones are the calcium carbonate skeletons of animals that live in these settings. Accordingly, limestones can often be identified by the presence of marine fossils such as **bivalves** (e.g., clams), **corals**, and the coiled shells of **gastropods** (snails). Other common fossil organisms that are less familiar to most people include bryozoans and crinoids. Fossils of **bryozoans** commonly look like small pieces of lace or like a corkscrew (see following photo plate). The most common fossil remains of **crinoids** are the discs that once comprised the stalk of this animal; in rocks these fossils look like small buttons or poker chips (see following photo plate). Another distinct type of grain that is common in limestone is an **ooid**, a BB-sized spherical or ellipsoidal grain that is composed of concentric bands of calcite around a central sand grain (see Examples of Grainy Textures Plate). Ooids form in very shallow marine environments where waves agitate and roll sand grains, allowing them to be coated on all sides by calcite precipitates. As with other sedimentary rocks, limestones commonly exhibit **bedding**.

Calcite is a relatively soluble mineral. (Remember that a diagnostic property of calcite is that it effervesces with dilute acids.) Ground water seeping through limestone may result in local dissolution to form caves and caverns. The weight of overlying rock may cause the roofs of such caves to collapse, filling the caves with broken pieces of limestone with irregular, angular shapes. When such deposits of broken rock are cemented together, they form a rock called **breccia** in which the irregular, angular fragments are still evident (see Examples of Grainy Textures Plate). Pressure increases the solubility of calcite, and so the burial of limestones may result in the formation of **stylolites**, a distinctive form of highly localized dissolution defined by a dark, irregular, zigzag discontinuity in the rock that looks like an irregular pencil line on the rock (see Examples of Rock Fabrics plate).

If a limestone is deeply buried then it will metamorphose to become a **marble**. During the process of metamorphism, the calcite (and/or dolomite) grains in the limestone will recrystallize, grow larger, and form crystals. Primary features such as fossils and ooids are usually destroyed in this process, leaving a more uniform rock in which the calcite occurs as polygonal, interlocking crystals that commonly have a sugary appearance. Layering such as bedding or stylolites (see Examples of Rock Fabrics plate) that once existed in the limestone precursor may be deformed and diffused, forming a wispy, "marbled" pattern (see Examples of Rock Fabrics plate).

To a geologist a marble is a metamorphosed limestone. However, to an architect, stone mason, or sculptor, a marble is defined as any soft rock that will take a polish. This includes marbles, as well as densely-packed limestones, and some less common rocks such as serpentinites. This difference in the specific meaning of the word "marble" commonly leads to confusion. Some of the most common stones that are referred to as marble by builders, are actually not metamorphosed and retain primary features such as fossils, ooids, and bedding. To determine whether a polished soft rock is a true marble, you must examine the components and fabrics of the rock carefully. Are there fossils or ooids that would indicate that it is a limestone? Are there angular fragments that would indicate that it is a breccia? Or are there polygonal or sugary crystals of calcite, and wispy marbling that are characteristic of a true marble?

What color are the stylolites in Sample L4? ________________________________

Based on the color, what mineral is likely concentrated along these stylolites? ____________

What other evidence is there in this sample that indicates that it is a limestone rather than a marble?

____

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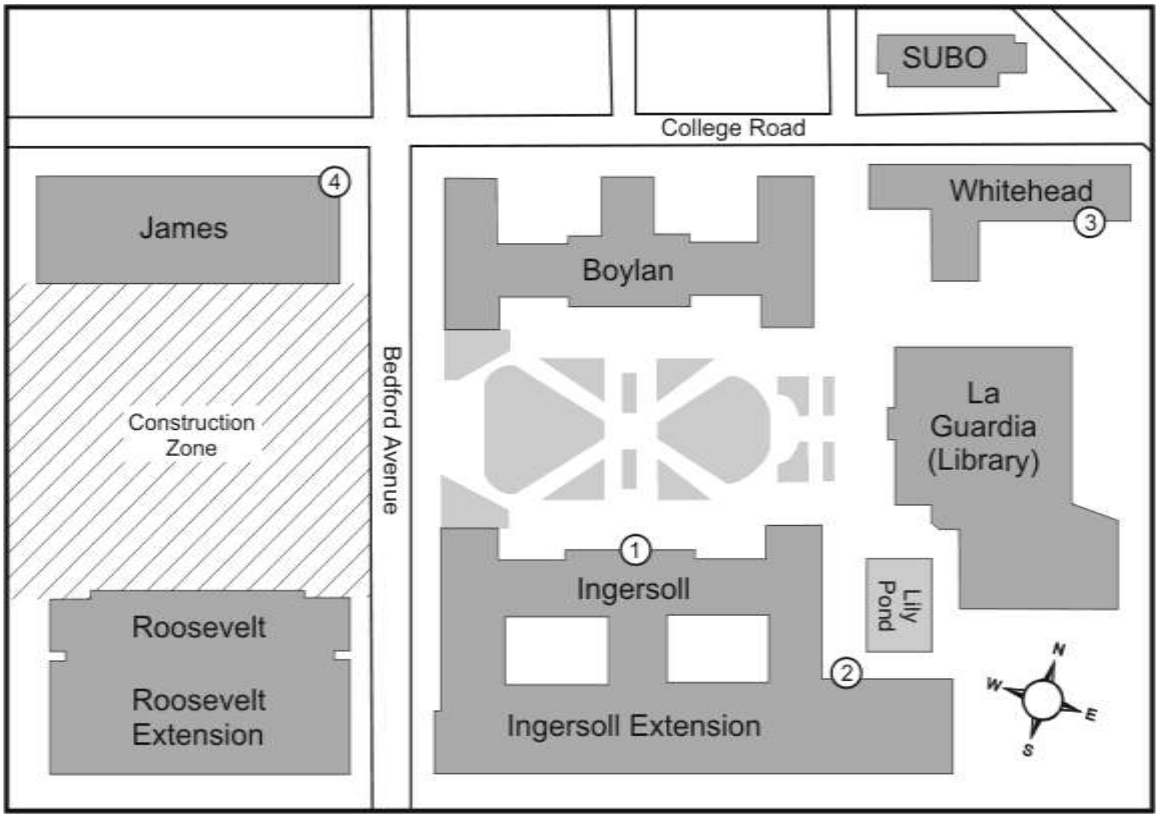
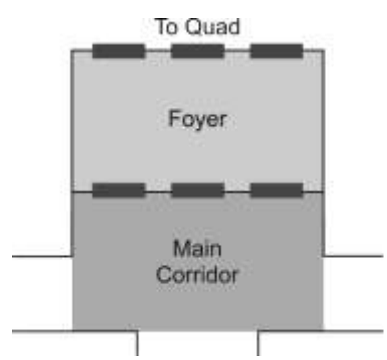
The Field Trip



Station 1: Ingersoll Hall Foyer and Main Corridor

The foyer and main corridor immediately inside of the main doors of Ingersoll Hall are lined with four examples of polished stone that would be classified as marble by a stone mason or architect. The foyer contains a pinkish-tan stone on the walls, and a pink-grey stone on the corners and decorative false columns. The main corridor contains a medium grey stone on the walls and a deep pink stone on the corners and decorative false columns.

Examine each of the three stones listed below and determine whether each of these building stones is a limestone or a true marble (metamorphosed limestone). Document your evidence and provide sketched of the diagnostic features.



Main Corridor Grey Stone: Limestone Marble (Circle One)

Supporting Evidence 1: ____

Supporting Evidence 2: ____

Supporting Evidence 3: ____

Sketch 1	Sketch 2	Sketch 3

Foyer Pinkish-Tan Wall Stone: Limestone Marble (Circle One)

Supporting Evidence 1:

____

____

Supporting Evidence 2:

____

____

Sketch 1	Sketch 2

Foyer Pink-Grey Corner Stone: Limestone Marble (Circle One)

Supporting Evidence 1:

____

____

Supporting Evidence 2:

____

____

Sketch 1	Sketch 2

Station 2: Ingersoll Extension Steps by the Lily Pond

Sketch 1

Examine the components of the multi-colored rock that comprises the steps to Ingersoll Extension. What are the grains? Sketch characteristic grains.

Pebbles Fossils Crystals (Circle all that apply)

Identify the rock (Circle One):

Sandstone Limestone Marble Granite Gneiss

Describe Your Supporting Evidence:

____

____

____

Station 3: Wall of Whitehead Hall

Examine the pale beige rock that covers the lower walls of Whitehead Hall.

Run your hand along the surface of this unpolished rock. Describe how it feels.

____

What are the rusty-orange bands within the pale beige rock?

Bedding Gneissosity Stylolite (Circle One)

Identify the pale beige rock: Sandstone Limestone Marble Granite Gneiss (Circle One)

Describe Your Supporting Evidence:

____

____

____

Station 4: Wall around James Hall

The 3 to 4 foot wall around James Hall is composed of two rocks. Most of the wall is covered with a pale beige rock. The lowest 6 to 12 inches of the wall is composed of a multi-colored rock. Examine these two rocks and answer the following questions:

Examine the components that comprise the **beige rock**. What are the grains? Sketch characteristic examples.

Sand Fossils Crystals (Circle all that apply)

Sketch 1 | Sketch 2

Is the **beige rock** metamorphosed? Yes No (Circle One)

Describe Your Supporting Evidence:

Identify the **beige rock**: Sandstone Limestone Marble Granite Gneiss (Circle One)

Describe Your Supporting Evidence:

Examine the grains within the **multi-colored rock** at the base of the wall. What are the grains? Sketch characteristic grains.

Sand Fossils Crystals (Circle all that apply)

Has this rock been metamorphosed? Yes No (Circle One)

Identify the beige rock (Circle One):

Sandstone Limestone Marble Granite Gneiss

Sketch 1

Describe Your Supporting Evidence:

____

____

____

Which of the two rocks in this wall is more resistant to weathering and erosion?

Top of Wall Base of Wall (Circle One)

Describe Your Supporting Evidence:

____

____

____