Name: **Grade:**

GEOL 101 - Physical Geology Laboratory
Sedimentaryand Metamorphic Rocks – Lab #6

PRELAB SECTION – To be completed before labs starts:

I. Introduction & Purpose:

The purpose of this laboratory exercise is to become familiar with identifying common sedimentary and metamorphic rocks and understanding their origin. In this lab you will learn to identify sedimentary and metamorphic rocks in hand samples from their physical properties. You will become familiar with the most common sedimentary and metamorphic rock-forming minerals and processes. The nature and origin of sedimentary and metamorphic rocks, the major types of sedimentary and metamorphic rocks, and their structures, and the connection between plate tectonics and sedimentary and metamorphic rocks in the rock cycle will be explored.

II. General Overview and Classification of Sedimentary Rocks

A. The classification of sedimentary rocks is based upon two major criteria (see page 110 in text)

1. Texture = grain size and rock "fabric"

2. Composition = mineralogy

Sedimentary rocks are divided into **three major groups**:

1) Detrital clastic

2) Biochemical crystalline

3) Chemical crystalline

Detrital sedimentary rocks consist of sediment grains (called clasts) that are cemented together; these rocks have a "**clastic**" sedimentary texture. The sediment grains consist of one or more mineral crystals that come from the weathering and erosion of preexisting source rock, such as granite or volcanic rock; any source rock type is possible. Detrital sedimentary rocks are classified primarily upon grain size, e.g. sand(-sized)stone versus silt(-sized)stone.

In contrast, **biochemical** and **chemical** sedimentary rocks consist mainly of mineral crystals that have crystallized directly out of aqueous solutions (water), either secreted by living organisms (biochemical), or by inorganic precipitation (chemical), respectively. Most of these chemically derived sedimentary rocks have a "**crystalline**" sedimentary texture, much like that of igneous rocks. Biochemical and chemical sedimentary rocks are classified primarily upon mineral composition, e.g. limestone ($CaCO_3$) versus chert (SiO_2).

B. Grain Size and Texture: Examine **Figures 6.1 and 6.2** (pages 111-112) in your lab manual. These images of sediment grains and the major sedimentary rock types show the variation in sediment textures and chemical compositions by which sedimentary rocks are classified.

The 6 types of sedimentary grain sizes and the textures (1st column of Fig. 6.1)

	Grain Size Name	Grain Size Description Notes **(Not mandatory)**
1.	Gravel-size	
2.	Sand-size	
3.	Silt-size	
4.	Clay-size	
5.	Microcrystalline	
6.	Macrocrystalline	

C. Grain Shape: Detrital grains are typically rock fragments that have been weathered and eroded from pre-existing rock and transported, over time, a certain amount of distance from its source. As a general rule of thumb, the farther and longer the grains have been transported form their source, the more rounded they become. Thus, the detrital grain shape gives an

indication of its "**maturity**" in the sedimentary cycle.

1. List the three types of sediment grain ***shapes*** exhibited in detrital rocks (2nd column of Fig 6.1)

Detrital Grain Shapes

1. _____ 2. _____ 3. _____

2. Question: Which grain shape type would you expect to be the *least* "mature"? Why?

3. Question: Which grain shape type would you expect to be the *most* "mature"? Why?

D. Grain Arrangements: Transported sediment grains become sorted (according to size), over time, as the fluid mediums that transport them, such as running water and wind, selectively deposit some grains while continuing to carry the smaller grains ever greater distances from the source region. The causes for sorting include systematic variation in flow rate and turbulence of the transporting medium over distance and time. As a general rule of thumb, greatest sorting occurs within consistently medium to high energy transport mediums over long periods of time (effective winnowing of sediment), whereas the conditions of poorest sorting occurs where either, flow rate changes drastically or is very inconsistent (effective dumping of sediment). Additionally, non-fluid transport mediums such as glaciers do not have the capability to sort sediment by size, and therefore sediments directly deposited by glaciers are virtually unsorted.

1. **List** the three types of sediment grain ***arrangement****s* found in detrital rocks (3rd column of Fig 6.1)

Detrital Grain Arrangements

1. _____ 2. _____ 3. _____

E. Composition of Sedimentary Rocks: The mineral composition of a sedimentary rock is a reflection of 1) **source material** and 2) **sedimentary processes**. Sources include virtually all types of geologic, biologic, hydrologic, and cosmologic materials such as: 1) land-derived materials such as weathered and eroded igneous, metamorphic and sedimentary rocks; 2) hard-part remains (shells) of marine organisms; and 3) seawater chemical precipitates. Sedimentary lithification processes, termed "diagenesis" can both, alter and add chemicals and minerals to the rock, such as rock cement. A review of the composition of all the major sedimentary rock types shows a surprising conclusion: *that there are only a small number of major sedimentary rock-forming minerals and rock fragment detrital types*. The vast bulk of sedimentary rocks have one or more of the following mineral constituents: quartz/ silica, feldspar, mica, clay, iron oxide, amphibole, calcium carbonate, and various minor amounts of sulfate, phosphate, and halide minerals. The primary reason for this compositional simplicity, compared to those of igneous and metamorphic rocks, is the fact that most of the sedimentary rock-forming minerals are stable or meta-stable at Earth surface conditions; many of the igneous and metamorphic rock-forming minerals are unstable at the surface and with sufficient time will alter to minerals such as the clays, silica, and carbonates.

The major source materials for each of the three sedimentary rock types (see Figure 6.2 page 114)

Detrital (Clastic-origin)

1. Rock fragments 2. Quartz 3. Feldspar 4. Clay 5) Dark silicates and oxides

Biochemical (Organic-origin)

1. Shells and Shell and coral fragments (carbonates and silica) 2. Carbon and Charcoal

Chemical (Inorganic-origin)

1. Calcite 2. Dolomite 3. Quartz 4. Gypsum 5. Halite 6. Iron-bearing minerals

1. Question: Clay is the most common sedimentary mineral. How is it derived? Why so much?

2. Question: Calcium carbonate is another major sedimentary constituent. How is it derived?

F. Naming the Detrital Rocks: Detrital rocks are named based primarily upon their grain size, while their composition, which is a reflection of the source rocks and subsequent weathering erosion history, is secondary to naming a detrital rock, e.g. arkose and wacke.

1. The five major **detrital** (clastic) rock types that are based on grain size and shape. List the grain size and typical mineral(s)/material(s) associated with that rock type. Note: siltstone and shale are lumped together as "mudstones". (See top of Figure 6.8, page 118).

	Rock Name	**Grain Size**	**Texture and Distinctive properties**
1.	Breccia		
2.	Conglomerate		
3.	Sandstone		
4.	Siltstone		
5.	Shale		

2. List four types of cement that bond sediment grains together in detrital rocks (Fig. 6.4, page 114)

a. _____ b. _____ c. _____ and d. _____

3. Question: How might you test whether calcite is the cementing agent in sandstone?

4. Question: Based on your experience with mineral hardness, which of the above bonding agents would you expect to be the strongest? The weakest?

G. Naming of Biochemical Rocks: Biochemical rocks are named based primarily upon their composition, e.g. calcium carbonate fossil shell or plant material, and secondarily upon their texture, e.g. sandy, shelly, crystalline, microcrystalline, etc. Limestone is a sedimentary rock named primarily for being rich in calcium carbonate. The types of limestone are named by the type and texture of the calcium carbonate. As an example, coquina is a poorly cemented mass of large-sized shell fragments, whereas, chalk is a super fine-grained mass of microfossils.

1. Five major **biochemical rock** types are based primarily on mineral composition. List the distinctive mineralogy and texture of each rock type. (Middle section of Figure 6.8, page 116)

	Rock Name	***Rock Mineralogy***	***Textural and Distinctive properties***
1.	Coal		
2.	Coquina Limestone		
3.	Fossiliferous Limestone		
4.	Chalk Limestone		

H. Nomenclature of Chemical Rocks: Chemical sedimentary rocks are also named based primarily on composition. However, **all** chemical sedimentary rocks have **crystalline** textures that reflect their direct precipitation of ions from an aqueous fluid such as seawater.

1. Seven major **chemical** (inorganic) rock types that are based mainly on mineral composition, and describe the distinctive properties of each rock type. (Bottom far-right column of Fig. 6.8 page 116)

Rock Name	***Rock Mineralogy***	***Texture and Distinctive properties***
1. Oolitic Limestone		
2. Travertine Limestone		
3. Dolostone		
4. Rock salt		
5. Rock Gypsum		
6. Chert		

2. Question: What is the primary difference between a chemical and biochemical limestone?

III. Depositional Settings of Sedimentary Rocks

A. Sedimentary rocks retain a memory of the conditions in which they formed in, and that information is recorded by the rock's texture, composition, fossils, and structure. By observing and studying today's depositional environments and the type and structure of the sediments that collect there, we can infer the depositional setting and history of sedimentary rock assemblages by comparing their sedimentary characteristics to that of modern day depositional systems.

B. Examine **Figure 6.12** (page 128) in your lab manual. This illustration shows most of the major types of modern sedimentary environments where sediments are depositing and sedimentary rocks are forming. **Directions:** List the depositional environments where each type of sedimentary rock forms as shown in Figure 6.12 in your lab manual.

Sedimentary Rock	**List of Associated Depositional Environments**
1. Breccias and Conglomerates	
2. Sandstones	
3. Mudstones	
4. Limestones	
5. Cherts	
6. Rock Salt and Gypsum	

IV. General Overview and Classification of Metamorphic Rocks

A. Defining Metamorphism:

Directions: Answer the following (from lecture and lab text: see page 133):

1) Define "metamorphism" _____

2) Every metamorphic rock has a _____ rock (or protolith) - the original rock type that was metamorphosed into the resultant metamorphic rock, i.e. the source rock.

B. Conditions of Metamorphism:

Metamorphic rocks form as a result of changing crustal conditions, e.g. increasing pressures and/or temperatures, that are between that of igneous and sedimentary rock-forming environments.

1). The four major agents of change that cause rocks to metamorphose (see page 133):

a) _____ , b) _____ , c) _____ , and/or d) _____

C. Processes of Metamorphism:

Metamorphic processes that are forming the metamorphic rocks occur at various scales within the Earth, and the type of internal earth agents involved is used to define the type of metamorphism. One type is related to magmatism, and the other type is related to faulting and mountain building.

1) The two major types of metamorphism that are agent-dependent (page 134):

a) _____ , and b) _____

2) Question: Very briefly describe the differences between these two types of metamorphism:

_____

D. Classification and Identification of Metamorphic Rocks

1) Classification and identification of metamorphic rocks are based upon two major physical criteria - just like igneous and sedimentary rocks::

a) _____ , and b) _____

2) Metamorphic rocks are divided into two major groups based on whether the rock has a *layered* versus *non-layered* texture. See Figure 7.4, page 136. Special alternative names for these are:

a) Layered = _____ and b) Non-layered = _____

E. Foliated Metamorphic Rocks

1) Metamorphic rocks that possess a foliated and/or layered fabric have a crystalline texture consisting of elongate and/or platy crystals that all share a ***preferred orientation*** within the rock. Metamorphic rock s that have foliated/layered fabrics originate in two types of metamorphic environments: Regional Metamorphism (RM) and Dynamic Metamorphism (DM).

2) There are four common types of metamorphic rock s that have foliated-layered textures. Each foliation type is unique and represents a progressive increasing scale of intensity of regional metamorphism as go from slate to gneiss. The textural character of foliated and/or layered metamorphic rock can vary greatly as a function of 1) grain size, 2) degree of preferred orientation of the rock's mineral crystals, and 3) degree of layered segregation of light minerals from dark minerals.

3) The foliated/layered metamorphic rocks are classified primarily upon texture, with mineralogy a secondary criteria. There are four visually distinctive types of foliated rocks (listed below).

Directions: Describe the texture and mineralogy of the four foliated rock types (see Figure 7.15)

Rock Name	***Textural Features***	***Rock Mineralogy***
1. **Slate**	_____	_____
2. **Phyllite**	_____	_____
3. **Schist**	_____	_____
4. **Gneiss**	_____	_____

Please note that there are infinite shades of gray between these four types – no sharp divisions

F. Non-Foliated-Non-Layered Metamorphic Rocks

1) Metamorphic rocks that have non-foliated (non-layered) textures originate in two types of metamorphic environments: regional metamorphism (RM) and contact metamorphism (CM). **Note** that the nonfoliated metamorphic rocks that form by regional metamorphism RM are mostly *mono-mineralic (mostly of one mineral type)*, having mineral crystals that are neither platy nor tabular, such as quartz and calcite. Note that amphibolite and serpentinite may exhibit foliation.

2) As noted above, the non-foliated (non-layered) metamorphic rocks consist of equant shaped mineral crystals that have no preferred orientation or arrangement. These rocks have a massive, homogenous "crystalline" texture, much like that of either, *phaneritic* granite, or *aphanitic* basalt. The non-foliated metamorphic rocks are classified primarily upon mineral composition.

3) There are four common types of metamorphic rock s that have non-foliated/ non-layered fabrics: **Directions**: Describe the texture and mineralogy of the four non-foliated rock types (see Fig. 7.15)

Rock Name	***Textural Features***	***Rock Mineralogy***
1. **Quartzite**	_____	_____
2. **Marble**	_____	_____
3. **Amphibolite**	_____	_____
4. **Serpentinite**	_____	_____

SEDIMENTARY ROCKS IDENTIFICATION - IN-LAB SECTION

I. Preliminary Examination of the Sedimentary Rock Types:

A. Introduction: The instructor has assembled **3 reference collections** of sedimentary rocks for you to become familiarized with the three major types of sedimentary rocks.

Directions: Carefully study each rock's: 1) ***physical characteristics***, including texture and composition, and 2) ***sedimentary origin*** – the rock's original depositional environment. Make observational notes of the samples. Discuss your observations with your group.

B. The Detrital Rocks: Sample Collection "A"

Observational Notes

Sample # A1 – Conglomerate _____

Samples # A2 – Breccia _____

Samples # A3 and A4 – Sandstones _____

Samples # A5 – Siltstone _____

Samples # A6 and A7 – Shales _____

1 .Question: What is the primary difference between a breccia and a conglomerate?

C. The Biochemical Rocks: Sample Collection "B"

1. Directions: Carefully study the various samples of the biochemical rocks in your group. Make observational notes of the samples. Discuss with your group your observations and ideas, and the questions that are asked below. Note: Most bio-sedimentary rocks are fossil-rich limestone.

Observational Notes

Sample # B1 – Coal _____

Samples # B2 – Coquina (shelly) Limestone _____

Samples # B3, 4, 5 – Fossiliferous Limestone _____

Samples # B6 – Chalk _____

2. Questions: Which of the samples contain fossils you can see? _____

What types of fossils? _____

D. Chemical Rocks: Sample Collection "C"

1. Directions: Carefully study the various samples of the chemical rocks in your group. Make observational notes of the samples. Discuss with your group your observations and ideas, and the questions that are asked below. Note that most chemical sedimentary rocks are either limestone or chert; these rock types make "look" similar but have very different hardnesses.

Observational Notes

Sample # C1 – Travertine Limestone _____

Sample # C2 – Oolitic (Sandy) Limestone _____

Samples # C3 - Chert _____

Samples # C4 – Rock Salt _____

Samples # C5 – Rock Gypsum _____

2. Questions: Which of the "C" rocks fizzed in acid? _____ Which is very hard? _____

3. Question: Which of the above samples can be scratched by a fingernail? _____.

II. Classification of Sedimentary Rock Samples:

Introduction: Sedimentary rock classification is done in a systematic manner, utilizing a step-by-step procedure. Sedimentary rocks are identified based upon **1)** compositional make-up and **2)** textural and structural qualities. A sedimentary rock analysis and classification chart is shown in **Figure 6.8.**

The 3-step procedure for identifying sedimentary rock samples is as follows:

Step 1: Identify and record the rock's composition (rock fragments? minerals?, fossils?)
Step 2: Identify and record the rock's texture and other distinctive properties.
Step 3: Name the rock, including its most likely depositional setting

III. Analysis and Identification of 6 Unknown Sedimentary Rock Samples:

Directions: Identify the nine unknown sedimentary rock samples found in **sample Collection "D"**. Be sure to check the following information about the rock: **a)** Composition (circle one or more); **b)** Texture (grain type and size – circle one or more) **c)** Other distinguishing characteristics (fossils, layering, fizz in acid, etc); **d)** Rock name; **e)** Rock origin: Speculate as to what type of depositional environment the rock originated in? Depositional environments are shown in Figure 6.12, page 128

Sample# D1

a) Composition: Rock fragments; quartz; feldspar; clay; carbonate; fossils; gypsum; salt; carbon

b) Texture: Grain type? = Detrital; Biochemical; Chemical Grain size? = Very fine; Fine; Medium; Coarse

c) Other distinctive features _____

d) Rock name _____

e) Which depositional setting(s) did the rock form? _____

Sample# D2

a) Composition: Rock fragments; quartz; feldspar; clay; carbonate; fossils; gypsum; salt; carbon

b) Texture: Grain type? = Detrital; Biochemical; Chemical Grain size? = Very fine; Fine; Medium; Coarse

c) Other distinctive features _____

d) Rock name _____

e) Which depositional setting(s) did the rock form? _____

Sample# D3

a) Composition: Rock fragments; quartz; feldspar; clay; carbonate; fossils; gypsum; salt; carbon

b) Texture: Grain type? = Detrital; Biochemical; Chemical Grain size? = Very fine; Fine; Medium; Coarse

c) Other distinctive features _____

d) Rock name _____

e) Which depositional setting(s) did the rock form? _____

Sample# D4

a) Composition: Rock fragments; quartz; feldspar; clay; carbonate; fossils; gypsum; salt; carbon

b) Texture: Grain type? = Detrital; Biochemical; Chemical Grain size? = Very fine; Fine; Medium; Coarse

c) Other distinctive features _____

d) Rock name _____

e) Which depositional setting(s) did the rock form? _____

Sample# D5

a) Composition: Rock fragments; quartz; feldspar; clay; carbonate; fossils; gypsum; salt; carbon

b) Texture: Grain type? = Detrital; Biochemical; Chemical Grain size? = Very fine; Fine; Medium; Coarse

c) Other distinctive features _____

d) Rock name _____

e) Which depositional setting(s) did the rock form? _____

Sample# D6

a) Composition: Rock fragments; quartz; feldspar; clay; carbonate; fossils; gypsum; salt; carbon

b) Texture: Grain type? = Detrital; Biochemical; Chemical Grain size? = Very fine; Fine; Medium; Coarse

c) Other distinctive features _____

d) Rock name _____

e) Which depositional setting(s) did the rock form? _____

METAMORPHIC ROCKS IDENTIFICATION - IN-LAB SECTION

I. Preliminary Examination of the Metamorphic Rock Types:

A. Introduction: The instructor has assembled **2 reference collections** of metamorphic rocks for you to become familiarized with the two major types of metamorphic rocks: foliated and nonfoliated.

Directions: Carefully study each rock's: 1) ***physical characteristics***, including texture and composition, and 2) ***metamorphic origin***: the rock's metamorphic environment and parent rock. Make observational notes of the samples. Discuss your observations with your group.

II. Foliated-Non-Layered Metamorphic Rocks

A. Exercise 1 - **Sample Group "X"** has representative hand samples of each of the **foliated** rock types. Study each sample carefully and make some brief descriptions of the rock's character (texture, foliated fabric & minerals). Carefully study pages 137-139 for reference.

Observational Notes

Sample #s X1 and X2 = Slate _____

Sample #s X3 and X4 =Phyllite _____

Sample #s X5, and X6 = Schist _____

Sample #s X7 and X8 = Gneiss _____

B. Exercise 2 – Compare and contrast the foliated metamorphic rocks in **Sample Collection "X"**.

Question: How does slate differ from both phyllite and schist?

Question: How does gneiss differ from the other three foliated rocks?

Question: What are the main criteria you use to distinguish between these four rock types?

III. Non-Foliated-Non-Layered Metamorphic Rocks

A. Exercise 1 - **Sample Collection "Y"** has representative hand samples of the **nonfoliated** rock types. For each hand sample, briefly describe the rock's character (texture, fabric, minerals)

Observational Notes

Sample #s Y1 = Quartzite _____

Sample #s Y2 = Marble _____

Sample #s Y3 = Amphibolite _____

Sample #s Y4 = Serpentinite _____

B. Exercise 2 – Compare and contrast nonfoliated metamorphic rocks in **Sample Collection "Y"**.

Question: How does quartzite differ from marble? How are they similar?

Question: How does amphibolite differ from serpentinite? How are they similar?

Question: What are the main criteria you use to distinguish between these four rock types?

IV. Procedure for Describing and Identifying Metamorphic Rocks:

A 4-Step chart for the analysis and classification of metamorphic rocks is found in Figure 2.33 on page 32 . Use this chart, and the additional directions found on page 32 to help you learn to identify metamorphic rocks both, in hand sample and in the field.

A. Four-step Identification Procedure - A brief description of the 4 determinant steps:

Step 1: Texture = a) Foliated or Non-Foliated? AND b) Coarse-, medium-, or fine-grained?

Step 2: Rock Composition = Identifiable Minerals?

Step 3: Name the Rock.

Step 4: Name the Most Likely Parent Rock.

V. Identifying 6 Unknown Metamorphic Hand Samples

Instructions: **Sample Collection "Z"** has nine unknown metamorphic rock samples. Using the 4-step procedure outlined above, complete the worksheet chart below for all eight unknown samples. Be sure to Circle only the appropriate texture and mineralogy. List rock name and parent rock.

Unknown Metamorphic Rock Hand Samples Worksheet – Collection "Z"

Sample# Z1

a) Texture: Foliated or Non-foliated? ***AND*** Fine-Grained. or Medium-Gr. or Coarse-Gr.?

b) Mineralogy: Quartz; Feldspar; Mica; Amphibole; Carbonate; Garnet; Serpentine; None Obs.

c) Other distinctive features = _____

d) Rock name _____

e) Most likely parent rock _____

Sample# Z2

a) Texture: Foliated or Non-foliated? ***AND*** Fine-Grained. or Medium-Gr. or Coarse-Gr.?

b) Mineralogy: Quartz; Feldspar; Mica; Amphibole; Carbonate; Garnet; Serpentine; None Obs.

c) Other distinctive features = _____

d) Rock name _____

e) Most likely parent rock _____

Sample# Z3

a) Texture: Foliated or Non-foliated? ***AND*** Fine-Grained. or Medium-Gr. or Coarse-Gr.?

b) Mineralogy: Quartz; Feldspar; Mica; Amphibole; Carbonate; Garnet; Serpentine; None Obs.

c) Other distinctive features = _____

d) Rock name _____

e) Most likely parent rock _____

Sample# Z4

a) Texture: Foliated or Non-foliated? ***AND*** Fine-Grained. or Medium-Gr. or Coarse-Gr.?

b) Mineralogy: Quartz; Feldspar; Mica; Amphibole; Carbonate; Garnet; Serpentine; None Obs.

c) Other distinctive features = _____

d) Rock name _____

e) Most likely parent rock _____

Sample# Z5

a) Texture: Foliated or Non-foliated? ***AND*** Fine-Grained. or Medium-Gr. or Coarse-Gr.?

b) Mineralogy: Quartz; Feldspar; Mica; Amphibole; Carbonate; Garnet; Serpentine; None Obs.

c) Other distinctive features = _____

d) Rock name _____

e) Most likely parent rock _____

Sample# Z6

a) Texture: Foliated or Non-foliated? ***AND*** Fine-Grained. or Medium-Gr. or Coarse-Gr.?

b) Mineralogy: Quartz; Feldspar; Mica; Amphibole; Carbonate; Garnet; Serpentine; None Obs.

c) Other distinctive features = _____

d) Rock name _____

e) Most likely parent rock _____

IV. SEDIMENTARY AND METAMORPHIC ROCK LABORATORY REFLECTION

Directions: Write a 120 word minimum reflection of the lab activity, explaining its purpose, the methods used, the results obtained, and a brief personal reflection of what you enjoyed and learned about doing this lab (*3 points possible*). Answer the following 3-point question reflection set on a separate sheet of paper:

1) *What was the purpose of this lab? What did you actually discover and learn during this lab?*

2) *What did you enjoy most about this lab? Also, what was challenging or thought-provoking?*

3) *What are your constructive comments about the design and execution of this lab? What's good? What's bad? Offer suggestions for making the lab better.*