ES202 Lab 3 - Sedimentary Rock Analysis and Classification

Update Jan 21, 2012

Part 1 A. Cambridge Intro Rock Video Questions

(ROCKSandMINERALS_cambridge_science.mpeg; Time Mark: 12:40)

1. What is the definition of a "rock"

2. What are the three basic types of rocks?

3. How do igneous rocks form?

4. How do extrusive or volcanic igneous rocks form?

5. How do intrusive or plutonic igneous rocks form? Provide a common example of an intrusive rock?

6. What are sedimentary rocks? Where do they form and why?

7. List four types of surface environments in we find sediments that form sedimentary rocks?

8. What are the two types of sedimentary rocks?

9. In detrital sedimentary rocks, what is the difference between gravel, sand, silt and clay? What is the distinguishing characteristic?

10. Provide an example of biochemical or chemical sedimentary rocks. How are chemical rocks classified?

(End Video on Time Mark 18:53)

Part 1B. Sedimentary Rock Video Exercise (Earth Revealed: Sedimentary Rocks)

Watch the video in the lab and answer the questions below.

1. Who first explored the geology of the Grand Canyon? How did the Grand Canyon form?
2. How many years of Earth history are contained in the sedimentary rocks of the Grand Canyon?
3. What is the general goal of sedimentary geology?
4. What is sediment? How is it formed?
5. List and describe 3 examples of loose sediment at the Earth's surface.
6. How is loose sediment transformed into hard sedimentary rock?

7. True or False: sedimentary rocks most commonly occur inside the Earth, while igneous rocks are common at the Earth's surface. Explain your answer.

8. Define the term "clastic".

9. What is the smallest size of sediment particle called? What is the largest size of sediment particle called?

10. List and briefly describe 2 examples of how sediment may be transported at the Earth's surface.

11. List and describe 3 places at the Earth's where you would likely find sediment deposits. Why do you find deposits in these places?

12. Define the term "lithification". What are 2 processes that result in lithification of sediment?

13. List and describe 2 environments where chemical sediments may form.

14. What is the name of a sedimentary rock that forms from the skeletons and hard parts of dead sea animals?

15. Where does coal form? What is coal composed of?

16. What is the motto for the "principle of uniformitarianism"? What is the principle of uniformity and how is it used to interpret Earth history?

End Video at Uniformitarianism.

Part 2. Recognition of Sedimentary Process **(refer to 9th Edition of AGI Lab Manual)**

1-1. Based on your pre-lab questions and **p. 130** of your lab manual, match the sedimentary process term on the right with the sedimentary rock on the left.

______1. Sandstone
______2. Conglomerate
______3. Shale
______4. Rock Gypsum
______5. Coral Reef Deposits
______6. Sand on the beach
______7. Bonneville Salt Flats of Utah
______8. Shells on the beach
______9. Coal
______10. Breccia

A. Detrital Origin (weathering / fragmental)
B. Biochemical (biologically-derived rock)
C. Chemical (Physical-Chemical Process)

Part 3. General Questions on Sedimentary Texture

2-1. Using the attached grain size chart and the Wentworth scale, determine the grainsize of the following detrital sedimentary rock samples (derive the grainsize to the level of fine sand, medium sand, etc.)., and determine the sorting (well sorted, moderately sorted, poorly sorted).

Sample No.	Grainsize (list ~diameter and term)	Sorting
11	__________________	__________________
9B	__________________	__________________
15	__________________	__________________
4	__________________	__________________
6	__________________	__________________
14	__________________	__________________
Sample Jar S2-1	__________________	__________________
Sample Jar S2-7	__________________	__________________

2-2. Compare and contrast the sedimentary texture of sample 11 and sample 4. Which one do you think has sediment that was more greatly transported during it's formation?

2-3. Observe the characteristics of sample 35. Is this detrital or biochemical? What is this specimen?

2-4. Examine the deposit in the beaker labeled "2-4". Explain how this deposit formed. Is it chemical or detrital?

Part 4. Sedimentary Rock Identification

Using the sedimentary rock analysis and identification key on **p. 129 and p. 131** of the lab manual, complete the table on the following page.

Sample Number	**Detrital, Chem., or Biochem?**	**Composition:** choose all that apply: quartz, feldspar, clay, plant frags., calcite, halite, gypsum, iron minerals	**Grain Size** (for detrital) / **Crystal Size** (for chemical / biochemical)	**Other Characteristics** (e.g. fossils, grain shape, fizzes with HCl, scratchable, taste, etc.)	**Rock Name**
30					
1B					
14					
9B					
11					
8					
3					
13					
31					
32					
20					
16					
2					
7					
15					
12					
10					
6					
37					
4					

TABLE 5.2 Methods of measuring sediment grain size

Type of sample	Sample grade	Method of analysis
Unconsolidated sediment	Boulders Cobbles Pebbles	Manual measurement of individual clasts
	Granules Sand Silt	Sieving or settling tube analysis
	Clay	Pipette analysis, photohydrometer, Coulter counter
Lithified sedimentary rock	Boulders Cobbles Pebbles	Manual measurement of individual clasts
	Granules Sand Silt	Thin-section measurement
	Clay	Electron microscope

TABLE 5.1 Grain-size scale for sediments, showing Wentworth size classes, equivalent phi (ϕ) units, and sieve numbers of U.S. Standard Sieves corresponding to various millimeter and ϕ sizes

	U.S. Standard sieve mesh	Millimeters		Phi (ϕ) units	Wentworth size class
GRAVEL		4096		−12	
GRAVEL		1024		−10	Boulder
GRAVEL		256	256	− 8	
GRAVEL		64	64	− 6	Cobble
GRAVEL		16		− 4	Pebble
GRAVEL	5	4	4	− 2	
GRAVEL	6	3.36		− 1.75	
GRAVEL	7	2.83		− 1.5	Granule
GRAVEL	8	2.38		− 1.25	
GRAVEL	10	2.00	2	− 1.0	
SAND	12	1.68		− 0.75	
SAND	14	1.41		− 0.5	Very coarse sand
SAND	16	1.19		− 0.25	
SAND	18	1.00	1	0.0	
SAND	20	0.84		0.25	
SAND	25	0.71		0.5	Coarse sand
SAND	30	0.59		0.75	
SAND	35	0.50	½	1.0	
SAND	40	0.42		1.25	
SAND	45	0.35		1.5	Medium sand
SAND	50	0.30		1.75	
SAND	60	0.25	¼	2.0	
SAND	70	0.210		2.25	
SAND	80	0.177		2.5	Fine sand
SAND	100	0.149		2.75	
SAND	120	0.125	⅛	3.0	
SAND	140	0.105		3.25	
SAND	170	0.088		3.5	Very fine sand
SAND	200	0.074		3.75	
SAND	230	0.0625	1/16	4.0	
MUD – SILT	270	0.053		4.25	
MUD – SILT	325	0.044		4.5	Coarse silt
MUD – SILT		0.037		4.75	
MUD – SILT		0.031	1/32	5.0	
MUD – SILT		0.0156	1/64	6.0	Medium silt
MUD – SILT		0.0078	1/128	7.0	Fine silt
MUD – SILT		0.0039	1/256	8.0	Very fine silt
MUD – CLAY		0.0020		9.0	
MUD – CLAY		0.00098		10.0	Clay
MUD – CLAY		0.00049		11.0	
MUD – CLAY		0.00024		12.0	
MUD – CLAY		0.00012		13.0	
MUD – CLAY		0.00006		14.0	

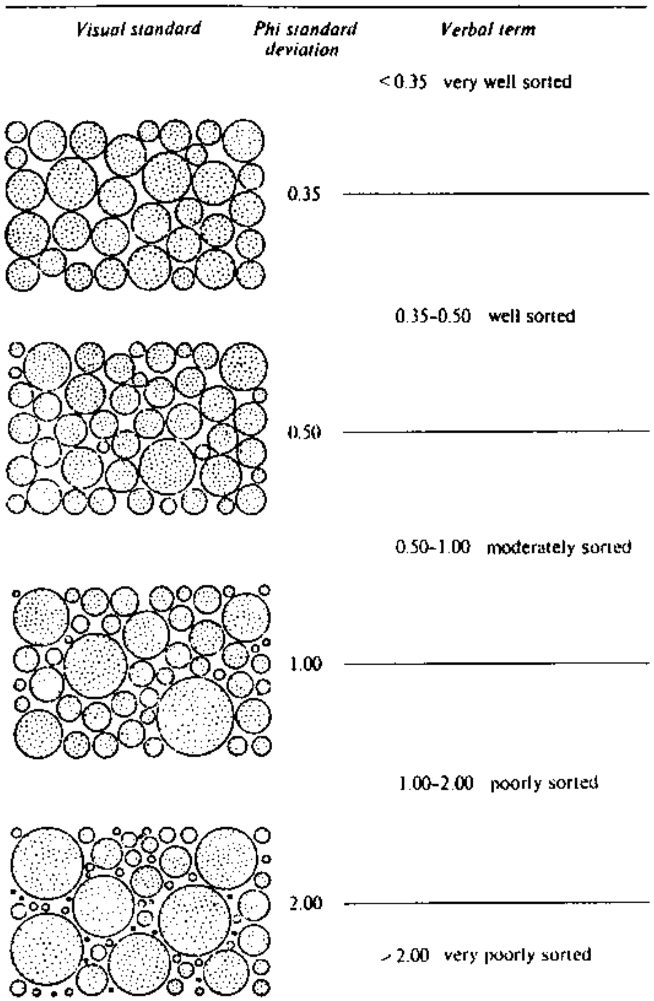


Figure 6.4 Chart for the field estimation of sorting (modified from Folk 1968).

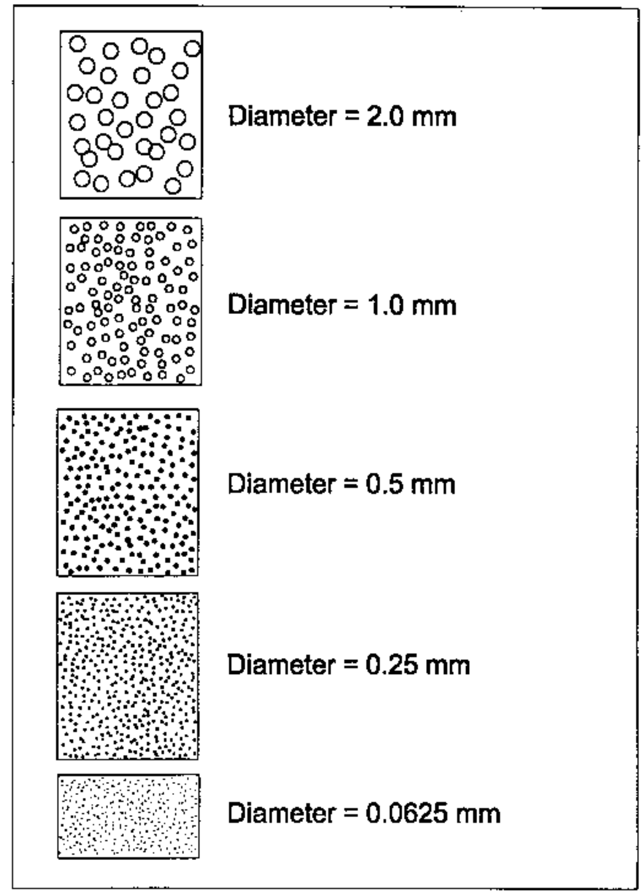


FIGURE 6.2 Compositional classification of sedimentary rocks. Scale for all images is ×1

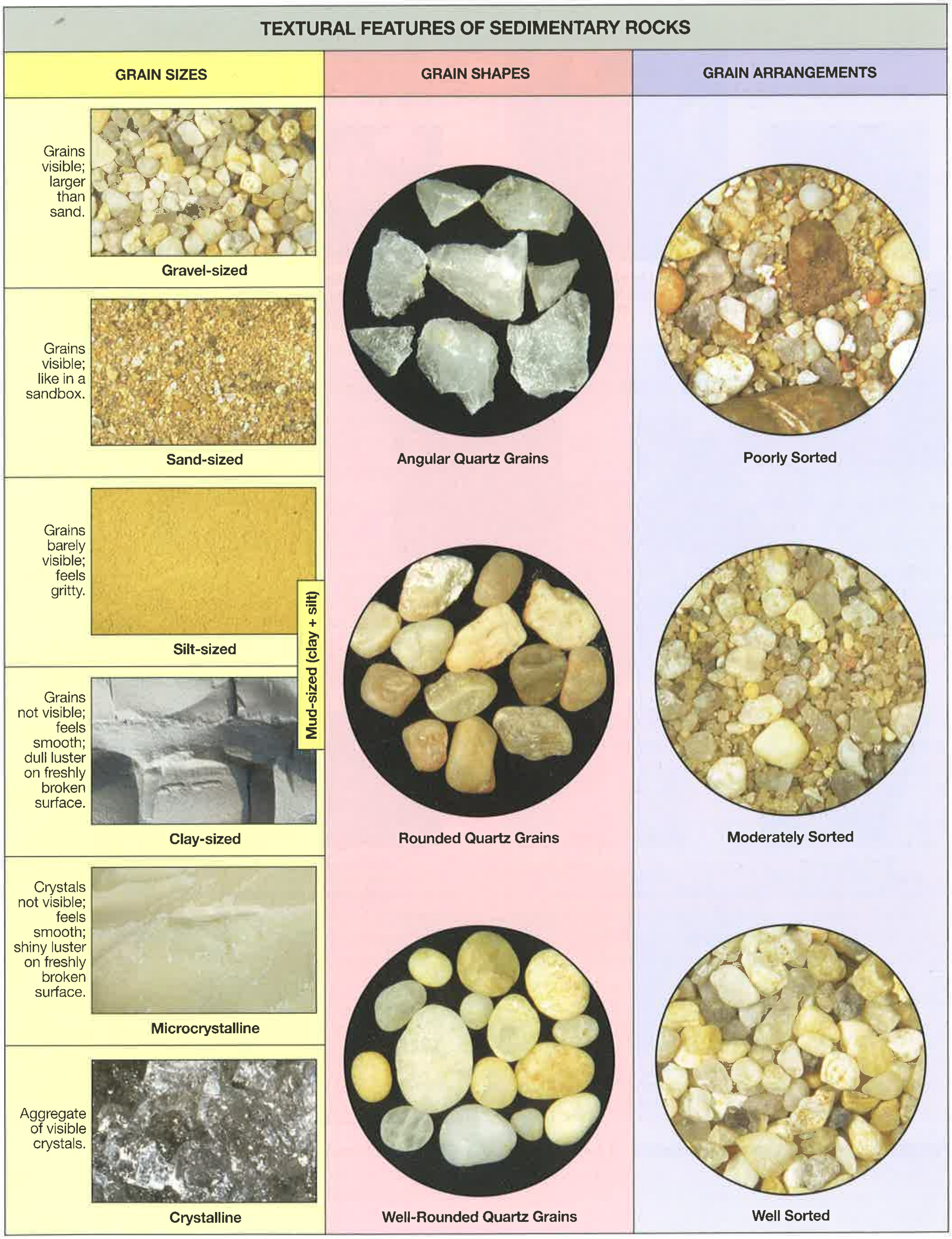


FIGURE 6.1 Textural features of sedimentary rocks. Scale for all images is ×1.

FIGURE 6.2 Compositional classification of sedimentary rocks. Scale for all images is ×1.

composition (Figure 6.2). **Biochemical (bioclastic)** sediments and rocks are composed mostly of the remains of organisms, such as shells, plant fragments, and carbon. **Chemical** sediments and rocks are composed mostly of intergrown mineral crystals precipitated from aqueous solutions and chemical residues. The precipitated minerals commonly include gypsum, halite, hematite, limonite, calcite, dolomite, and chert (microcrystalline variety of quartz). **Detrital** (Latin, "from rubbing or wearing away") sediments and rocks are composed mostly of *detrital* grains—worn rock fragments and mineral grains that were weathered and transported from their source. Because detrital sedimentary grains are mostly *clasts* (broken pieces) of silicate minerals such as quartz, feldspars, micas, and clay minerals, detrital sediments and rocks are also referred to as **siliciclastic**.

Formation of Sedimentary Rocks

Lithification is the hardening of sediment (masses of loose Earth materials such as pebbles, gravel, sand, silt, mud, shells, plant fragments, mineral crystals, and products of chemical decay) to produce rock. The lithification process usually occurs as layers of sediment are **compacted** (pressure-hardened, Figure 6.3) or **cemented** together (glued together by tiny crystals or chemical residues precipitated from fluids in the pores of sediment, Figures 6.4, 6.5). However, it is also possible to form a dense hard mass of intergrown crystals directly, as they precipitate from aqueous solutions (Figures 6.6 and 6.7).

Sand (a sediment) can be *compacted* until it is pressure-hardened into sandstone (a sedimentary rock). Alternatively, sandstone can form when sand grains are *cemented* together by chemical residues or the growth of interlocking microscopic crystals in pore spaces of the rock (void spaces among the grains). Rock salt and rock gypsum are examples of sedimentary rocks that form by the *precipitation* of aggregates of intergrown and interlocking crystals during the evaporation of salt water or brine.

Ocean water is the most common aqueous solution and variety of salt water on Earth. As it evaporates, a

A. Start with a handful of mud.

B. Compact the mud by squeezing it in your fist.

C. Release your grip to observe a piece of mudstone.

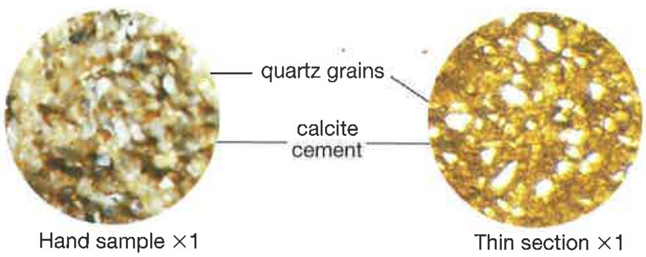
FIGURE 6.3 Compaction of a handful of mud to form a lump of mudstone. The more the mud is compacted, the harder it will become.

variety of minerals precipitate in a particular sequence. The first mineral to form in this sequence is aragonite (calcium carbonate). Gypsum forms when about 50–75% of the ocean water has evaporated, and halite (table salt) forms when 90% has evaporated. Ancient rock salt units buried under modern Lake Erie probably formed from evaporation of an ancient ocean. The salt units were then buried under superjacent layers of mud and sand, long before Lake Erie formed on top of them (see Figure 6.6).

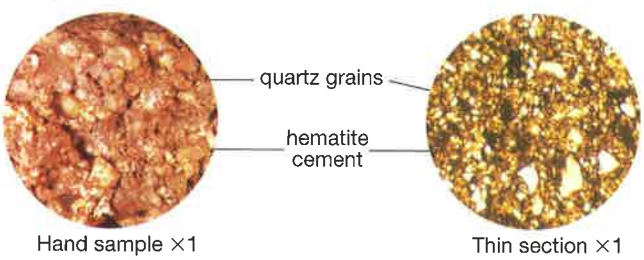
CEMENTATION

SEDIMENTARY ROCK:

1. Sandstone with white calcite or quartz cement.



2. Sandstone with redish hematite cement.



3. Sandstone with brown, black, or yellow limonite cement.

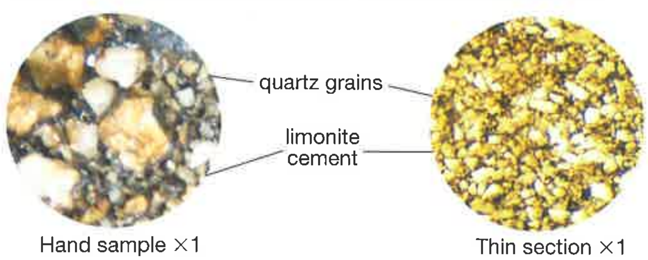
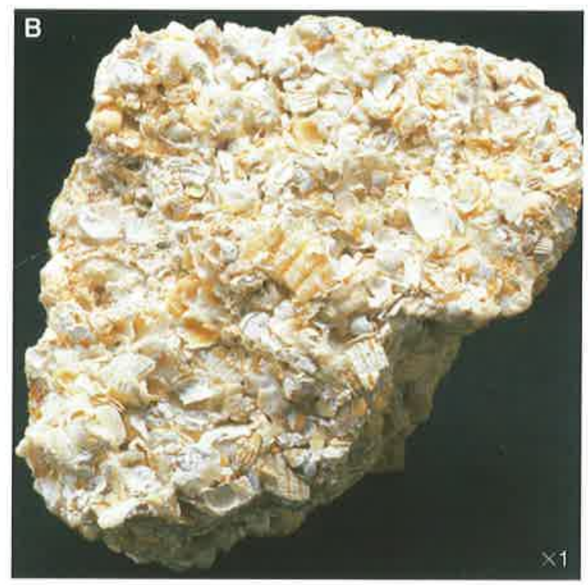


FIGURE 6.4 Cementation of quartz sand to form sand-stone.



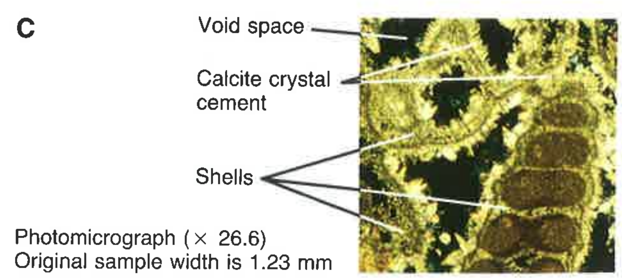


FIGURE 6.5 Formation of the biochemical (bioclastic) limestone. **A.** Shell gravel and blades of the sea grass *Thalassia* have accumulated on a modern beach of Crane Key, Florida. Note pen (12 cm long) for scale. **B.** Sample of gravel like that shown in part A, but it is somewhat older and has been cemented together with calcite to form lime-stone. **C.** Photomicrograph of a thin section of the sample shown in B. Note that the rock is very porous and that it is cemented with films of microscopic calcite crystals that have essentially glued the shells together.

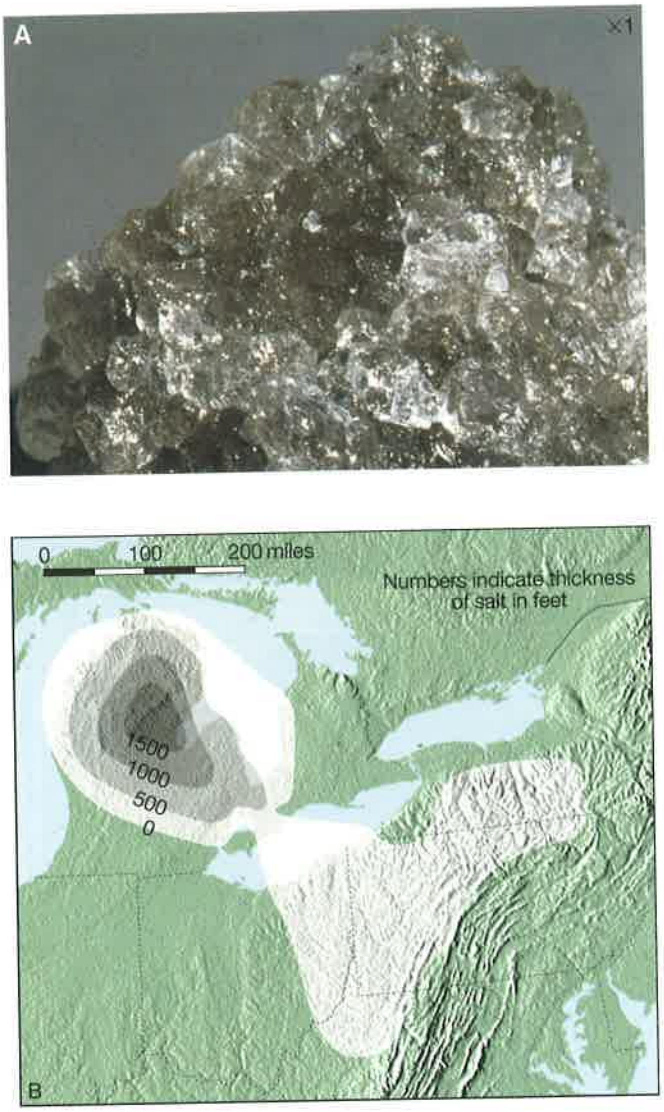


FIGURE 6.6 Rock salt, a chemical sedimentary rock with crystalline texture. **A.** Hand sample from salt mines deep below Lake Erie reveals that rock salt is an aggregate of intergrown halite mineral crystals. **B.** Map showing the thickness and distribution of rock salt deposits formed about 400 million years ago, when a portion of the ocean was trapped and evaporated in what is now the Great Lakes region, millions of years before any lakes existed.

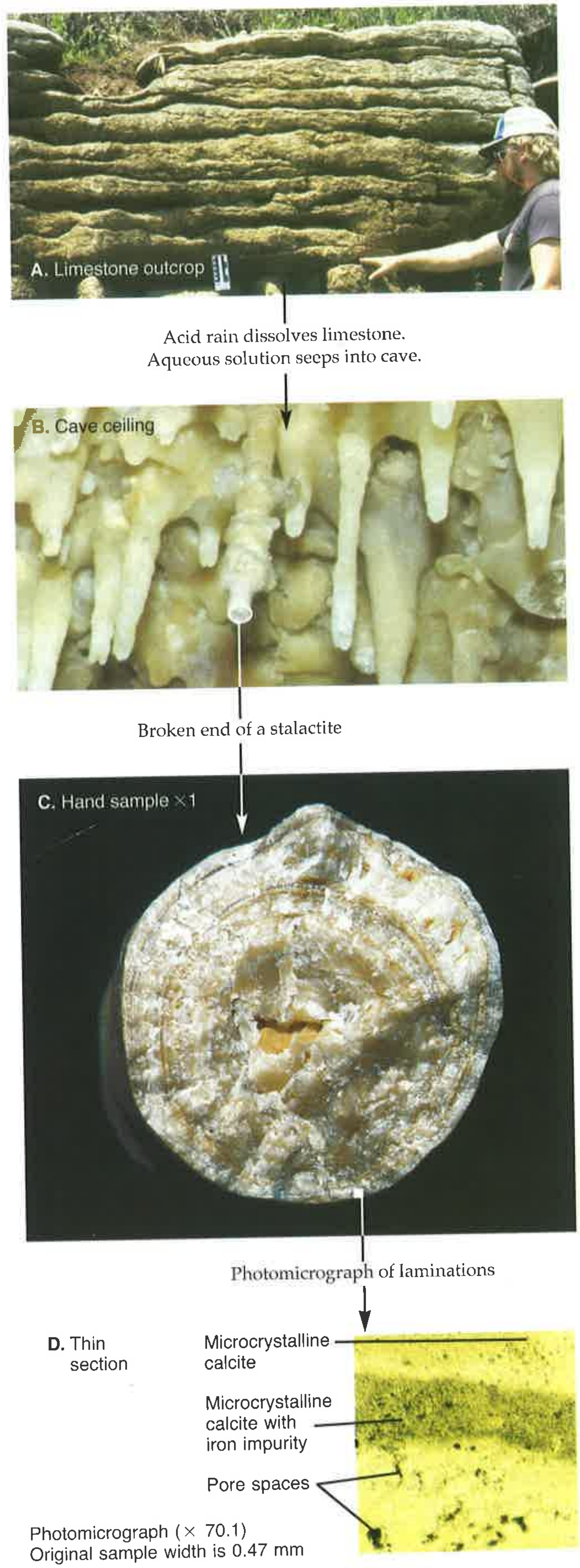


FIGURE 6.7 Formation of the chemical sedimentary rock, travertine. **A.** Limestone bedrock is dissolved by acidic rain near the Earth's surface. **B.** The resulting aqueous solution of water, calcium ions, and bicarbonate ions seeps into caves. As the solution drips from the roof of a cave, it forms icicle-shaped stalactites. **C.** Broken end of a stalactite reveals that it is actually an aggregate of chemically precipitated calcite crystals. **D.** Thin section photomicrograph reveals that the concentric laminations of the stalactite are caused by variations in iron impurity and porosity of the calcite layers.

SEDIMENTARY ROCK ANALYSIS AND CLASSIFICATION

STEP 1: Composition. What materials comprise most of the rock?		STEP 2: What are the rock's texture and other distinctive properties?			STEP 3: Name the rock based on your analysis in steps 1 and 2.		
Detrital (Siliciclastic) sediment grains: fragmented rocks and/or silicate mineral crystals	Rock fragments and/or quartz grains and/or feldspar grains and/or clay minerals (e.g., kaolinite) Detrital sediment is derived from the mechanical and chemical weathering of continental (land) rocks, which are comprised mostly of silicate minerals. Detrital sediment is also called terrigenous (land derived) sediment.	Angular gravel, poorly sorted grains larger than 2 mm			BRECCIA		Detrital (Siliciclastic) sedimentary rocks (clastic rocks)
		Rounded gravel, poorly sorted grains larger than 2 mm			CONGLOMERATE		
		Mostly sand (1/16 – 2 mm grains). May contain fossils		Mostly quartz	QUARTZ SANDSTONE	SANDSTONE	
				Mostly feldspar	ARKOSE	SANDSTONE	
				Mostly rock fragments	LITHIC SANDSTONE	SANDSTONE	
				Sand is mixed with much mud	WACKE (GRAYWACKE)	SANDSTONE	
		Mud (< 1/16 mm)	Mostly silt. May contain fossils	Breaks into blocks or layers	SILTSTONE	MUDSTONE	
		No visible grains; Mud (< 1/16 mm)	Mostly clay. May contain fossils	Fissile (splits easily into layers)	SHALE	MUDSTONE	
				Crumbles into blocks	CLAYSTONE	MUDSTONE	
Biochemical (Bioclastic) sediment grains: fragments/shells of organisms	Plant fragments and/or charcoal	Brown porous rock with visible plant fragments that are easily broken apart from one another			PEAT		Biochemical (Bioclastic) sedimentary rocks (clastic rocks)
		Dull, dark brown, brittle rock; fossil plant fragments may be visible			LIGNITE		
		Black, layered, brittle rock; may be sooty or bright			BITUMINOUS COAL		
	Shells and shell/coral fragments, and/or calcareous microfossils (rocks that effervesce in dilute HCl)	Mostly gravel-sized shells and shell or coral fragments; (Figure 6.5)			COQUINA	LIMESTONE (carbonate/calcareous rocks)	
		Mostly sand-sized shell fragments; often contains a few larger whole fossil shells			CALCARENITE (FOSSILIFEROUS LIMESTONE)	LIMESTONE (carbonate/calcareous rocks)	
		Silty, earthy rock comprised of the microscopic shells of calcareous phytoplankton (microfossils); may contain a few visible fossils			CHALK	LIMESTONE (carbonate/calcareous rocks)	
		No visible grains	Dark very fine-grained rock, usually breaks with a conchoidal fracture		MICRITE	LIMESTONE (carbonate/calcareous rocks)	
Mineral crystals (inorganic) or chemical residues (e.g., rust)	Calcite crystals and/or calcite spheres and/or microcrystalline calcite/aragonite (rocks that effervesce in dilute HCl)	Comprised of spherical grains that resemble miniature pearls (< 2 mm), called ooliths or ooids			OOLITIC LIMESTONE	LIMESTONE (carbonate/calcareous rocks)	Chemical sedimentary rocks
		Microcrystalline masses or masses of visible crystals (Figure 6.7); may have cavities, pores, and/or faint layering; usually light colored			TRAVERTINE	LIMESTONE (carbonate/calcareous rocks)	
	Microcrystalline dolomite	Effervesces in dilute HCl only if powdered. Usually light colored. (Commonly forms from alteration of limestone)			DOLOSTONE	carbonate/calcareous rocks; evaporite rocks	
	Halite mineral crystals	Salty taste, visible crystals, brittle. (Figure 6.6)			ROCK SALT	evaporite rocks	
	Gypsum mineral crystals	Gray, white, or colorless. Visible crystals or microcrystalline. Can be scratched with your fingernail			ROCK GYPSUM	evaporite rocks	
	Iron-bearing minerals crystals or residues	Dark-colored, heavy, amorphous chemical residues (limonite) or microcrystalline nodules (e.g., hematite, goethite)			IRONSTONE		
	Microcrystalline varieties of quartz (flint, chalcedony, chert, jasper)	Microcrystalline, may break with a conchoidal fracture. Hard (scratches glass). Usually gray, brown, black or mottled mixture of those colors. May contain fossils, as the silica in most chert is derived from dissolution of siliceous phytoplankton ooze (diatoms, radiolaria)			CHERT (a siliceous rock)		

FIGURE 6.8 Sedimentary rock analysis and classification. See text for steps to analyze and name a sedimentary rock.

FIGURE 6.9 Photograph of hand sample X and close-up photomicrograph of same (magnified 5×) for example on Sedimentary Rocks Worksheet. See Row 1 of the worksheet (Figure 6.10) to see how this rock's composition, texture, and origin were described.

Classifying Sedimentary Rocks

The complete classification of a sedimentary rock requires knowledge of its composition, texture(s), and other distinctive properties (Figure 6.8). The same information used to name the rock can also be used to infer its origin. Refer to the example for sample X (Figures 6.9 and 6.10).

Follow these steps to classify a sedimentary rock:

Step 1: Determine and record the rock's general composition as *biochemical (bioclastic), chemical,* or *detrital (siliciclastic)* with reference to Figure 6.2, and record a description of the specific kinds and abundances of grains that comprise the rock. Refer to the categories for composition in the left-hand column of Figure 6.8.

Step 2: Record a description of the rock's texture(s) with reference to Figure 6.1. Also record any other of the rock's distinctive properties as categorized in the center columns of Figure 6.8.

Step 3: Determine the name of the sedimentary rock by categorizing the rock from left to right across Figure 6.8. Use the compositional, textural, and special properties data from Steps 1 and 2 (left side of Figure 6.8) to deduce the rock name (right side of Figure 6.8). For assistance, refer to the discussion below.

Step 4: After you have named the rock, then you can use information from Steps 1 and 2 to infer the origin of the rock. See the example for sample X (Figures 6.9 and 6.10).

The main kinds of biochemical (bioclastic) sedimentary rocks are limestone, peat, lignite, and coal. Biochemical limestone is composed of animal skeletons (usually seashells, coral, or microscopic shells), as in Figures 6.2 and 6.5. Differences in the density and size of the constituent grains of a biochemical (bioclastic) limestone can also be used to call it a **coquina, calcarenite (fossiliferous limestone), micrite**, or **chalk** (Figure 6.8). **Peat** (Figure 6.2) is a very porous brown rock with visible plant fragments (like peat moss). **Lignite** is brown but more dense than peat. **Bituminous coal** (coal in Figure 6.2) is a black rock composed of charcoal or brittle shiny layers of carbon from plants.

There are seven main kinds of chemical (inorganic) sedimentary rocks in the classification in Figure 6.8. **Travertine** is a mass of intergrown calcite crystals that may have faint layering, cavities, or pores (Figure 6.7C). **Oolitic limestone** is composed mostly of tiny spherical grains that resemble beads or miniature pearls and are made of concentric layers of microcrystalline aragonite or calcite. **Dolostone** (Figure 6.2) is an aggregate of dolomite mineral crystals that are usually microcrystalline. Because calcite and dolomite closely resemble one another, the best way to tell them apart is with the "acid test" that you learned in Laboratory 3. Calcite will effervesce (fizz) in dilute HCl, but dolomite will fizz *only* if it is powdered first. **Rock gypsum** is an aggregate of gypsum crystals, and **rock salt** is an aggregate of halite crystals (Figures 6.2 and 6.6). Two other chemical sedimentary rocks are **chert** (composed of microcrystalline quartz) and **ironstone** (composed of hematite, limonite, or other iron-bearing minerals or chemical residues).

The main kinds of detrital (siliciclastic) sedimentary rocks are mudstone, sandstone, breccia, and conglomerate. It is very difficult to tell the percentage of clay or silt in a sedimentary rock with the naked eye, so sedimentary rocks composed of clay and/or silt are commonly called **mudstone.** Mudstone that is *fissile* (splits apart easily into layers) can be called **shale.** Mudstone can also be called siltstone or claystone, depending upon whether silt or clay is the most abundant grain size. Any detrital rock composed mostly of sand-sized grains is simply called **sandstone** (see Figures 6.4 and 6.8); although you can distinguish among *quartz sandstone* (composed mostly of quartz grains), *arkose* (composed mostly of feldspar grains), *lithic sandstone* (composed mostly of rock fragments), or *wacke* (composed of a mixture of sand-sized and mud-sized grains). **Breccia** and **conglomerate** are both composed of gravel-sized grains and are often poorly sorted or moderately sorted. But the grains in breccia are angular, and the grains in conglomerate are rounded or well rounded.

Questions

1. What specific kind of biochemical limestone is shown in Figure 6.5B? Explain how you determined this name.
2. What simple chemical test could you use to distinguish chalk from white claystone? Explain.
3. How would you distinguish limestone from dolostone using dilute HCl?
4. How would you distinguish a sample of calcarenite (fossiliferous limestone) from a sample of mudstone with fossil shells?
5. How would you distinguish a sample of peat from a sample of mudstone with fossil plant fragments?

PART 6B: HAND SAMPLE ANALYSIS AND INTERPRETATION

Question

6. Obtain a set of sedimentary rocks (as directed by your instructor) and analyze the rocks one at a time. For each sample, complete a line on the Sedimentary Rocks Worksheet (Figure 6.10) using the steps to classify a sedimentary rock that you learned in Part 6A.