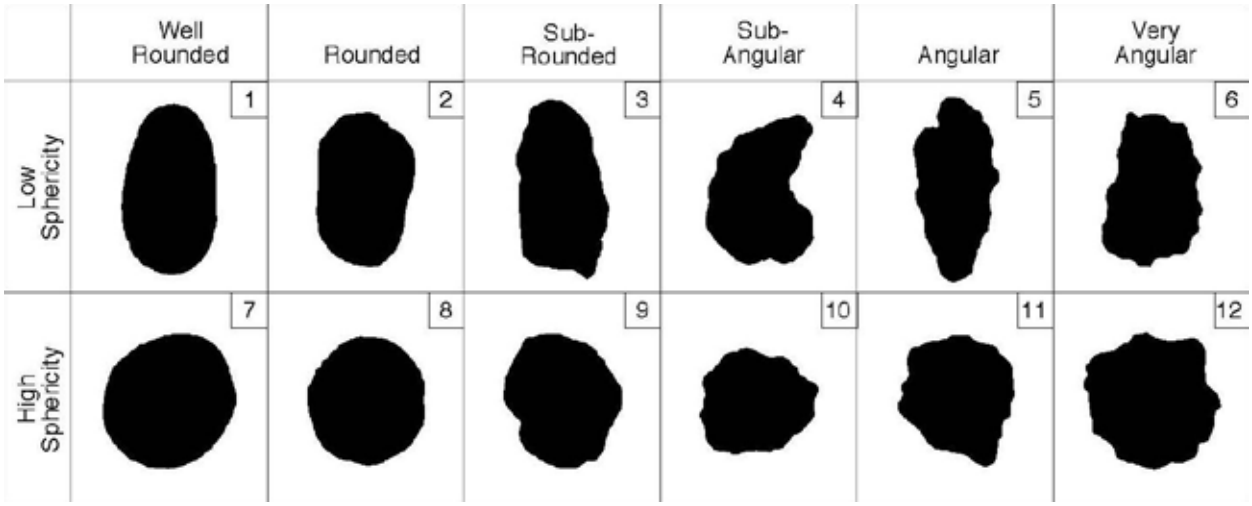
Paleo Lab #4 - Sedimentary Environments

1. CHARACTERISTICS OF SEDIMENT

Grain size and grain shape: The sizes and shapes of sedimentary particles (grains) are modified considerably during their transportation to the site of deposition. For example, abrasion of particles tends to round off jagged edges and corners, producing smaller grains with smooth, rounded surfaces and spherical shapes. Thus, a sand grain eroded from a hill in Wisconsin and carried down the Mississippi River will be smaller, better rounded, and more nearly spherical when it gets to New Orleans than it was when it passed Memphis. In addition, the higher the velocity (or energy) of the transporting agent (wind, water currents), the larger the grains that can be moved. An example of this is commonly seen in marine environments where, as the distance from shore increases, particle size of the sediments decreases due to the decreasing energy of water currents and increasing distance from the sediment source (i.e., land). Finally, continuous transportation tends to produce a well-sorted sediment in which all of the particles are more or less of the same size. A good example is a beach, where the constant swash and backwash of waves tend to produce well-sorted sand deposits.



Mineral composition: Detrital grains (composed of particles derived from pre-existing rocks), which occur in a variety of sizes, (e.g., boulders, pebbles, sand, silt, and mud) may be found in almost any environment. The percentage of quartz present is commonly taken as a measure of the maturity (degree of weathering) of the detrital sediment prior to deposition. Typically the percentage of quartz increases relative to the other silicate minerals that are less resistant to chemical weathering (e.g., feldspars, micas, ferromagnesium minerals) with increasing distance from the sediment source.

Color: Colors of sedimentary rocks are highly variable but can have some environmental significance.

1. **Black or dark brown** indicates deposition in a stagnant environment deficient in dissolved oxygen, such as might occur in a swamp, lagoon, or deep marine basin. The absence of oxygen allows for preservation of abundant organic matter, imparting the dark color.

2. **Green or gray** indicates deposition under chemically reducing conditions, generally in a marine environment. The green color is due to an abundance of ferrous (Fe2+) iron and low levels of free oxygen.

3. **Red or orange** indicates deposition under chemically oxidizing conditions, generally in a terrestrial environment. The color is due to an abundance of ferric (Fe3+) iron.

2. SEDIMENTARY STRUCTURES

By far the most diagnostic features (in addition to fossils) for paleoenvironmental interpretation of sedimentary rocks are sedimentary structures. Sedimentary structures are features produced in sediment during transport and deposition, by both physical and biological processes. These large-scale features are easily observed in outcrops in the field, and in large hand specimens. Sedimentary structures are important because they directly record processes occurring within the sedimentary environment at the time of deposition. The more common sedimentary structures are shown in the photographs on the following pages. Most of these features occur in both detrital and nondetrital rocks.

Bedding: Bedding is the most common structure of sedimentary rocks and is the product of the layer-by-layer process of sediment accumulation. The thickness of beds may reflect the rate of sediment deposition - thick beds generally represent rapid sedimentation, whereas thin beds may represent slower sedimentation. The following is an abbreviated list of some of the important bedding features which are commonly observed in sedimentary rocks.

1. **Massive bedding** has no apparent internal structure and is generally considered to be produced under constant conditions in the environment of deposition. In some cases it may reflect complete mixing and homogenization of the sediment by organisms.

2. **Horizontally laminated beds** are internally comprised of thinner horizontal layers and may indicate alternating conditions of deposition (e.g., “high” and “low” energy).

3. **Cross-beds** are characterized by a series of layers which are inclined relative to the overall external bedding. This structure can be produced both by wind (as in sand dunes) and by water currents (as in sand bars), and it is often difficult to distinguish between the two.

Other Features: There are many sedimentary structures other than the layering of sedimentaiy rocks. The following is a brief discussion of some of these.

1. **Ripple marks** are produced on the top surfaces of beds by either wind or water movement. Asymmetrical ripple marks indicate a current flowing in only one direction (e.g., in a river), whereas symmetrical ripple marks are generally produced under the influence of bidirectional currents (e.g., in a beach swash zone).

2. **Graded beds** show a systematic change in grain size called grading. Normally graded beds (particle sizes decrease towards top of bed) are most common, because as a mixture of sediment grains of various sizes is deposited under the influence of gravity, the coarser particles settle faster to the bottom than the finer ones.

3. **Mudcracks** are found at the tops of beds and are characterized by an irregular pattern of polygons resulting from the desiccation or drying of a muddy sediment. The presence of mudcracks suggests an environment where alternate wetting and drying was common.

4. **Trace fossils** are a class of sedimentary structures different from those previously described because they are not produced by physical sedimentary processes (e.g., wind, water currents), but instead record the various life activities of the living organisms that produced them (Figure I- 8). The most common forms are burrows, tracks and trails. Trace fossils occur both on the surfaces of, and internally within beds. They are extremely useful in paleoenvironmental interpretation because they may be the only evidence of biologic activity in any otherwise unfossiliferous sedimentary rocks.

3. FOSSILS

We can tell a great deal about the paleoenvironment of a sedimentary rock just by noting the general type of fossils present (e.g., marine vs. non-marine, terrestrial vs. aquatic) or recognizing the remains of plants or animals with particular adaptive properties.

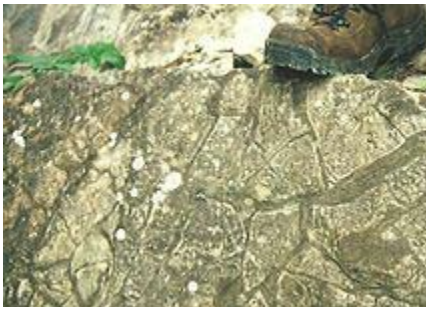
4. SHAPE (GEOMETRY)

The overall shape or geometry of the sedimentary deposit may provide an additional clue to its paleoenvironment. For example, in plan or map view, a river deposit might be expected to be sinuous, whereas a lake deposit should be circular or elliptical. In cross-sectional view the river deposit would be narrow and lenticular in shape, whereas the lake deposit would be wider and more sheet-like.

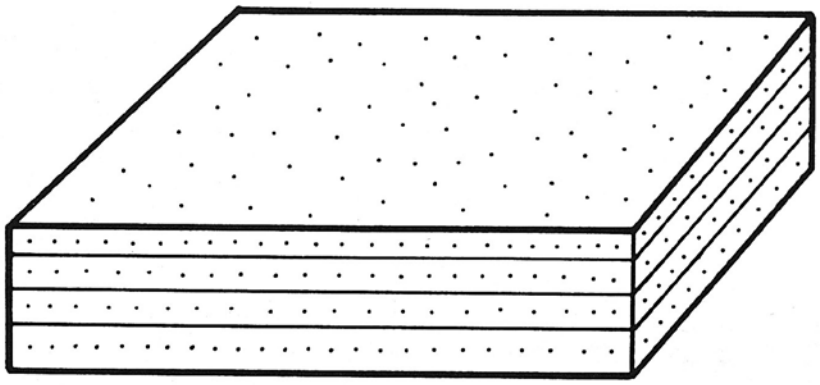
A. Burrows in a sandstone

B. Cross-bedded sandstone

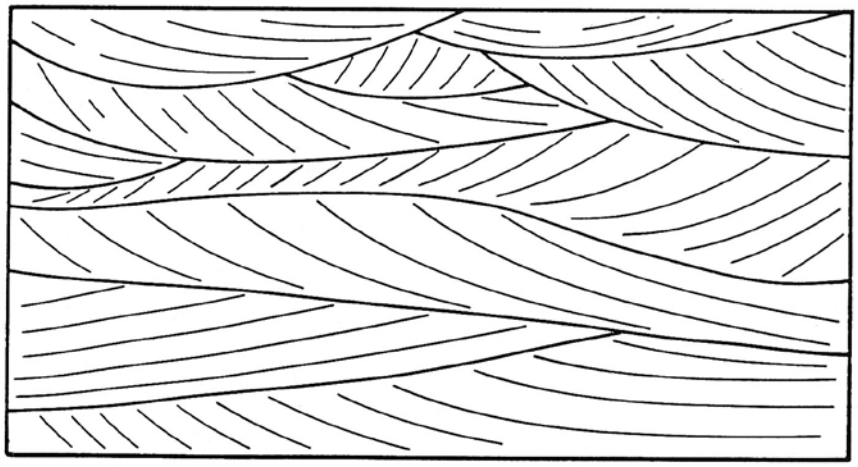
C. Symmetrical ripple marks.



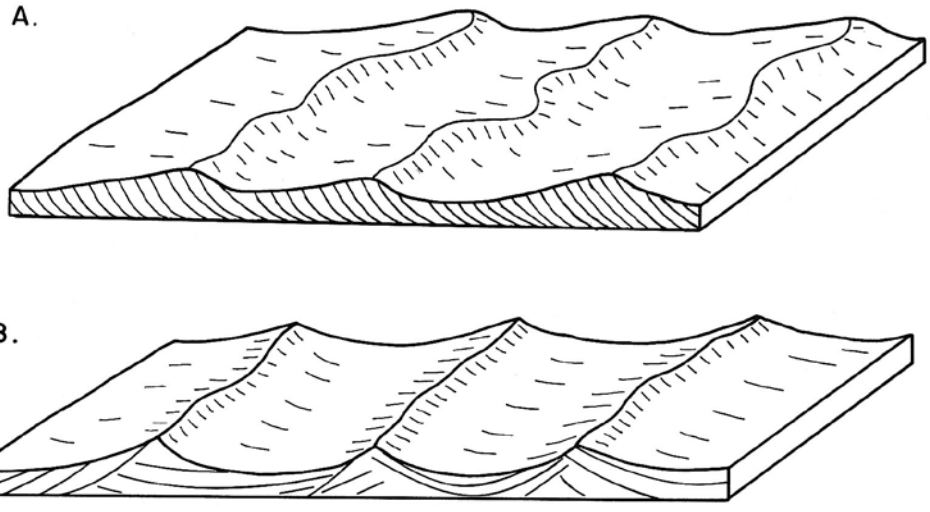
D. Shales and siltstones with mudcracks.



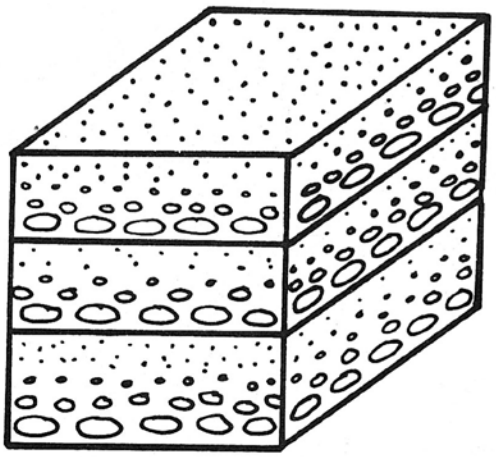
Block diagram showing horizontally laminated beds.



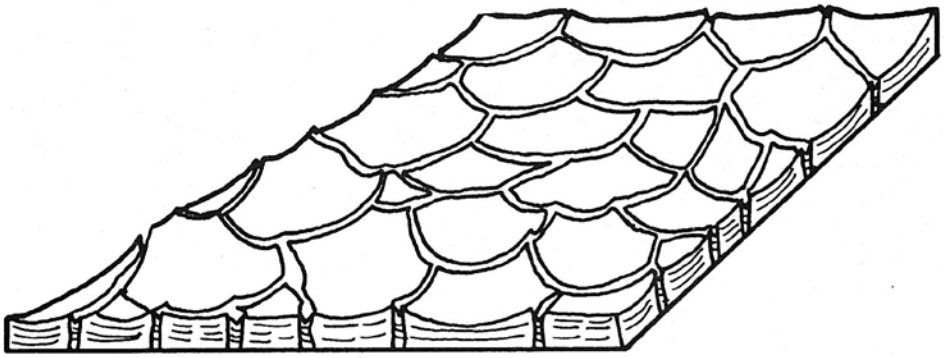
Cross section of cross-bedding developed within a bed.



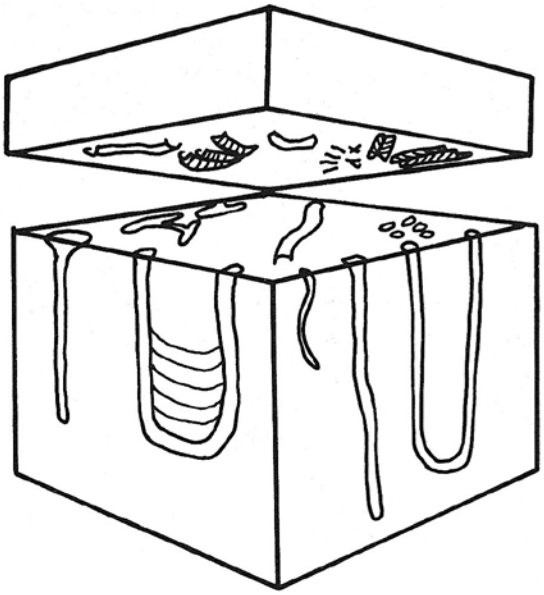
Block-diagram examples of two common types of ripple marks: (A) Asymmetrical ripple marks, (B) Symmetrical ripple marks. Note how the internal cross-laminations for each ripple type are also different, in addition to their different morphologies as viewed on a bedding-plane surface (top of block).



Several beds exhibiting normal size-grading.



View of bedding plane surface containing mudcracks.



Block diagram showing many different types of trace fossils, including horizontal and vertical burrows, and various tracks and trails.

ABBREVIATED CLASSIFICATION OF SEDIMENTARY ENVIRONMENTS

The following is an abbreviated classification of siliciclastic sedimentary environments. Although this is by no means a comprehensive listing, it does include most of the geologically significant sites of deposition. Under each major heading, environments are listed in order of estimated importance in the geological record. After each environment, the typical lithologies, sedimentary structures, general fossil characteristics and shapes of deposits are given.

I. **Nonmarine (Continental)**. Most nonmarine environments are typically the sites of erosion or nondeposition, although a small percentage of deposits may be preserved.

A. **Aqueous**

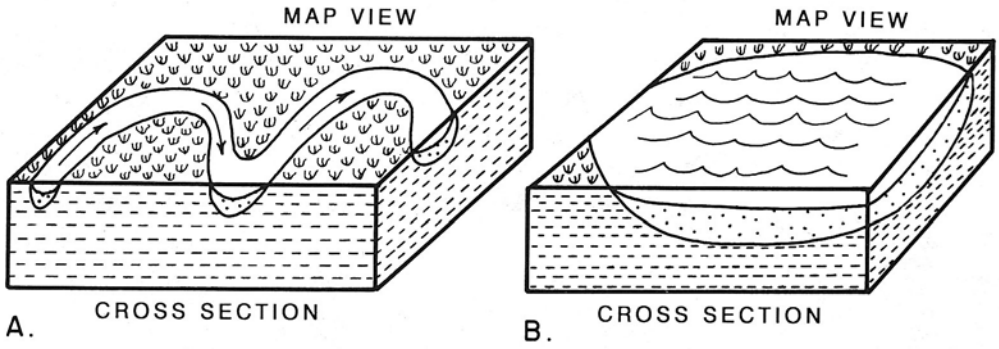
1. Fluvial (streams and rivers)
   (a) Floodplain - Sandstone, siltstone and shale with some conglomerate and coal, moderate sorting, moderately quartz-rich; horizontal laminations, asymmetric (current) ripple marks, animal tracks and trails, mudcracks, raindrop impressions; plant debris and tree fossils; irregular and thin-sheet shape.
   (b) Channel - Sandstone and conglomerate, moderately sorted and quartz-rich; crossbedding, current ripple marks, scour of channel surfaces; may contain plant debris, nonmarine (aqueous and terrestrial) fossils; irregular lenticular to sinuous shape, closely associated with floodplain deposits.

2. Swamp - fine-grained deposits (siltstone, shale, coal) with dark color and high organic content; thin horizontal laminations or massive (no visible sedimentary structures); abundant plant fossils; irregular lens to sheet shape.

3. Lacustrine (lake) - fine-grained shale and some limestone; varved (alternating thin, light and dark layers) clay common; possible freshwater fossils (e.g., snails); irregular lens to sheet shape.

B. **Terrestrial (subaerial)**

1. Desert
   (a) Eolian dune - fine-to medium-grained sandstone with excellent rounding and sorting; large-scale cross-bedding common; fossils rare; extensive sheet-like or “blanket” shape.
   (b) Alluvial fan - poorly sorted arkosic sandstone and conglomerate, abundant feldspar and mica; cross-bedding, massive bedding, inverse and normally graded beds; fossils rare to absent; thick fan- or wedge-shaped deposits.



Block diagrams showing expected differences in two- and three-dimensional geometries of (A) meandering river deposit, and (B) lake deposit.

2. Glacial - poorly sorted massive sandstone and conglomerate containing angular particles, striated pebbles, large pebbles and boulders, variable mineralogy; massive or crude horizontal laminations; fossils absent; irregular shape and patchy distribution.

II. **Transitional (Marginal Marine)**

A. **Delta** - a complex assemblage of environments including channels, floodplains, swamps, bays, etc. Deposits range from sandstone to siltstone and shale, and generally become finer-grained outward from the shoreline; cross-bedding, horizontal laminations, current ripple marks and animal burrows are common in some parts; fossils generally rare but may include locally abundant plant stems and roots and rare marine fossils; delta complexes are generally fan- or wedge-shaped.

B. **Barrier Island/Lagoon**

1. Barrier Island - mostly high-energy deposits consisting of well-sorted and rounded quartz- rich sandstone, grain size decreasing systematically in a seaward direction; large-scale crossbedding; current and symmetrical (wave) ripple marks, horizontal laminations and animal burrows common; fragmented marine fossils may be present; sand body shape is narrow and elongate parallel to the shoreline and a lagoon is typically present between the barrier and the mainland.

2. Lagoon - lower-energy environment dominated by fine-grained sandstone, siltstone, and shale; horizontal laminations, ripple marks, and animal burrows, tracks and trails are common; carbonate lagoons contain abundant and diverse marine fossils; shape is characteristically elongate parallel to shore, and a barrier island is typically present immediately offshore from the lagoon.

C. **Littoral (between mean high and low tides)**

1. Beach - a high-energy environment dominated by medium- to coarse-grained sandstone, well-sorted and rounded; horizontal laminations, low-angle cross-bedding, and wave ripple marks are most abundant; fossils are rare and typically broken into fragments; sand body is elongate in shape and trends parallel to shore.

2. Tidal flat - consists of interbedded sandstone, siltstone and shale, with grain size increasing in a seaward direction; cross-bedding (some large-scale), wave and current ripple marks, mudcracks, scour or channel surfaces, and animal burrows, tracks and trails are common; fossils (marine) are rare to abundant; wedge to irregular sheet shape.

III. **Open Marine**

A. **Pelagic** - These environments are within the ocean water mass, thus they do not have characteristic features preserved in the geologic record. Organisms which live in these environments fall to the ocean bottom upon death and become part of the record of one of the benthic environments listed below.

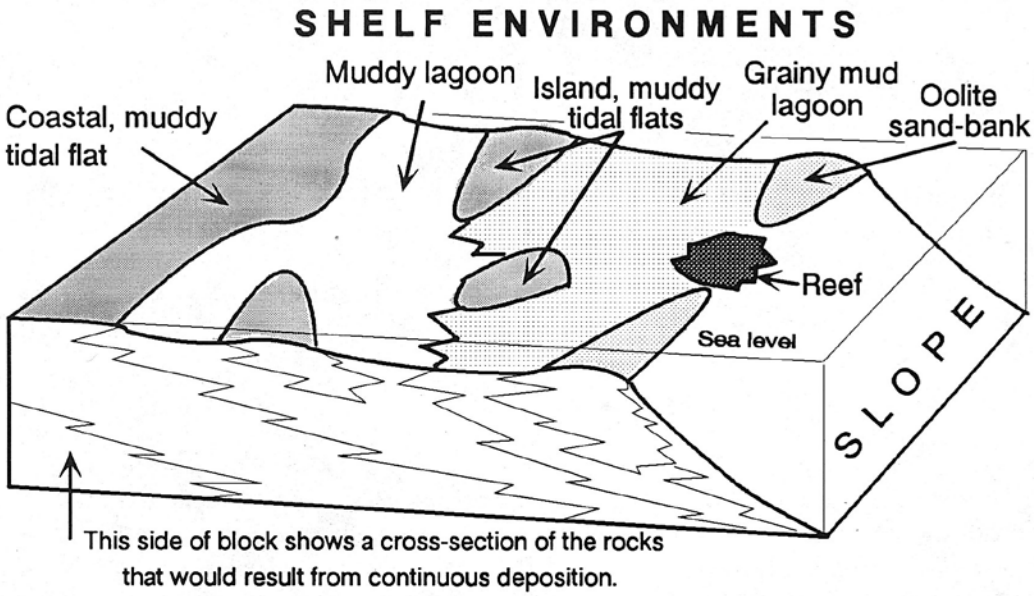
1. Neritic - depth to seafloor less than 200 meters
2. Oceanic - depth to seafloor greater than 200 meters

B. **Benthic (bottom environments)**

1. Shallow marine (Shelf) - sandstone, siltstone, limestone and shale interbedded, sandstone composed predominantly of quartz but with some marine fossil fragments; cross-bedding (some large-scale), ripple marks, and marine burrows, tracks and trails common; marine fossils locally abundant; widespread sheet-like or blanket shape. Water depths are typically less than 200m.

2. Carbonate Reef/Platform

3. Deep Ocean - shale, fine-grained limestone and/or sandstone; graded bedding and ripple marks produced by turbidity currents; fossils rare; sheet to fan-like shape.



A block diagram of a carbonate shelf showing some of the common environments (upper surface), and the mosaic-like stratigraphic facies pattern that results from migration of these environments during sediment accumulation.

Some common carbonate depositional environments , their sedimentary characteristics, and some sedimentary features to be expected in resultant limesones.

ENVIRONMENT	DOMINANT CHARACTERISTIC	SEDIMENTARY FEATURES
Reef	Abundant, often large, organisms attached to the sea-floor. High energy.	Unbedded, very fossiliferous, very coarse grained sediment.
Ooid sand-bank	Wave swept, with strong currents.	Mud (micrite) free, cross-bedded ooid-rich sandstone.
Grainy-mud lagoon	Less wave and current energy than near shelf-edge.	Micritic (mud-rich) sediment with scattered ooids or fossil grains.
Muddy lagoon	Very quiet water.	Organic-rich, very fine grained, dark-colored micrite; burrows or "churns". Few fossil grains.
Tidal flat (may be "attached" to a coastline or occur on offshore islands.)	Alternately covered and uncovered by the tides (ie., wetted, then dried).	Thinly layered micrite, sometimes with broken grains. Mud-cracks and intraclasts.

 # 1. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

_____

Color: _____

Structures: _____

_____

Rock Name: _____

Sketches / Notes

Environment: _____

_____

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 # 2. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

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Color: _____

Structures: _____

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Rock Name: _____

Sketches / Notes

Environment: _____

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 # 3. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

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Color: _____

Structures: _____

_____

Rock Name: _____

Sketches / Notes

Environment: _____

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 # 4. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

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Color: _____

Structures: _____

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Rock Name: _____

Sketches / Notes

Environment: _____

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 # 5. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

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Color: _____

Structures: _____

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Rock Name: _____

Sketches / Notes

Environment: _____

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 # 6. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

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Color: _____

Structures: _____

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Rock Name: _____

Sketches / Notes

Environment: _____

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 # 7. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

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Color: _____

Structures: _____

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Rock Name: _____

Sketches / Notes

Environment: _____

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 # 8. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

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Color: _____

Structures: _____

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Rock Name: _____

Sketches / Notes

Environment: _____

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 # 9. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

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Color: _____

Structures: _____

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Rock Name: _____

Sketches / Notes

Environment: _____

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 # 10. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

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Color: _____

Structures: _____

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Rock Name: _____

Sketches / Notes

Environment: _____

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 # 11. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

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Color: _____

Structures: _____

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Rock Name: _____

Sketches / Notes

Environment: _____

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 # 12. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

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Color: _____

Structures: _____

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Rock Name: _____

Sketches / Notes

Environment: _____

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 # 13. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

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Color: _____

Structures: _____

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Rock Name: _____

Sketches / Notes

Environment: _____

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 # 14. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

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Color: _____

Structures: _____

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Rock Name: _____

Sketches / Notes

Environment: _____

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 # 15. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

_____

Color: _____

Structures: _____

_____

Rock Name: _____

Sketches / Notes

Environment: _____

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 # 16. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

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Color: _____

Structures: _____

_____

Rock Name: _____

Sketches / Notes

Environment: _____

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 # 17. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

_____

Color: _____

Structures: _____

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Rock Name: _____

Sketches / Notes

Environment: _____

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 # 18. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

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Color: _____

Structures: _____

_____

Rock Name: _____

Sketches / Notes

Environment: _____

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 # 19. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

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Color: _____

Structures: _____

_____

Rock Name: _____

Sketches / Notes

Environment: _____

_____

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 # 20. Detrital or Nondetrital or Chemical

Detrital - Grain size: Coarse or Medium or Fine

Detrital - Grain shape: Round or Angular

Detrital - Sorting: Good or Poor

Mineralogy: _____

_____

Color: _____

Structures: _____

_____

Rock Name: _____

Sketches / Notes

Environment: _____

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