EART120
Lab 1: Siliciclastic Petrology in Hand Sample

The composition, texture, and structures of siliciclastic rocks provide key clues to help you interpret depositional environments. For that reason, it's critical to practice making systematic and detailed observations and descriptions.

Grain size

The size of particles in clastic sedimentary rocks provides important information about water energy during transport and deposition. Larger particle sizes (coarse sand or gravel) indicate higher energy/faster flow and small particle sizes (silt and mud) indicate lower energy or even no water flow.

Grain sizes are divided into size classes on a logarithmic (base-2) scale, called the Wentworth or Phi scale. For example, medium sand is everything between $\frac{1}{2^1}$ ($\frac{1}{2}$, or 0.5) and $\frac{1}{2^2}$ ($\frac{1}{4}$, or 0.25) mm in diameter. Fine sand is everything between $\frac{1}{2^2}$ ($\frac{1}{4}$, or 0.25) and $\frac{1}{2^3}$ ($\frac{1}{8}$, or 0.125) mm in diameter. The exponents in $\frac{1}{2^\varphi}$ are the phi values, but when describing rocks it's more typical to use the size class (for example, medium sand or fine sand) rather than the numerical value.

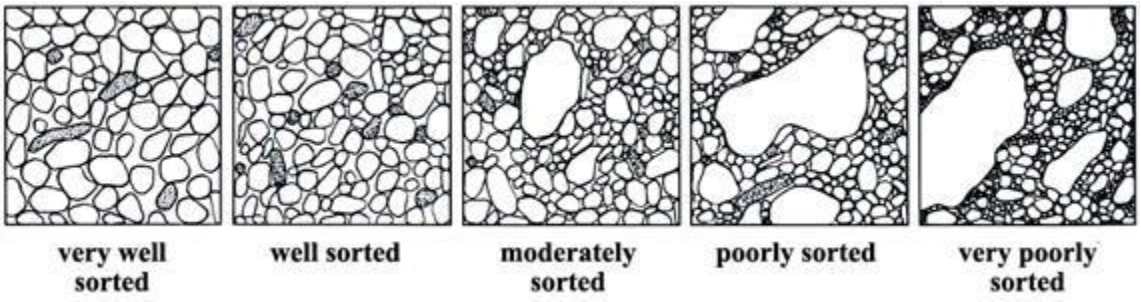
Silt and mud/clay are difficult to distinguish in hand sample because the grain size is too small to be seen even with a hand lens. Silt should feel somewhat gritty if you rub a wet powdered sample between your fingers or on your teeth. For sedimentary rocks, it's uncommon to subdivide silt into very fine, fine, medium, or coarse.

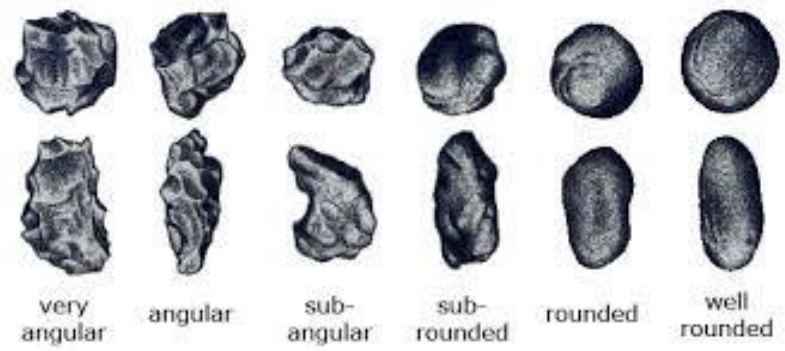
Millimeters (mm)		Micrometers (μm)	Phi (ϕ)	Wentworth size class	
	4096		-12.0	Boulder	
	256		-8.0	Cobble	Gravel
	64		-6.0	Pebble	
	4		-2.0	Granule	
	2.00		-1.0	Very coarse sand	
	1.00		0.0	Coarse sand	
1/2	0.50	500	1.0	Medium sand	Sand
1/4	0.25	250	2.0	Fine sand	
1/8	0.125	125	3.0	Very fine sand	
1/16	0.0625	63	4.0	Coarse silt	
1/32	0.031	31	5.0	Medium silt	
1/64	0.0156	15.6	6.0	Fine silt	Silt
1/128	0.0078	7.8	7.0	Very fine silt	
1/256	0.0039	3.9	8.0	Clay	Mud
	0.00006	0.06	14.0		

Sorting and rounding

These parameters are important components of *textural maturity*, as both relate to the amount of transport. A texturally mature sandstone will be better sorted and more rounded, likely suggesting long transport distances (or sourcing of sediments from existing sedimentary deposits). An immature sand will have poorer sorting and more angular particles, suggesting short transport distances with little particle wear.

Sorting and rounding are both measured on a continuum, so there isn't a sharp boundary between subangular and subrounded particles, for example. Sediments also can have a range of rounding depending on mineral properties and other factors, so there's a fair amount of subjectivity involved.

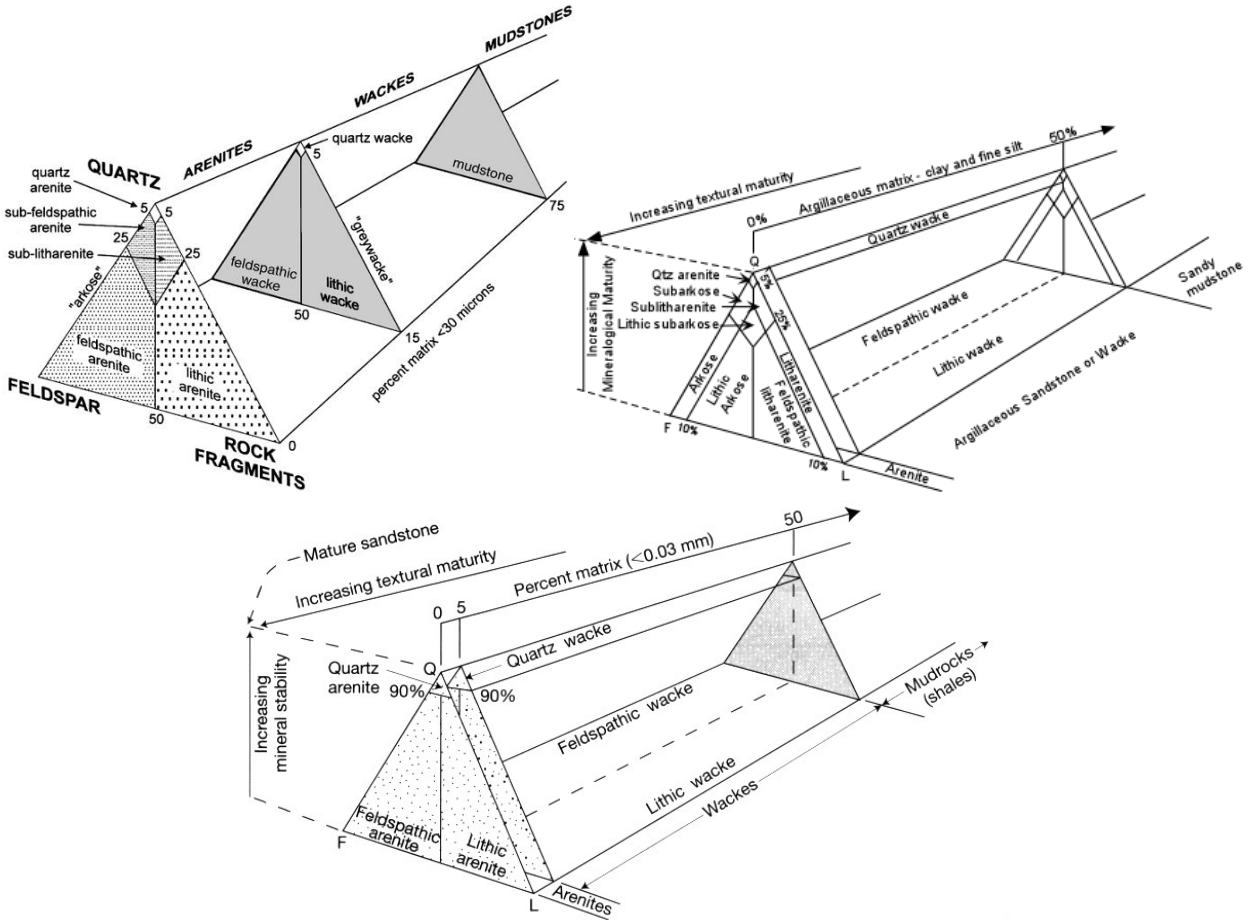




Composition

Sandstones are named on (1) the abundance of muddy matrix and (2) the composition of the sand grains.

Matrix: arenites vs. wackes. Sandstones can have matrix (silt and mud-sized particles) between the sand-sized grains, or can have cement (precipitated mineral, mostly calcite or quartz) between the grains. When the muddy matrix is abundant, the rock is a *wacke*. When there is little or no muddy matrix, the rock is an *arenite*. The cutoff between the two is generally placed at 5%-15% matrix. The exact number isn't important, but these percentages roughly correspond to when the matrix become apparent in hand sample. When less than 25%-50% of the rock is made up of sand-sized grains, it becomes a mudstone or siltstone. It's possible to call something a sandy mudstone/siltstone, or a muddy/argillaceous sandstone.



Grain composition: QFL. Sandstones are further named using a ternary (triangular) diagram called a "QFL" diagram – for quartz, feldspar, and "lithics" (basically everything except quartz and feldspar). A sandstone with more than 90-95% quartz grains would be called a quartz arenite or quartz wacke, depending on the amount of matrix. Rocks with <90% quartz but a majority of feldspar grains would be a feldspathic or arkosic arenite (or wacke). Rocks with <90% quartz but a majority of "lithic" grains would be a lithic arenite or wacke. (You may see the term "greywacke" for a lithic wacke.)

Arenites can sometimes be subdivided even further. If quartz is more abundant (10-25%) the rock might be called subfeldspathic (subarkosic) or sublithic. The terms arkose or lithic can be restricted only to "pure" end members and subdivided into "lithic arkose" or "feldspathic litharenite" for more mixed compositions.

Coarse-grained clastics: breccia and conglomerate

Rocks with a lot of coarse-grained, gravel-sized particles – pebbles, cobbles, and boulders – are primarily subdivided on the basis of rounding. The pebbles or cobbles are called *clasts*, and there usually is a finer-grained (mud, silt, or sand-sized) *matrix* between the clasts. If the clasts are angular, the rock is a *breccia*. If the clasts are rounded, the rock is called a *conglomerate*.

Note: although granules aren't technically sand-sized, rocks composed of granules are often called "granule sandstones", particularly if they are well-sorted and have few other particle sizes. Also, sometimes a mudstone, siltstone, or sandstone may have very sparse pebbles scattered within it. If the pebbles are rare, the rock may be called a pebbly mudstone or pebbly sandstone.

Matrix content. Breccias and conglomerates are not described as arenites or wackes. However, if the clasts are primarily touching each other, the rock can be described as *clast-supported*. Note that clasts are three-dimensional, so they may not all be in contact on the outcrop surface. If they are close and many are touching, it's probably clast-supported. If the clasts are more scattered and appear to be floating in the matrix without touching each other, the rock can be described as *matrix-supported*. You may see the terms *orthoconglomerate* (clast-supported) and *paraconglomerate* (matrix-supported), but it's simpler to just say clast- or matrix-supported.

Sorting and rounding. You should use the same terms for sorting and rounding that you would with sandstones. Sorting and rounding are based on the clasts only.

Composition. Unlike the formal names for sandstones, conglomerate and breccia compositions are described in a more free-form way. If there only one clast type (or nearly all clasts belong to a single rock type), you can describe it as a "chert-pebble conglomerate" or "limestone breccia" for example. The technical term for this type of conglomerate is *monomictic*. If there are a couple of dominant clast types, you could call it a "basalt-greenstone conglomerate" or "granitic-rhyolitic breccia" for example (you may see the term *oligomictic* when there are just a few clast types). Finally, the term for conglomerates with a wide range of clast composition is *polymictic*. Here, you could list some of the more important clast types: "a polymictic conglomerate containing low-grade metamorphics, serpentinite, blueschist, and chert" for example.

Describe the matrix separately. Conglomerates and breccias are described from their clasts, but it's often useful to describe the nature of the matrix as well. The matrix will often be a sandstone (but could be a siltstone or mudstone), so use the sandstone description procedure.

Building rock names

Clastic rock names are constructed by combining the various terms into a concise string. For example, a "medium- to coarse-grained, moderately sorted and subrounded lithic arenite" or a "polymictic cobble conglomerate dominated by well-sorted and well-rounded chert, sandstone, and rhyolitic clasts."

Questions

Sandstones

Sample 1: Old Red Sandstone (Devonian, Northern Ireland)
Link: https://viewer.gigamacro.com/view/WF8lLfmr2mtSsp1b

As the name of the image indicates, this is an arkose (a feldspathic arenite). There is no matrix apparent. The vast majority of grains are feldspars – plagioclase and potassium feldspar – with opaque white, gray, pink, or reddish colors. Some of the darker red grains are actually volcanic rock fragments with visible feldspar phenocrysts; one is highlighted in a snapshot. There are also rare "lithic" grains – mostly biotite.

1. How would you describe the sorting of this sandstone? How would you describe the rounding?

Sample 2: Flathead Sandstone (Cambrian, Wyoming)
Link: https://viewer.gigamacro.com/view/R18YnTUnDPrMgYLN

This sample is composed nearly entirely of quartz. Quartz grains are typically somewhat translucent (partly see-through) and usually have a milky gray color. The rusty bands and tiny rusty specks are iron minerals that formed after deposition due to water flowing through the rock.

2. Is this rock an arenite or a wacke?

3. How would you describe the sorting of this sandstone? How would you describe the rounding?

Sample 3: Graywacke (Silurian, Scotland)
Link: https://viewer.gigamacro.com/view/hzEtKlYvS2aSy6BU

This is an example of a "graywacke" (or "greywacke") – a lithic wacke. In this case the muddy matrix appears to have been recrystallized or slightly metamorphosed, and looks somewhat shiny as a result.

4. How would you describe the sorting of this sandstone? How would you describe the rounding?

Sample 4: Martinsburg Formation (upper Ordovician, Virginia)
Link: https://viewer.gigamacro.com/view/9aZu4oVqExdWox5Y

5. Describe the prominent contact between the two units (marked with one of the snapshots). Would you describe it as gradational or sharp? Would you describe it as planar or erosive/scoured?

The sandstone above the contact is probably a wacke, as the darker-colored laminations certainly contain visible matrix (see snapshot "wacke"). However, there are areas where the matrix is much less apparent (see snapshot "arenite").

6. Discuss the composition of the sandstone – how abundant are quartz, feldspar, and lithic grains? Estimate an approximate percentage of each. Given that, what compositional name would you give this rock?

Sample 5: Core, unknown location (unlithified, so perhaps modern)
Link: https://viewer.gigamacro.com/view/76c924b303e909e6

7. Will this sediment become an arenite or a wacke?

8. Give a complete description, including grain size, composition, sorting, and rounding.

Sample 6: Franconia Formation (Cambrian, Minnesota)
Link: https://viewer.gigamacro.com/view/2OJzlEYt9mFQqAKi

This sediment is a *flat-pebble conglomerate*, where thin sediment layers lithified on the seafloor and then were ripped up by storm waves as flat or tabular clasts. The orange clasts here are presumably carbonate-rich, in order to lithify on the seafloor. Focus instead on the matrix around the clasts. The green sand grains are a mineral called *glauconite*. Glauconite grows within the sediment (the technical term is *authigenic*), typically when sedimentation rates are slow.

9. Glauconite is an important accessory mineral, so is often used as an adjective in a rock name. This rock (the matrix) would be described on the basis of composition and matrix as a glauconitic…?

Siltstones, mudstones, and shales

Sample 7: Millboro Formation (Devonian, West Virginia)
Link: https://viewer.gigamacro.com/view/9oXHaZ0aYLOzXk7U

This is described as a siltstone in the photo information. Zoom in close and it's still not possible to see individual grains. There are abundant *trace fossils*, mostly horizontal burrows made by the movement of worms or other animals. These would be given the name *Planolites*. In places, you can see circular cross-sections of vertical burrow tubes that are filled with sandy sediment (see the snapshot).

Sample 8: Brallier Formation (Devonian, West Virginia)
Link: https://viewer.gigamacro.com/view/ji322Y0Ozuo1dD7Q

This sample is described as a shale, which is a mud/silt-dominated rock that typically has some kind of platy fabric. Like in the previous sample, no grains are visible even at high magnification. Fine-grained rocks (mudstone, siltstone, shale) are often dark in color: black, dark gray, or dark brown because they tend to contain more organic matter, although not always. This specimen shows the bottom surface of a bed, with *flute casts* (small v-shaped scours eroded by flowing water) and *tool marks* (grooves made by objects dragging along the seafloor). Explore the snapshots to observe those features.

Coarse-grained rocks

Sample 9: Crazy Cat Breccia (Texas)
Link: https://viewer.gigamacro.com/view/KXmYPLBCd4A45aea

This is actually a landslide/fault breccia, where a large block of limestone slid down along a bedding surface, but it demonstrates the angularity typical of breccias.

10. How would you describe the sorting of clasts in this breccia?

Sample 10: Cerro Toro Formation (Cretaceous, Chile)

Link: https://viewer.gigamacro.com/view/Jck0gYABP29Q4L7Y

11. Would you describe this conglomerate as matrix-supported or clast-supported?

12. How would you describe the sorting and rounding of clasts?

13. Is the clast composition best described as monomictic or polymictic?

Rock names

Sample 11: Lab Sample D
Link: https://viewer.gigamacro.com/view/Jn8Tq8tqqW8ZN3Sw

14. Give a complete description of the sandstone just above the contact with the dark shale.

Sample 12. Conemaugh Formation (Pennsylvanian, West Virginia)
Link: https://viewer.gigamacro.com/view/hzfHohNpwrzz5U8Z

15. Give a complete description of the sample. Grain size is difficult to determine because the scale bar isn't overlaid on the sample, so do your best. There are scattered pebbles along certain horizons; you would want to note them in a description, but name the sandstone without them.

Sample 13: Martinsburg Formation (upper Ordovician)
Link: https://viewer.gigamacro.com/view/w6OKQHGfpAxFN5Vm

16. Give a complete description of the sample. Grain size is difficult to determine because the scale bar isn't overlaid on the sample, so do your best. The nature of the sediment changes from the base to the top of the bed. Describe the grain size in the bottom part and in the top separately.

Sample 14: Ghaub Formation (Neoproterozoic, Namibia)
Link: https://viewer.gigamacro.com/view/2MDJrFlK92cSsGb5

17. Give a complete description of the sample. You do not need to identify the clast types, but should either use the term monomictic or polymictic. According to the info, the sample is 13 cm wide.

Sample 15: Hampshire Formation (Devonian, Virginia)
Link: https://viewer.gigamacro.com/view/qmMCLnxlF3m8AbjO

18. Give a complete description of the sample. The holes are from weathering and are not a primary feature.