Geology of the Pacific Northwest: Rocks and Minerals
GEO143 Lab 5: ROCKS

Name: _______________________________ Date: ________________

Igneous Rocks

Igneous rocks form from the solidification of magma either below (intrusive igneous rocks) or above (extrusive igneous rocks) the Earth's surface. For example, the igneous rock granite solidified below the Earth's surface and is composed of several visible (to the naked eye) mineral grains such as quartz, orthoclase, biotite, and hornblende. The igneous rock basalt solidified above the Earth's surface and is composed of non-visible (to the naked eye) mineral grains.

Sedimentary Rocks

Pre-existing rocks (igneous, sedimentary, and metamorphic) on the Earth's surface that have been weathered, broken down into smaller particles, transported, deposited, and lithified (made solid) form sedimentary rocks. Sandstone, a sedimentary rock, is composed of inorganic sand-sized (1/16 to 2 mm) particles that have been lithified together, forming clastic-type sedimentary rocks. Limestone sedimentary rocks are typically formed by chemical precipitation of calcium carbonate or by lithified biogenic skeletal fragments of marine organisms comprised of calcium carbonate.

Metamorphic Rocks

Metamorphic rocks result from pre-existing rocks that have been altered physically and/or chemically without melting. The agents of these changes include intense heat and pressure and/or chemical actions of hot fluids. The word metamorphic means meta (change) and morphic (form) – to change the pre-existing rock's form. All metamorphic rocks form through a solid-state transformation. For example, when the intrusive igneous rock granite is subjected to high pressures and temperatures, the original granite texture will transform to a new texture consisting of alternating light and dark mineral bands. The new rock is a metamorphic rock known as gneiss. Because every metamorphic rock is a changed rock, each metamorphic rock has a precursor or a parent rock (or protolith) that existed prior to metamorphism. According to the rock cycle, any one of the three major rocks (ign, sed, or met) can be precursors for metamorphism. For example, shale (sedimentary rock) is subjected to high pressures and temperatures and changes through a solid-state transformation, forming the new metamorphic rock schist.

Earth processes continually produce new rock through volcanic activity, the breakdown, transportation, as well as deposition of pre-existing rock, and the subjection of pre-existing rock to varying pressures and temperatures caused by tectonic forces. In this lab, the student will learn how to identify common rocks (igneous, sedimentary, and metamorphic) using rock properties such as composition and texture. In the next lab, students will associate the common rocks with the rock's geologic environment and its relationship to the rock cycle.

<u>Lab Objectives:</u>

- Students will use the relations between composition and texture of the rock specimen and classify the rock as igneous, sedimentary, or metamorphic.
- Students will learn various geologic terms that describe compositional and textural characteristics of igneous, sedimentary, and metamorphic rocks.
- Students will make use of various rock classification charts and properly name the rock specimen.

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Igneous Rock Classification

Igneous Rock Texture

Igneous rocks are identified and classified based on textural and compositional properties. The various textures of igneous rocks are directly related to the rate of cooling magma. For example, magma that cools very slowly will allow mineral crystals to form producing coarse-grained textures that can be observed with the naked eye. Coarse-grained igneous textures are produced below the earth's surface, where magma cools slowly, and are referred to as intrusive igneous rocks. On the other hand, magma that cools very quickly will produce fine-grained textures in which mineral grains typically cannot be observed with the naked eye. Fine- grained igneous textures are produced above the earth's surface, where magma cools quickly, and are referred to as extrusive or volcanic igneous rocks.

Igneous Rock Textural Terms

Before properly classifying and naming igneous rocks, it is highly essential that the student master the textural characteristic and properly apply the geologic term that describes each texture. Below are definitions of various igneous textural terms used in this lab:

<u>phaneritic</u> – minerals are visible to the naked eye and form a "mosaic" of interlocking crystal aggregates. Typically, mineral grains are greater than 1 mm.

<u>aphanitic</u> – mineral grains are too small to see without a hand lens and generally cannot be observed with an unaided eye. Mineral grains are less than 1 mm.

<u>vesicular</u> – "sponge-like appearance" textures that contain numerous cavities or holes.

<u>pyroclastic</u> – textures created by volcanic material that cooled rapidly as it was hurled through the air, picking up various rock fragments.

<u>glassy</u> – a texture created by extremely fast cooling or quenching of magma. Appears as glass or similar to the end of a broken coke bottle.

Igneous Rock Composition

Composition of igneous rocks is related to the various observed mineral assemblages. Depending on the chemical make-up of the cooling magma, igneous rocks will form groups of mineral assemblages that represent the igneous rock's composition, mineral make-up, or chemistry. For example, igneous rocks that form at higher temperatures contain mineral assemblages that are rich in iron (Fe), magnesium (Mg), and calcium (Ca), creating a dark-colored rock or a mafic composition. Mafic igneous rocks lack quartz and orthoclase and possess high concentrations of ferromagnesian minerals such as olivine, pyroxene, and amphibole. Igneous rocks that form at lower temperatures contain mineral assemblages rich in potassium (K), aluminum (Al), and sodium (Na), creating light-colored rocks or a felsic composition. Felsic igneous rocks are abundant in quartz, orthoclase, and sodium-rich plagioclase minerals. However, most felsic rocks will have small percentages of ferromagnesian minerals such as hornblende (amphibole) and biotite (mica mineral).

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As mentioned previously, igneous rocks are classified using both texture and composition. Using the igneous rock classification chart, note the textural terms located along the y-axis and compositional terms located along the x-axis. To properly use the igneous chart, you will simply perform a cross reference of texture and composition. The rock name is determined by the intersection point between the texture and composition. Use the igneous rock chart and follow the procedure below:

1. Identify the rock's texture. Inspect the rock using the hand lens and determine if the rock is either phaneritic, aphanitic, vesicular, glassy, or porphyritic.
2. If the rock appears phaneritic, estimate the percentage of felsic minerals compared to ferromagnesian minerals. If there is a higher percentage of felsic minerals, then the rock is of felsic composition. If the rock contains a higher percentage of ferromagnesian minerals and is predominantly dark-colored, then the rock is mafic. In other words, is the rock predominantly light or dark? If the rock appears aphanitic, then look for modifying textures such as glassy, vesicular, or porphyritic.
3. Use the igneous rock chart and cross reference the observed texture with the observed composition. Where the two "lines" cross is the rock name.

Sedimentary Rock Classification

Sedimentary Rock Textures

Sedimentary rock textures are typically characterized by observing lithified (cemented) inorganic grains, minerals, organic material, or fossil fragments. The wide range of textures common in sedimentary rocks is separated into clastic, chemical, and bioclastic (biochemical) groups.

<u>Clastic rocks</u>

Clastic textures are composed of cemented inorganic particles (clasts) that typically range in size from 1/256 mm (very fine) to grains measuring > 2 mm (coarse-grained). Particle size is described in three major categories, gravel (all particles > 2 mm in diameter), sand (particles < 2 mm but > 1/16 mm), and mud (particles < 1/16 mm). The proper classification (rock name) of clastic sedimentary rocks is dependent on particle (grain) size and composition.

<u>Chemical rocks</u>

Chemical sedimentary rocks are directly precipitated from bodies of aqueous solutions such as an ocean or lake environment through inorganic processes. The formation of chemical rocks is not dependent on currents or energy, and particle size is not as important in classification as in clastic rocks; instead, chemical sedimentary rocks are classified based on the chemical make-up of dominant minerals. Carbonates, evaporites, and chert form the three common chemical groups. In most cases, chemical rock textures lack the "clastic" nature of the other two sedimentary rock groups.

<u>Bioclastic (biochemical) rocks</u>

Biochemical rocks result from the weathering, transportation, and lithification of animal and plant parts as well as from animal and plant secretions. Bioclastic sedimentary rocks will typically display their "clastic" nature by revealing particles of lithified shell fragments, plant material, or fossil parts.

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Sedimentary Rock Composition

A sedimentary rock composition is dependent on varying mineral assemblages produced from the duration of weathering and transportation of sediment. For example, quartz is much more resistant to weathering than are feldspar minerals, and, therefore, the presence of quartz sandstone (chiefly composed of quartz grains) indicates the rock is mature and spent a long time in its depositional environment. However, sandstones rich in feldspar (arkosic sandstone) indicate the rock is immature and has spent less time in its depositional environment. Typically, feldspars will quickly weather to clay. Common minerals associated with clastic sedimentary rocks are quartz, feldspar, and rock fragments. Common minerals associated with chemical and bio-clastic sedimentary rocks are calcite ($CaCO_3$) and various forms of quartz.

Sedimentary Rock Classification Procedure

Step One:

Examine the rock and determine if the rock is clastic or has a non-clastic type textural characteristic. To be clastic, the rock must contain inorganic particles, notably sand, pebbles, or fine-grained sand grains. Note: Most non-clastic rocks are soft and do not scratch glass but can be scratched by a knife blade.

Step Two:

If the rock is clastic, use the provided rock charts and determine the grain size, features of the grains, and any diagnostic characteristics that can be used to narrow down the identification. For example, sub-divide your rock into coarse (gravel), medium (sand-sized), or fine-grained material (mud). Use your provided rock chart and ID the rock.

Step Three:

If the rock is non-clastic, determine if the rock is a chemical or biochemical (bio-clastic) rock.

Chemical rock: Typically, a chemical sedimentary rock will not contain any particles. Chemical rocks may be soft and react with acid (HCl), indicating the chemical composition possesses carbonates. In some cases, a chemical rock may display banding or layering and show fossil impressions.

Bioclastic (biochemical): These rocks will display various particles (clastic) composed of animal and plant remains. Some bio-clastic rocks are composed of shell fragments and decayed organic matter. In some cases, the rock will contain carbonaceous material and fizz when acid is present. Use your provided rock chart and study the various descriptions to properly ID the specimen.

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Metamorphic Rock Classification

Metamorphic Rock Texture

Like igneous and sedimentary rocks, metamorphic rocks are identified on the basis of both composition and texture. Metamorphic textures consist of two main types: foliated and non-foliated textures.

Foliated Textures

Foliated textures consist of various mineral constituents that are oriented in parallel, sub-parallel to platy type characteristics. As pressure and temperatures increase, metamorphic rocks will predominantly exhibit defined parallelism or definite alignment of minerals perpendicular to directed stress. In other words, low pressure-low temperatures produce poorly defined parallelism vs. high pressure-high temperatures, which result in well- defined parallelism. In addition to parallel orientation of minerals, foliated textures will consist of grain sizes ranging from fine-grained to coarse-grained mineral alignments. Typically, lower pressure-temperature relationships will produce finer grain size. Conversely, higher pressure-temperature relationships will produce coarse-grained metamorphic rocks.

Non-foliated Textures

Non-foliated textures have no visible grains or grain orientation. In fact, non-foliated textures are metamorphic rocks containing one single mineral type chemistry. For example, the metamorphic rock quartzite is composed entirely of SiO_2. The metamorphic rock marble is composed of CaCO3. Both the quartzite and marble are the same color and texture. How would one distinguish between them?

Metamorphic Rock Composition

Compositionally, quartz, feldspar, and muscovite make up the common metamorphic mineral constituents. However, there are numerous minerals that are primarily restricted to metamorphic rocks. These include garnet, chlorite, and talc, among others. The presence of these minerals indicates the various temperature and pressure relationships to which the parent rock was subjected.

Metamorphic Rock Classification Procedure

In this procedure, you will predominantly rely on the texture of the metamorphic rock. Any minerals (composition) you observe will serve as “modifiers” to the metamorphic rock name. For example, one might classify a foliated metamorphic rock by identifying it as a biotite, hornblende, and quartz gneiss.

Step One:

Examine the rock’s texture and determine if the rock is foliated or non-foliated (foliated = contains banding, layering, and grain sizes whereas non-foliated = no banding, one single chemistry).

Step Two:

If the rock is foliated, observe the grain size distribution in addition to the degree of parallelism. For example, one can have a metamorphic a rock that is coarse-grained with alternating bands of light and dark minerals. Refer to the rock chart under the foliated category and match the grain size distribution with diagnostic properties. ID the metamorphic rock.

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Step Three:

If the rock possesses a non-foliated texture, determine the composition and special features associated with the rock. For example, how would one determine the chemical compositional differences between the marble ($CaCO_3$) and quartzite (SiO_2)? Refer to the rock chart under the non-foliated category and match the chemistry with diagnostic properties. ID the metamorphic rock.

Part A. Igneous Rock Identification (20 pts)

For each vocabulary word below, write the definition and draw a diagram that illustrates the term:

- texture:
- composition:
- intrusive igneous rock:
- extrusive igneous rock:
- ferromagnesium:
- mafic composition:
- felsic composition:

Using the text book, draw an illustration in each circle (hand lens view) that represents each igneous rock texture. In your own words, describe each texture.

phaneritic aphanitic

glassy vesicular pyroclastic

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The silicate minerals are the most common minerals in the earth's crust. What two chemical elements are the silicates made of? _______________ ___________________

Using the following chart, identify the igneous rock specimens:

Texture		Color (Mineral Composition)		
		Light	Medium	Dark
Intrusive	Coarse-grained	Granite	Diorite	Gabbro
Extrusive	Fine-grained	Rhyolite	Andesite	Basalt
	Vesicular	Pumice		Scoria
	Glassy	Obsidian		
	Fragmental	Tuff and Breccia		

Sample #	Name
B-2	
B-9	
B-13	
B-10	
B-3	

Part B. Sedimentary Rock Identification (20 pts)

For each vocabulary word below, write the definition and draw a diagram that illustrates the term.

- clastic sedimentary rock:
- chemical sedimentary rock:
- bioclastic (bio-chemical) sedimentary rock:
- lithification:
- non-clastic:

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Using the text book, draw an illustration in each circle (hand lens view) that represents each igneous rock texture. In your own words, describe each texture.

clastic chemical bioclastic (biochemical)

Use the following charts to identify the sedimentary rock specimens:

Dominant Constituents	Textural Features	Composition and Diagnostic Features	Rock Name
INORGANIC CLASTIC (DETRITAL)	Pebbles imbedded in matrix of cemented sand 2+ mm diameter	Angular rock / mineral fragments	BRECCIA
		Rounded rock and / or mineral fragments	CONGLOMERATE
Sandstone Family	Coarse sand particles 1/16 – 2mm in size	Angular fragments of feldspar mixed with quartz and other minerals	ARKOSE SANDSTONE
	Sand sized particles 1/16 – 2mm in size	Angular to rounded grains of quartz. Various color staining and may appear banded.	QUARTZ SANDSTONE
	Sand sized particles mixed with clay or mud	Quartz with other mineral grains mixed with clay. Gray, gray-green color	GRAYWACKE SANDSTONE
	Fine-grained sand and clay Mix, 1/256 – 1/16 mm	Fine particles of quartz and clay, grains are too small to be seen. Feels gritty -- when rubbed across your teeth	SILTSTONE
	Fine-grained clay minerals Less than 1/256 mm	Fine clay and mud. Visible layering and lamination. Variable color.	SHALE
INORGANIC CHEMICAL PRECIPITATES (Non-clastic)	Medium to coarse-grained, Crystalline (shows xls)	Calcium Carbonate ($CaCO_3$ - calcite) Effervesces in HCL. White, gray, black	CRYSTALLINE LIMESTONE
	Medium to coarse-grained	Calcium carbonate ($CaCO_3$– calcite) Effervesces in HCL	LIMESTONE
	Dense, banded layers	Calcium carbonate (calcite), Effervesces Banded layers, light to dark colors.	TRAVERTINE
	Dense, Cryptocrystalline	Silica, quartz alteration. May have fossils Variations include: jasper, flint, agate.	CHERT
BIOCLASTIC (ORGANIC)	Fine-grained, earthy soft	Microscopic protozoa shells (calcite) typically white.	CHALK
	Medium to coarse-grained abundant fossils	Calcium carbonate (calcite) Effervesces in HCl. Light to dark colors	FOSSILIFEROUS LIMESTONE
	Coarse, fragmental	Poorly cemented aggregate of sea shells	COQUINA
	Fine-grained, earthy	Microscopic siliceous plants, soft, white Readily absorbs liquids	DIATOMITE
	Fibrous, spongy, carbonaceous	Decayed and compacted plant material. non-marine, soft, brown	PEAT
	Dense, Carbonaceous	Compacted, non-marine plants. Brn-blak	LIGNITE
	Dense, Carbonaceous	Lithified plant materials. Harder than Peat and lignite. Smudges hands, black	BITUMINOUS COAL

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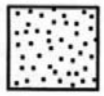
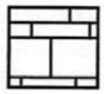
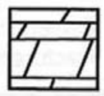
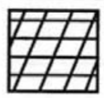
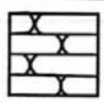
Origin	Sediment	Sedimentary Rock	Symbol	Characteristics
Terrigenous Clastics	Clay	Shale		Primarily clay and quartz grains of silt-size (<1/16 mm) or smaller having a thin platy structure.
	Sand	Sandstone		Sand-sized grains, (1/16 mm – 2 mm) composed of quartz, feldspar and rock fragments cemented by silica, calcite, or clay.
	Gravel	Conglomerate		Rounded coarse-grained (>2 mm) rock particles usually cemented by silica or calcite.
Carbonates	Calcite $CaCO_3$	Limestone		Calcareous grains and skeletal fragments cemented with calcite, often containing fossils. Effervesces in dilute HCl.
	Dolomite $CaMg(CO_3)_2$	Dolomite		Dolomite grains commonly resulting from alteration of limestone. Effervesces only in powdered form.
Other	Plant remains	Coal		Lignite, bituminous, or anthracite, formed by the alteration of plant debris.
	Gypsum $CaSO_4 \cdot 2H_2O$	Gypsum		Occurs normally in sedimentary rocks as thin interbedded layers, formed by the evaporation of mineral-rich waters.
	Halite NaCl	Rock Salt		Accumulated by the evaporation of sea water.
	Silica SiO_2	Chert		Dissolved from rocks by water, precipitated by both physical and biological means. Occurs in both fresh water and marine deposits.

Sample #	Name
C-15	
C-9	
C-10	
C-8	
C-2	

(9 – 1 pt) When preexisting rocks are subjected to ___________, ___________, and chemically active fluids they can be converted into metamorphic rock.

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Part C. Metamorphic Rock Identification (20 pts)

For each vocabulary word below, write the definition and draw a diagram that illustrates the term.

- metamorphism:
- metamorphic rock:
- parent rock (protolith):
- solid-state transformation:
- foliated texture:
- non-foliated texture:

Using the text book, draw an illustration in each circle (hand lens view) that represents each metamorphic rock texture. In your own words, describe each texture.

Gneissic texture   schistose texture   slaty texture

Non-foliated texture   Marble   Quartzite

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Use the following charts to identify the metamorphic rocks.

TEXTURE	DIAGNOSTIC FEATURES	PARENT ROCK	ROCK NAME
FOLIATED	Dense microscopic grains. Foliation appears compacted with distinct planer "layering" Dark colors.(slaty texture)	shale, mudstone, tuff	SLATE
	Thin parallel arrangement of platy minerals usually micaceous (barley microscpic). Often exhibits a sheen like luster (phyllitic texture)	shale, mudstone, tuff	PHYLLITE
	Coarse to fine-grained. Sub-parallel to parallel orientation of platy minerals, Common minerals: mica, quartz, amphibole (schistose texture)	shale, slate, tuff, basalt	SCHIST
	Coarse-grained alternating light (felsic) and dark (mafic) mineral bands.	granite, gabbro, diorite Graywackie	GNEISS
NON-FOLIATED	Fine to coarse-grained. Soft and usually light colors with occasional Banding. Effervesces in HCl	Limestone, Dolomite	MARBLE
	Fine to coarse-grained. Hard re-crystallized quartz. Quartz grains appeared fused together. Occasionally banded.	Sandstone	QUARTZITE
	Very fine-grained, dense and massive.	Shale, Intermediate extrusive rocks	HORNFELS
	Fine to medium-grained, Green to yellow Compacted grains, Commonly appears Waxy with slickenslides. Common minerals: Serpentine, hornblende, pyroxene and olivine.	Ultramafic igneous rocks Peridotite, Dunite	SERPENTINITE
	Fine-grained to massive. Dark green in color	Basalt, Schist	GREENSTONE
	Fine-grained to massive. Dark gray to black, shiny luster with occasional iridescent sheen, conchoidal fracture	Bituminous Coal	ANTHRACITE

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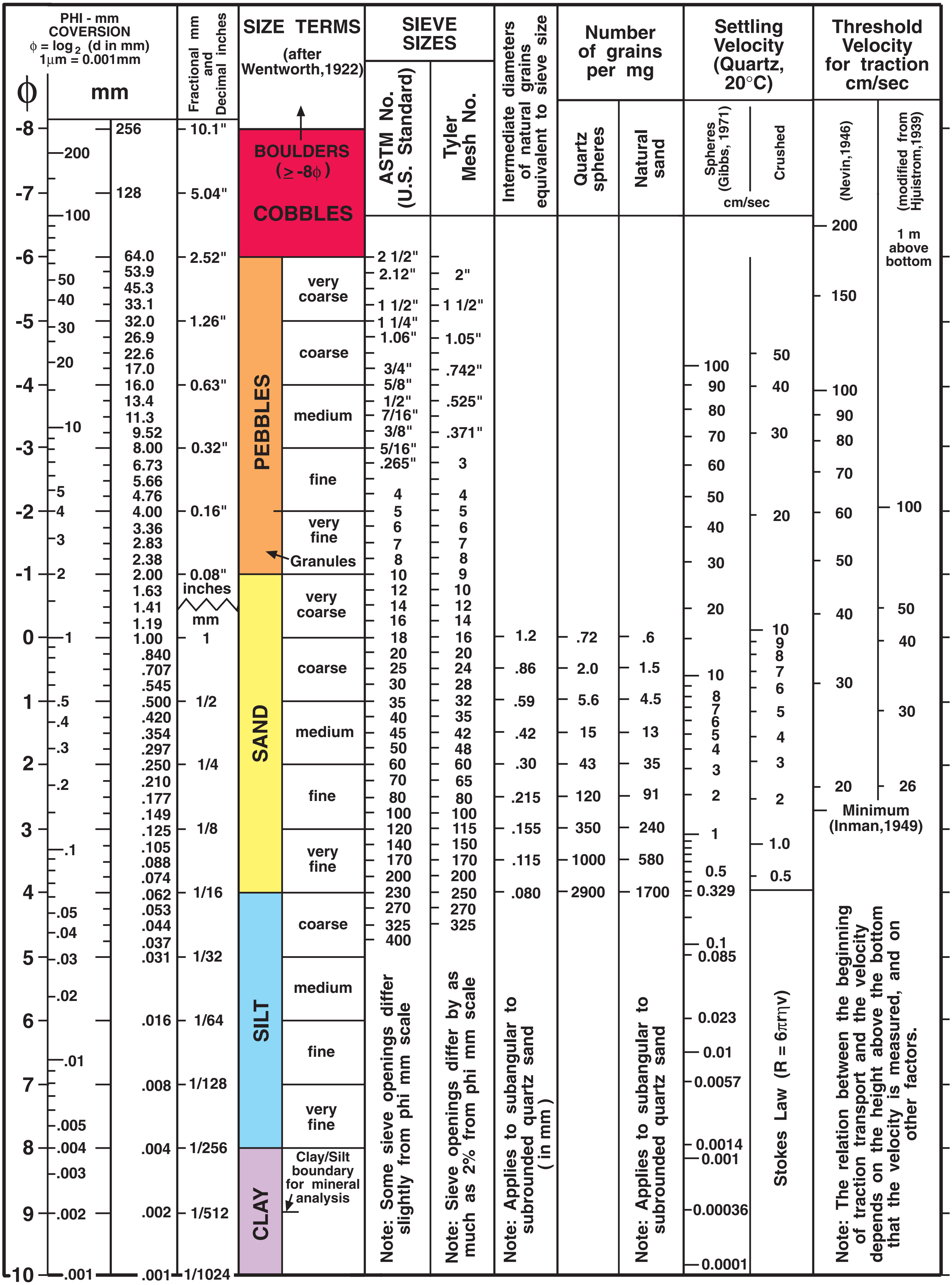
Parent Rock	Metamorphic Rock	Characteristics
Limestone or Dolomite	Marble	Coarsely crystalline, commonly white, though variable in color, effervesces in dilute HCl.
Shale	Slate	Resembles shale, except much harder, cleavage plates form at angles to bedding of parent rock.
Quartzose Sandstone	Quartzite	Massive, hard, interlocking grains of quartz bound so tightly that fracturing will break through the individual grains of quartz.
Virtually Any Igneous and Sedimentary Rock	Schist	Mineral grains are elongated, producing a laminated appearance called foliation. Garnet and mica are common minerals.
Conglomerate	Metaconglomerate	Resembles conglomerate, except much harder, fractures break through the pebbles.
Impure Sedimentary Rocks and Granite	Gneiss	Mineral grains form sub-parallel light and dark bands.

Sample #	Name
D-3	
D-7	
D-2	
D-4	
D-5	



PHI - mm COVERSION
ϕ = log2 (d in mm)
1µm = 0.001mm
ϕ
mm
Fractional mm and Decimal inches
SIZE TERMS
(after Wentworth,1922)
SIEVE SIZES
ASTM No. (U.S. Standard)
Tyler Mesh No.
Intermediate diameters of natural grains equivalent to sieve size
Number of grains per mg
Quartz spheres
Natural sand
Settling Velocity (Quartz, 20°C)
Spheres (Gibbs, 1971)
Crushed
cm/sec
Threshold Velocity for traction cm/sec
(Nevin,1946)
(modified from Hjulstrom,1939)
1 m above bottom
-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10
200 100 50 40 30 20 10 5 4 3 2 1 .5 .4 .3 .2 .1 .05 .04 .03 .02 .01 .005 .004 .003 .002 .001
256 128 64.0 53.9 45.3 33.1 32.0 26.9 22.6 17.0 16.0 13.4 11.3 9.52 8.00 6.73 5.66 4.76 4.00 3.36 2.83 2.38 2.00 1.63 1.41 1.19 1.00 .840 .707 .545 .500 .420 .354 .297 .250 .210 .177 .149 .125 .105 .088 .074 .062 .053 .044 .037 .031 .016 .008 .004 .002 .001
10.1" 5.04" 2.52" 1.26" 0.63" 0.32" 0.16" 0.08"
inches
mm
1 1/2 1/4 1/8 1/16 1/32 1/64 1/128 1/256 1/512 1/1024
BOULDERS (≥ -8ϕ)
COBBLES
PEBBLES
very coarse
coarse
medium
fine
very fine
Granules
SAND
very coarse
coarse
medium
fine
very fine
SILT
coarse
medium
fine
very fine
CLAY
Clay/Silt boundary for mineral analysis
2 1/2" 2.12" 1 1/2" 1 1/4" 1.06" 3/4" 5/8" 1/2" 7/16" 3/8" 5/16" .265" 4 5 6 7 8 10 12 14 16 18 20 25 30 35 40 45 50 60 70 80 100 120 140 170 200 230 270 325 400
2" 1 1/2" 1.05" .742" .525" .371" 3 4 5 6 7 8 9 10 12 14 16 20 24 28 32 35 42 48 60 65 80 100 115 150 170 200 250 270 325
Note: Some sieve openings differ slightly from phi mm scale
Note: Sieve openings differ by as much as 2% from phi mm scale
1.2 .86 .59 .42 .30 .215 .155 .115 .080
Note: Applies to subangular to subrounded quartz sand (in mm)
.72 2.0 5.6 15 43 120 350 1000 2900
.6 1.5 4.5 13 35 91 240 580 1700
Note: Applies to subangular to subrounded quartz sand
100 90 80 70 60 50 40 30 20 10 8 7 6 5 4 3 2 1 0.5 0.329 0.1 0.085 0.023 0.01 0.0057 0.0014 0.001 0.00036 0.0001
50 40 30 20 10 9 8 7 6 5 4 3 2 1.0 0.5
Stokes Law (R = 6πrηv)
200 150 100 90 80 70 60 50 40 30 20
100 50 40 30 26
Minimum (Inman,1949)
Note: The relation between the beginning of traction transport and the velocity of traction depends on the height above the bottom that the velocity is measured, and on other factors.