Soil Formation and Properties

Background

All things on the surface of the earth are worn away over time. Organic materials decay, metals rust, and rocks weather. These ongoing processes form the soils that many organisms depend on, and they help determine the types of soil found in any environment. As these processes continue, soil changes. Some changes are accomplished relatively quickly, while others take place over millennia.

Rocks are the primary component of soil. As rocks weather, they are broken into smaller pieces, which become soil particles. These particles are composed of different minerals depending on the makeup of the parent rock, but that is only part of what makes up soil. Organic material from decomposing plants and animals supplies soil with valuable nutrients needed to sustain life. Some ecosystems, such as deserts, have a small biological community, so the soil has less organic material. Other ecosystems, such as temperate forests, produce a great deal of organic material, causing the soil to be quite rich.

PART I: Mechanical & Chemical Weathering

There are three main ways in which soils are formed. The three processes are mechanical, chemical, and biological weathering. All three processes are working at the same time to break down rocks. Mechanical weathering breaks rocks into smaller pieces. This process is called disintegration. Chemical weathering can change the mineral makeup of the rock. This is called decomposition. Biological weathering can take the form of disintegration or decomposition, but always involves living organisms.

There are several forces that cause physical weathering of rock. Water is one of the most powerful causes of physical weathering. Over time, rocks are worn away as water flows over them. Rocks in fast-moving streams can also be tumbled, impacting each other and chipping or fragmenting. Water also penetrates cracks in rocks. At lower temperatures, the water freezes and expands, further breaking apart the rock. Mechanical weathering also occurs from friction, for example, when wind blows sand and dust particles across the surface of rocks.

Chemical weathering is the decomposition of rock, the result of chemical reactions between minerals in the rock and the environment. Water not only causes physical weathering by wearing away the rock, it also dissolves minerals out of rock. Some common minerals, such as feldspar, chemically react with water to form clay. Oxygen reacts with certain minerals and elements found in rocks, too, forming compounds called oxides. For example, iron-bearing minerals exposed to oxygen will form iron oxide, commonly called rust. The result is the formation of red-brown rings on the rocks. Rust can form in the presence of air, but the process is sped up when water comes into contact with iron. These processes alter the structure of minerals, allowing other weathering processes to further break down the rock.

Acids occur naturally in the environment, and many acids are created by natural processes. However, human activities such as burning fossil fuels have increased the quantity of carbon, nitrogen, and sulfur in the atmosphere. These elements react with water in the air to produce carbonic acid, nitric acid, and sulfuric acid, respectively. These acids bind with rainwater to form acid rain. Some minerals, and many living organisms, are decomposed by acid rain. Long-term exposure to acid deposition in certain areas of the world has had a profound effect, not only on the natural environment, but also on human-built structures composed of similar minerals.

Materials: samples of presoaked granite, marble, and basalt, hand lens, 3 small vials w/caps, HCl, forceps, paper towels, weigh boats

Procedure – Mechanical Weathering:

1. Acquire about 10 g each of presoaked granite, basalt, and marble.
2. Using paper towels, dab each rock so that there is no water dripping from it.
3. Weigh the granite, basalt, and marble samples. Record the initial masses in Table 1.
4. Using hand lens, inspect each group of rocks. In Table 1, make notes about surface texture, sharp edges, and general appearance.
5. Place the granite, basalt, and marble samples in three separate small, capped vials.
6. Fill each vial with just enough water to cover the rocks.
7. Secure the lids to the top of the vials.
8. With your lab partners, shake all of the vials continuously for three minutes. Be sure that all samples of rocks are shaken with the same vigorousness (ie. the shake “rhythm” must be the same).
9. Using forceps, remove the rocks from the vials, towel them off, and reweigh each group. Record the masses in Table 1 in the "3 min" column.
10. Place the rocks back in the vials. Add water if necessary, so that the rock are submerged, and then shake the vials continuously for another three minutes. Record the masses in Table 1 in the "6 min" column.
11. Repeat Step 10 and Step 11 two more times and record the results in Table 1.
12. Using a hand lens, inspect each group of rocks. In Table 1, describe any changes in surface texture, edges, size, or general appearance.
13. Plot the mass results for the granite, basalt, and marble samples on a line graph, showing mass changes over time. Include a trend line on your graph.
14. Answer the questions in the *Results & Analysis* section.

Table 1: Mechanical Weathering

Rock Type	Mass (g)				
	Initial	3 min	6 min	9 min	12 min
Granite					
Basalt					
Marble					

Rock Type	Visual Observations	
	Initial	Final
Granite		
Basalt		
Marble		

Procedure – Chemical Weathering:

1. Use the granite, basalt, and marble samples you used for the “Mechanical Weathering” activity.
2. Using paper towels, dab each rock so that there is no water dripping from it.
3. Weigh the granite, basalt, and marble samples. Record the initial masses in Table 2.
4. Using a hand lens, inspect each group of rocks. In Table 2, make notes about surface texture, sharp edges, and general appearance.
5. Place the granite, basalt, and marble samples in three separate small, capped vials.
6. Carefully pour enough hydrochloric acid (HCl) into each vial to cover the rocks. Observe the results.
7. ***Do not cap the vials immediately.*** After several minutes have passed, secure the lids to the vials and place them in a secure area to be stored overnight.

8. After approximately 24 hours have passed, carefully uncap the vials. Without disturbing the rocks, drain the acid into the sink. Turn on the faucet and wash the acid away with copious amounts of water.
9. Wash the acid from the rocks; fill the vials with water and, without disturbing the rocks, pour the water into the sink. Repeat this step two more times.
10. Using forceps, remove the rocks from the vial and place them on paper towels to absorb the excess water.
11. Once there is no water dripping from the rocks, reweigh each sample and record the results in the "Final Mass" column.
12. Using a hand lens, inspect each group of rocks. In Table 2, describe any changes in surface texture, edges, size, or general appearance.
13. Plot the mass results for the granite, basalt, and marble samples on a bar graph, showing the mass before and after the rocks were weathered by the acid.
14. Answer the questions in the *Results & Analysis* section.

Table 2: Chemical Weathering

Rock Type	Mass (g)	
	Initial	Final
Granite		
Basalt		
Marble		

Rock Type	Visual Observations	
	Initial	Final
Granite		
Basalt		
Marble		

PART II: Soil Texture

In this activity, you will use the "Texture by Feel Analysis of Soil" flow chart to determine the texture of your soil sample. First, familiarize yourself with the procedure by practicing the soil analysis using the known samples, sand and clay. Then, determine the texture of your soil sample.

Groups will be provided with samples of sand and clay, typical components of soil. Sand should not form a ball even after water is added. Use the clay sample analysis to practice forming a soil ribbon. Clay should form a ribbon that is at least 5 cm long before it breaks. If you have trouble getting a 5 cm ribbon, make sure the ribbon is of uniform thickness and width. Practice with the clay until you can confidently make a ribbon. Then, use this technique to determine the texture of your soil sample.

Materials: sand sample, clay sample, collected soil sample, spray bottle w/water, hand lens

Procedure – Soil Texture:

1. Follow the “Texture by Feel Analysis of Soil” procedure on the following page for the sand and clay sample. This is to familiarize you with samples that are 100% sand and 100% clay, respectively.
2. Use the same procedure to determine the soil texture of your collected sample. Write your soil texture determination in the space below.
3. Answer the questions in the *Results & Analysis* section.

Soil Texture: ____

Texture by Feel Analysis of Soil

START

Place a small fistful of soil in the palm of your hand. Mist it with tap water from the spray bottle. Knead the soil to break up aggregates (clumps). If too wet, add soil one pinch at a time; if too dry, mist the soil again. Squeeze the sample. Does it form a ball when squeezed?

- NO → Add water. Does it form a ball when squeezed?
  - NO → **SAND**
  - YES → (go to the ribbon step)
- YES → (go to the ribbon step)

Place the ball between thumb and forefinger. Try to form a ribbon of soil, pressing the sample flat by gently pushing down and forward with your thumb. Allow the ribbon to extend over the forefinger and break under its own weight. Does the soil form a ribbon?

- NO → **LOAMY SAND**
- YES → Estimate the length of the soil ribbon. Is the ribbon less than 2.5 cm?
  - NO → Between 2.5 cm–5.0 cm?
    - NO → Greater than 5.0 cm?

In the palm of your hand, excessively wet a pinch of the sample and rub it with your forefinger.

Ribbon less than 2.5 cm (YES):

- Does the soil feel gritty? YES → **SANDY LOAM**
- NO → Does the soil feel smooth? YES → **SILTY LOAM**
- NO → Neither grittiness nor smoothness predominates. YES → **LOAM**

Between 2.5 cm–5.0 cm (YES):

- Does the soil feel gritty? YES → **SANDY CLAY LOAM**
- NO → Does the soil feel smooth? YES → **SILTY CLAY LOAM**
- NO → Neither grittiness nor smoothness predominates. YES → **CLAY LOAM**

Greater than 5.0 cm (YES):

- Does the soil feel gritty? YES → **SANDY CLAY**
- NO → Does the soil feel smooth? YES → **SILTY CLAY**
- NO → Neither grittiness nor smoothness predominates. YES → **CLAY**

PART III: Particle Size Distribution

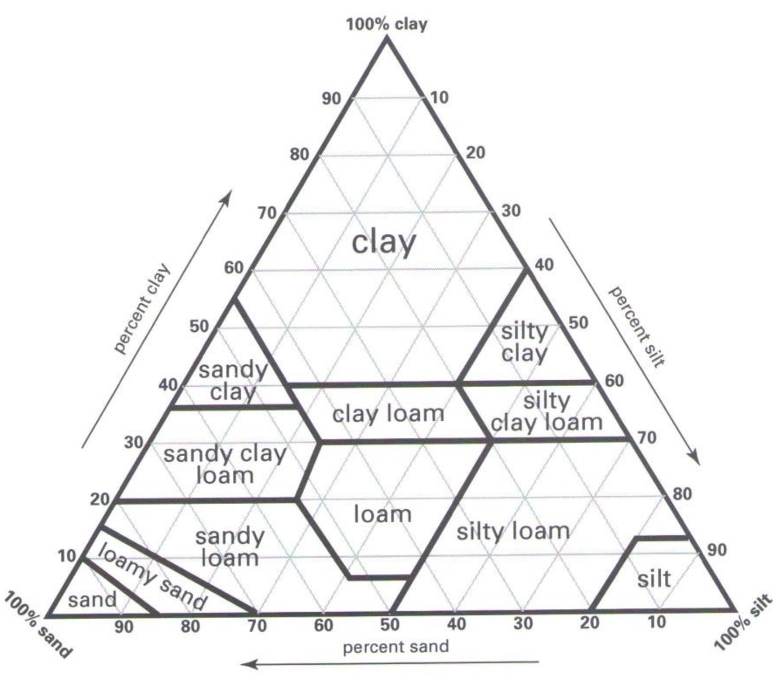
The sizes and proportions of the particles of sand, rocks, pebbles, and other components of soil determine its ability as a substrate for trees, shrubs, and other plants. Soil's ability to properly anchor plants to the ground, retain moisture, and support subterranean organisms is directly connected to its texture and particle size distribution.

Materials: collected soil sample, clear jar w/lid, china marker, ruler

Procedure:

1. Use the china marker to label the lid of your sample with your group number.
2. Fill the jar about halfway full with your collected soil sample. Break up any large clumps prior to filling the jars. You should also remove any particularly large pebbles.
3. Add tap water to just below the rim of the jar and tighten the lid.
4. Shake the jar vigorously for 30 seconds.
5. Place the jar in a location where it can remain undisturbed and perfectly level for at least 24 hours.

6. After at least 24 hours, carefully move your sample jar to a location where you can observe it easily. Using a white piece of paper as a backdrop behind the jar may help you to visualize the layers better.
7. With the china marker, label each layer. The dark layer at the top is humus (organic material), the next layer down is clay, followed by silt, and finally sand at the bottom.
8. Measure the thickness of each layer with a ruler and record it in Table 3. Since humus is an organic component of soil, do not measure this layer.
9. Calculate the particle size distribution: Divide the total depth of the soil (not including the humus layer), into the depth of each soil layer. Multiply this value by 100 to determine the percentage. Record the percentages of clay, silt, and sand in your sample in Table 3.
10. Follow the instructions below to use the Soil Analysis Triangle. Record your results in Table 3.
11. Answer the questions in the *Results & Analysis* section.



Soil Analysis Chart
(patterned after USDA Soil Analysis Chart)

<u>How to Use the Soil Analysis Triangle</u>:

1. The corners of the triangle represent 100% of each of the three classes of soil-silt, sand, and clay. Locate these. Loam soil is a mixture of all three, and is found in the center of the triangle. Point your finger to the loam.
2. Follow the arrows on the sides of the triangle. The right side of the triangle indicates the percentage of silt, the bottom of the triangle indicates the percentage of sand, and the left side of the triangle indicates the percentage of clay.
3. Find the percentage of silt (calculated on the data sheet) of your soil sample on the right side of the triangle and point to it.
4. Find the percentage of sand of your soil sample on the bottom of the triangle, and with your other hand, point to it.
5. Following the corresponding diagonal lines, move your fingers toward each other until the lines intersect.
6. If you have found the correct intersecting lines, your sample's percentage of clay should be lined up horizontally to the left of where your fingers meet. This point of intersection indicates the soil's texture class.

Table 3: Particle Size Distribution

	Depth of Clay Layer	Depth of Silt Layer	Depth of Sand Layer	Total Depth	% Clay	% Silt	% Sand	Soil Type
Collected Sample								

PART IV: Water-Holding Capacity and Capillary Action of Soil

The capillary action of soil can be observed by placing columns filled with different soil samples in water. Weighing the saturated samples will determine the water-holding capacity of each soil type. Soil samples must settle overnight so that you can interpret their water-holding capacities the next day.

Materials: sand sample, clay sample, humus sample, collected soil sample, 4 plastic columns, 4 vials, 4 rubber bands, 8 2.5 cm squares of cheesecloth, china marker, scissors, ruler, 10 mL graduated cylinder, paper towels

Procedure:

1. Cut two squares of cheesecloth that will fit securely over the end of the small plastic column. Secure the cheesecloth over the end of a column with a rubber band. Use just enough cloth to cover the end to be able to see the soil in the column and to minimize the amount of water absorbed by the cheesecloth. Do the same for three more columns.
2. Using the china marker, label the four columns as follows: Clay, Sand, Humus, and Soil.
3. Lay the columns side by side, and make a mark 7 cm up the column from the end covered by cheesecloth. The mark must be at the same level on each column.
4. Weigh each empty column and record the mass on the data sheet.
5. After all the columns have been weighed, take them to the soil station. Pour some clay onto a paper towel and carefully crush or remove every lump and rock. Fill the Clay column to your mark with this clay, the Sand column to your mark with sand, and the Humus column to your mark with humus.
6. Pour some of the collected soil sample onto a paper towel and carefully crush any lumps. Fill the Soil column with this soil.
7. Take the columns back to the balance and weigh the columns containing the dry samples. Record the masses on Table 4.
8. Pour 10 mL of water into each of the four vials, using the graduated cylinder to measure the amount.
9. Place the column of sand into one of the vials of water so that the bottom of the cylinder rests on the bottom of the vial (*Fig. 1*). Observe what happens to the water.
10. Repeat the procedure with the collected soil sample, clay, and humus columns. If the column is not completely saturated by the end of the laboratory period, add a little more water to each vial and let the columns sit, undisturbed, overnight.
11. Calculate, on the data sheet, the mass of soil for each column.

12. After 24 hours have passed, all of the soil columns should now be saturated. Remove the columns from the vials and hold them until the dripping stops.
13. Weigh each column. Record the mass on the data sheet.
14. Calculate the mass of the water and the water-holding capacity on the data sheet.
15. Answer the questions in the *Results & Analysis* section.

Table 4: Water-Holding Capacity

	Clay	Sand	Humus	Collected Soil
1. Mass of Empty Column (g)				
2. Mass of Column and Soil (g)				
3. Mass of Soil (g) (row 2 – row 1)				
4. Mass of Column and Saturated Soil (g)				
5. Mass of Water (g) (row 4 – row 2)				
6. Water Holding Capacity (row 5 / row 3)				

Low Capacity	Medium Capacity	High Capacity
< 0.4	0.4 – 0.6	> 0.6

Results & Analysis

On a separate sheet of paper, answer the following questions thoroughly using complete sentences. You may complete your work on the computer. Staple your work to the back of this packet.

PART I

1. In terms of mass and shape, which rock seems most affected by mechanical weathering? Which seems least affected?
2. Calculate the final mass of each rock type if the samples were shaken in the vials for 24 hours. Be sure to show your work.
3. List some regions where mechanical weathering caused by water is likely to have a significant impact. What regions are less likely to experience this type of weathering?
4. What are some signs of mechanical weathering on rocks?
5. In terms of mass and shape, which rock seems most affected by chemical weathering? Which seems least affected?
6. Describe the difference between physical and chemical weathering of rocks.

PART II

7. Consider the soil sample you analyzed and describe the relationship between texture and consistence.
8. How might consistence of soil affect the growth of plants? Think about both wet and dry soil conditions.
9. Based on your analysis, what type of soil do you believe your sample to be? (see *PART II*)

PART III

10. What happened to the soil particles in the jar overnight? Explain.
11. Based on your analysis, what type of soil do you believe your sample to be? (see Table 3)
12. How do you answers to #11 and #9 compare? Explain why they may differ.

PART IV

13. Consult with other group's results for the soil sample's water-holding capacity. How do the water-holding capacities compare from group-to-group?
14. What characteristic of soil seems to be most important in determining its water-holding capacity? Explain your answer.