USDA Natural Resources Conservation Service
U.S. DEPARTMENT OF AGRICULTURE

AGI american geosciences institute
connecting earth, science, and people

Earth Science Education Activity

Investigating Clay Properties in Soil

Background: Wetlands, though covering only about 4–6% of Earth's surface, play a vital role in ecological and human systems. They buffer storm impacts by absorbing runoff, filter and purify water, protect shorelines, and store carbon, while also supporting biodiversity, agriculture, and recreation. Defined by prolonged soil saturation, wetlands develop low-oxygen conditions that support specialized plant, microbial, and animal communities. The soils within wetlands strongly influence how water is stored and moves through these environments.

Clay minerals are especially important in determining wetland behavior. These sheet-like minerals (phyllosilicates) can be classified as 1:1 or 2:1 based on their structure. Non-expansive 1:1 clays, such as kaolinite, limit water movement between layers, while expansive 2:1 clays—such as montmorillonite and vermiculite—allow water to enter between layers, causing soils to swell when wet and shrink and crack when dry. This shrink-swell behavior directly affects wetland hydrology, influencing water retention during wet periods and water loss during dry periods. Beyond wetlands, clay composition also impacts land stability, agriculture, and susceptibility to hazards such as erosion and landslides.

Key Question: How do the structures of different clays shape wetland soil behavior and influence land use decisions?

Wetlands can be found in agricultural fields, such as this one near Montgomery, Alabama. During the wet season, soils rich in 2:1 clay minerals absorb water and swell, becoming sticky and plastic-like as water enters the spaces between the mineral layers.

Credit: Lauren Cooper

Soils with high clay content (typical of the Vertisol order) can shrink during dry seasons and swell during wet seasons..

Credit: Lauren Cooper

STANDARDS

NGSS: HS-ESS2-5, HS-PS2-6
SDG 15: Life on land
SDG 6: Clean water and sanitation

Learn more about the United Nation's Sustainable Development Goals (SDGs) and explore resources for educators from UNESCO.

MATERIALS

- two different soils samples:
  - Sample 1: dry a kaolinite, non-expanding 1:1 clay
  - Sample 2: a dry smectitic 2:1 clay, like montmorillonite or bentonite
- squirt bottles of water or cups of water with pipettes
- small metal trays or small petri dishes
- mixing bowl or beaker (200 ml works best)
- spatula or wooden stick
- tablespoon
- tablecloth or similar (optional)

Acknowledgement: This lesson was developed by Lauren Cooper in collaboration with AGI.

The USDA NRCS delivers science-based soil information to help farmers, ranchers, foresters, and other land managers effectively manage, conserve, and appraise their most valuable investment — the soil.

PROCEDURE

1. Make visual and physical observations of each sample. For each,

    a. Describe the color. For a precise color description, utilize the **Munsell color chart**.)

    b. Take a dry sample in the palm of your hand. Rub the sample between your fingers. What does the sample feel like? (Gritty, smooth, powdery, dense, light, etc.)

2. Make predictions: What do you think will happen when water is added to each sample initially and after one week?

3. Place 3–4 tablespoons of a dry sample in the palm of your hand.

4. Slowly add water until the sample is tacky enough to form a golf ball size without falling apart.

    a. Record how many squirts or pipettes of water you used.

    b. Note changes in the color and behavior as water is added.

5. Repeat steps 3 and 4 with the other sample and record observations. Also note differences between the samples.

6. Prepare long-term observation dishes:

    a. In a mixing bowl or beaker, add five tablespoons of a sample and slowly begin to add water, about 10ml at a time. Add enough water so it starts to form a thick slurry. There should be no standing water or large dry chunks of the sample in the bowl/beaker. Mix thoroughly.

Clay mineral kaolinite sample (left) and montmorillonite sample (right) in a thick slurry with no standing water in a 200 ml beaker.
Credit (both): Lauren Cooper

    b. Using a spreading tool, start to add the sample mixture into the petri dish or tin can. Make sure to evenly coat the entire area by gently tapping it on the table between scoops to avoid air bubbles and uneven coating. Add excess sample to the top, and in one fluid motion, evenly scrape excess sample from the surface. If there are still air bubbles or an uneven surface, repeat until it is as smooth and even as possible.

Slurry added to tins.
Credit: Lauren Cooper

7. Let the sample dry for over one week and return for observations.

ANALYSIS

1. Which sample needed more water to form a golf ball size? Which one felt stickier?

2. Describe each sample after one week in the tin can.

3. Visit the Virtual Museum of Molecules and Minerals (**https://virtual-museum.soils.wisc.edu/**) to understand the samples better at a molecular level. Explore the structure of "kaolinite" (similar to sample 1) and "smectite" (similar to sample 2) by utilizing the search bar at the top of the page.

   a. With words and pictures, describe the structure of each clay.

   b. In your own words, describe the difference between a 1:1 clay and a 2:1 clay.

   c. How do you think these structural differences impact water absorption and swelling?

4. How do the molecular structures explain what you observed in the activity? Which sample do you think is a 1:1 clay and which is a 2:1 clay? Provide evidence for your reasoning.

SYNTHESIS

The Blackland Prairie region of Alabama contains soils of the Vertisol order rich in 2:1 smectitic clays. These soils exhibit unique characteristics like shrinking when dry and swelling when wet. The Blackland Prairie is a distinct region within the Alabama Coastal Plain, which contains a variety of soil types. The eastern part of the Lower Coastal Plain is abundant with more stable, non-expanding 1:1 clay minerals like kaolinite. Based on your molecular observations and hands-on testing, which clay mineral (montmorillonite or kaolinite) would be better for supporting a healthy wetland ecosystem during seasonal flooding? Which clay mineral would be more suitable for building structures? Support your answers with specific evidence from how each clay is impacted by differences in moisture.

EXTENSION

Visit Web Soil Survey and learn about your soil. In your own words, describe 3 features of your soil series. If you have a soil that is kaolinitic or smectitic, what does this tell you about the shrink-swell potential? If your soil does not have either of these clay minerals, what is the texture? Hypothesize, do you think your soil would have a good ability to retain water? Why or why not?

USING WEB SOIL SURVEY to ASSES THE CLAY CONTENT IN YOUR SOIL

1. Visit **https://websoilsurvey.nrcs.usda.gov/** and get acquainted with the site.

2. Select the green button that says "START WSS."

3. Select an Area of Interest (AOI):

   a. Under the brown Quick Navigation tab, select Address.

   b. Type in a specific address, or just a city and/or state for an area where you'd like to learn more about the soil. Hit "Enter" or select the "View" button.

   c. Use the magnifying glasses  to zoom in or out. If you'd like to zoom in, select the + magnifying glass, then click on the map. Similarly, select the – magnifying glass and click on the map to zoom out.

   d. Use the hand button  to move the map around until your desired AOI is centered.

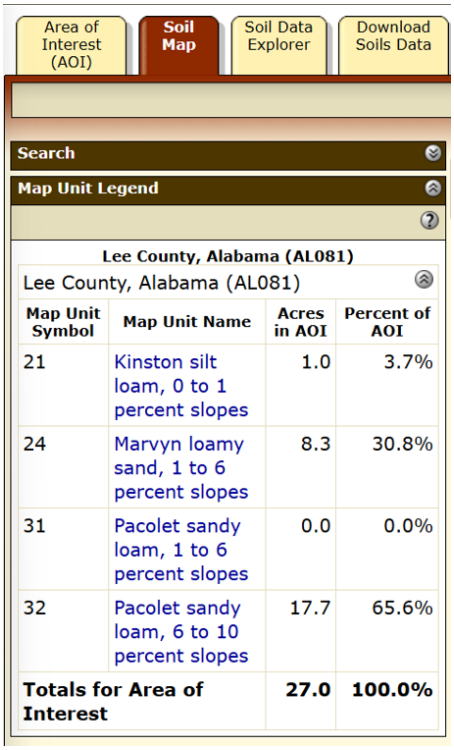
   e. Select an AOI in a rectangular shape using the square AOI button  or select an AOI in any polygon using the polygon AOI button  . Once an AOI button is selected, select your area on the map. The application has a limit of 100,000 acres. If you exceed that size, an error box will pop up and ask that you make your AOI smaller.

4. Display and learn more about the soil in your selected AOI:

   a. Navigate to the map search bar near the top of the website, and click on "Soil Map."

   b. The Map Unit Legend will pop up, showing the soil series within your chosen AOI.

   c. Choose at least one Soil Series and write down/copy the name(s).



Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
21	Kinston silt loam, 0 to 1 percent slopes	1.0	3.7%
24	Marvyn loamy sand, 1 to 6 percent slopes	8.3	30.8%
31	Pacolet sandy loam, 1 to 6 percent slopes	0.0	0.0%
32	Pacolet sandy loam, 6 to 10 percent slopes	17.7	65.6%
Totals for Area of Interest		**27.0**	**100.0%**

In this image, examples of Soil Series names are Kinston, Marvyn, and Pacolet.

Credit: Web Soil Survey

   d. In a new tab, visit the main Web Soil Survey Website (**https://websoilsurvey.nrcs.usda.gov/**) and select "Official Soil Series Description" from the left-hand panel.

   e. Type in or paste your selected Soil Series name.

   f. Read your description thoroughly Each Official Soil Series Description is different from one another; certain sections may be missing between series descriptions. Look for the words, "shrink swell potential, smectitic, kaolinitic." If your description does not have any of these words, search for soil texture. This will likely be in the "Range of Characteristics" section.

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