Angle of Repose

Carla Whittington and Dr. Eric M. D. Baer (derived from material originally published in Whittington and Baer, 2005)

Geology Program, Highline Community College

Summary

In this activity students measure the maximum slope at which grains are stable (angle of repose). They explore how different properties of the sediment influence slope stability and lead to different slope failures (mass movements). The results are then used to examine the nature, frequency, timing, and causes of landsliding events in Seattle.
Students make piles from a variety of sediments and measure (either with a protractor or using basic trigonometry) the angle. They examine sediments with different sizes as well as different angularities. They also add water to the piles to evaluate its impact.

Learning Goals

Upon completion of this exercise, students should be able to:

- measure the angle of repose
- determine how grain size, angularity, and water content impact the angle of repose
- relate angle of repose to mass wasting types and causes
- apply knowledge gained during the experiments to patterns of mass wasting in the Seattle area.

Context for Use

This is a short activity we use in a variety of classes including an intro to geohazards course, physical geology, and an intro level geomorphology course. There is no previous knowledge required.

Teaching Notes and Tips

Students need to be warned to take their measurements with care and precision. If they are little off, they could have difficulty answering the questions well. Also, students tend to make small piles which increases error. (This is a terrific place to discuss error and propagation of error).

This activity requires some additional materials:

- sand
- rounded gravel
- angular gravel
- coarse gravel
- protractors and rulers
- trays to contain the experiments

  The gravel can be easily purchased at a pet shop - aquarium gravel works wonderfully. Most hardware or home improvement stores sell sand and gravel as well.

Angle of Repose

(Materials provided in class)

In this activity you will measure the maximum slope at which grains are stable (angle of repose). You will explore how different properties of the sediment influence slope stability and lead to different slope failures (mass movements).

Materials

- Pan or tray
- Sediment samples: dry sand, damp sand, angular gravel, rounded gravel
- protractor
- small scoop
- container of water

Instructions (Read these carefully or you will have to redo your responses!)

1. Slowly pour a stream of dry sand into the center of your pan or tray. Avoid disturbing your pile and carefully measure the maximum angle, or steepest slope, of the dry sand. This slope is called the angle of repose. Record your answer on the data sheet (1).
2. Add a few grains (a pinch) of dry sand to the top of your pile and see how the grains move. Repeat, observing the movement again. Describe the downward movement of the dry sand on the data sheet (2). Note whether the sand grains move individually or in large groups.
3. Put all your dry sand back into its container. Sweep your tray clean (use the garbage cans).
4. Repeat the experiment using damp sand. Place a pile of damp sand in the center of your pan or tray. You will probably have to scoop the sand instead of pour it. You can gently pack the pile together, but use only gentle pressure. What is the maximum angle of the damp sand? (3)
5. Add a pinch of the damp sand to the top of the pile and see how the grains move. Repeat, observing the movement again. Describe the downward movement of the damp sand on the data sheet (4). Note whether the grains move individually or in large groups.
6. With the cup, *slowly* pour water onto the pile of damp sand and observe what happens to the sand pile as the sand becomes saturated. Can the saturated sand maintain its angle of repose? (5).
7. Again, clean up your mess and answer questions (6) – (9).
8. Slowly pour the rounded gravel into the center of your tray or pan. Make sure your pile is large enough to get the true angle of repose! Carefully measure the angle of repose, without disturbing the pile. Record angle (10). Pour the rounded gravel back into the container.
9. Repeat the experiment using the angular gravel and record the results (11). Answer questions (12 and 13).
10. Put all materials away. Clean up your area.

Angle of Repose

(Materials provided in class)

DATA SHEET

Name: _____

Group Members: _____

_____

_____

_____

1. Dry sand angle of repose is _____ degrees.
2. Dry sand movement:

_____

_____

3. Damp sand angle of repose is _____degrees.
4. Damp sand movement:

_____

_____

5. Can the **saturated** sand maintain a steep angle of repose? _____
6. Which sediment condition – dry or damp – permits steeper slope angles? _____
7. Which sediment condition – dry or damp – lends itself to the most dramatic, quickest, and therefore most dangerous style of slope failure? _____
8. Explain why you think the damp sand can maintain a higher angle of repose than the dry sand. _____

_____

_____

9. Suppose a house is built on a slope made of sediment. The slope is slightly greater than the angle of repose. Is this house at risk from mass movement?

_____

10. Rounded gravel angle of repose is _____ degrees.
11. Angular gravel angle of repose is _____ degrees.
12. Compare the angle of repose for the dry sand and the dry gravel. What impact does grain size have on the angle of repose?

_____

_____

_____

13. Compare the angle of repose for the rounded gravel and the angular gravel. What impact does grain shape have on the angle of repose?

_____

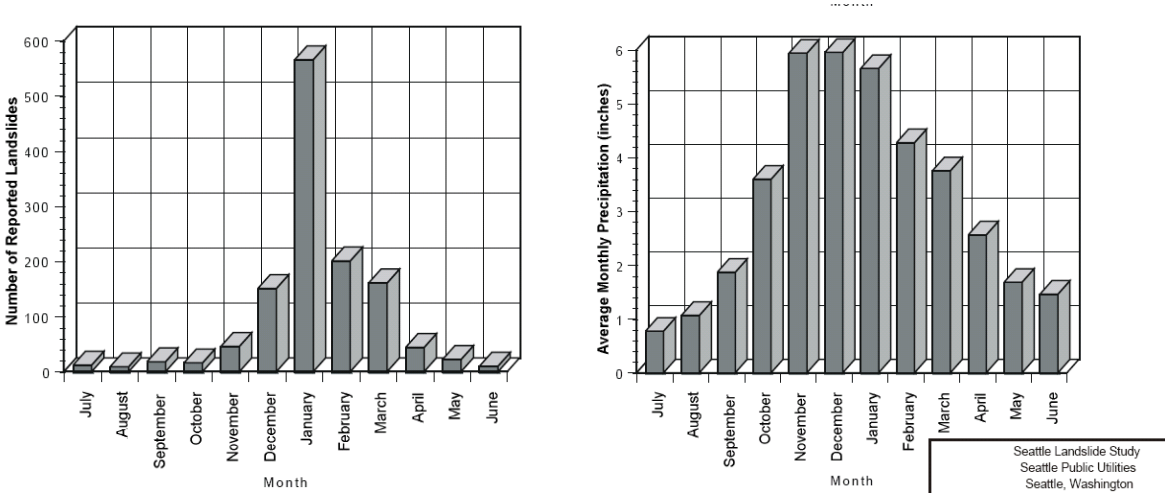
_____

_____

Angle of Repose

(Materials provided in class)

Use the results of your experiments and the graphs below to answer the following questions. (If you are completing this at home, please type your answer otherwise, please use a separate sheet of paper.)



Source of data: City of Seattle, 1999. Seattle Landslide Study
http://www.seattle.gov/DPD/Landslide/Study/default.asp accessed August, 2005.

14. In the Seattle area, which four months experience the greatest amount of rainfall?

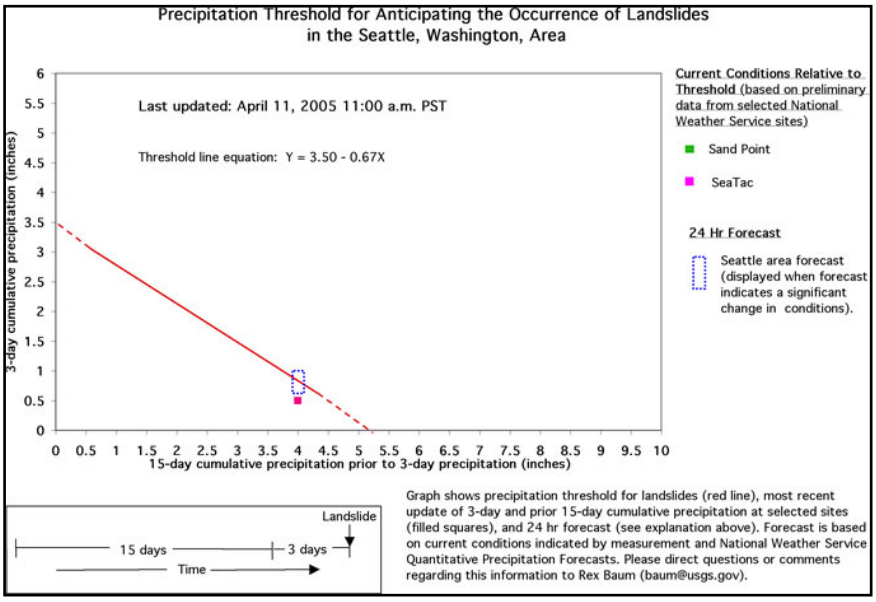
15. In the Seattle area, which four months experience the highest number of landslides?

16. Thinking about the results of your experiments (especially in Step 6), explain why the peak landslide activity occurs later than the peak rainfall activity.

Angle of Repose

(Materials provided in class)

The USGS has recently developed and tested a model that establishes a precipitation threshold for the Puget Sound Area as it relates to landslides. In this area, landslides tend to occur if the precipitation amount for a 15 day period exceeds a specified level, and that 15 day period is followed by 3 days of rain at certain levels. The graph below shows the Precipitation Threshold for Anticipating the Occurrence of Landslides.



Source: Chleborad, A.F., (2003) Preliminary Evaluation of a Precipitation Threshold for Anticipating the Occurrence of Landslides in the Seattle, Washington, Area. U.S. Geologic Survey OFR 03-463. Available online: http://pubs.usgs.gov/of/2003/ofr-03-463/ofr-03-0463.html.

17. Place and label a point on the graph for the following days:

Date	15 day cumulative precipitation	3 day cumulative precipitation	Landslides expected? (Yes, no, maybe)
1/5/56	4.73	3.38	
1/6/96	1.27	0.55	
1/7/96	1.33	1.27	
2/11/96	4.94	0.07	
2/21/96	5.87	0.56	

18. Explain why the 15 day and 3 day cumulative precipitation would be critical in determining when landslides might occur.

Angle of Repose

(Materials provided in class)

19. Why might landslides not occur after even several inches of rain in 3 days if the amount of rain in the preceding 2 weeks has been low?

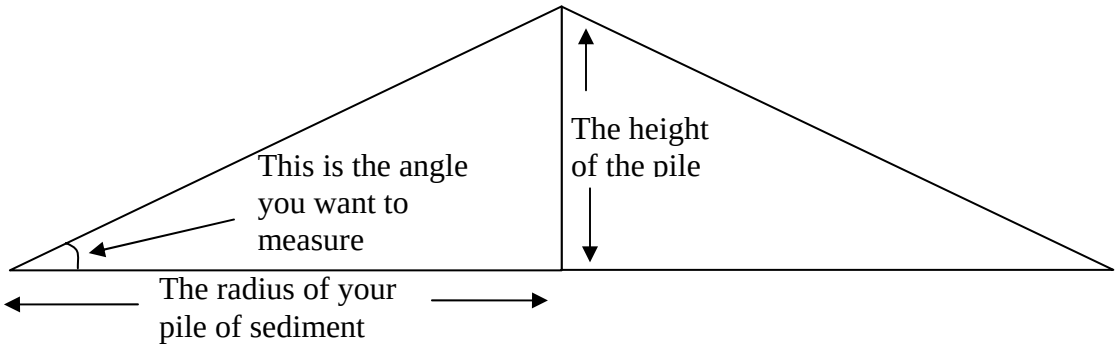
20. Why would landslides not occur even if there had been a large amount of rain in the previous 2 weeks, but little rain in the last 3 days?

Angle of Repose

(Materials provided in class)

How to measure the angle of repose

You can measure he angle one of two ways, with a protractor or by using simple trigonometry. Either way. make sure you are measuring the correct angle:



To measure with a protractor, carefully line up the center point of the protractor with the edge of the pile and determine the angle.

An easier way to measure the angle is to use trigonometry. As you can see from above, the pile of sand can be thought of as 2 right triangles. For a right triangle,

TAN (A) = Opposite/Adjacent (remember SOHCAHTOA!?)

So the TAN(A) = height of the sand pile (h) / radius of the sand pile (r)

To find the angle, you need to take the inverse tangent of both sides….

$A=TAN^{-1}(h/r)$

For most calculators you will need to first divide the height by the radius and then press the TAN^{-1} button on your calculator. If the number comes out to something that doesn't make sense, make sure your calculator is in degree mode, not radian mode!