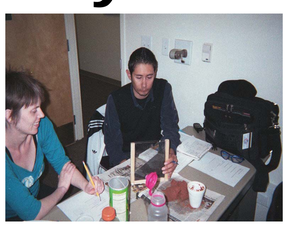
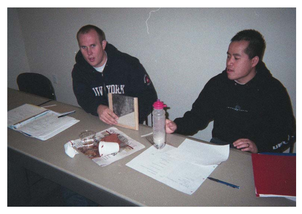
ANGLE OF REPOSE

Salt Lake Community College

An activity for an “Introduction to Geology” Science-Elective Class for Non-Science Major Students at a 2-year Community College.





This activity investigates angle of repose and the factors that determine the angle value. Comparisons of the angle of repose values on Earth and Mars helps the understanding of the factors of the angle of repose. Activities include making a “sand castle”, measurement of the slope of a cone of sand and cinders, measurement of the angle of repose using a Hele-Shaw cell, and calculation of the angle of repose using a Möller “sphere”.

Along the way the scientific method and its principles will be visited including:

1. **Description** of the Angle of Repose to be investigated,
2. **Multiple hypotheses** for factors that determine the Angle of Repose,
3. **Measurement** of the Angle of Repose,
4. **Accuracy and Precision** of the measuring instrument,
5. Dealing with **Data Ambiguity** and measurement value deviations,
6. Picking **Patterns** from the data,
7. **Statistical Population** of tests?
8. **Conclusions**.

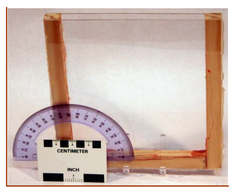
Definition: The Angle of Repose is the slope angle of granular material measured from the horizon.

Factors: The Angle of Repose is a function of all or some of the following factors:

- c ohesion (electrostatic, magnetic, water film, mud) between grains,
- size of grains,
- substrate roughness,
- shape of grains,
- density of grains,
- stress perpendicular to the surface (normal stress),
- shear-stress friction,
- medium: ice, atmosphere, slurry, or water,
- gravity (weight stress).

Occurrence: Common landforms such as dunes, ripples, river bars, talus, rock falls, beaches, moraines, deltas have components that were deposited at the angle of repose by wind, water, ice, and landslides. The angle of repose occurs on all the rocky planets and satellites, wherever there is gravity, slopes, and granular materials.

Materials:



- Hele (Helle) -Shaw cells
- protractors,
- Styrofoam cups,
- Coins,
- magnifiers
- water,
- billiard ball,
- plastic baseball,
- granular materials
  i. red dune sand (spherical quartz grains),
  ii. oolitic sand (spherical ooid grains),
  iii. gypsum crystal sand (monoclinic crystals),
  iv. Morton salt (cubic crystals),
  v. black sand (dense, mostly magnetite),
  vi. BBs,
  vii. JSC Mars Stimulant Soil (palagonitic tephra),
  viii. volcanic cinders (irregular shapes, up to marble sized), and
  ix. Aurora Silt Loam.

Background:

Movement of geologic materials includes sliding, flowing, heaving, and free-falling. Landforms that have a component of free-fall have slopes at an angle of repose.

Activity References:

Schlumberger SEED: Building and Exploring with a Hele-Shaw Cell, Angle of Repose experimental results,
http://www.seed.slb.com/en/scictr/lab/heleshaw/index.htm

SNOOPY, **S**tudent **N**anoexperiments for **O**utreach and **O**bservational **P**lanetary Inquir**Y** http://www.uidaho.edu/marsdust/

Impact of water on the angle of repose, the Sand Castle activity:

1. Each group of two students gets a Styrofoam cup filled with red dune sand. They stick a finger into the sand, easily. Next they add water noting bubbles from air between the grains. Water must not be evident on the surface of the sand but the sand must be moist, excess water is poured off. The ideal amount of water has been added if the surface is shiny from water reflectance when the cup is squeezed and the surface is dull from moist sand when the cup is expanded. They stick a finger into the sand, difficultly. Observations are recorded. This is the optimum water-sand mixture for liquefaction demonstration; a coin placed on the sand will gradually sink as the cup is vibrated. Student groups record what they learned.
2. Sand Castle. The groups invert the cup expecting the sand to pour out. They tear off the bottom of the cup to see if suction is keeping the sand in the cup. Finally they remove the entire cup to show the “sand castle”. Adding water to the sand castle produces a sand flow. Student groups record what they learned, particularly about in influence of a water film on the grains.

Cone at the maximum slope, the angle of repose.

a. Groups pour a large cup of sand onto paper and make the steepest cone

possible. They then insert a protractor into the cone to measure the angle of the slope, the angle of repose. They remove part of the cone and describe what happens and measure the slope angle of the failed sand. Discussion about road cuts steeper than the angle of repose. They try the same thing to the sand castle.

b. A group is given the volcanic cinders and asked to measure its angle of repose using the cone method. It was about 50°.

c. Student groups record what they learned.

What factors determine the Angle of Repose? Discussion ensues about grain friction, size, shape, surface smoothness, cohesion such as electrostatic attraction, water film on grains, mud coating.

Sands are dispersed to groups.

Each group describes size, shape, & surface smoothness of the sand.

A Hele-Shaw Cell, funnel, & protractor are given to some groups. They are instructed to keep pouring the sand into the cell at one side until the slope reaches the other side, then measure the angle of repose. This is described at Schlumberger SEED: Building and Exploring with a Hele-Shaw Cell, Angle of Repose experimental results,

http://www.seed.slb.com/en/scictr/lab/heleshaw/index.htm

Results of two readings using the Hele-Shaw Cell.

Sand	Grain Description	Reading 1	Reading 2
Red dune sand	Well-sorted, spherical, smooth	32°	28°
Oolitic sand	Moderately sorted, spherical, smooth	30°	35°
Morton salt	Well-sorted, cubic, angular, fine sand	33°	33°
JSC Mars	Poorly sorted, silt-sand, irregular	45°	32°
Black sand	Well-sorted, dense, spherical, smooth,	45°	30°
BBs	Well-sorted, dense, 2mm diameter, spherical, smooth	30°	35°
Gypsum dune sand	Moderately sorted, monoclinic crystals, irregular	38°	36°
CONCLUSIONS: The angle of repose of sand spans 28°-38°. The two 45° readings may be measurement error. The protractor angle origin may have been misplaced, it was not fastened to the cell			

ANGLE OF REPOSE ON MARS: L.E. Möller and others (2006, Mars dust micromechanics: MER Marsdial and laboratory observations, Lunar and Planetary Science XXXVII, 2p.) devised a system using spheres, such as the Marsdial, to collect martian dust. The diameter of the base of the dust cone that collects on top of the sphere divided by the diameter of the sphere is the sine of the angle of repose. They reported an angle of repose for Mars dust on the Marsdial as 52.3° during sols 583 to 585 (August 24-26, 2005) on the summit of Husband Hill.
http://www.lpi.usra.edu/meetings/lpsc2006/pdf/2407.pdf

Figure 1. NASA Spirit MER Marsdial color image extracted from the panorama photograph taken from the summit of Husband Hill during sols 583 to 585 (August 24 to 26, 2005). Inset photo shows the reddish brown, apparent dust deposition cap. Image analysis used the elliptical planes shown for the extraction of dust deposition; θ_r = 52.3° from $\sin(\theta_r) = m/d$.

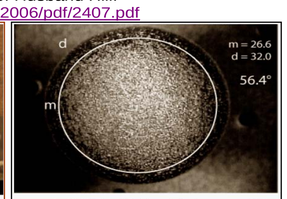
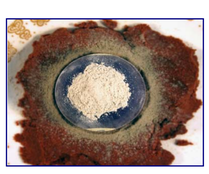


Figure 3. MDEC validation trial of surrogate Mars-dial dust deposition behavior using < 100 µm fraction JSC Mars-1 dust simulant (102 kPa CO_2, -5.7 °C, <10 mg H_2O/m^3). Airborne deposition on a sphere coated with non-reflective black paint (top view, d = 32 mm). Black and white video-graph obtained using a 700 nm bandpass filter (80 nm FWHM) and red-IR lighting. JSC Mars-1 dust simulant is seen as the white dust cap in the image. Calculated θ_r = 56.4° for this trial.

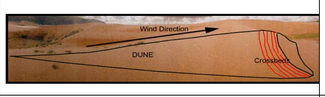
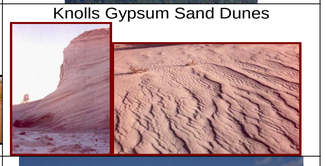
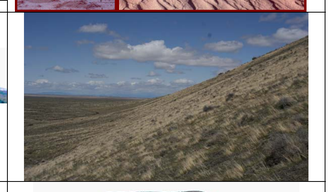
Two groups measured the angle of repose of fine materials using an apparatus similar to Möller's.

One group used a dark billiard ball and sprinkled white Aurora Silt Loam on the ball. Silt loam is predominantly silt with small amounts of sand and clay.

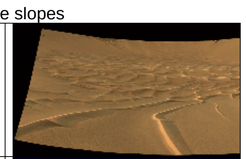
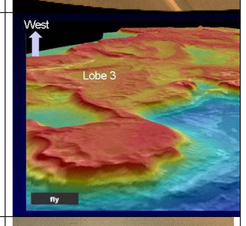


The cone diameter/ball diameter is 0.75 to 0.67; the angle of repose is 48°- 42°.

What landforms are deposited at the Angle of Repose on Earth?

Talus, Devil’s Castle, Little Cottonwood Canyon, Salt Lake County, Utah. Christine Wilkerson, UGS	
Sand Dunes, Interpretive Sign, Snow Canyon State Park, Utah. 	Knolls Gypsum Sand Dunes 
Beach Slope on Pavant Butte Volcano, Central Utah. 	
Cinder Cone Slope, Diamond Cinder Cone, Snow Canyon State Park, Utah.	

Landforms on Mars that have angle of repose slopes

Opportunity Rover, Endurance Crater Floor Dunes, Sol211, NASA/JPL/Cornell, http://marswatch.astro.cornell.edu/pancam_instrument/**endurance_dunes**.html	
NE Holden Delta, Wood, Lesli J., 2005, Geomorphology of the Mars Northeast Holden (Eberswalde) Delta: http://www.searchanddiscovery.com/documents/2005/av/wood/wood.pdf	
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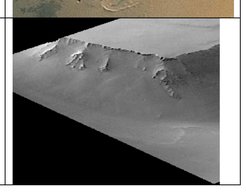
Talus, MOC image P005_03, http://www.msss.com/mars_images/moc/p3_p7_release/index.html	

Is the Angle of Repose on Mars the same angle as on Earth?

COMMENTS