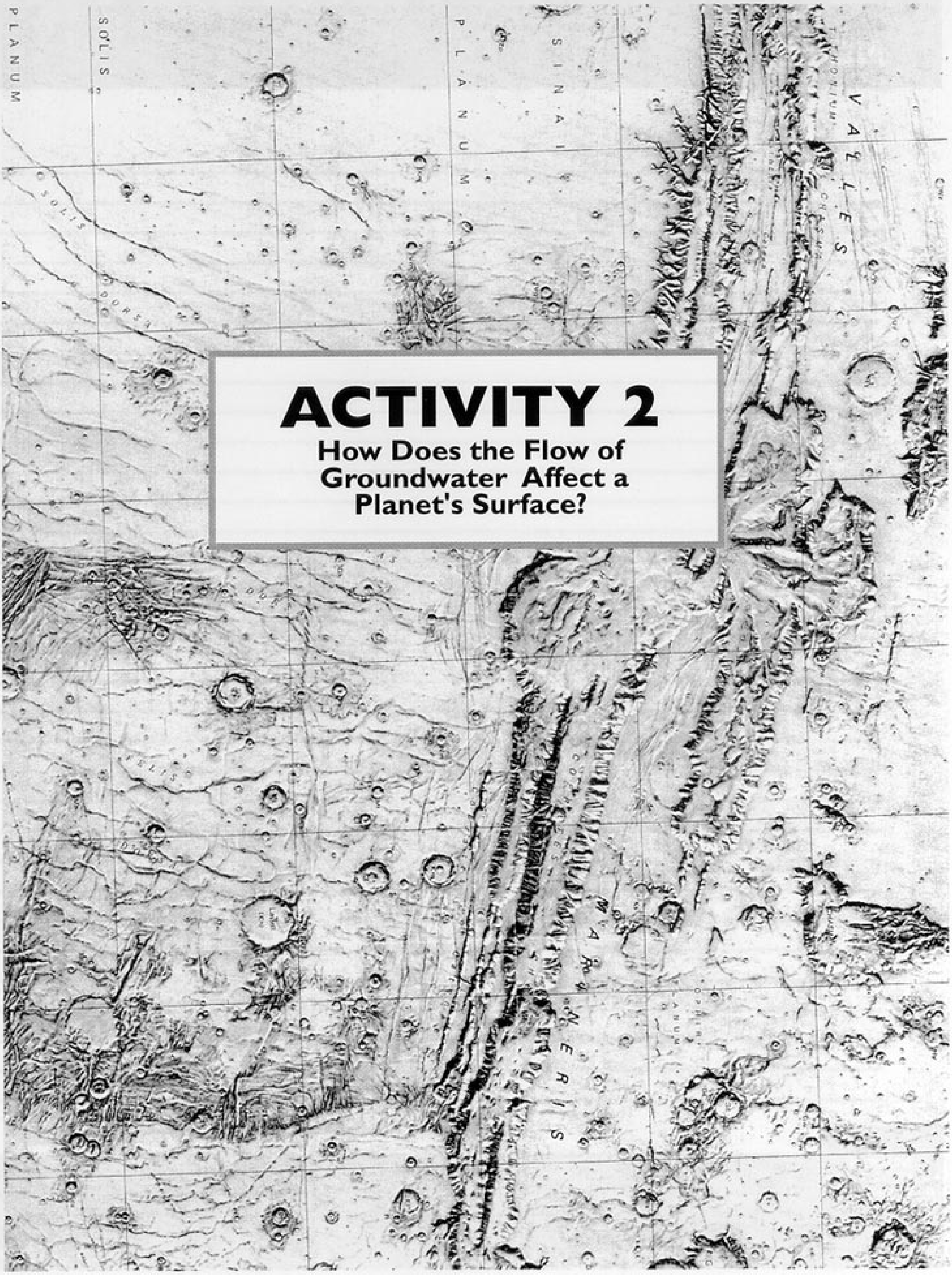
ACTIVITY 2

How Does the Flow of Groundwater Affect a Planet's Surface?



NOTES

AT A GLANCE

Overview
Using a stream table, students investigate the effects flowing subsurface water has on a planet's surface, such as slumping and sapping. By observing that water flows out from beneath the sand in the stream tray, students realize that water can flow beneath the surface. They also see that when water saturates the ground, the ground can slump – a process that has occurred frequently in Valles Marineris.

Content Goals
- Water can flow beneath the surface.
- The flow of subsurface water can alter the appearance of the land above it.
- Slumping is a landslide in which rocks and soil slide as a single unit.
- Sapping is when groundwater breaks the surface and undermines rock and sediment, causing them to collapse. It can cause the progressive collapse of rocks and soil resulting in the headward retreat of a canyon.

Skill Goals
- *Modeling* how subsurface water contributes to slumping.
- *Observing* changes and patterns in the cliff face after slumping.
- *Measuring* the widths and lengths of slumps.
- *Comparing* the effects of sapping and slumping.
- *Analyzing* the data collected in a data table.

Possible Misconception
Fluids such as water and petroleum exist beneath the soil as large puddles, lakes and streams rather than occupying the pore spaces between particles of sand or soil and percolating through these tiny regions.
Ask: What is subsurface water like? Also, consider using the soil permeability extension activity .

Materials
Standard 3-foot wallpaper tub (or similar container), board to slightly elevate one end of the tray, trowel, funnel and means of supporting it, water, a dozen cups of sand per setup, graduated cylinder, large (24 oz) plastic cup, waste water bucket.

Time
1-2 class periods

BACKGROUND

After the initial opening of the Valles Marineris canyons, the walls eroded and some canyons widened to as much as three times their original width. Mechanisms associated with the erosion and modification the canyon walls are landslides, removal of material by wind, the physical weathering of walls to produce talus slopes, and sapping. The tops of most of the canyon walls in Valles Marineris have a jagged or scalloped appearance, referred to as spur and gully morphology (Fig. 2.1). Because they have not been observed on young wall surfaces, spur and gullies seem to have formed early in the history of Valles Marineris and might be an old erosional form, perhaps related to a different climate or even an underwater environment.

Landslides can be dry or can involve subsurface water or ice in some way. Since present-day Mars lacks surface water, where might such water come from? The water on Mars could have been acquired during the formation of the planet or added to Mars after its formation as comets collided with it. If the water was original, subsurface water might have been brought to the surface from deep within the planet by magma. Although the amount of water varies for each volcano on Earth, water is one of the most common constituents in volcano gas. Scientists estimate that as much as 99% of the gas given off by Hawaii 's Katmai Volcano is water. One reservoir for water is subsurface pore space. On Earth, water infiltrates the ground and moves downward until the pore spaces are filled. Similarly, Mars might have a lot of water in its subsurface pore spaces. If this water exists as permafrost, magma near the surface can produce water by melting it. In any case, detecting groundwater is very difficult and requires seeing something on the surface that suggests its presence. Surface evidence for groundwater movement includes slumping and sapping, the topics of Activity 2.

Fig. 2.1

Canyons with a spur and gully morphology have steep upper walls that are broken into vertical, nearly parallel ribs. Lower on the walls, sharp-crested, downward branching spurs descend to the canyon floors. Contrast the small section of spur and gully morphology in the central right section of the image to the three scalloped-shaped scars from the collapse of the canyon wall due to slumping. Image Set image # 9.

Slumping

Slumping (Fig. 2.2) seems to have been a significant process in the widening of Valles Marineris. The plateau at the top edges of Valles Marineris seems to consist of resistant rock layers, and they form steep cliffs at the upper edges of the canyon. When the rock layers and the material beneath them become saturated with water, the internal adhesion is reduced and they become vulnerable to breaking free of the canyon walls. Water can also act as a lubricant, facilitating the slumping of the block. Slumping can be triggered by tremors, and faults and other weaknesses behind a slump block can hasten the slumping. One can recognize slumping by the scalloped appearance of the canyon walls and the presence of landslide debris across the canyon floor (Fig. 2.1). Parts of Valles Marineris show massive landslides extending across the canyon floor more than 50 km from their points of origin.

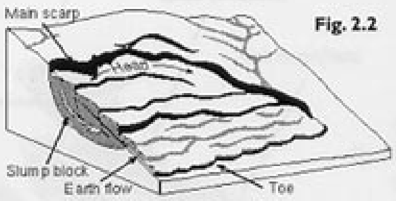


Fig. 2.2

Slumping is a kind of landslide in which rocks and soil slide as a single mass along a curved slip surface.

Sapping

Sapping valleys (also called tributary canyons) are formed when groundwater breaks the surface and undermines rock and sediment, causing it to collapse (Fig. 2.3). Because groundwater flow tends to exploit planes of weakness in the terrain, sapping valleys often form along fractures and joints in the bedrock. On Mars, this type of erosion has created a distinctive morphology. Figure 2.4 shows the south wall of the Ius Chasma dissected by sapping valleys. It has been suggested that aquifers in this region dip to the north. This would deliver groundwater to the southern edges of Valles Marineris. Over time, continued sapping caused the headward retreat of the valleys giving them their compact, non-dendritic appearance. Some features of sapping valleys include:

- canyon segments that tend to be short and straight, and that join at high-angle bends;
- areas between channels which show no drainage networks;
- valley heads which are blunt and bowl-like;
- valleys which are nearly of equal width throughout;
- an average depth of the valley heads of 1 km, a depth which coincides with the depth of the permafrost in this area;
- a smooth merger with the floor of the main canyon.

Fig. 2.4

Sapping Valleys on the south wall of the Ius Chasma.

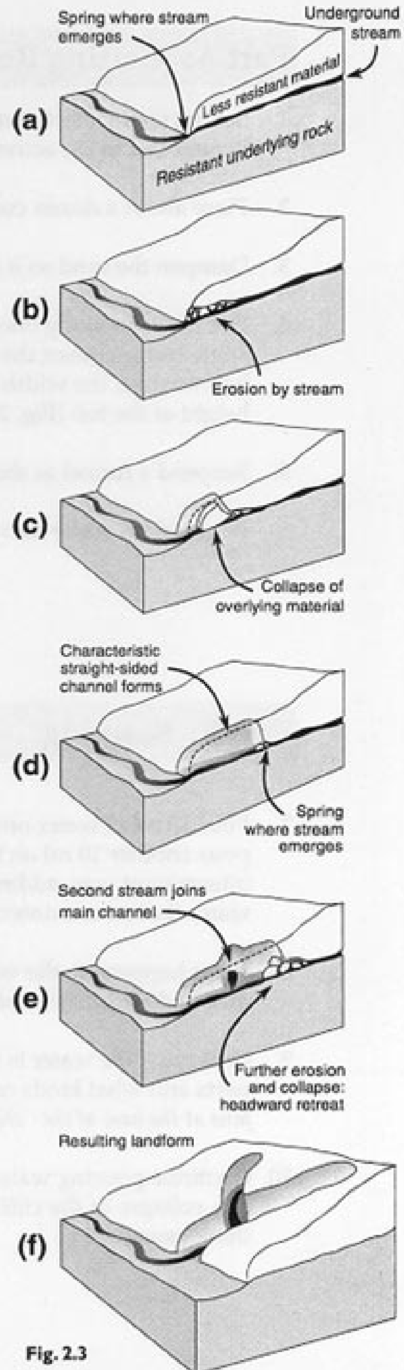


Fig. 2.3

Sapping is when groundwater breaks the surface and undermines rock and sediment, causing it to collapse It can cause the progressive collapse of material resulting in the headward retreat of a canyon.

PROCEDURE

Part A: Getting Ready

1. Set the wallpaper tub on a board and prop one end up about 1 cm so any water used in the activity will collect at one end, making bailing easy.

2. Place about a dozen cups of sand in the wallpaper tub.

3. Dampen the sand so it holds its shape nicely.

4. Pile the sand along one-half of the wallpaper tub forming a sharp right-angle terrace down the full length of the tub. The terrace will extend about half way out the width of the tub and a little more than half way up the height of the tub (Fig. 2.5).

5. Suspend a funnel as shown near the tub wall at one end of the tub (Fig. 2.5).

6. Pour 100 ml water into a graduated cylinder.

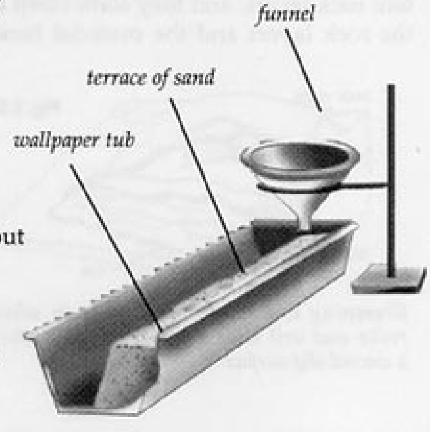


Fig. 2.5
Arrangement of sand in the tray and activity setup.

Part B: Sapping

7. Pour 10 ml of water onto the center of the terrace. Wait a few seconds and pour another 10 ml on the same place. Continue adding water in this intermittent way, adding a total of 60-80 ml of water. Avoid using so much water that it runs down the cliff face or makes a deep puddle.

8. What happens to the water? Observe where the water goes. *(Water flows from underneath the sand terrace into the open part of the tray.)*

9. Observe if the water is having an effect on any part of the cliff. If so, which parts and what kinds of effects? *(Sand particles will form small alluvial fans at the base of the "cliffs"* [Fig. 2.6].)

10. Continue pouring water until there is a noticeable change at the cliff base or a collapse of the cliff face. Describe the change or collapse and what you think caused it.

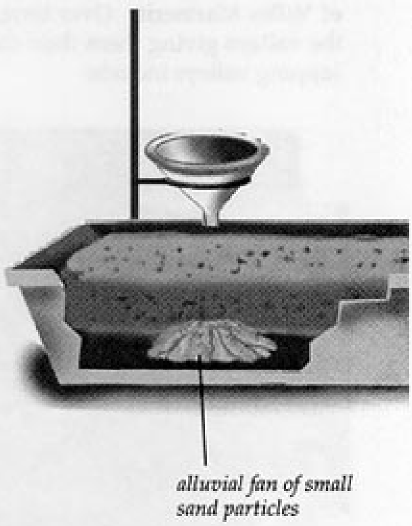


Fig. 2.6
Evidence of sapping as seen in the tray

Sapping causing the headward retreat of small canyons on a beach.

Part C: Slumping

11. In contrast to how you poured the water in Part B, pour about 5 ml of water at a time very slowly and steadily into the funnel so it soaks into the soil without forming a puddle or running off the surface.

12. At some point a block of the canyon wall will break off and fall (Fig. 2.7). This is called a slump. Record how many ml are needed for the embankment to suddenly slump. (*Usually between 50 and 80 ml.*)

13. Measure and record the width and depth of the slump.

14. Record the data in a data table and make a graph relating the amount of water required to cause the slump to its length and width. *(To reinforce the key elements of the activity, consider designing a data table as a class exercise.)*

15. Move the funnel to another position further along the length of the tub and repeat Steps 11-15.

16. After creating several slumps, sketch the shape of the top edge of your cliff.

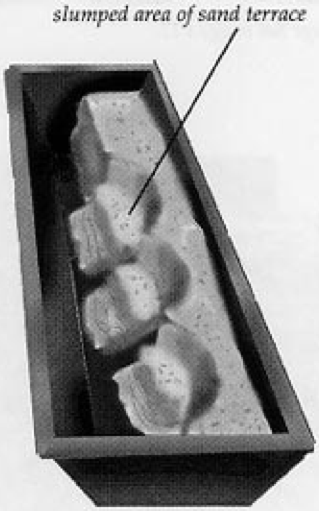


Fig. 2.7
Slumping in the tray.

Questions

1. Where do the slumps occur in relation to where the water is being added? *(They usually occur just beneath the water source.)*

2. Describe the top edge of your cliff before and after you started adding water. *(The straight edge should have a scalloped appearance after several slumps.)*

3. On a regular basis, did you see sapping before slumping or slumping before sapping? (*It may depend on the subsurface arrangement of sand grains and how this unseen structure directs the flow of the water.*)

4. What might happen to a canyon if slumping occurred for millions or billions of years?

APPLYING THE MODEL TO MARS

Image Set image #12.

Have students examine images of Valles Marineris. Do any sections look like the slump blocks they saw in the tray? Which features suggest slumping? Where does slumping seem to have widened the canyon? If slumping is responsible for widening the canyon, why doesn't the canyon fill up? Are there additional features nearby that might be associated with slumping?
Students should immediately recognize the scalloped edges of the canyon walls and landslide debris at the foot of the cliffs as similar to the features they saw in their trays.

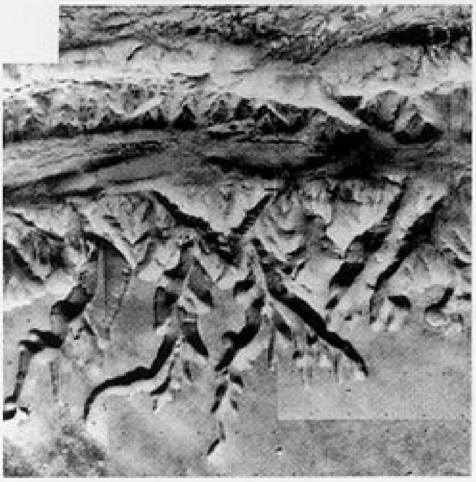


Image Set image #13.

Have students look at Image 13. Are these valleys common throughout Valles Marineris or concentrated in certain areas? Ask them if the valleys remind them of anything they have seen. Do these valleys look typical of valleys on Earth? Why or why not? Have them explain how these valleys might have formed. If present-day Mars is dry, how would this fact affect their ideas?
Image 13 shows tributary valleys which are thought to have been created by sapping. It has been suggested that aquifers south of Valles Marineris dip to the north, and this would deliver groundwater to the southern edges of Valles Marineris. This groundwater would flow along underground faults and joints and percolate out, eroding the nearby ground and ultimately flowing into the main canyon. Over time, continued sapping would cause the headward retreat of the valleys observed in these images giving them their compact, uniform, non-dendritic appearance.

TEACHING POINTERS

Students should not use more than 100-200 ml of water for these activities. This amount may be taken to their table in a large plastic cup. Having a limited amount of water focuses students' attention on pouring very slowly and using only about 50 ml per slump. Also, the total volume of waste water in the tubs will be minimized, making clean-up easier.

Large (i.e., 24-ounce) cups enable students to remove most of the water, but they will need smaller cups such as nine-ounce paper cups to eliminate all the standing water. Students should be given clear instruction on how to empty the water from the puddle formed at the downhill end of the wallpaper tub and how to transport it to the collection bucket. All waste water should be dumped outside or in a toilet. IF SAND-LADEN WATER IS PUT INTO A SINK, IT WILL CLOG THE SINK.

EXTENSIONS

- After a cliff face has slumped, find out what happens if more water is added to the terrace just behind the slump block. Can you get a slump behind a slump?
- Is there a difference in the slump shape if the water is poured intermittently rather than in a steady dribble?
  Yes, larger, more coherent slumps form from continuous water flow.
- Have students calculate whether the width of Valles Marineris could have been generated by slumping. Since it is up to 700 km (438 mi) wide and has been in existence around 3 billion years, the canyon walls would have to retreat at an average rate of only about 1.4 mm (0.06 in) per year. Does this seem possible given what they have seen in their models? Would the canyon floor fill up preventing additional slumping? *It is highly unlikely that any one process is responsible for creating the present-day width of the canyons. That several processes work in conjunction to shape a landscape is an important point for students to understand.*

EXTENSION ACTIVITY 2A: Soil Permeability

Overview
A misconception students often have is that underground water exists as subterranean lakes and rivers, similar to above-ground water. By conducting tests of water percolation in soils with different *pore sizes* (the space between soil particles), students discover that: a) water is held in a sediment's pore space; b) water percolates most rapidly through sediments with large pore spaces; and c) water rises highest in sediments with the smallest pore spaces.

Background
The motion of groundwater is controlled largely by the size of the spaces between soil particles. Water moving down through these pores is said to be percolating, and water moving sideways or upwards is said to move by capillary action. On Earth, about 20% of the soil zone is filled with water held in pore spaces, and it is thought that Martian pore spaces contain water or ice.

Materials
30 cm plastic tubes about 3.5 cm in diameter, soil samples, sand, clay powder, beakers, cheese cloth, plastic wrap.

Brief Description:
1. Seal one end of the tubes with a layer of cheese cloth and a layer of plastic wrap.
2. To each tube, add 100 ml of either dry sand, silt or clay powder.
3. To measure pore space, place each tube in a beaker and fill the tube until the water reaches the top of the soil. No water should dribble out the bottom. Determine the amount of water poured into the soil.
4. To measure water holding capacity, remove the plastic wrap but leave the cheesecloth in place. Record the amount of water that flows out of the soil. Calculate the volume of water retained by the soil.
5. To measure permeability, pour 300 ml of water in the top of each tube and record the time it takes for the continuous flow out the bottom to stop and change to a drip.
6. To measure how fast soils absorb water, place 100 ml of dry soil samples in each tube. Lower the cheesecloth covered end into about 1 cm of water. Measure the water height in the tube every 25 seconds.
7. Design a table to compare each soil's characteristics. Display this data in a bar graph.
8. Why do finer sediments tend to retain more water?
9. Design experiments that systematically vary the percentage of sand and clay. Display this data in a line graph.