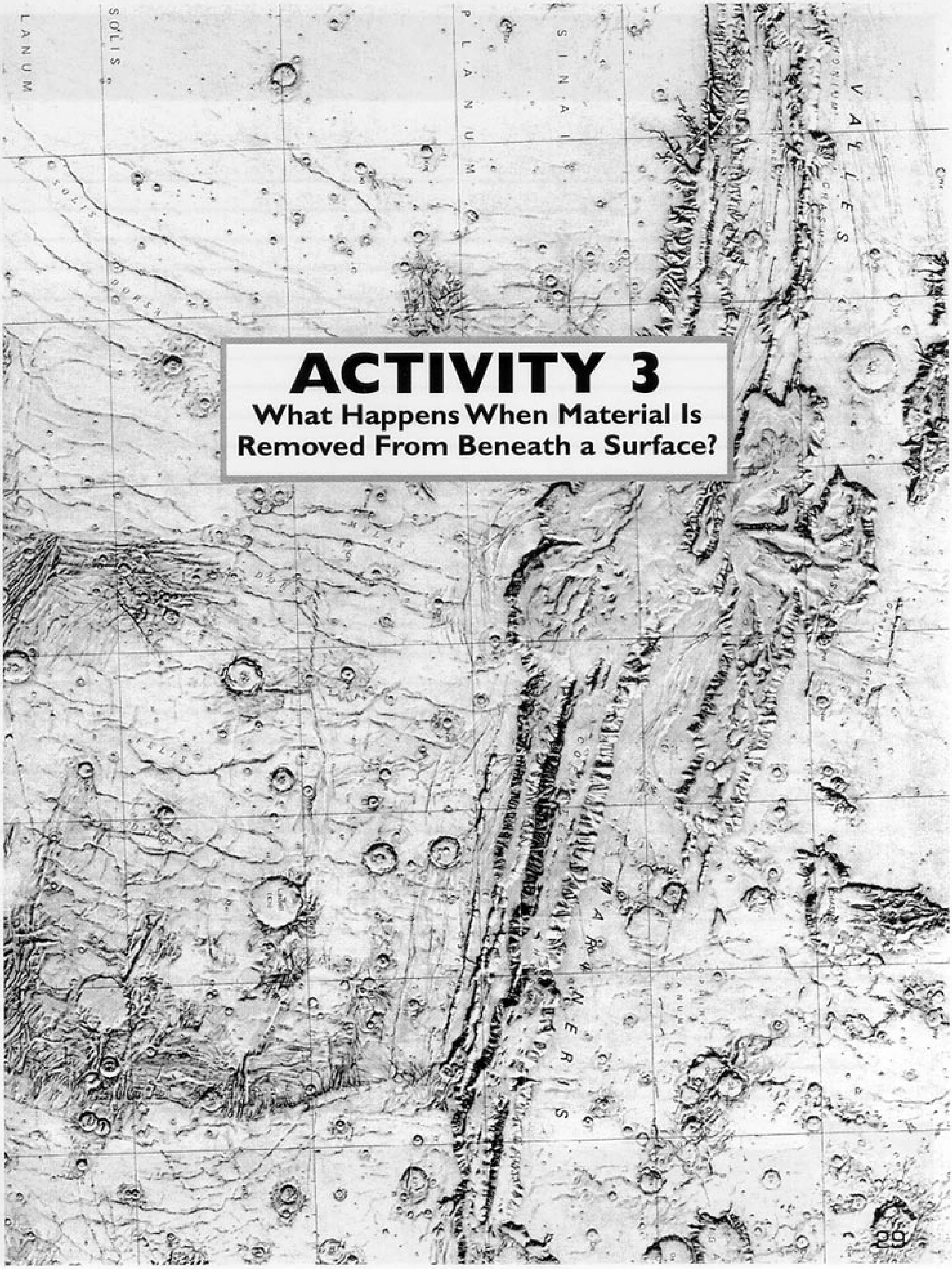

ACTIVITY 3

What Happens When Material Is Removed From Beneath a Surface?

NOTES

Overview

In Activity 2, students saw that slumping caused entire sections of "ground" to fall away creating cliffs with crisp edges. However, can a planet's surface slump without producing a cliff. Using sugar cubes and dice, students construct a "landscape" and use water to dissolve some of the sugar. As it dissolves, the surface of the "landscape" collapses. In addition, students see that subsidence can create a variety of landforms.

Content Goals

- Subsidence is the sinking of the ground surface due to the removal, dissolving or shrinkage of material below that ground surface.
- Rocks dissolve slowly, such as over thousands, millions and billions of years.

Skill Goals

- *Observing* and *recording* the changes in the sugar cube-dice set up.
- *Appreciating* the power and limitations of models when representing actual processes.

Possible Misconceptions

- Rock cannot dissolve.
  Ask: List ways in which rocks can be destroyed.
- Subsidence occurs on a local, small-scale level, such as sinkholes.
  Ask: What is the biggest area you think could be affected by subsidence?

Materials

Same-sized dice and sugar cubes, deli or cottage cheese containers, water, and applesauce or other viscous liquid.

Time

One class period

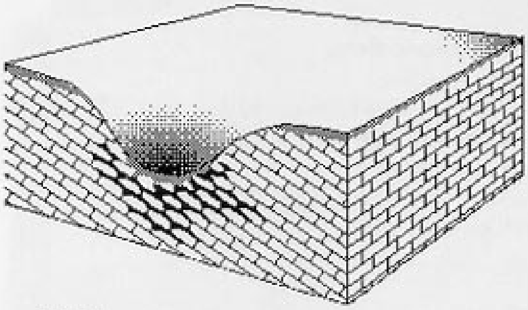

Fig. 3.1
An Earth example of subsidence due to the dissolving of carbonate rocks.

Subsidence

Subsidence is the sinking of a ground surface due to the physical removal, dissolving or shrinkage of material below that ground surface (Fig. 3.1). Some examples of subsidence include land affected by lowered water tables and sinkholes caused when the ground collapses into spaces created by the dissolution of limestone or by the physical removal of material. On Mars, acidic groundwater may have dissolved carbonate rocks underlying Valles Marineris to create (or help create) some of the large canyons.

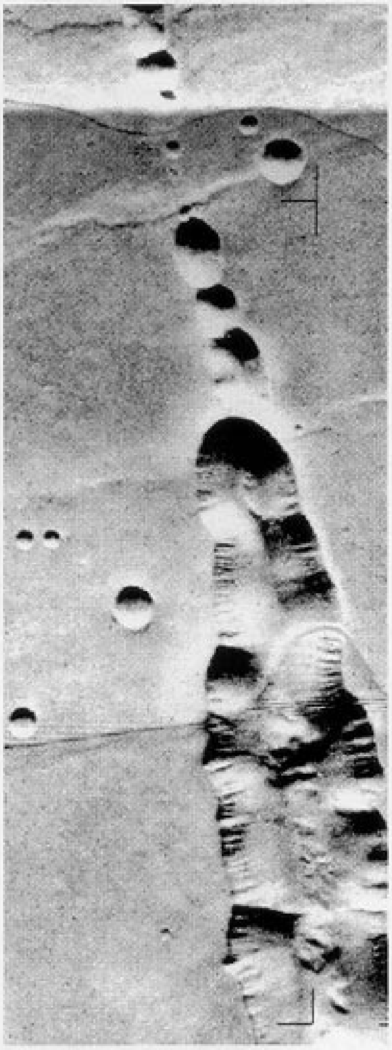

Fig. 3.2
Pits, pit chains and coelesed pits in the Ganges Cantena (2.5 °S,69 °W). Image size is 75 x 28 km (47 x 18 mi). North is toward the left.

On Mars, there are two main examples of subsidence: pits and chaotic terrain. In a number of places in Valles Marineris, one can see what looks like a pits (Fig. 3.2). The pits are depressions 1-10 km wide, 1-2 km deep, generally rimless (in contrast to craters) and smooth-walled. They have talus-covered slopes descending to flat, narrow floors. Pits can be *isolated, coalesced* (several pits merging to create a large depression) (Fig. 3.2) or in *pit chains* (liner arrays of pits formed along faults) (Fig. 3.6). The alignment of chains on or parallel to shallow grabens suggest *structural control* – where bedrock and even the lithosphere control the way surface features manifest themselves. Examples of structural control include fault planes, resistant bedrock, lava dikes, subduction, and rifting – all below-surface features or processes that strongly influence above-ground morphology. Images 6, 7 and 8 show examples of these pits.

Explanations for these pits include the subsidence of their floors due to :

- the withdrawal of magma;
- the withdrawal of ice;
- the dissolving of carbonates beneath the pits;
- explosive steam venting and subsequent collapse;
- surface materials collapsing into subsurface cracks opened by crustal tension.

Fig. 3.3
Chaotic Terrain on the floor of the Ganges, Capri and Eos Chasmas. Image Set image #11.

A larger-scale type of subsidence is *chaotic terrain*, a landscape created when sections of the Martian crust collapsed. It is thought that removal of fluid from below the surface caused a loss of support, and the ground collapsed under its own weight leaving irregularly-shaped, variously-sized blocks of crust on the depression floor. Within Valles Marineris, chaotic terrain is found primarily in the eastern canyons where it makes up much of the floor of the Eos and Capri Chasmas. This area is approximately the size of Montana. The large channels leading away from the chaotic terrain lend strong support to the idea that it is the loss of a fluid that gave the landscape its characteristic look.

Several hypotheses for the collapse of the Martian crust seen in chaotic terrain include:

- the withdrawal of subsurface ice;
- the withdrawal of subsurface magma;
- the flow of groundwater;
- the draining of an aquifer – groundwater might have been kept under pressure by a permafrost or rock cap and was released catastrophically when the cap ruptured;
- a combination of several of these mechanisms.

PROCEDURE

1. In a container, create a 4x4 stack of dice and sugar cubes as shown in Fig. 3.4.
   If dice and sugar cubes are the same size, the stack will be easier to build and it will be easier to create a flat surface.

2. Fill the container so that the water covers approximately half of the bottom row.

3. After a minute, press gently on the top layer observing what happens at the "surface".

4. As a class, create a 4x4x4 sugar cube-dice block with sugar cubes in the center enclosed by a wall of dice (Fig. 3.5). Repeat Steps 2 and 3.
   Additional questions for speculation and/or experimentation might include:
   - *What different effects can we create if we arrange the dice and sugar cubes in different ways (i.e., an irregular pattern, more sugar cubes than dice, more dice than sugar cubes, or alternating layers of dice and sugar cubes.*
   - *If we constructed a vast "landscape" of dice and sugar cubes (in contrast to the one-dimensional stack in this activity), what kinds of landforms might we be able to create?*

5. Demonstrate subsidence using a thick, flowing substance such as applesauce, slurpies or milk shakes. As the ice slurry or viscous liquid is withdrawn from the bottom of the cup through a straw, the surface right above where the material is being sucked out sinks *(i.e., subsides).*

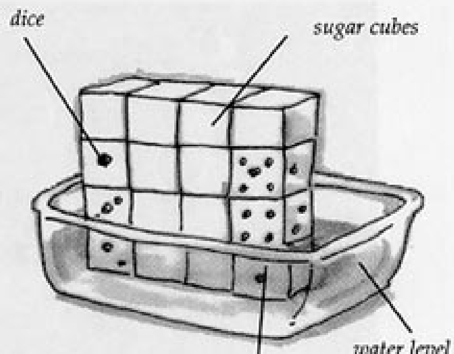

Fig. 3.4
Activity setup.

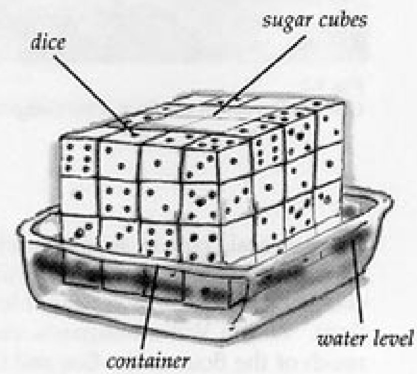

Fig. 3.5
The 4x4x4 block for demonstrating subsidence in a three-dimensional model.

Questions

1. In this activity, you modeled a process where material was removed from below the surface. How can materials from below the surface be removed? *They can shrink, be dissolved, or be physically removed.*

2. How long does it take rocks to dissolve? Do all rocks dissolve at the same rate? *Rocks dissolve slowly, such as over thousands, millions or billions of years. Different rock types have different rates of dissolution. This is in contrast to the rapid dissolution of sugar by water.*

3. Predict some of the characteristics of materials prone to being dissolved. Can you name any rock types that fit the characteristics you listed? *As a model, the sugar cubes might represent 1) salt which can be dissolved by water, or 2) carbonate rocks which can be dissolved by acids such as carbonic or sulfuric acid.*

4. How could you increase subsidence in your model?
   Students could use more water or increase its dissolving power by heating it.

5. Research sink holes to find out what they are, where they are found and how they affect the area surrounding them.

APPLYING THE MODEL TO MARS

Have students look at Images 6, 7 and 8. Do they see any evidence of subsidence? What characterizes subsidence? Can students tell subsidence pits and craters apart?
Craters often have ejecta blankets around them and a small mound in their centers. The floors of subsidence pits appear flat, and they have no ejecta blankets where their walls intersect the surrounding plain.

How do the Martian subsidence features compare to what students saw in their models? Are these pits large or small?
The signature of a subsidence pit is a depression with steep walls. It is often circular, and can range in size from small pits such as those at the eastern end of the Tithonium Chasma to large depressions such as the Hebes and Juventae Chasmas. To see pit chains, look along the south edge of the Coprates Chasma, north and east of the Candor Chasma and south of the Ius Chasma. These pit chains seem to follow fault lines.

Have students examine Image 11. How large an area is shown in this image? Are these canyons deep or shallow? Describe the look of the canyon floor. What features stand out? Describe any similarities to the pits, coalesced pits or pit chains? Can you see any channels? What might channels indicate?
Chaotic terrain is not found on Earth, and on Mars it occurs mainly between Valles Marineris and the Chryse Planitia. The elevated plateau in this part of Mars is interrupted by the chaotic terrain and outflow channels. The kilometer-sized knobs and irregularly-shaped mesas strewn through this landscape apparently derive from the breakup of plateau rocks. When the sub-surface fluids were removed, the plateau materials subsided, fractured and slumped resulting in the characteristic chaotic landscape. Outflow channels and chaotic terrain are almost always found together, suggesting that they are related in origin. The channels extend downslope from the chaotic terrain, indicating that the fluid which excavated the channels flowed from the chaos. While scientists have proposed runny lava, mud flows, and ice as eroding fluids that might have created the outflow channels, the fluid is generally thought to be water or ground ice whose melting produced the channel-cutting fluids.

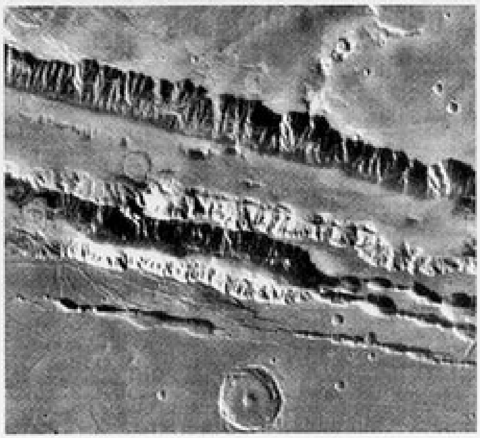

Fig. 3.6
Pit chains south of the Coprates Chasma.

TEACHING POINTERS

You might want students to collect data on things such as:

- How long does it take to dissolve the bottom rank of sugar cubes?
- Does the dissolving of the sugar cubes continue at the same rate? Does it slow? Does it ever stop?
- How tall must a dice-sugar cube stack be before the dissolving of the bottom layers does not affect the surface layers?
- Do different kinds of sugar cubes dissolve differently?

EXTENSION

This is an excellent opportunity to have students conduct solubility experiments testing such things as concentration of solvents, the susceptibility of materials to being dissolved, the effects of temperature on the rate of dissolving, etc. Such experiments would give students the opportunity to actually design labs, control variables, and produce graphs from their data tables.