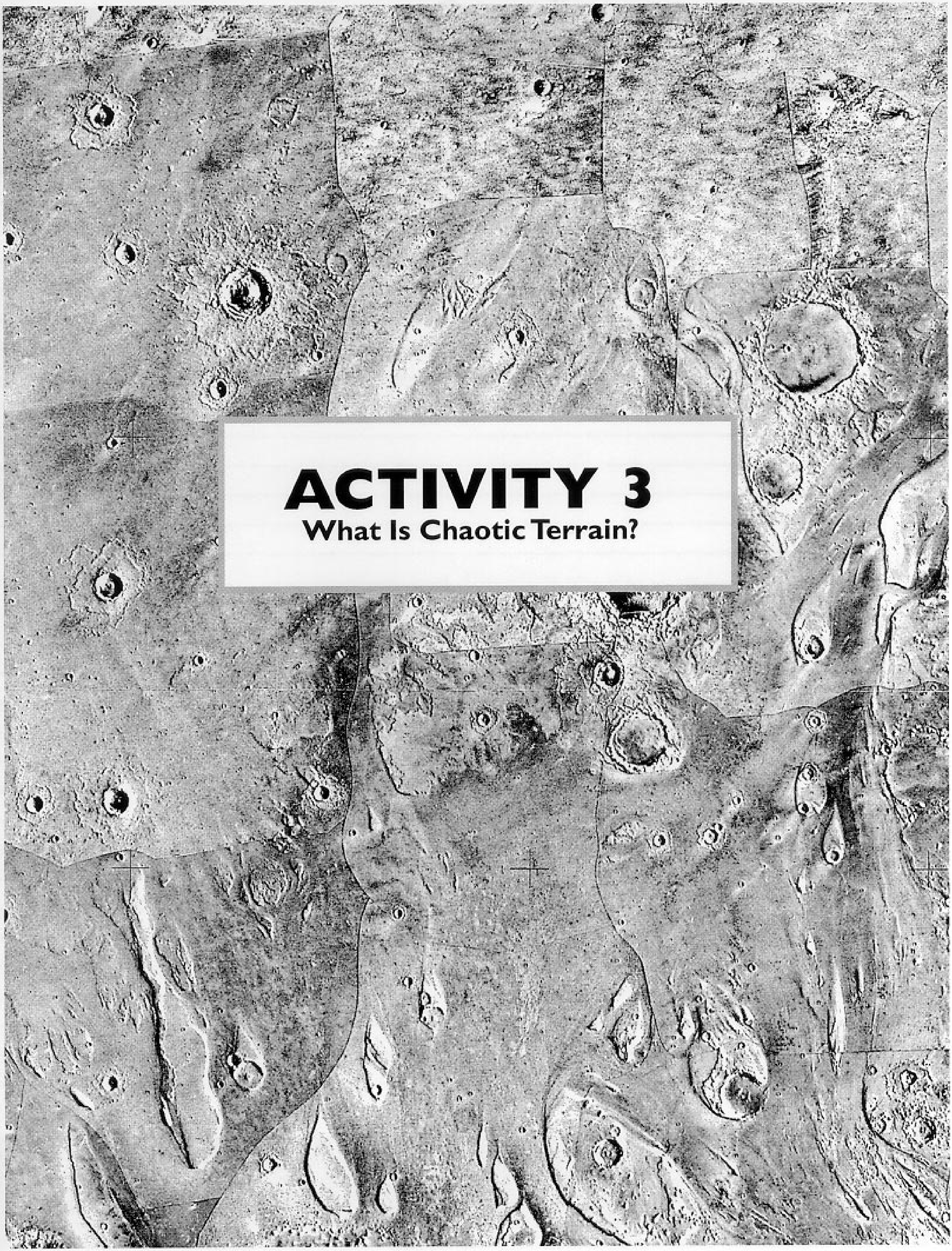
ACTIVITY 3
What Is Chaotic Terrain?



NOTES

Overview

By having ice melt from under a layer of sand and causing the surface to deform, students create a simplified model of the formation of chaotic terrain. Then, students compare their models to images showing chaotic terrain on Mars. They learn several identifying features and try to identify additional examples of chaotic terrain seen in the image set. Finally, they consider ways to improve their models to resemble the Martian chaotic terrain more closely.

Content Goals

- Chaotic terrain is thought to form when the removal of subsurface water or ice causes a loss of support, and the ground collapses under its own weight.
- Areas of chaotic terrain are lower than the surrounding plateau, have irregularly-shaped, variously-sized blocks of crust on the depression floor, and have channels leading away from them.
- Chaotic terrain is considered a source for the fluid(s) that created the channels.

Skill Goals

- *Model* a distinct landscape, chaotic terrain.
- *Compare* the model with images of chaotic terrain on Mars.
- *Identify* areas of chaotic terrain in the images based on several characteristic features.
- *Redesign* the model to resemble the Martian chaotic terrain more closely.

Possible Misconception

Ice and water reside or flow through soil but lend it no structural support.

Ask: Where might ice or water give the ground some structural support?

Materials

Trimmed, disposable aluminum cookie sheet, ice, sand, and washers or blocks of wood.

Time

Two class periods.

Fig. 3.1
The Hydaspis Chaos at the head of the Tiu Vallis.

Chaotic terrain is a common feature found within the outflow channels, along their banks, and at their heads. It is a landscape consisting of a haphazard jumble of large, angular blocks of crust and arc-shaped slump blocks (Fig. 3.1). Chaotic terrain is not found on Earth, and on Mars it occurs mainly between Vallis Marineris and the Chryse Planitia. 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.

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.

Outflow channels and chaotic terrain are almost always found together, suggesting that they are related in origin. Channels extend downslope from the chaotic terrain, indicating that the fluid that 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 some ground ice whose melting produced the channel-cutting fluids.

The elevated plateau east of Vallis Marineris 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 materials were removed, the plateau materials subsided, fractured and slumped, resulting in the characteristic chaotic landscape.

Note the regular distribution of the collapsed plateau materials at the eastern end of Vallis Marineris (Fig. 3.2). This appearance is similar to patterns seen in areas affected by *crustal extension*. In these areas, blocks of crust separate in response to forces tending to pull them apart and have a regular pattern.

Fig. 3.2
An example of chaotic terrain at the eastern end of Vallis Marineris. Image Set image #15.

Examples of crustal extension can be seen at the top of domes that have been uplifted. In fact, the chaos and channels are on the periphery of an enormous, 11-km dome called the Tharsis Rise, so uplift is a very likely cause of the regional crustal extension and the regularly fractured distribution of the plateau material on the canyon floors. One of the mechanisms associated with uplift is a rising magma plume. Since such plumes bring magma close to the surface, ice and permafrost may have been melted, resulting in the release of large volumes of water.

One possible sequence explaining the chaotic terrain is as follows:

- magma plumes uplift a large area including the plateau at the head of the Ares Vallis;
- the magma's heat melts subsurface ice or permafrost, releasing water, or, if the permafrost acted as a cap to an underlying aquifer, the aquifer releases its water;
- the released water creates large channels as it flows from the elevated plateau to the low-lying plains to the northeast;
- the removal of the water or ice causes a loss of support, and the ground collapses under its own weight leaving irregular blocks of crust on the depression floor;
- the blocks form a characteristic pattern due to further crustal extension and erosion.

PROCEDURE

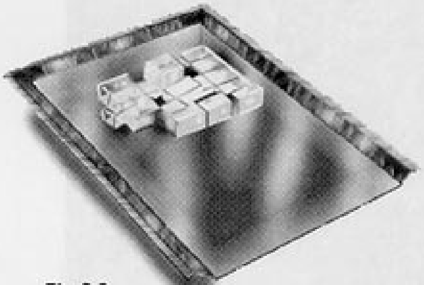


Fig. 3.3
How to layer the ice.

1. Lay at least 12 ice cubes or several sheets of ice on a disposable cookie sheet (Fig. 3.3).
   Prior to starting, trim away one end of the disposable aluminum cookie trays so water can drain out rather than pool under the sand.

2. Surround the ice with sand so that the ice is totally surrounded by sand (Fig. 3.4).

3. Cover the ice and surrounding sand with a 1-cm (0.5 inch) layer of sand.

4. Set the cookie tray in a place where the water from the melting ice can safely drain.

5. Using washers or blocks of wood, elevate the uncut end of the tray 5 cm (2 inches).

6. Gently pack the sand so its surface is smooth and without any obvious cracks (Fig. 3.5).

7. After the ice melts, observe what the surface looks like (Fig. 3.6).

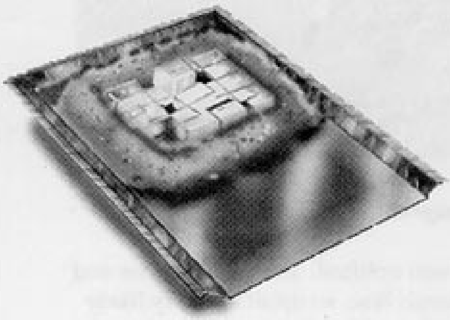


Fig. 3.4
How to arrange the sand around the ice.

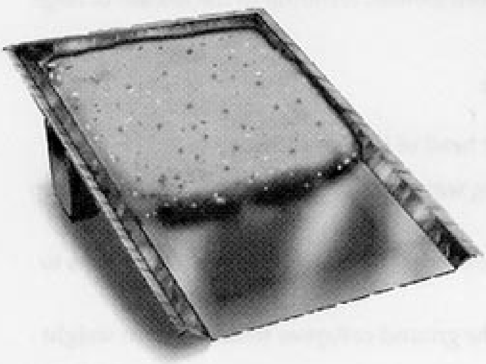


Fig. 3.5
The completed activity setup.

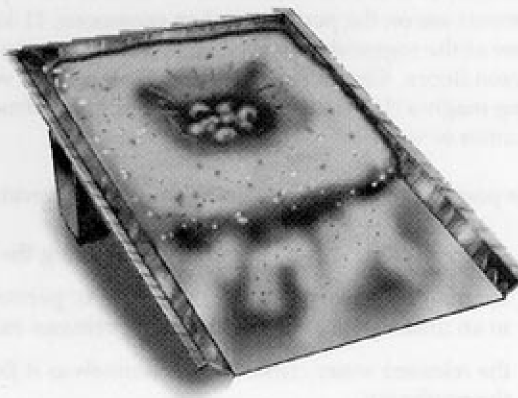


Fig. 3.6
What surface looks like after the ice melts.

Questions

1. What are the key elements and conditions necessary in order for chaotic terrain to form?

2. What are the strengths and weaknesses of this model?

APPLYING THE MODEL TO MARS

1. Have students compare Image 15 to the surface of the sand in their model. How are they alike and different?

2. Search for areas of chaotic terrain that feed Ares Vallis. How many are there? *(Four.)* Where are they? *(Two at the head [Margaritifer and Iani] and two along the margin about mid-way [Aram and Hydaspis].)*

3. Search for other areas of chaotic terrain, such as near the Tiu Vallis just west of Ares Vallis.

4. Describe the features that these areas have in common. *(See below)*

5. How might students improve their models to resemble the Martian chaotic terrain more closely? Have them try their modified procedures. *(They can use sand with a different grain size, use a mix of sand and pebbles, layer the ice and sand to produce a multi-layered sandwich of sand and ice, use crushed ice, space the ice cubes more or less widely, use a deeper or shallower layer of sand or have a semi-rigid cap layer above the ice.)*

The landscape being modeled is termed *chaotic terrain*. Chaotic terrain has several identifying features:

- Areas of chaos are lower than the surrounding plains. Small areas of chaos often look like large depressions, and large areas of chaotic terrain often look like broad, shallow canyons.

- The bottom of the chaotic terrain is covered with sections of crust that have been broken into blocky chunks arranged randomly across the floor of the depression. At a 1:2,000,000 scale, the collapsed surface can look granular as if it were strewn with fine, angular pebbles (Fig. 3.2). However, when the crust blocks are larger, the smooth, elevated surface of the surrounding plateau is retained except that it is dissected by large fractures that form irregularly-shaped blocks (Fig. 3.1). Some describe the fractured plateau and these blocks as looking similar to the lines on the palm of a hand.

- Channels lead away from chaotic terrain, and some chaotic terrain may exhibit features associated with flowing water, such as streamlined shapes.

TEACHING POINTERS

Ice cubes arranged in a pile work well. You might contrast the different effects of various arrangements of ice cubes. For example, is the effect different when the ice cubes are neatly arranged versus when they are jumbled and randomly oriented in a pile? In addition, cottage cheese containers can be used to form disks of ice – pucks. What is the effect of a puck versus some ice cubes? Pucks of different thicknesses? A combination of pucks and ice cubes?