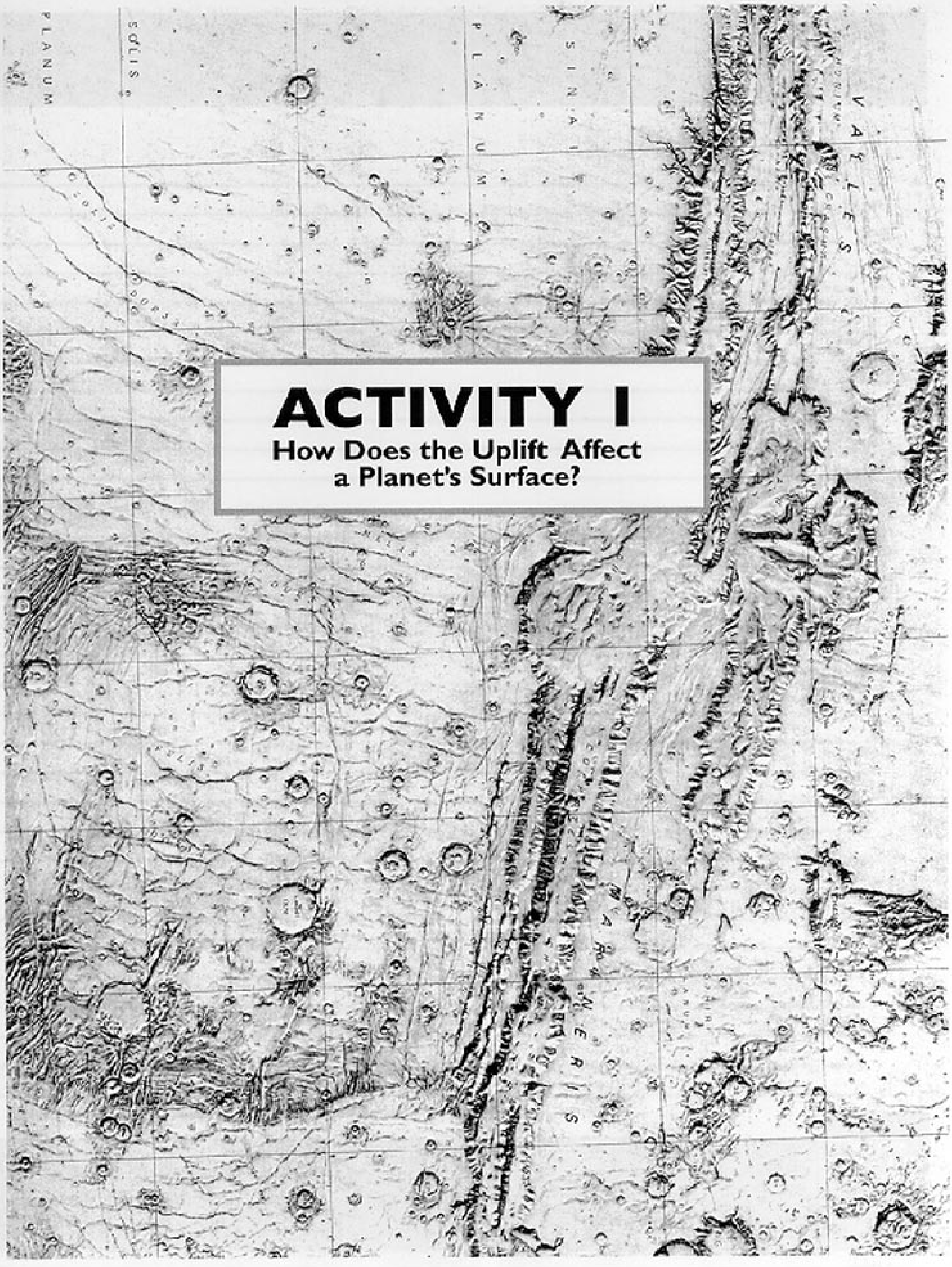
ACTIVITY 1

How Does the Uplift Affect a Planet's Surface?



NOTES

AT A GLANCE

Overview

Students experience how a planet's surface can become fractured and deformed as a result of pressures from below its surface. By modeling uplift, a process thought to be responsible for the formation of a large dome on Mars, students see one way a planet's surface can be altered in the absence of water. Students model the cracking of a surface using a pan lined with a layer of cornstarch. They measure and record the size of the fractures and learn to recognize characteristic fracture patterns.

Content Goals

- A planet's surface can be deformed by uplift.
- Fracturing is one example of a surface change resulting from uplift.

Skill Goals

- *Modeling* planetary uplift and the fracturing of a planetary surface.
- *Observing* changes and patterns in the cornstarch as it fractures.
- *Calibrating* a measuring device.
- *Measuring* the size of the fractures.
- *Assessing* what information is important to collect and *creating* an appropriate data table.
- *Comparing* the degree of fracturing at different stages of the uplift.
- *Graphing* fracture size in relation to the height of the uplift.

Possible Misconceptions

- All planets are perfectly spherical.
  Ask: Are all the planets the same shape? or What shape do planets have?
- The surface of a planet is stable.
  Ask: How can a planet's surface change shape?
- Large planetary domes are probably steep and quite noticeable to someone on the surface.
  Ask: How steep does an incline have to be before you can recognize it as an incline?

Materials

Pan with a flexible bottom such as a disposable aluminum cookie sheet, corn starch, toothpick, ruler, magnifying glass, items to create the bulge such as large washers, and an empty milk carton or other flat object to pack down the corn starch.

Time

1-2 Class Periods

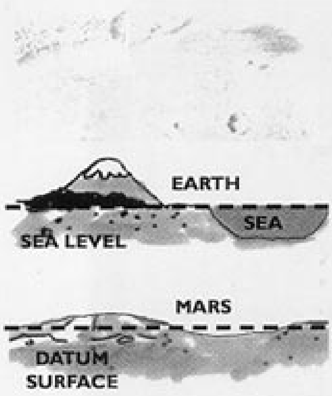


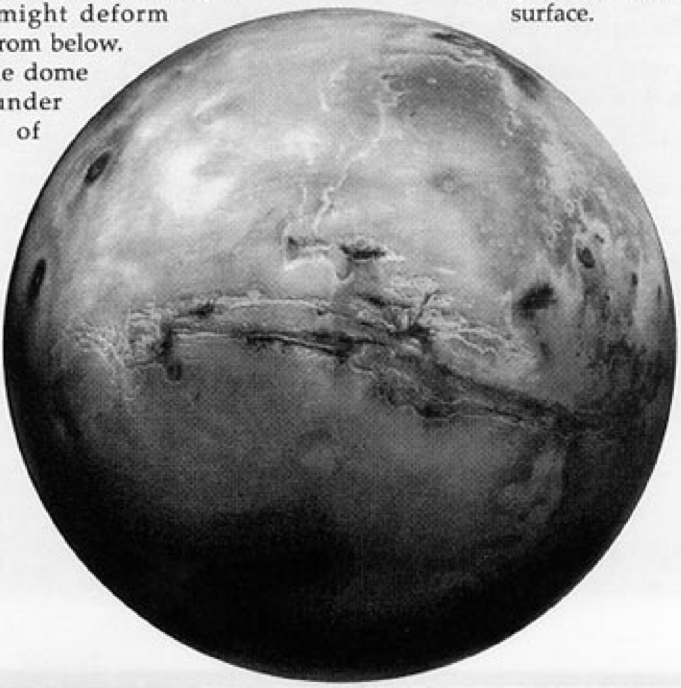
Fig 1.1

On Earth we use sea level to define zero elevation and measure the height and depth of landforms in relation to sea level. We describe elevations on Mars in a similar way relative to a zero level called datum surface.

Mars is not a perfect sphere. A 30 million km^2 (12 million mi^2) part of the northern hemisphere, roughly equivalent to the combined size of the United States and Canada, bulges nearly 11 km (6.9 mi) above the Martian *datum surface* (Fig. 1.1). This bulge is called the Tharsis Rise, and it may have formed when magma rose from deep within the planet causing the lithosphere to dome upward and fracture. The huge volcanoes sitting on top of the dome attest to the existence of an active magma chamber at one time.

As a consequence of this large dome, a system of fractures extending nearly halfway around Mars developed. These fractures are nearly radial to the center of the Tharsis Rise, and can be one to five kilometers wide and several thousand kilometers long. This system of fractures could have been created either during the uplift or after it. During the uplift, a brittle lithosphere could have cracked and developed this radial pattern of long fractures. This is the process modeled in Activity 1. Alternatively, the Tharsis could have risen with no significant cracking of the surface, much the way a sheet of clay might deform when pressed from below. However, as the dome flattened out under the influence of gravity, its edges would have begun to spread. Such spreading would increase the circumference of the dome, and cracks would develop radially across the dome. This can be demonstrated by taking an orange peel from half an orange, inverting on a table so it looks like a dome, and pushing down on the top of the "dome." As the peel becomes increasingly flat, the edges of the orange peel will rip apart forming a radial pattern of long, wide fractures.

One set of these fractures define the edges of an east-west oriented canyon named the Valles Marineris. Valles Marineris is the largest canyon in the solar system – 4000 km (2,500 mi) long, up to 700 km (438 mi) wide and as much as 10 km (33,000 feet) deep. The western end of Valles Marineris sits over the highest part of the Tharsis dome. Descending from the crest of the Tharsis dome, the canyon drops at a gentle angle of 0.2-0.4 degrees. While the dome is large in a planetary sense and might have important effects such as affecting the planet's center of gravity and causing subsurface water to flow down its flanks, the ground appears virtually flat to an observer on the surface.



PROCEDURE

1. Have your students examine the Two Faces of Mars poster which shows the huge Valles Marineris stretching thousands of miles across Mars. Have them describe what they see and speculate how big it is and what they think might have caused it. After some discussion, explain that they will do a series of classroom experiments and make models that will help them understand some of the processes that created Valles Marineris.
Some teachers see a value in having their students initiate an activity without knowing exactly why they are doing it or how it relates to their studies. After completing the activity, students speculate on what the activity was about and what kinds of topics could be studied based on it. Such teachers might want to skip this step and complete the activity before making the Mars connection.

2. Cover the bottom of the pan with a layer of corn starch. With a milk carton or can, press the layer so it packs into a firm, 2 cm layer. If necessary, smooth the top with an index card or pencil.
Corn starch is recommended instead of flour because it is finer grained, cracks more easily and cleans up easily. If corn starch is unavailable, fine flour will also work.

3. Ask your students what would happen if you put a pile of washers underneath the middle of the tray.

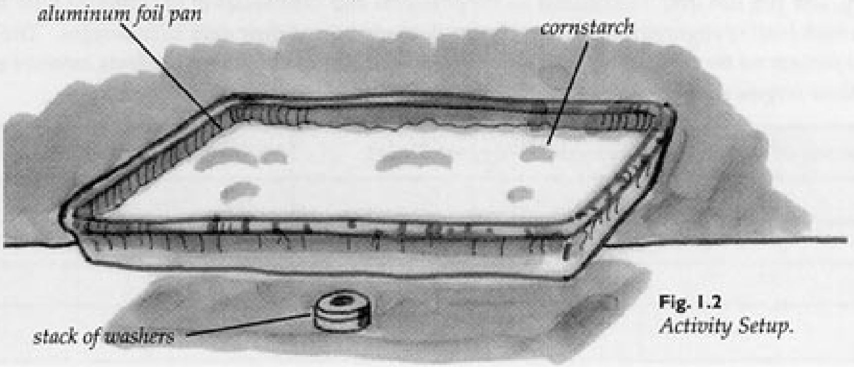
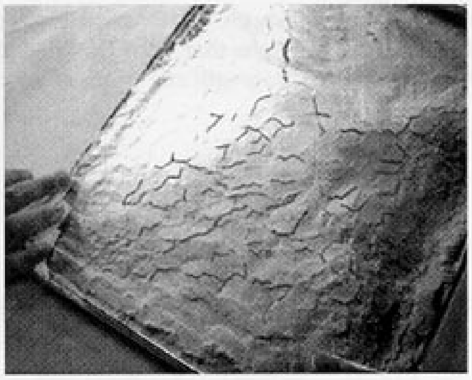


Fig. 1.2
Activity Setup.

4. Lay one of the washers on the table and create a small "dome" in the corn starch by setting the pan over the washer so that the washer is as close to the middle of the pan as possible (Fig. 1.2).

5. Observe what happens. If cracks form, describe them or draw the patterns.



6. Calibrate a toothpick by transferring ruler markings every 2 mm to the toothpick. Use it to measure the depth of any cracks created and a ruler to measure their lengths (Fig. 1.3). Do the cracks go all the way down to the aluminum or do they stop before they reach it?

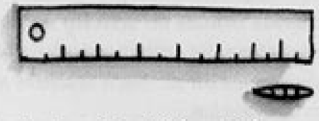


Fig. 1.3
Calibrating a toothpick.

7. Have students record their measurements in a data table. Make sure their data table organizes all the relevant information.
An initial class discussion will help everyone focus on what they should do as well as understand what data they should collect and why that data is important. Depending on how experienced your class is with making data tables, you can either furnish them a data table, have the class design a table that everyone will use, or let each group design its own data table. While possibly requiring more time, an advantage of letting each group design its own table is that each group is forced grapple with what data to collect. There will probably be a variety of data tables at the end of the activity, and you can lead a discussion on the strengths and weaknesses of the different table designs. Students will have a high level of engagement as they present the logic behind their data table designs. The sample table below (Fig. 1.4) focuses on the largest crack produced each time. You can also have students measure every crack, or the two or three largest ones.

	Number of Cracks	Length of Biggest Crack	Width of Biggest Crack
1 Washer			
2 Washers			
3 Washers ...			
Average			

Fig. 1.4
Sample data table for Step 7.

8. Repeat steps 4-7, adding another washer to the pile each time.
If the items used to make the stack are small in diameter, set a larger disk (such as the top of a juice bottle or an orange juice can) on the top of the stack to distribute the lift across the bottom of the pan more evenly.

9. After creating some cracks, have students use a magnifying glass to look closely at the crack walls as well as down into the cracks.

10. Discuss with your students how the cracks changed in terms of length, width, depth and pattern as the height of the pile of washers increased. Have students design graphs that show the effect the number of washers has on: a) the number of the cracks in the cornstarch; b) the length and width of the cracks in the corn starch.

Questions

1. What are the variables in this activity? Which were controlled? Uncontrolled?

2. What could rise from a planet's interior to produce an upward push similar to the one modeled in this activity? *(Magma.)*

3. What could enable a planet's surface to resist upward pushes and prevent it from cracking? *(Having a thick crust or lithosphere.)*

APPLYING THE MODEL TO MARS

Noctis Labyrinthus. Image Set image #4.

1. Examine the images of the entire Valles Marineris. Ask students if any sections look like the patterns of cracks they saw in the corn starch? Do any images remind them of what they saw when they looked at the cracks with a magnifying glass? If so which ones? Where are these sections in relation to the highest part of the bulge (i.e., the western end of Valles Marineris)?
2. The dome caused cracking in the corn starch. But the model is limited in how it reflects the actual situation on Mars. Discuss how forming cracks with corn starch in a classroom is similar to and different from the way a dome might actually produce cracks on a planet's surface. The Tharsis Rise is approximately 10 km high and 4000 km across, yielding a ratio of 10:4000 (i.e., 1:400). This means that the elevation changes 1 km for every 400 km traveled across the diameter of the dome. Although the Tharsis rise is large by planetary standards, it still has an extremely shallow angle. Calculate the dome's height to length ratio for the long dimension of the pan when it had the maximum number of washers under it. Repeat for the pan's short dimension. Is either dome close to the actual shape of the Tharsis dome? How might one model the shape accurately?

   Undoubtedly, we have scaling problems. The corn starch in the tray is meant to represent a huge area – 4000 km north and south and 3000 km east and west. Even though corn starch particles are small, when the pan and its contents are thought of at this larger scale -- enlarged millions of times -- each corn starch particle assumes the size of hill-sized boulders! Obviously, the surface of Mars is made up of material considerably smaller than hill-sized boulders and behaves differently to the stresses produced by the uplift than did the corn starch in the classroom model. How might this be improved? Is it still a useful model?

   Students can also be misled if they think of the dome rising out of a flat plain. Remind students that this dome arises off the curved surface of a small planet, one half the size if Earth, making it even more pronounced. Even so, a 1:400 slope is equivalent to raising the end of a four-meter board one centimeter or a 40-centimeter item one millimeter. This angle is so gentle that one would probably not even notice being on a slope.

TEACHING POINTERS

Problems in this activity can arise from repeated handling of the tray. Creating a pile of washers necessitates lifting the pan. When the pan is lifted, the bulge disappears and the corn starch "relaxes" as it returns to its former position. Working the corn starch this way four or five times may cause the cracks to develop in a way they would not if the doming were a constant process. You might want to inflate a plastic bag under the pan or use a ruler to create a continuous bulging effect (Fig. 1.5). Using a ruler this way also opens the door to a lesson on levers. Students can calculate the amount of force generated on the base of the pan. Other extensions include seeing the effect of sudden movements.

For additional ways to demonstrate doming, you might coat a balloon with plaster of Paris and then inflate it to show how cracks (i.e. faults) develop in a surface stressed in this way.

Teaching good data collection and analysis habits is an important element of any science program. One hallmark of valid experimentation is obtaining enough data to support or cast doubt on a pattern or trend. In this activity, each group collects data on the effects of each additional washer. One way to strengthen their conclusions is for them to repeat the experiment and collect a second set of data. Another way to obtain a large data set is to have each group do the activity following a standard procedure. Each group's results then become a data set, and these combined data sets serve as the equivalent of multiple trials. It is very useful for students to understand that duplicate experiments often do not produce identical results.

Advanced classes could quantify the radial pattern by measuring the fracture angles around the center of the rise and generating accurate diagrams illustrating the fracture pattern.

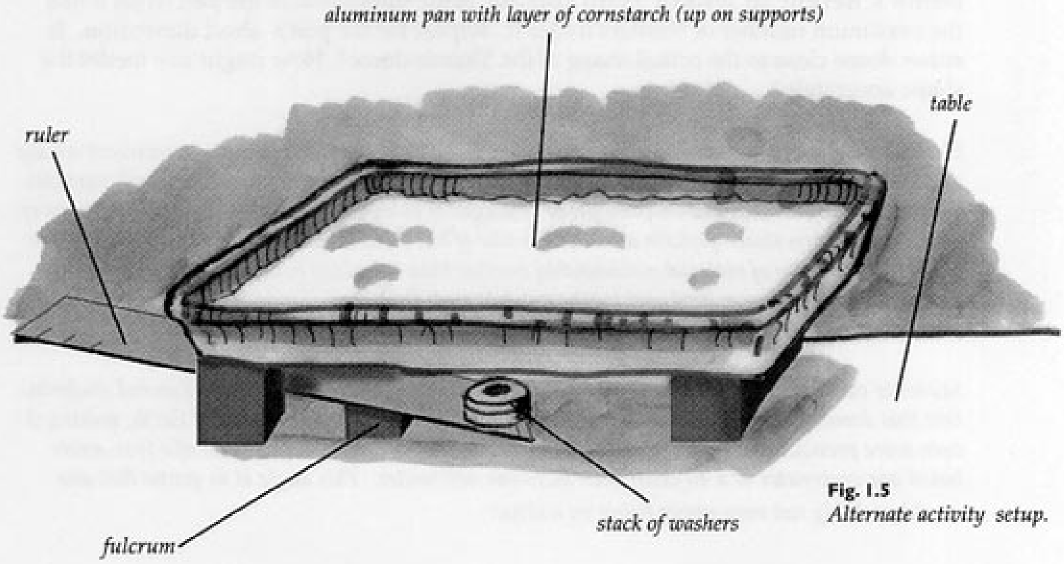


Fig. 1.5
Alternate activity setup.