Voyages to the Terrestrial Planets – *Making impact craters*

Overview: We have discussed impact craters several times this term, but have never really thought about what makes them or the processes involved in their formation. Here we are going to explore the impact cratering process and consider the energy involved in their formation.

Due: Do not turn this in…

To do:

Activity:

Do each of the steps below. Make sure to record your answers and work on a sheet of paper for your own notes.

1) Select a golf ball and whiffle ball as well as three pie pans.
2) Measure the mass of the golf ball and whiffle ball. Record this information.
3) Fill one pie pan with a layer of cocoa and then a layer of flour – do not mix the two layers.
4) Fill the other two pie pans with sand. Dampen one of these pie pans with water – don't make it too soupy!
5) From various heights, drop the golf ball and then the whiffle ball into each of the pie pans. Sketch the resulting hole that forms onto a sheet of paper.
    - Make sure to measure the height from which you drop each of your objects
    - Drop your objects from a variety of heights and see if there is a difference in the resulting hole
    - Determine the velocity of your falling object
6) After you have performed these steps, answer the questions below.

Questions:

1) Based on what you observed from above, explain what happens during the impact process. Draw sketches to illustrate what happens to the ground during this process.

2) Kinetic energy (KE) is the amount of energy an object possesses due to its motion. It is defined by the following equation: $KE = 0.5(mv^2)$ where m = mass and v = velocity. Based on the masses and velocities you measured above, how much KE does the golf ball possess when hurtling towards the pie pan? How about the whiffle ball?

3) Does that difference in kinetic energy make sense with the resulting craters that formed in your pie pans?

4) OK, we will revisit kinetic energy in a short bit, but let's think about the impact craters that formed in your pie pans. How was the morphology for each of the craters different for the different substrates you impacted into? Was the morphology the same for each of the substrates?

5) How about for the flour and cocoa pie pan? Was any cocoa expelled onto the surface from under the cocoa? What might the implications of that be when thinking about the impact cratering process on another planet?

6) Let's now bring this together.
a) We have spent much time in this class discussing the usefulness of impact craters for dating a planetary surface. However, what are two other potential uses of impact craters when studying other planets?

b) Let's think about kinetic energy again. Can the lessons of the golf ball vs. the whiffle ball be translated to small solar system objects such as asteroids and comets?

c) We are going to take that last question a step further and calculate the kinetic energy of a comet vs. an asteroid slamming into the Earth. Specifically, on February 15th 2013 (next Friday), asteroid 2012 DA14 will pass within 17,200 miles of the Earth's surface – to put that into perspective, that is 1/13th the distance from the Earth to the Moon and is actually inside the ring of communications and weather satellites we have currently orbiting Earth. The asteroid is not expected to hit us, but if it did, how much kinetic energy would it deliver to the Earth? It is 45 m in diameter with an assumed mass of 0.2×10^{15} kg (probably better to use 200,000 tons – 10^11 kg) and is moving at a velocity of 7.8 km/s. For a sense of scale, compare to the energy sheet I handed out to you.

d) Let's do that calculation now assuming that object is a comet and not an asteroid. Comets typically have about four times less mass than an asteroid and travel at velocities that are twice as fast.

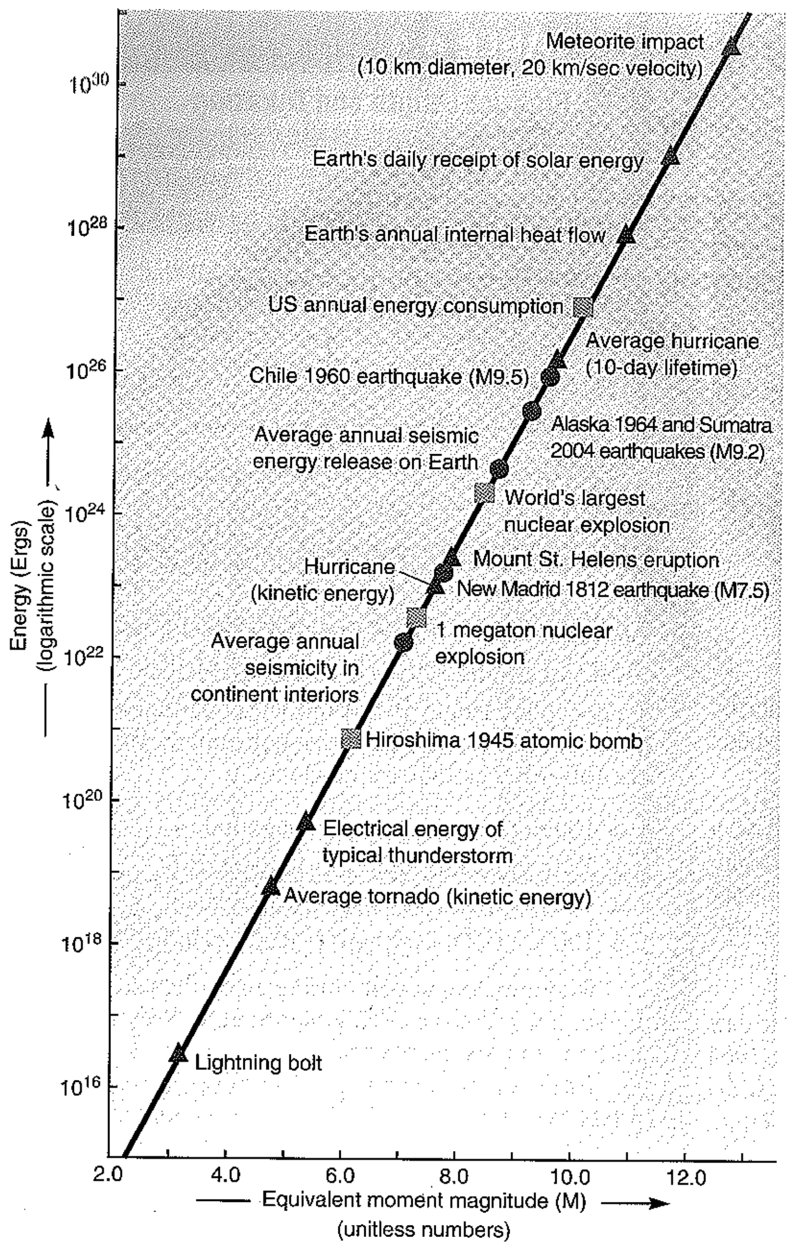

Figure 4.25

Equivalent moment magnitude of a variety of seismic (green dots), human-made (yellow squares), and other phenomena (red triangles).

Source: A. C. Johnston, "An earthquake strength scale for the media and the public" in *Earthquakes and Volcanoes* 22 (no. 5): 214–16. *US Geological Survey.*

ground both vertically and horizontally. Buildings usually are designed to handle the large vertical forces caused by the weight of the building and its contents. They are designed with such large factors of safety that the additional vertical forces imparted by earthquakes are typically not a problem. Usually, the biggest concern in designing buildings to withstand large earthquakes is the sideways push from the horizontal components of movement (figure 4.26).

ACCELERATION

Building design in earthquake areas must account for **acceleration.** As seismic waves move the ground and buildings up and down, and back and forth, the rate of change of velocity is measured as acceleration. As an analogy, when your car is moving at a velocity of 25 mph on a smooth road, you feel no force on your body. But if you stomp on the car's accelerator and rapidly speed up to 55 mph, you feel a force pushing you back against the car's seat. Following the same thought, if you hit the brakes and decelerate rapidly, you feel yourself being thrown forward. This same type of accelerative force is imparted to buildings when the ground beneath them moves during an earthquake.

Continuing the analogy further, if you hold your arm upright in front of you and wave it back and forth, you cre-