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Cookie Tectonics

An Introduction to Earth Hazards & Tectonic Fundamentals

by Renee Clary and James Wandersee

While we may have to work hard as teachers to spark students' interest in "everyday" science, the news media regularly inspires our students with detailed reporting and images of natural disasters (Figure 1). Following events such as earthquakes, volcanoes, and hurricanes, students come to class with questions about the science behind the incidents. Unfortunately for the humans affected by them, there are numerous natural disasters during any school year that can be used to introduce students to Earth hazards and the fundamentals of tectonics. Using natural hazards as the backdrop, we developed and refined a fun and interesting teacher-directed classroom review of basic Earth concepts that functions as a formative assessment of incoming student knowledge.

Lithospheric cookie models: A tectonic activity

A series of photographs in a college textbook (Lillie 2005) inspired us to integrate cookies in science classrooms as a review with what we termed our "lithospheric cookie model" activity. We have since discovered that an earlier Lillie version of the activity, with additional details, is available online (see Resource).

Lithospheric cookie models

This lithospheric model activity provides direct instruction and a fun way to review the basic principles of plate tectonics. Provide each student with a paper towel or napkin and two cream-filled sandwich "lithospheric" cookies. (Safety note: This activity should not be performed in a laboratory. Instead, teachers should make arrangements to use a "food safe" classroom, such as a cooking classroom, or the cafeteria; this is especially true if students are going to be allowed to eat the food. Teachers should check for student food allergies before using this activity, and attention should be paid to cleanup to prevent insect or rodent infestation resulting from leftover crumbs.)

Begin by asking students the "official" method of disassembling a lithospheric cookie; most will propose the "twist and separate" method. Once students have separated their sandwich cookie (the extra one will serve as a replacement if models are botched at any point during the process), they should have two hard cookies, with cream filling attached to one of them. We focus attention on the single hard cookie wafer and the soft cream filling. The hard cookie attached to the cream is for support only.

FIGURE 1 **Mount Etna, Italy, has the capacity to affect a large number of people**

GNUCKX, VIA WIKIMEDIA COMMONS

Earth divisions

Most students come to middle school with only a very basic understanding of the layers of the Earth, and they may have had an introduction to plate tectonics, depending upon their elementary science program. Therefore, at this point, we begin our activity by explicitly differentiating between the *chemical* divisions of the planet and the *physical* divisions that are used in plate tectonics.

We first provide an overview of the characteristics of the lithosphere (hard, brittle, broken into plates) and the asthenosphere (plastic, flows, layer beneath the plates). Students often have misconceptions about

FIGURE 2 **Students sliding the two pieces of their top cookie past each other to demonstrate a transform plate boundary (A), while gently pushing down on the two lithospheric pieces and pulling apart yields a divergent plate model (B)**

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FIGURE 3 The final convergent lithospheric model

PHOTOGRAPH COURTESY OF THE AUTHORS

these physical layers of Earth, since they don't quite align with the Earth layers they learned in elementary school, the core, mantle and crust. In order to illustrate the differences, we provide an analogous classroom classification: Just as we can divide students into a "girl group" and a "boy group," we can also divide the class in a *different* way based upon birthday months, with a winter group (January–March birthdays), a spring group (April–June birthdays), a summer group (July–September birthdays), and a holiday group (October–December birthdays). Although the divisions are different, we are still referencing the same classroom of students. We next point out that scientists can divide the Earth in the "classic" way that students learned in elementary grades (into a mantle, core, and crust) by looking at the *chemical* and mineral composition of its layers. When scientists looked at the *physical* properties of the layers, though, as determined by earthquake wave behavior, they realized that there are different divisions, including the lithosphere, asthenosphere, and mesosphere. Only the lithosphere and asthenosphere are used in this activity, because these are the layers relevant to plate tectonic movement.

Next, we inform students that we will model tectonic processes using cookies. In a whole-group discussion, ask students to hold up the part of their lithospheric model that represents the lithosphere—the plain hard cookie (*yes*) or the malleable cream filling? Allow students to offer comparisons between the hard, breakable cookie wafer and the brittle lithosphere, as well as comparisons between the cream filling and the plastic, slowly flowing asthenosphere. In order to demonstrate the movement of the plates, ask students to place the "lithosphere" cookie gently on top of the "asthenosphere" cream and slide the lithosphere around in a

Plate tectonics: A unifying theory of Earth

Just as evolution serves as the dominant theory in biology, so the theory of plate tectonics provides a unifying theory in geology. Plate boundaries explain the location of most of our planet's volcanoes, earthquakes, mountains, and natural resources. The theory of plate tectonics also integrates with organic evolution, since plate boundaries help to explain the distribution of life-forms. Supported by a multitude of evidence, the theory is predictive within geologic time frames.

The importance of this theory is underscored by the *Next Generation Science Standards*, which allocate Earth- and space-science disciplinary core idea MS-ESS2 (Earth's Systems) toward plate tectonic study (NGSS Lead States 2013). The theory also addresses crosscutting concepts of Cause and Effect, Systems and System Models, Energy and Matter, and Stability and Change.

The development of plate tectonic theory proceeded via several scientists, including German meteorologist Alfred Wegener, who proposed a theory of continental drift in his 1915 book *The Origin of Oceans and Continents*. Wegener built his proposal upon the research of other scientists (e.g., Antonio Snider-Pellegrini, Eduard Suess, Frank Taylor) and cited a large amount of fossil, continental-fit, and rock data. However, his theory was not accepted by the majority of the scientific community because he did not provide a convincing mechanism for continental movement. Other scientists continued to gather data, and it was partly with Henry Hess' recognition that the mid-Atlantic was the site of seafloor spreading that the theory of plate tectonics was finally acknowledged. An acceptable mechanism now accompanied the theory of plate movement, in the form of convection cells within the mantle (see also Falk and Brodsky 2013).

Plates may pull apart (divergent boundaries), come together (convergent boundaries), or slide past each other (transform boundaries). Because there are two types of crust (continental and oceanic), a convergent plate boundary may result in subduction of an oceanic plate (with two oceanic plates, or an oceanic and a continental plate), or the collision of two plates and resultant crustal thickening (with two continental plates). Student understanding and application of plate tectonics is extremely important for their comprehension of Earth hazards and how future generations can prepare for them.

manner analogous to the way the plates move on top of the plastic asthenosphere.

Plate boundaries

Students should then take their lithosphere cookie, and by gently placing their thumbs underneath it, break it into two parts. Next, have students investigate different plate boundaries using the lithospheric models. We suggest doing the activities in this suggested order, since convergent plate boundaries tend to result in the destruction of the cookie models. We have also found that it helps to keep the class on the same task, because there are invariably students who move their cookie "plates" in the wrong direction.

Transform boundaries exist when two plates slide past each other. Ask students to gently place the two half pieces of their lithosphere (i.e., the hard cookie broken in half) back on top of their asthenosphere (cream) and have them slowly move the two pieces of the lithosphere past each other (Figure 2). Although the pieces initially fit together as one cookie top, they will grate when sliding past each other, often producing crumbs. This underscores that plates do not move past each other easily but proceed with friction and jerking motions.

Divergent boundaries exist when a plate fractures and the two plates move off in opposite directions. Ask students to return the two lithospheric halves (i.e., hard cookie halves) to the top of the asthenosphere (cream) layer. Supporting the cream layer cookie below, students should gently press on the two lithosphere halves while slowly moving them away from each other in opposite directions (Figure 2). If carefully done, "upwelling" of the asthenosphere cream can occur with initial pressure and divergence; sometimes students will see the creation of a "rift valley" in models. As a class, we discuss how divergent plate boundaries are responsible for the creation of new oceanic lithosphere.

Convergent boundaries are lastly demonstrated through an oceanic-oceanic convergent model. Students place the two lithospheric cookie halves back on top of the asthenosphere (cream), slightly separated in the middle by a few millimeters. Holding the asthenosphere firmly below, or resting it on top of a desk, students attempt to "subduct" one lithospheric plate beneath the other. This often results in crumbling and uplifted areas (mountains) with some cream (lava) exposed at the top of the cookie (Figure 3). It is at convergent boundaries that lithosphere is consumed. At this point, we invite our students to "consume" their lithospheric model.

FIGURE 4 Students using their hands to represent the tensional force associated with divergent plate boundaries

PHOTOGRAPH COURTESY OF THE AUTHORS

FIGURE 5 Students using their hands to represent the shear stress of transform plate boundaries

PHOTOGRAPH COURTESY OF THE AUTHORS

Review of associated tectonic stresses

To review the tectonic stresses present in each plate boundary, we invite students to put their hands together. First, students place the palms of their right and left hands together, pushing their hands together as hard as they can. This represents *compression*, the stress associated with convergent plate boundaries. For divergent plate boundaries, students should cup their palms and interlock the fingers of their right hand (top) with the fingers of their left hand (bottom) (Figure 4). We ask students to try to pull their left and right hands apart, but not to let go of their hands. This represents tension, the force associated with divergent plate boundaries.

The stress associated with transform plate boundaries is best represented by having students place their

FIGURE 6 Tectonic organizer

Students are provided with the basic outline and complete the information for the table. The content in italics represents what a teacher should expect as far as student responses.

Tectonic boundary	Symbol	Stress	Lithosphere effect	Earthquakes?	Volcanoes?	Faults and folds	Other features
Divergent	← →	*Tension*	*Creation*	✓	✓	*Normal faults*	*Rift valleys*
Convergent*: O-O	→ ←	*Compression*	*Destruction*	✓	✓	*Folding, reverse faults*	*Volcanic islands*
Convergent*: O-C	→ ←	*Compression*	*Destruction*	✓	✓	*Folding, reverse faults*	*Volcanic arcs*
Convergent*: C-C	→ ←	*Compression*	*Destruction*	✓		*Folding, reverse faults*	*Mountains*
Transform	→ ←	*Shear*	*Conservation*	✓		*Strike-slip faults*	*Fracture zones, offset streams and fences*

* The O and C in convergent boundaries represent crust type, where O = oceanic and C = continental.

right and left palms together. While pushing their palms against each other, students should try to slide their left hand upward, toward the ceiling, and the right hand downward, toward the floor. This produces shear stress (Figure 5).

Tectonic organizer

To help students organize and assimilate the information, we provide a chart for them to complete. Students, working individually or in groups, complete their charts by drawing symbols to represent each plate boundary, identifying the primary stress, hypothesizing whether earthquake and volcanic activity are found at the boundary, and then identifying the associated primary faulting or folding. Students can also investigate and identify additional characteristics of divergent, convergent, and transform plate boundaries in the "Other Features" column of the chart. A partially completed version is presented in Figure 6.

Follow-up inquiry investigations

After reviewing the basics of plate tectonics, students can next engage in meaningful learning of Earth hazards by conducting inquiry-based volcano, earthquake, tsunami, and landslide investigations.

There are numerous classrooms options: Students can actively monitor volcanoes (Clary and Wandersee, forthcoming), and explore volcanic events such as mudslides (lahars), pyroclastic flows, lava flows, or ash falls. An alternative unit exploring volcanoes can begin with students researching a historic eruption and participating in sensory-priming activities such as viewing floating pumice, smelling sulfur, and feeling the glassy, irregular surface of vesicular volcanic rocks. Following the sensory-priming activities, students conduct an inquiry investigation where they generate and explore their own research questions (Clary and Wandersee 2011).

There are many notable earthquake events each year. Students can sign up for earthquake notifications and graph the magnitudes and dates of the events at any one location. Students can also investigate secondary earthquake events such as liquefaction, fires, and landslides.

Tsunamis are currently in the news: A 2011 Japanese earthquake generated a tsunami that resulted in the meltdown of a nuclear reactor, while the massively destructive 2004 Indonesian tsunami resulted in the deaths of over 230,000 people (Figure 7). See also "Exploring Earthquakes and Tsunamis: Integrating Science, Social Studies, and Technology" in this issue.

The long periods of "stability" between tectonic hazards are best viewed in the context of geologic time so that students can gain a better appreciation for the regularity of events within the correct time frame. Classroom activities are readily available for easy investigation of geologic time (Clary and Wandersee 2009).

FIGURE 7 Trash and debris in Banda Aceh, Sumatra, from the December 26, 2004, tsunami in Indonesia

PHOTOGRAPH COURTESY OF MICHAEL L. BAK, U.S. NAVY

Conclusion

This inexpensive activity engages students while reviewing the basic concepts of plate tectonic theory. Graphic organizers then help students summarize the associated stress, landforms, and products of plate tectonic boundaries and facilitate a "big picture" understanding before teachers launch investigations into specific associated Earth hazards. These activities can also easily be turned into guided inquiry investigations by soliciting more student input before providing them with the directions and content information. The activities can be used to introduce disciplinary core ideas MS-ESS2 Earth's Systems (e.g., geoscience processes have changed Earth's surface; provide evidence of past plate motions), and MS-ESS3 Earth and Human Activity (natural hazards and forecasting future catastrophic events) (NGSS Lead States 2013). We encourage our colleagues to implement lithospheric cookie models in their own classrooms; you'll be pleasantly surprised by the student interest they generate. ■

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Resource

Fun with food! Plate tectonics and our national parks—*https://dl.dropboxusercontent.com/u/16150330/may2013/oreo-cookie.pdf*

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