Teaching About Plate Tectonics and Faulting Using Foam Models

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Teacher notes

Objective: Demonstrate plate tectonic principles, plate boundary interactions and the geometry and relative motions of faulting of geologic layers using 3-D foam models. The foam models aid in visualization and understanding of plate motions and faulting because the models are three-dimensional, concrete rather than abstract descriptions or diagrams, can be manipulated by the instructor and the students, and the models can show the motions of the plates and faults through time in addition to the three-dimensional configuration of the plates or layers. The fault and plate boundary models shown here illustrate relatively simple motions and geologic structures. Although these models are accurate representations of real Earth faulting and plate tectonic structures and motions, the spherical shape of the Earth and the complexity of geological features caused by varying rock types and rock properties and geological development over many millions or hundreds of millions of years, result in significant complexity and variability of actual fault systems and plate tectonic boundaries.

Materials:

- Pre-made foam block models

OR

- Foam (open cell, foam mattress type) "blocks" shown in Figure 1A
- Felt pens (permanent marker, red and black)
- Manila folders or thin poster board
- Rubber cement
- Closed cell foam ("sleeping bag pads," camping equipment) as shown in Figures 3 and 5
- Pins
- Open cell foam as shown in Figure 3A
- Styrofoam core poster board, 0.6 cm (1/4 in) thick, as shown in Figure 3B
- Razor blade knife
- Metric ruler

Procedures:

Types of Faulting and Plate Boundaries –

Prepare foam block models as shown in Figure 1A. The cardboard (cut from manila folders or thin poster board) attached to both faces of the fault plane allows the blocks to slip easily along the fault as forces are applied to the blocks.

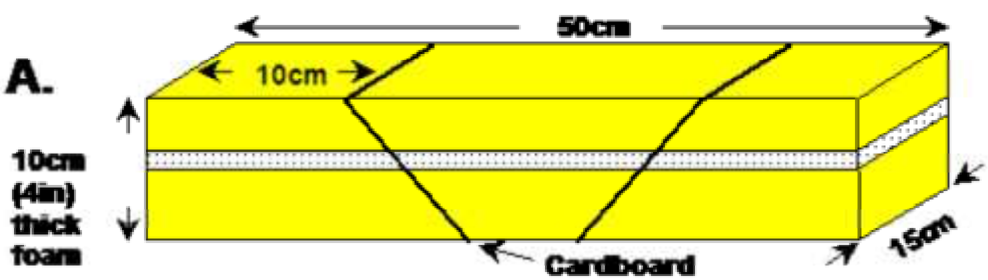
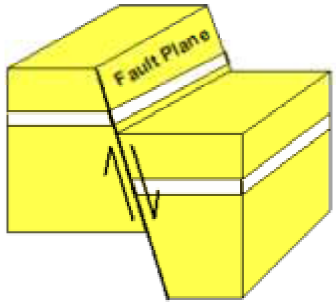


Figure 1A. Foam block model

Normal Faulting (Extension)

Use the block models to demonstrate **normal faulting** as the two outer blocks are moved **apart** as shown in Figure 1B. This procedure is best performed by holding the blocks "in the air" in front of you, supporting the model by the two outer blocks, rather than on a table. Note that as the two outer blocks are moved apart, the inner block drops downward or "subsides." This relationship between extensional motion of geologic layers and downdropped fault blocks (graben or rift valley if the downdropped block is bounded on both sides by normal faults, as in this block model) produces normal faulting. It also represents the extensional motion and resultant rift development associated with divergent plate boundaries (Table 1).



Normal Fault

Examples of divergent plate boundaries, where extensional faulting is prominent, are the mid-ocean ridge system in which a narrow rift or graben (downdropped fault block) is commonly observed along the highest part of the ridge and the East African Rift in which extension has been occurring in the continental lithosphere for about 30 million years and the resulting rift system of normal faults is beginning to break apart the continent. In a plate-tectonic-related, but not plate boundary environment, the Basin and Range area of the Western United States displays a prominent topographic signature of extensional faulting with many adjacent downdropped fault blocks or grabens and the topographic "high" areas between the grabens are called horsts

B.

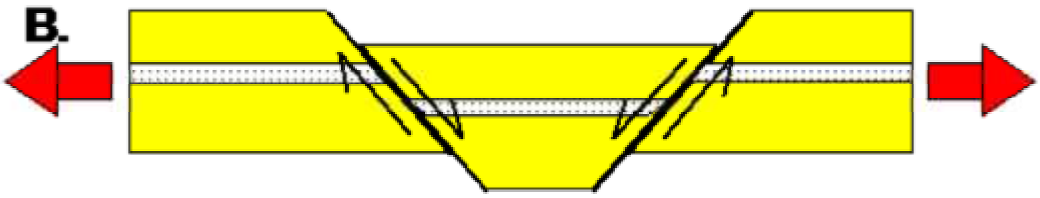
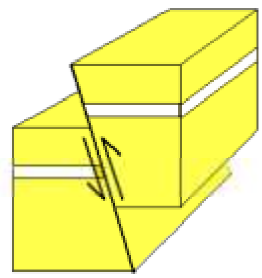


Figure 1B. Normal faulting using the foam model. Red arrows represent extension. Half-arrows along faults show direction of relative motion along the fault plane.

Reverse (Thrust) Faulting (Compression)

To demonstrate compressional motion and resulting **reverse** (also called thrust) faults hold the foam block models as described above and then move the two outer blocks **together** as in Figure 1C. The inner block will be thrust upwards producing reverse faults and an uplifted block. In a plate tectonic setting, such compressional motion is associated with convergent plate boundaries (Table 1) where two lithospheric plates are moving together or colliding (see also section 3 below). Not surprisingly, these convergent zones are associated with mountain ranges (Himalayas, Alps, Andes, etc.).



Reverse Fault

C.

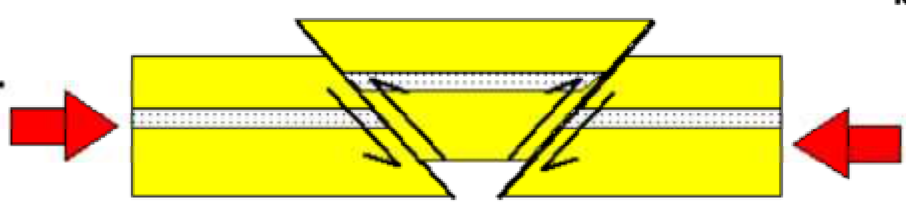
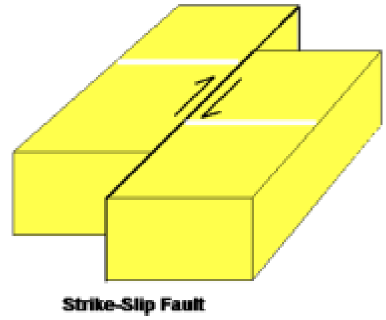


Figure 1C. Reverse faulting using the foam model. Red arrows represent compression. Half-arrows along faults show direction of relative motion along the fault plane.

Strike-slip or Horizontal slip fault motion (Shear)

Note: This does not require the building of a second model as suggested here. This motion can be modeled by looking at the top of the foam block model used above. Coloring in a feature to be offset such as a road or river shows the lateral offset of strike-slip faulting.

To demonstrate horizontal slip or strike-slip fault motion, prepare foam blocks as shown in Figure 1D. Moving the blocks horizontally on a tabletop, as shown in Figure 1E, demonstrates strike-slip or horizontal slip fault motion. This motion along a plate boundary is also called **transform** (Table 1). The San Andreas Fault zone is a system of strike-slip faults that form the transform plate boundary at the western edge of the North American Plate. Transform faults also occur as oceanic fracture zones between segments of the mid-ocean ridge spreading zones



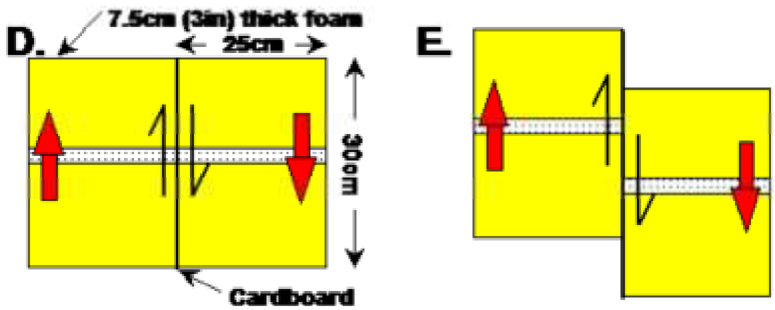


Figure 1D and 1E. Strike-slip faulting using the foam model. Red arrows represent shearing. Half-arrows along faults show direction of relative motion along the fault plane.

Table 1: Faults, Plate Boundaries and Relative Motions

Relative Motion of Layers or Plates	Fault Names	Plate Boundary Descriptions	Related Tectonic and Geologic Features
Extension	Normal	Divergent (extensional, moving apart, spreading, construction - because new lithosphere is generated in the extended zone)	Rifts, grabens, sometimes volcanism, regional uplift but local downdropped fault blocks, shallow earthquakes
Compression	Reverse or Thrust	Convergent (compressional, collision, subduction, moving together, destructive - because one plate is often thrust into the mantle beneath the other plate)	Folded mountain ranges, uplift, reverse faults, volcanic arcs (usually andesitic composite volcanoes), deep ocean trenches, shallow and deep earthquakes in subducted slab
Translation or horizontal slip	Strike-slip	Transform (horizontal slip, translation)	Linear topographic features, offset stream channels, lakes in eroded fault zone, pull-apart basins and local uplifts along fault bends or "steps" between offset fault segments, oceanic fracture zones, offsets of mid-ocean ridges

Transform or Strike-Slip Plate Boundaries and Elastic Rebound:

Use a razor-blade knife to make the foam "plate" models shown in Figure 2. The foam is 1.25 cm (1/2") thick closed-cell foam often used for "sleeping pads" for camping. It is available at camping supply stores and Wal-Mart and Target. The foam pieces can be used on a tabletop or on an overhead projector (the slits cut in the foam allow the 10 cm long tabs which bend to be seen projected onto a screen). By continuously sliding the two plates past each other with the "tab" edges touching (Figure 5), the foam pieces represent lithospheric plates and the "zone" where the plates touch is a strike-slip (transform) fault. Note that as the plates move slowly with respect to each other (just as Earth's lithospheric plates move at speeds of centimeters per year), the area of the plates adjacent to the fault (the tabs) becomes progressively bent (deformed), storing elastic energy. As the process continues, some parts of the fault zone will "slip" releasing some of the stored elastic energy. This slip occurs when the stored elastic energy (bending of the tabs) results in a force along the fault which exceeds the frictional strength of the tabs that are in contact. Sometimes, only small segments of the fault zone (one or two tabs) will slip, representing a small earthquake. At other times, a larger segment of the fault will slip, representing a larger earthquake. Note that although the plate motions are slow and continuous, the slip along the fault is rapid (in the Earth, taking place in a fraction of a second to a few seconds) and discontinuous. The motions and processes illustrated by the foam model effectively demonstrates the processes which occur in actual fault zones and the concept of the elastic rebound theory (Bolt, 1993). A brief segment during the beginning of the video "Earthquake Country" illustrates a similar "stick-slip" motion using a model made of rubber strips.

QuickTime™ and a
decompressor
are needed to see this picture.

Figure 2: Foam pieces used to demonstrate strike-slip faulting, elastic rebound theory, and slipping along the fault plane during earthquakes. Cut out slits with razor blade knife and straight-edge.

Extensions, Connections, Enrichment:

1. Good preparatory lessons for these activities are studies of elasticity (a spring and masses can be used to demonstrate the two fundamental characteristics of elasticity - the stretching is proportional to the force (suspended mass) and the existence of the "restoring force" (elastic energy is stored) in that the spring returns to its original length as the force (mass) is removed), and seismic waves which are generated as the fault slips.

2. The stick-slip process is well illustrated in a segment of the NOVA video "Killer Quake" in which USGS geophysicist Dr. Ross Stein demonstrates this process using a brick which is pulled over a rough surface (sandpaper) using an elastic cord (bungy cord). An experiment using this same procedure is described in "Seismic Sleuths" (AGU/FEMA).

3. Additional information on plate tectonics is available in Bolt (1993), Ernst (1991), Simkin et al. (1994), the TASA CD "Plate Tectonics," "This Dynamic Earth," and nearly any secondary school or college level geology textbook. Elastic rebound is well illustrated in Lutgens and Tarbuck (1996), Bolt (1993) and the TASA CD. A color map of the Earth's plates is available on the Internet at: http://www.geo.arizona.edu/saso/Education/Plates. An excellent description of plate tectonics can be found at: http://pubs.usgs.gov/publications/text/understanding.html.

4. An additional plate tectonic activity is the EPIcenter lesson plan "Voyage Through Time - A Plate Tectonics Flip Book" in which continental drift during the past 190 million years - a consequence of plate tectonics - is effectively illustrated; and Plate Puzzle which uses the "This Dynamic Planet" map.

5. Additional plate tectonic activities, especially for younger students, are contained in "Tremor Troop" (NSTA/FEMA).

6. A leading theory explaining why the Earth's plates move is convection currents in the Earth's mantle. The interior structure of the Earth is described in Bolt (1993) and is the subject of the EPIcenter activity "Earth's Interior Structure." Good activities illustrating convection are contained in the GEMs guide "Convection - A Current Event" (Gould, 1988), or "Tremor Troop" (NSTA/FEMA).

References:

Bolt, B.A., *Earthquakes and Geological Discovery*, Scientific American Library, W.H. Freeman, New York, 229 pp., 1993.

Braile, L.W., "Earth's Interior Structure" - http://web.ics.purdue.edu/~braile/educindex/educindex.htm.

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Braile,L.W. and S.J. Braile, "Plate Puzzle" – http://web.ics.purdue.edu/~braile/educindex/educindex.htm.

Ernst, W.G., *The Dynamic Planet*, Columbia University Press, New York, 281 pp., 1990.

FEMA/AGU, *Seismic Sleuths - Earthquakes - A Teachers Package on Earthquakes for Grades 7-12*, American Geophysical Union, Washington, D.C., 367 pp., 1994. (FEMA 253, for free copy, write on school letterhead to: FEMA, PO Box 70274, Washington, DC 20024).

Gould, A., *Convection - A Current Event*, GEMS, Lawrence Hall of Science, Berkeley, California, 47 pp., 1998.

IRIS, Western US Seismicity and Topography Poster, www.iris.edu.

Lutgens, F.K., and E.J. Tarbuck, *Foundations of Earth Science*, Prentice-Hall, Upper Saddle River, New Jersey, 482 pp., 1996.

NSTA/FEMA, *Tremor Troop - Earthquakes: A teacher's package for K-6 grades*, NSTA Publications, Washington, DC, 169 pp., 1990. (This book contains a reasonably complete curriculum for teaching earthquake and related Earth science topics; FEMA 159, for free copy, write on

school letterhead to: FEMA, PO Box 70274, Wash., DC 20024).
Simkin et al., *This Dynamic Planet*, map, USGS, 1:30,000,000 scale ($7 + $5 shipping), 1994, also at: http://pubs.usgs.gov/pdf/planet.html; 1-888-ASK-USGS.
TASA "Plate Tectonics" CD-Rom - Plate tectonics, earthquakes, faults, ($59 or $155 for site license), (800-293-2725) http://www.tasagraphicarts.com, Mac or Windows.
U.S. Geological Survey, *This Dynamic Earth: The Story of Plate Tectonics*, available from: U.S. Geological Survey, Map Distribution, Federal Center, PO Box 25286, Denver, CO 80225, $6, (800 USA MAPS). Also available (full text and figures) for viewing at: http://pubs.usgs.gov/publications/text/dynamic.html.

Videos (NOVA "Killer Quake," and "Earthquake Country") - information available in "Seismology-Resources for Teachers" online at: http://web.ics.purdue.edu/~braile/edumod/seisres/seisresweb.htm.