Session No. 46--Booth# 420

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Inexpensive Physical Model of Elastic Deformation Around a Strike-Slip Fault

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Abstract

The use of physical models in structural geology courses is a widely employed strategy for active learning. Education research has demonstrated that effective active-learning strategies employed in science courses significantly increase student learning and decrease the incidence of failure (Freeman and others, 2014, PNAS).

The deforming medium in the physical models used to illustrate Earth structures is often dry/wet sand, wet clay, dry powder, or some layered combination of these. Physical models of strike-slip faults are commonly built upon rigid lower plates that are slid horizontally past one another along straight edges that parallel the direction of relative motion. As the lower plates are moved relative to each other, the deforming medium is sheared and produces various deformation effects on its upper surface that are of interest to students: en echelon cracks or folds, sags and pop-ups, and small faults that coalesce into a through-going fault.

Elastic deformation away from the principle fault trace has been described many times since it was noticed in the great San Francisco earthquake of 1906 (Reid, in Lawson, 1908). Elastic effects were reported in the M6 South Napa earthquake of 24 August 2014, documented by relative displacement of GPS stations before, during and after the main shock (Hammond et al., 2014, c/o http://geodesy.unr.edu), by progressive displacement of markers along the ground surface, and by various observations of deformation by residents of the Browns Valley community through which the West Napa fault passes.

We developed a small (~30 cm x 30 cm x 6 cm), inexpensive (<~$10) physical model to help students visualize elastic deformation adjacent to a strike-slip fault. The model is made of foamboard, open-cell foam rubber in 2.5 cm-thick sheets, and adhesives, and is usually topped by a deforming medium (sand, clay, powder). Frictional drag along a vertical fault through the foam causes elastic strain in the foam, decreasing over ~7 cm from the fault surface to the line along which the foam is adhered to the foamboard below. Given enough displacement of the foamboard at the base of the model, slip releases elastic strain in the foam and produces surface rupture and audible sound. Details of the model design and use are available via http://CroninProjects.org/Abbuhl/.

What did we set-out to do?

One of the most interesting observations made in the wake of the M 7.8 San Francisco earthquake of 1906 is that the blocks on either side of the San Andreas fault behaved in an elastic manner, showing a displacement gradient with distortion extending on either side of the fault for several meters (Reid, in Lawson, 1908). GPS data from the 2014 South Napa earthquake clearly showed this same behavior (Hammond and others, 2014; Melgar and others, 2015). GPS data associated with the South Napa earthquake was subsequently incorporated in an educational module to be used in undergraduate structural geology and geophysics courses, developed with support from UNAVCO (Resor and others, 2014).

The purpose of our work is to create an inexpensive physical model of a strike-slip fault that displays some of the elastic behavior we observe along actual faults. While this model provides excellent support for the UNAVCO GPS-strain module, it would also be useful to teach a broad spectrum of age groups about faulting, from grammar school through graduate school.

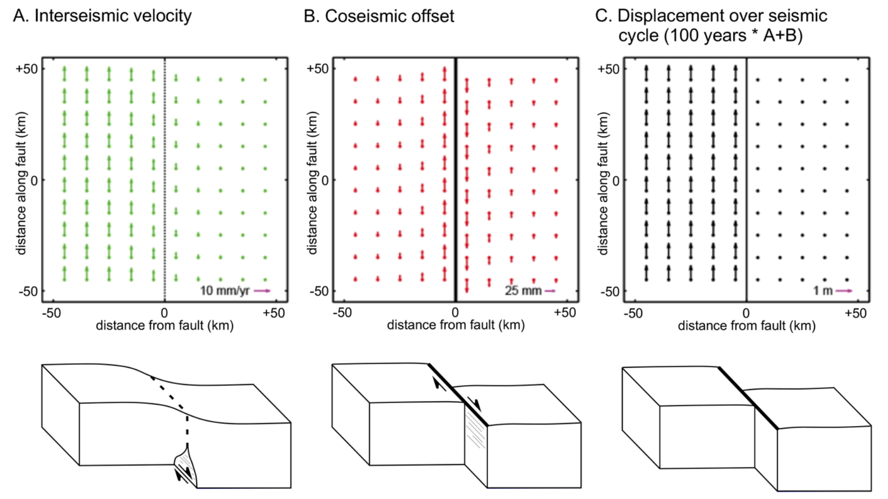


Illustration after Resor and others, 2014.

Materials for the basic model

Elmers glue-all, 8-ounce bottle, $2.47
DAP Strong Stik adhesive, 5 ounce tube, $3.49
2 inch wide plastic putty knife, $0.98
2 inch foam brush, $0.77
4-pack of 1 in. x 16 in. x 16 in. foam rubber, $6.97
Elmers foam board, 3/16 in. x 20 in. x 30 in., $2.99
Elmers foam board, 1/2 in. x 20 in. x 30 in., $6.99

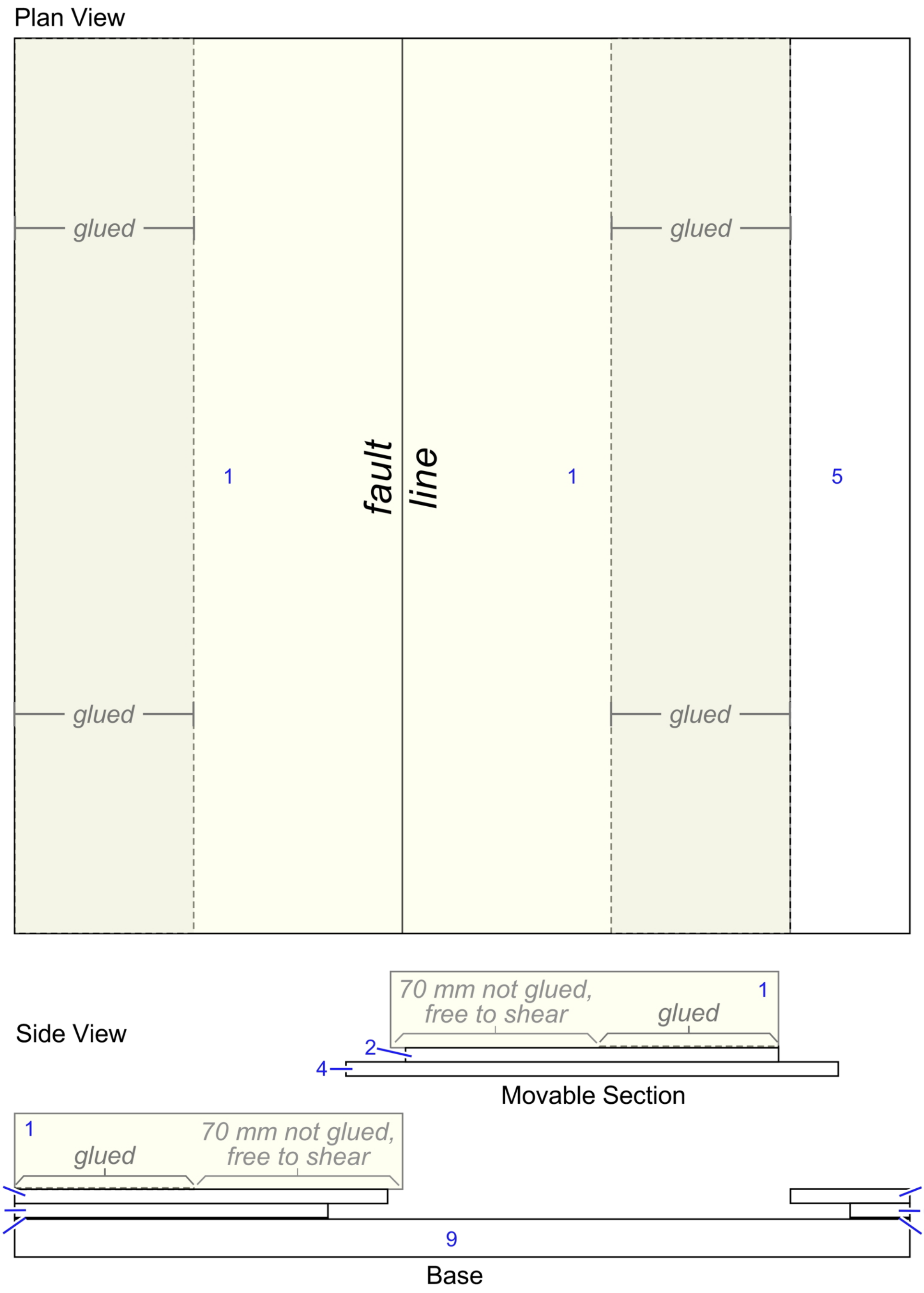
Tools

metal ruler
craft knife
sanding block
carpenters square
cutting board

Additional Materials for Experiments

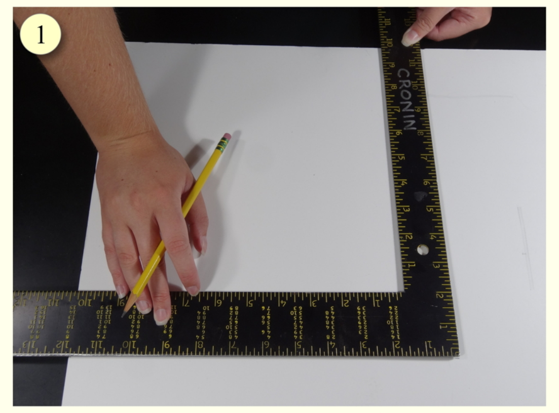
Black thread and a needle
Plastic cup with a sturdy rim
Dry joint compound (white powder)
Black sand
Wide drywall knife
Handi wipe
Dots candy

Design of the Physical Model

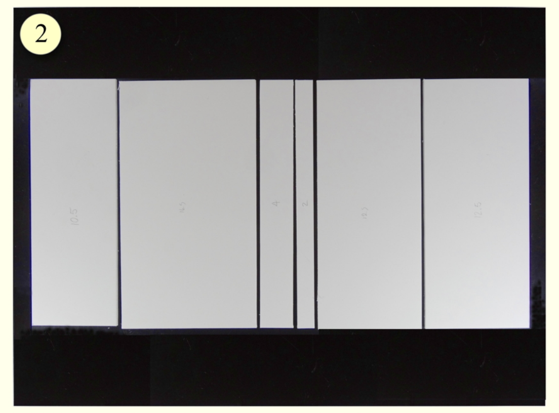


Part No.	Dimensions	Qty.	Description
1	300 x 130 x 25.4 mm	2	open-cell upholstery foam (1" thick)
2	300 x 125 x 4.75 mm	2	foam board (3/16" thick)
3	300 x 105 x 4.75 mm	1	foam board (3/16" thick)
4	300 x 165 x 4.75 mm	1	foam board (3/16" thick)
5	300 x 40 x 4.75 mm	1	foam board (3/16" thick)
6	300 x 20 x 4.75 mm	1	foam board (3/16" thick)
7	300 x 20 x 0.5 mm	1	cardboard
8	300 x 105 x 0.5 mm	1	cardboard
9	300 x 300 x 12.7 mm	1	foam board (1/2" thick)

Instructions: How to build the model



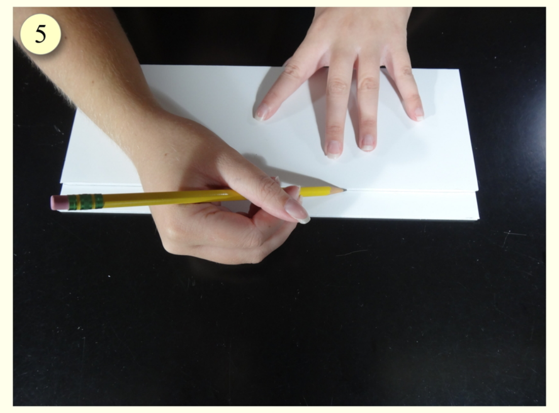
Measure and cut-out the various pieces of foamboard and foam rubber.



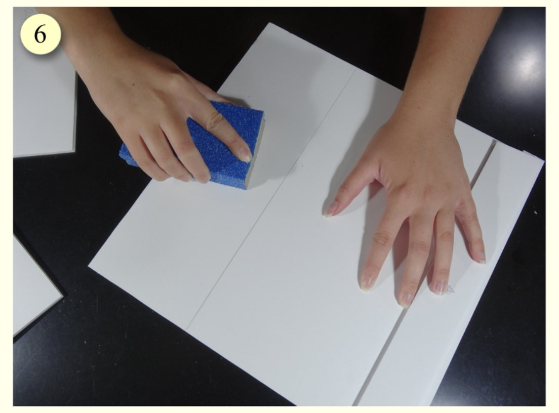
3/16" foamboard pieces needed for each model.

Cutting the foam rubber with a craft knife or drywall knife takes some practice. We used the factory-cut edges of the foam rubber for the fault surfaces because they were more uniform.

The final foam rubber pieces.

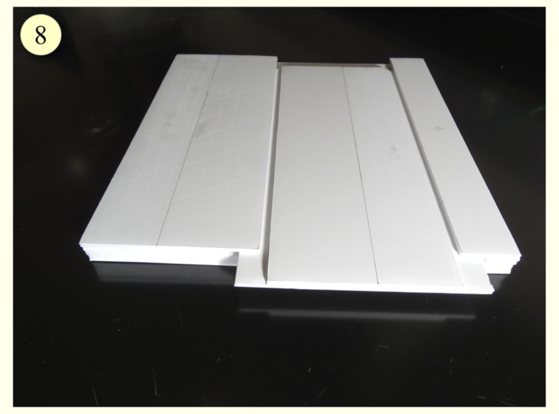


Measure and mark the places where one piece of foam or foamboard is glued to another.

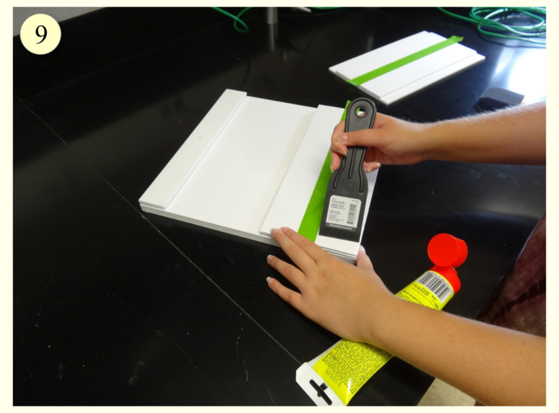


Roughen the foamboard surfaces to be glued with a sanding block.

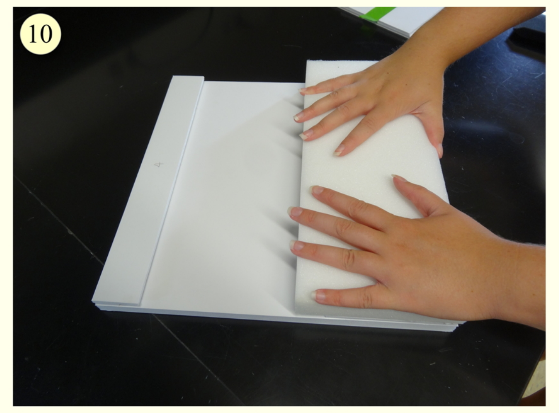
Mask the edges of the areas to be glued, so that glue is not spread onto sliding surfaces.



Make sure the model fits together correctly before gluing the foam.

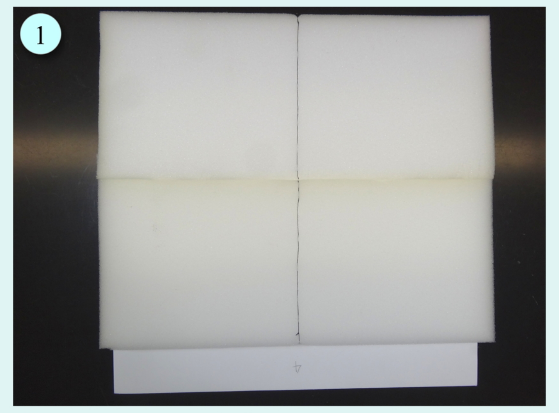


Use the DAP Strong Stik adhesive to glue the pieces of foam to the foamboard. Remember to glue the foam rubber so that the factory-cut edges are the fault surfaces.

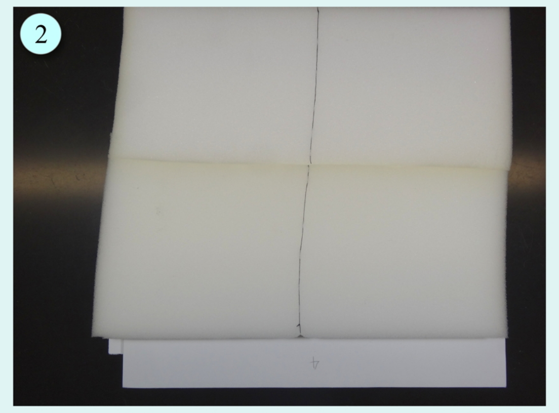


Apply pressure to the foam rubber after gluing. We recommend placing a heavy book on the foam as the adhesive dries to maintain pressure on the assembly.

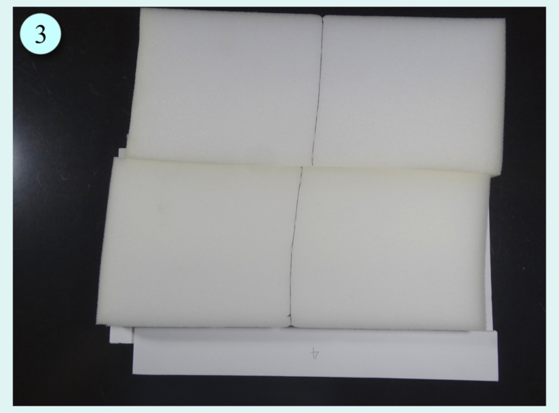
Experiment 1: Model with just the rubber foam, with a thread marker but without any deformable upper layer



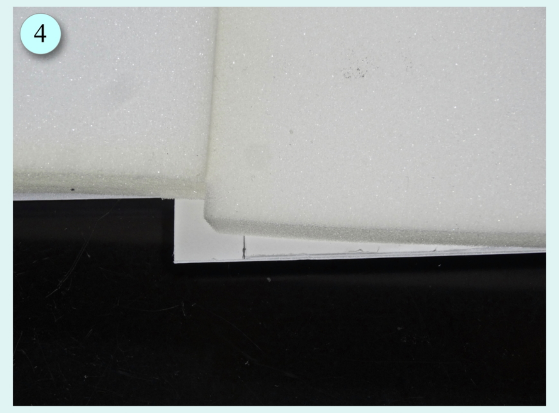
Use a needle and black thread to sew a straight line on the foam using shallow stitches. You can sew the foam pieces separately or sew them together and snip the thread at the fault line.



Begin to slide the foamboard to slowly deform the rubber foam and thread. Continue until slip occurs along the model fault. In this figure, the rubber foam has begun to deform but the model fault has not yet slipped.



Slide the foamboard until the rubber foam slips along the model fault line. The thread shows the displacement along as well as the elastic deformation adjacent to the fault core.

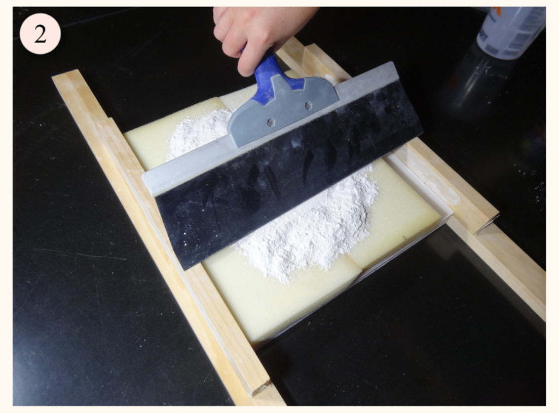


This is a close up of the corners of the rubber foam at one end of the model fault. A tiny, audible foamquake occurs when the model fault slips.

Experiment 2: Model with a deformable upper layer spread uniformly on top of the rubber foam

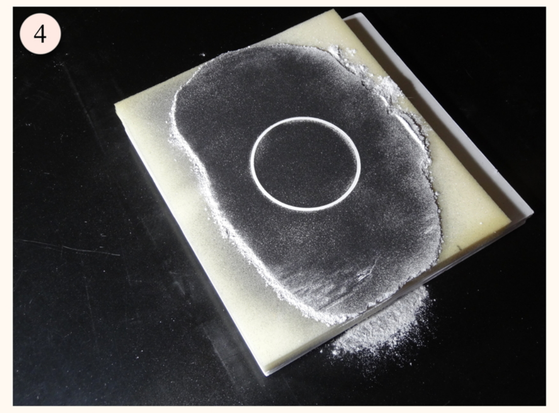
How to Set Up the Experiment

Cut off the top of a firm plastic cup. This will be used to create a passive circular marker on the model.



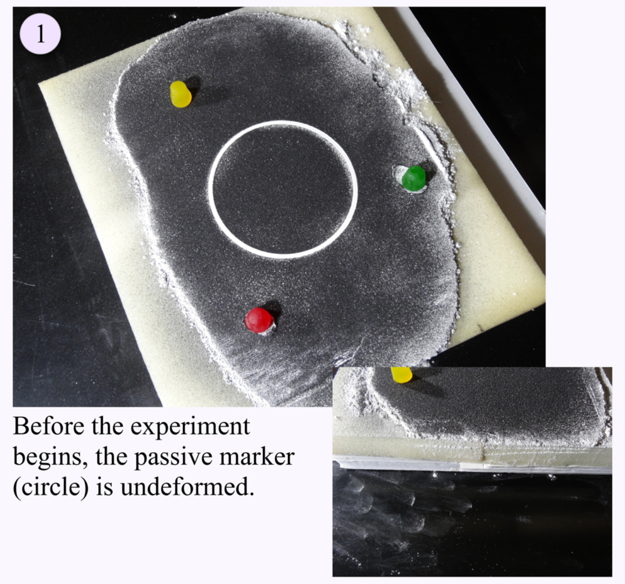
Pour powder onto the foam. Place pieces of wood as shown so that the top of the wood is ~0.5-1 cm higher than the model. Use a wide drywall knife to smooth the powder until the surface is completely smooth. This insures that any cracks you see on the model during the experiment are from deformation.

Place the cup top on the white powder so that the resulting circle is centered along the fault line. Use a Handi Wipe to sprinkle and evenly disperse black sand on top of the white powder.

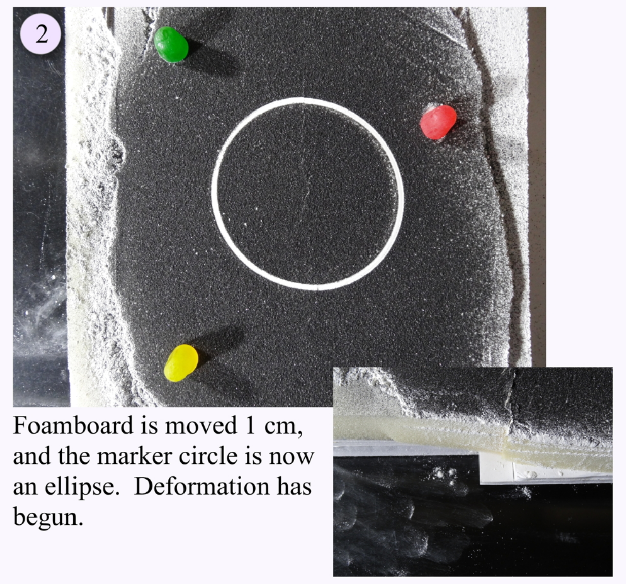


Carefully remove the cup top to reveal the white circle. This will be your base for the rest of the experiment. You can choose to add Dots candy to represent GPS stations, or just continue on as is.

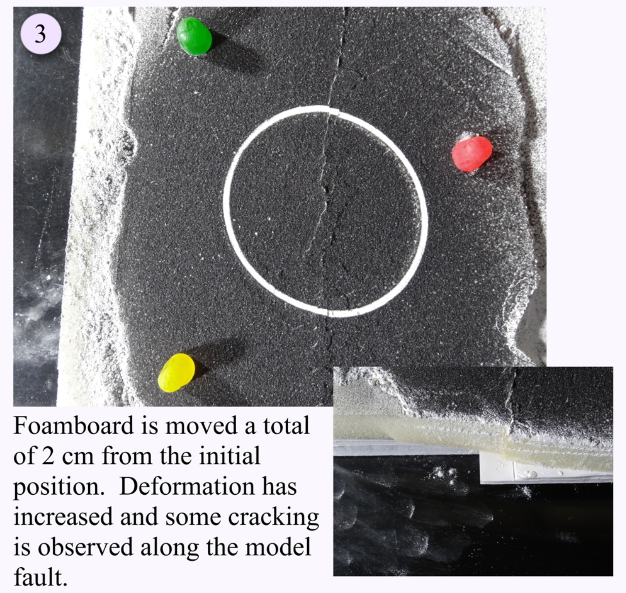
Experiment Results



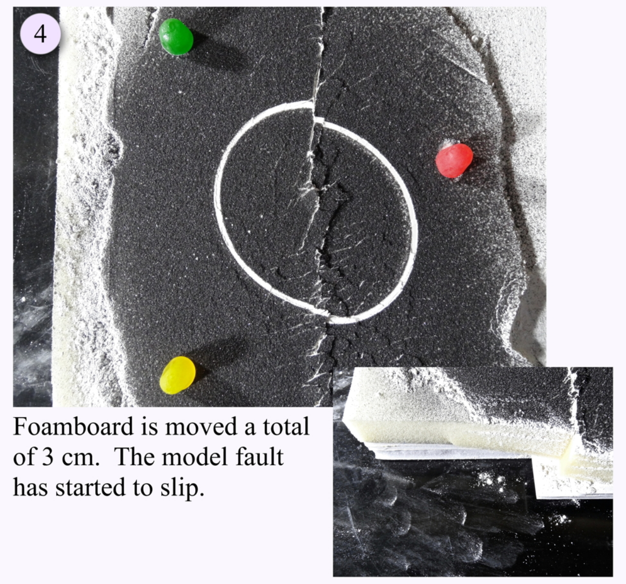
Before the experiment begins, the passive marker (circle) is undeformed.



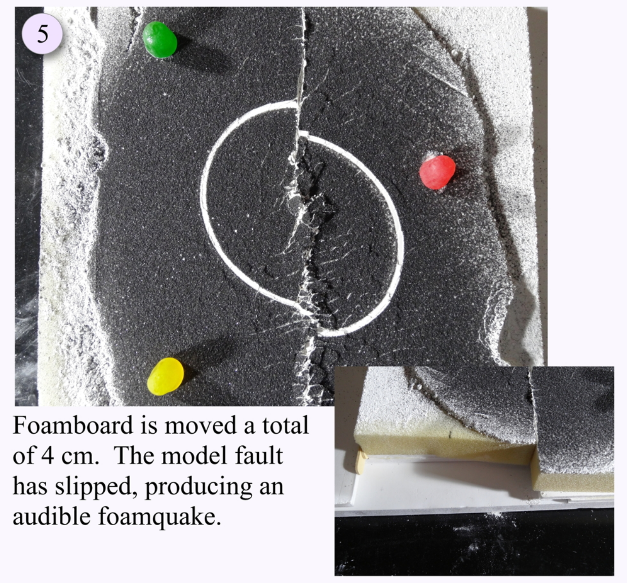
Foamboard is moved 1 cm, and the marker circle is now an ellipse. Deformation has begun.



Foamboard is moved a total of 2 cm from the initial position. Deformation has increased and some cracking is observed along the model fault.

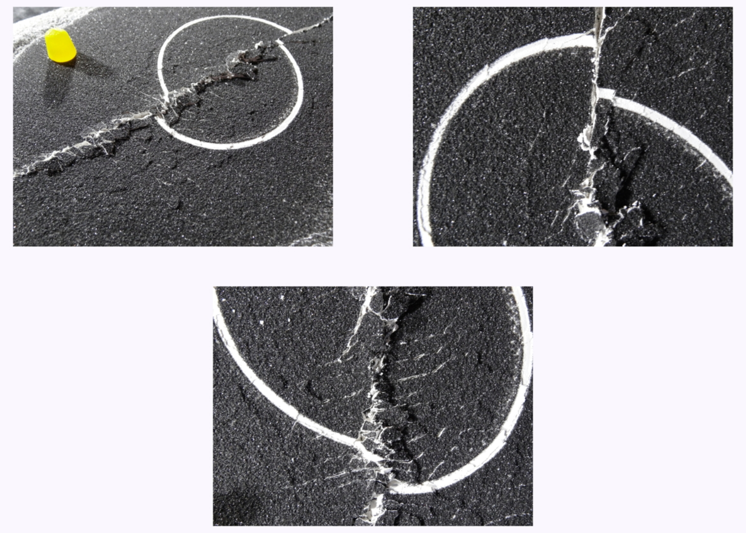


Foamboard is moved a total of 3 cm. The model fault has started to slip.



Foamboard is moved a total of 4 cm. The model fault has slipped, producing an audible foamquake.

Details of deformation at step 5



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