Quick-and-Dirty Sandbox Models for Teaching and Learning Structural Geology

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Motivation

Sandbox models of faults allow students to
- Observe the development of structures in 4D (3D plus time)
- Think about faults as part of a system, linking strain and fault geometry

Traditional sandbox models include:
- Contractional and extensional sandboxes, designed to observe development of faults in cross-section (e.g. Del Castello and Cooke, 2008; Davis, 2014).
- Strike-slip sandboxes, designed to show horizontal movement (e.g. Cooke et al., 2013) with or without bends.

In contrast, the workbench-based sandboxes make it possible to:
- Model all three basic tectonic settings using the same equipment.
- Allow students to quickly re-build the models, allowing replication of the experiments in a short amount of time.
- Focus on 3D aspects of all systems by looking at the surface, similar to viewing 3D seismic data.
- Explicitly think about driving forces and boundary conditions on the open sides of the model.

Equipment and set-up

Basic design

The basic design uses a workbench (Fig. 1) that can be expanded or contracted with a pair of hand cranks. Various metal sheets or wooden blocks can be clamped to the base to make it possible to model contraction, extension, strike-slip movement, and various kinds of oblique movement. The basic set-ups for each type of setting are shown in the sections below.

Modeling materials

We have used two different materials in our models:

Sand
- Garnet sandblasting sand, 80 or 120 grit
- Plaster of Paris or flour, sifted on the surface (to show developing fractures)

Clay
- Pottery clay, as fine and homogeneous as possible.
- Enough added water to make a similar consistency as cake batter.
- Thin layer (1 to 2 cm) to show small fractures and folds.

Figure 1. The basic workbench used as the basis for all sandbox set-ups.

Equipment needed

- Black and Decker Workmate 225 bench
- Aluminum sheets (36 x 36 inches, 0.019" thick)
- 2 x 12 wood, cut into 24-inch long segments
- 2-inch aluminum angle (1/8 inch thick)
- Various clamps (at least 4 small and 4 large)
- Garnet sand-blasting sand (80 or 120 grit)
- Pottery clay
- Tin snips (to cut aluminum sheets)
- Silly Putty
- Pasta roller (for making layers of Silly Putty)
- Glue stick (to create higher friction beneath thrust wedges
- Tarp (to catch sand)
- Plaster of Paris (or flour)

Use in classes

Because the models are inexpensive and easy to set up and modify, workbench sandboxes lend themselves to any kind of lab that allows students to explore variations in fault behavior. Some possibilities include:

- Jigsaw labs involving three workbenches, with groups of students exploring variations in behavior (e.g. faults without bends, restraining bends, and releasing bends).
- Write-ups using concept sketches (Reynolds and) to show the progressive development of structures through time.
- Annotation of photos with map symbols (practice describing and symbolizing structures).
- Forward-modeling experiments, in which students develop hypotheses about what structures will develop under what conditions, and test their hypotheses.
- Interpretation labs, such as thrust experiments in which students do not know what basal conditions each model uses, and need to interpret the basal conditions from the model.
- Labs that introduce concepts of geometric, kinematic, and dynamic analysis.

Contraction

Basic set-up

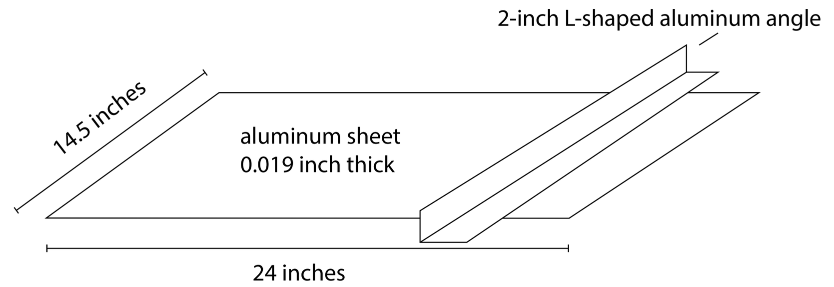

Figure 2. Schematic of materials used for modeling contractional deformation.

Figure 5. Oblique view of contractional folds and faults in clay.

The basic set-up for modeling contraction uses an aluminum sheet that slides under a backstop made of a 2-inch angle (Fig. 2; Fig. 3). The aluminum sheet is clamped to one side, and the angle is held in place by clamps that go through the holes in the workbench.

Open the workbench as wide as possible before adding about a cm of sand or clay. Slowly close the workbench to create a thrust wedge (Fig. 4; Fig. 5; Fig. 6).

Figure 3. Aluminum sheet and angle used for contractional modeling.

Figure 6. Oblique view of contractional folds and faults in sand.

Figure 4. Cross-section view of contractional wedge in clay.

Variations

Increased friction at base:
- Rub a glue stick over the aluminum sheet before spreading sand.
- Let the sand sit before deforming the sand. The bottom layer of sand will stick to the sheet, creating a similar effect to putting sandpaper on the aluminum sheet (Fig. 7; Fig. 8).

Plastic material at the base:
- Use a pasta maker to shape Silly Putty into a thin sheet.
- Stick the Silly Putty onto the aluminum sheet before adding the layer of sand.

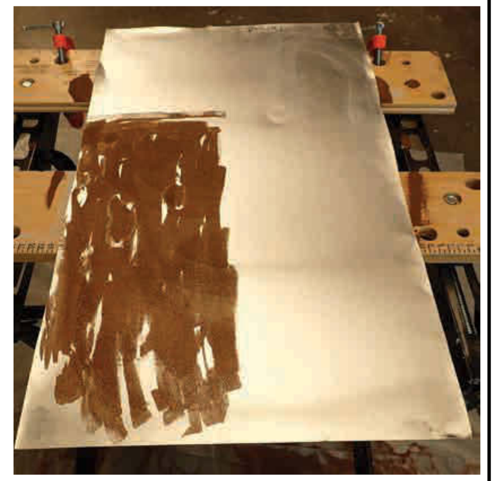

Figure 7. The left side of the aluminum sheet has had glue rubbed onto it. When the sand is removed, it is possible to see the bottom layer of sand stuck to the sheet.

Figure 8. Sand wedge with glue on the left side and no glue on the right side, creating different critical tapers and different widths of the thrust belt.

Extension

Basic set-up

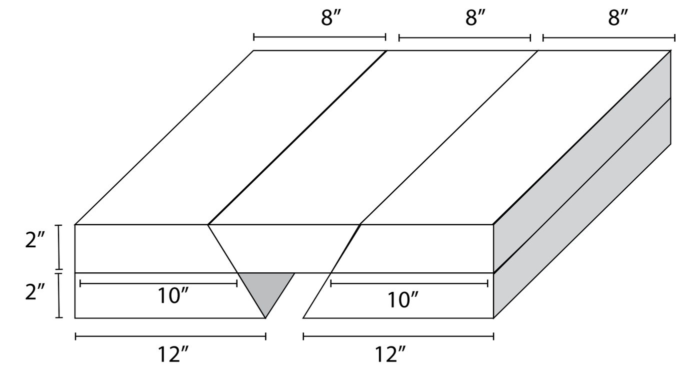

Figure 10. Schematic drawing of wooden blocks used as the base for normal fault models.

Normal faulting above rigid basement blocks can be modeled using blocks cut from 2-inch wooden boards (Fig. 10; Fig. 11). Each horst block is clamped to one side of the workbench, with the graben block fit between them. As the workbench is expanded, the graben block drops, creating normal faults in the sand or clay above the blocks (Fig. 12; Fig. 13).

Figure 11. The wooden blocks used in the normal fault models are clamped to the workbench while it's closed.

Figure 12. Normal faults in clay.

Figure 13. Close-up view of faults developed in sand during extension.

Variations

Oblique extension can be modeled by turning the blocks at an angle to the extension direction (Fig. 14; Fig. 15; Fig. 16).

Dip-slip deformation can be forced on one of the blocks by screwing a flat metal plate to one side of the blocks.

Figure 14. Cross-section view of faults developed in clay during oblique extension.

Figure 15. Oblique extension can be modeled by turning the blocks at an angle to the extension direction.

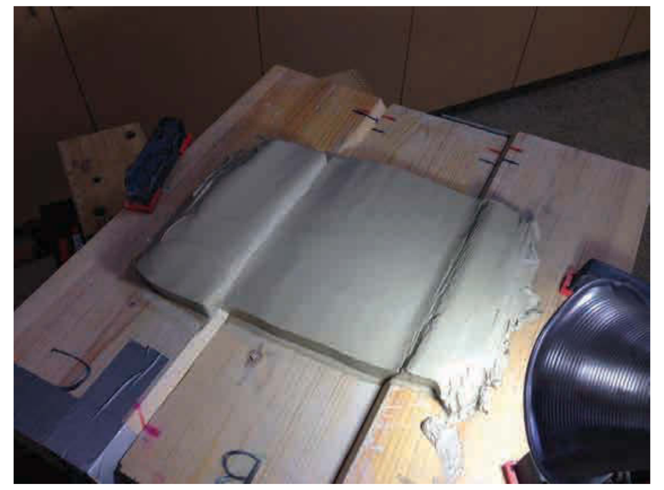

Figure 16. Oblique extension in clay tends to develop en echelon oblique-slip faults above the basement blocks.

Strike-slip

Basic set-up

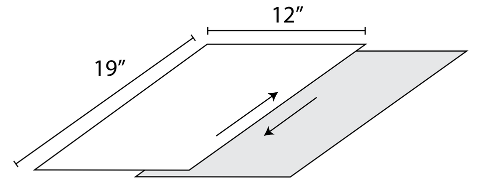

Figure 17. Schematic drawing of the metal sheets used as the base for strike-slip faulting.

Strike-slip faults can be modeled by clamping two aluminum sheets to the two sides of the workbench. Right-lateral and left-lateral faults can be created from the same set-up, one by expanding the workbench and one by contracting it.

Figure 18. Each metal sheet is clamped to one side of the workbench.

Figure 19. Left-lateral strike-slip fault in clay. Strike-slip faulting in clay usually forms Riedel shears, folds, and shutter ridges.

Variations

Figure 20. Bends in faults can be modeled by cutting one of the aluminum sheets at an angle. This fault bends at 45 degrees.

Bends in strike-slip faults can be modeled by cutting one of the aluminum sheets at an angle. The bends can be cut at various widths and various angles to explore the factors that control the shape of pop-up structures or basins.

Figure 21. Restraining bend (45 degrees) in clay.

Figure 22. A thick sand layer (10 cm) deformed in a releasing bend developed flower structures.