

Modeling Plate Tectonics

Objective:

This activity is designed to introduce you to the 3-dimensional nature of geologic information stored in geologic maps and the concepts of stratigraphy by which we determine the relationships between the layers. This is a chance to play detective, look for clues, and unravel the parts of the story recorded in the limited data set visible in any one location. Most interesting, and vexing, about this type of work, is that only parts of the story remain for us to see, forcing us to extrapolate from available information while leaving some permanent uncertainty. Enjoy the mystery!

PBJ and Stratigraphy:

DO NOT EAT ANYTHING IN THIS ACTIVITY!!!! THE MATERIALS ARE NOT STERILE!

You will get your hands dirty by creating some “rock” layers and deforming them to create your own stratigraphic cross section. Working with 2 partners you will make a total of 3 sandwiches for use in our experiments. Each lab partner should make his/her own! You will need the following items to represent different rock types and geologic forces:

Materials & Their Real World Counterparts:

Grape Jelly	Mafic Magma	Ketchup	Felsic Magma
Toast	Quartzite/Marble Salt		Evaporites
Wheat Bread	Sandstone	Straw	Volcanic Pipe
White Bread	Limestone	Knife	Tool
Creamy Peanut Butter	Shale	Plastic Bags	Tool
Crunchy Peanut Butter	Conglomerate	Shell & Pinwheel Pasta	Fossils
Nutella	Coal	Plastic Lid	Crystalline Bedrock

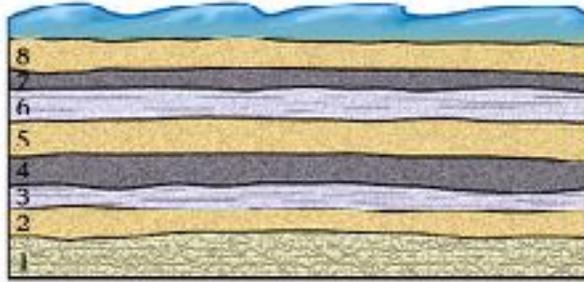
Building a Sedimentary Rock Pile

1. Begin with a basin underlain by crystalline bedrock. Place the lid of a plastic container on the desk to represent the base of your basin.
2. Let us assume your basin is in relatively clear water in a warm environment like the Caribbean Sea. The warm clear water allows deposition of tiny amounts of calcite from the shells of marine plankton, which form a calcareous ooze that lithifies to form the rock limestone. Place a slice of white bread on the lid.
3. Let's assume your basin begins to receive fine muddy sediments from a nearby river system. These clay rich sediments form an impervious layer of mud, which eventually hardens to form the rock shale. Spread a layer of creamy peanut butter on the white bread. Snails living in this environment get caught up and buried in the mud. Add a few pieces of shell pasta to represent their fossils.
4. An ice age causes sea level to drop over your basin as large amounts of seawater are trapped in continental ice sheets. Your site is now very close to the shore and gets covered by beaches, which eventually harden to form sandstone. Add a layer of wheat bread to your growing sandwich to represent the sandstone.
5. The ice age ends and sea level rises as the glaciers melt. The warming climate causes large amounts of organic matter to be produced on land and in the sea around your basin. A layer of organic matter rich shale forms. Add a layer of Nutella to your sandwich. Plants growing in the sediments get buried in the mud. Add some pinwheel pasta to represent the plant fossils.
6. The seas drop somewhat as the climate cools causing a marine regression and allowing another layer of sandstone to be deposited on your landscape as it returns to a beach like environment. Add a piece of wheat bread to your sandwich.

STOP!

Examine your sandwiches. See how all the layers are built upon top of each other? Can you tell which must have come first and which second, third, etc.? This is the Principle of Superposition on display. Note how all the layers are essentially horizontal. This is the Principle of Original Horizontality being set up. Now that we have built your landscape in triplicate we will then continue by using individual sandwiches to represent different evolutionary paths for the landscape. **Before proceeding....make a drawing or take a picture of one of your sandwiches.** Label it to reflect what the “rock” layers represent.

Modeling Plate Tectonics



Path 1: Mountain Building at Continent-Continent Convergent Plate Boundary

Sandwich 1

Stage 1A: Burial Metamorphism

As burial occurs, the pressure from the weight of material overlying your layers is so great that your rock is compressed. Place a piece of cardboard on top of the sandwich. Have the heaviest person in your group sit on the sandwich, then remove the cardboard. (Be careful of messes!) Cut the sandwich into 2 rectangular parts...one about 3/4" thick with the rest of the sandwich forming the other part. Label the thin piece of the sandwich as stage 1A and set aside. Continue with the other half sandwich.

Stage 1B: Continental Collision-Tilting

As two continents start to collide your rock layers are tilted nearly on end. Place the sliver of the sandwich 1A on its side such that is now flipped 90 degrees from its original position.

Stage 1C: Continental Collision

An adjacent continent with similar rocks becomes welded to your continent. Notice that the rocks do not line up. Add the untouched larger part of sandwich 1 adjacent to the tilted half sandwich.

Stage 1D. Deposition Resumes

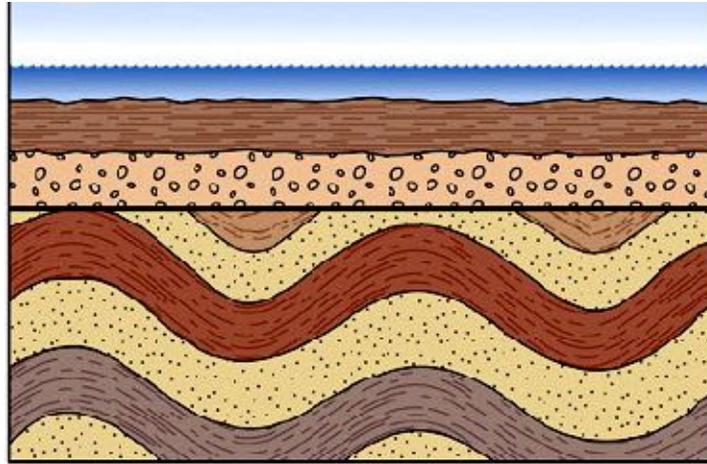
Following the continental collision, large amounts of terrestrial sediment are eroded from the nearby mountains covering both parts of your welded sandwich with a thick layer of conglomerate. Add a layer of crunchy peanut butter across your welded sandwich. Note the peanut butter may not be of uniform thickness to achieve this. That is appropriate.

Stage 1E. Ocean Returns

The ocean rises to flood your continental suture with a layer of limestone. Add a layer of white bread to your sandwich. Cut this sandwich in half such that you preserve both the tilted and un-tilted sections.

STOP!

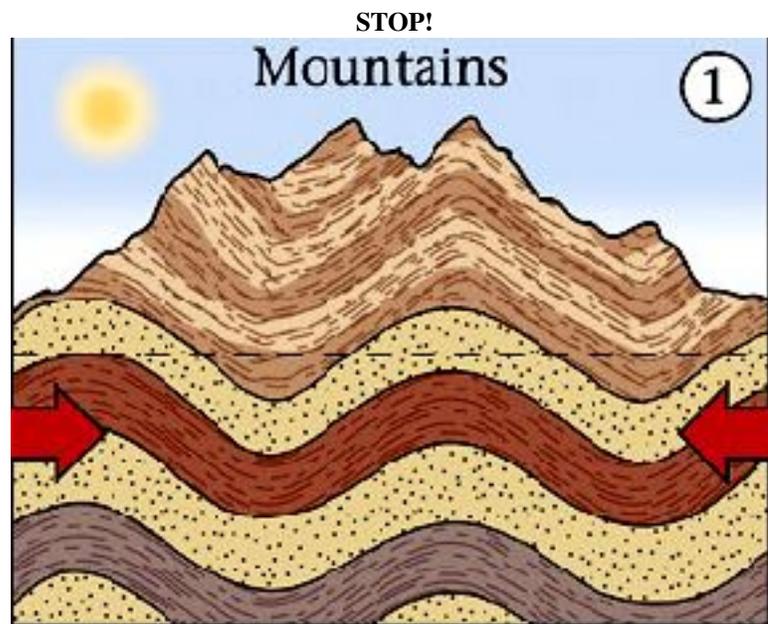
Modeling Plate Tectonics



Note how, the seemingly smooth surface layers cover tilted layers of different ages? Here you see the value of the Principal of Original Horizontality in determining the age and relationship of rock structures. Note how this principal still relies on the Law of Superposition. We also begin to see the Principle of Cross-Cutting relations in action. See how the top, flat layers of bread and peanut butter CUT ACROSS the lower materials? Any material that cuts across another substance must be YOUNGER than that which it cuts. We also see the presence of an unconformity. An unconformity marks a place where the rock record has a break in continuous deposition. You see this between the tilted and untilted layers compared to the flat continuous layers above. In both instances, events occurred in between the top and bottom, which are not recorded at that location. Such a gap in the rock record can only be filled in with information from other locations. **You will want to make a drawing or take a picture at this stage before proceeding.** Again label the rock layers.

Stage 1F. Continental Collision - Folding

A renewed period of convergence causes horizontal compression of your continent. Using cardboard pieces and the remaining half sandwich from the previous step, squeeze the sandwich together, reducing its length by 1/3. Note the folding which occurs and how the sandwich grows in height. **Again make a drawing or take a picture** before labeling this piece of the sandwich and set aside.



Modeling Plate Tectonics

Path 2A: Rifting at a Divergent Plate Boundary within a Continent

Sandwich 2:

Begin by cutting this sandwich in half to create 2 rectangular pieces and set half aside for Step 2D.

Stage 2A: Doming

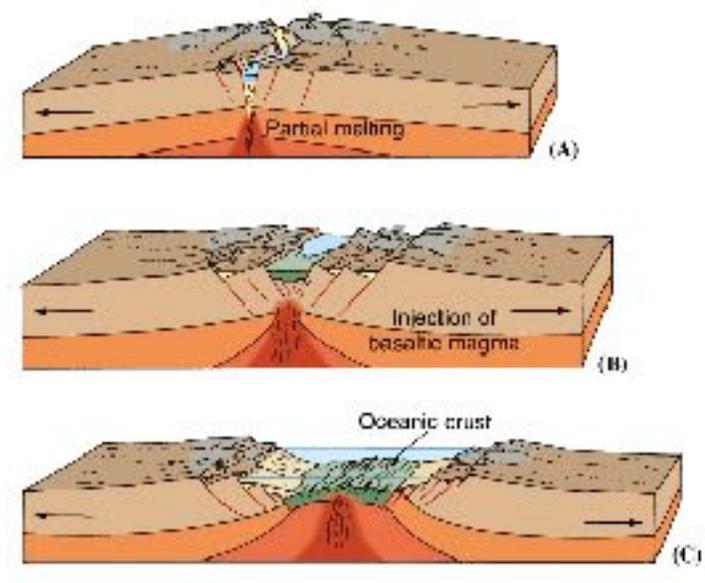
Your segment of the crust begins to dome up as magma begins to well up under your area. Take half of sandwich 2 and dome it up about half an inch under the center.

Stage 2B: Crustal Thinning

As divergent convection begins under your crustal segment, the crust is placed under tension and begins to thin. Pull evenly outward on the sides of your sandwich along the long axis, but do not tear.

Stage 2C: Extrusive Volcanism

As your crust finally ruptures, basaltic magma erupts from the fissures of the new rift, spreading out across the land from a long linear valley in the tear. Tear your sandwich into 2 parts. Place the parts on the table and fill the narrow gap with grape jelly. Preserve this half sandwich. **Make a diagram or take a picture of this half sandwich before proceeding.** Be sure to label the rock layers.



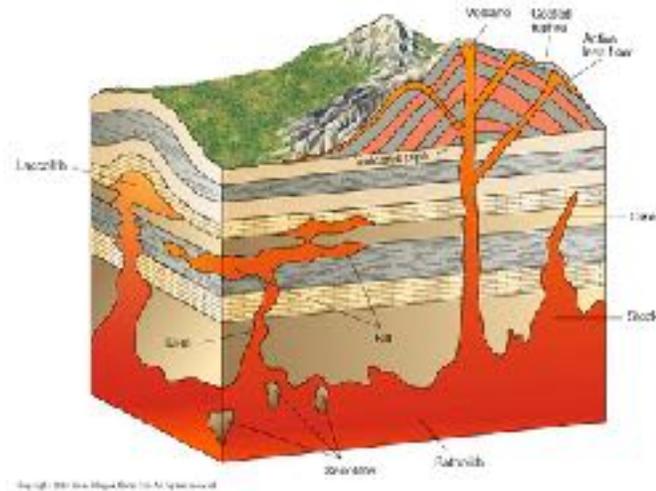
Path 2B: Localized Intrusive Volcanism

(as seen near a convergent plate boundary/subduction zone)

Stage 2D: Magma Arrives

An intermediate magma intrudes below your segment of the crust, melting some of the local country rock and rises through a conduit to the surface to form a small volcano. Use a straw to hollow out a small hole at the base of the other half of sandwich 2. Squeeze ketchup up from below into this hole and up the straw onto the surface so that it oozes out a hole at the surface. Place this sandwich back down on the towel to avoid a mess. Cut this half sandwich in half again through the axis of your "volcano". Note how the ketchup spread more through some layers of the sandwich than others creating sills and dikes. Preserve this cross-section. **Make a diagram or take a picture of this half sandwich.** Label the rock layers.

Modeling Plate Tectonics



STOP!

Note how the 2 different types of magma interact with the layers of their respective sandwiches. In both cases we see contact metamorphism where the magma alters the material through which it is passing. Some materials, (white bread) are altered more than others (peanut butter) as seen in reality. Also, note the Principle of Cross-Cutting Relations. The young basaltic and granitic magma flows can only tear and intrude pre-existing older rock. When the material emerges at the surface it flows outward under the sky.

Path 3: Metamorphism

Sandwich 3:

Stage 3A: Formation of Evaporite Rocks

A shallow sea covers your area for a brief period, but succumbs to intensive evaporation and deposition of salt. Add a decently thick layer of salt to your sandwich.

Stage 3B: Shallow Sea Returns

A brief return of the shallow sea allows limestone to be deposited on the evaporites. Add a layer of white bread to your sandwich. Cut this sandwich in half into 2 rectangular halves.

Stage 3C: Contact Metamorphism 1

Chemically active fluids flow down through your rock layers, altering some severely. Pour water gently through the top of one half of your sandwich. Cut this open to view the internal effects. Preserve this stage.

Stage 3D: Contact Metamorphism 2

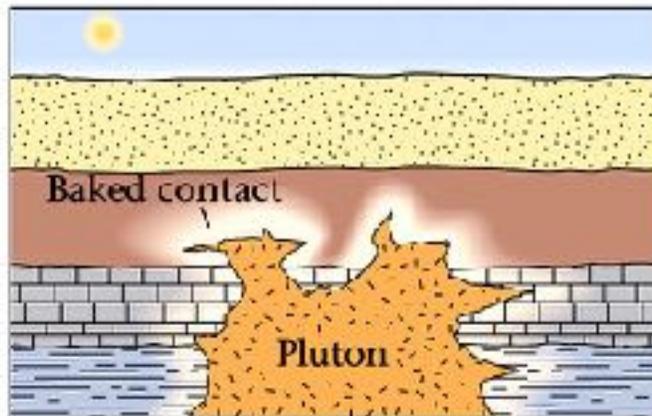
Rising magma from below causes heat based contact metamorphism. Take the remaining half of Sandwich 3 and heat in on the frying pan and hot plate. Be careful not to singe the sandwich too badly. Once this segment has cooled, cut it open to examine the interior and preserve.

STOP!

Contact Metamorphism

Modeling Plate Tectonics

Look at the sandwich 3B. Note how the salt has been removed from its original layer by the water and re-deposited in lower layers and along flow channels, altering their nature. This is a common process, which accounts for many of our commercial ore deposits. Note how some layers, such as the shale (creamy peanut butter) served as an inhibitor to flow of these liquids. Contrast this with the heat-based contact metamorphism in Stage 3D. Note how some layers were strongly deformed (bottom layer of sandstone by toasting) and removal. This shows how the degree of metamorphism can change from low to very severe over a short distance to the heat source. The toasted “sandstone” is now “quartzite” with distinctly different properties than the sandstone that did not get such extensive heating. Note the melting of the Nutella (coal swamp) material is analogous to the low temperature metamorphism, which creates oil and natural gas from these organic deposits.



Burial & Regional Metamorphism

Look back at the flattened sandwich from 1A and the folded half sandwich from Stage 1F. These provide examples of burial and regional metamorphism respectively. In each case, the mineral crystals and rocks react to stress by recrystallizing and altering their structures to reduce the pressures upon them. In the flattened sandwich you see relatively uniform deformation due to the uniform crushing stress field to which the “rocks” were exposed. There is no particular alignment because the pressure is uniform in all planes and directions. This leaves an unfoliated metamorphic rock such as marble or quartzite. This differs from the unidirectional stress and ever-increasing metamorphism of the shale, slate, schist, gneiss facies in the folded sandwich. Here the stress is coming in a plane and can be responded to by aligning mineral crystals into uniform bands. This directional metamorphism gives you the banding (foliation) associated with gneiss.

In Conclusion.

Assemble all your final product sandwiches, drawings and pictures. Feel free to color them to help keep the layers distinct. All layers should be labeled as to the rock type they represent! Once this is done, please create a timeline of events for the converged and tilted sandwich 1. Use the DIAGRAM you drew to infer the order of events. Include the order from oldest to youngest, what happened, how you know what happened and the type of environment that the rock was ORIGINALLY for med in.

Notice how the divergent and convergent plate tectonic forces play out very differently on the same “rocks” present in an area at the start of the geologic event. Note the different types of structures these events create and leave behind for us to see even after the forces of tearing, squeezing, heating, etc. have run their course and are no longer present.