How'd That Happen?

Overview

Students will make models of geologic strata and then manipulate them to simulate the action of geologic processes. They will also examine and analyze photographs and diagrams of geologic formations.

Background

The information and concepts presented in this exercise are covered well in the textbooks.

Materials

*Materials marked with an asterisk must be supplied by the teacher or the students.

Materials for the whole class

- Supplies of clay, flour, potting soil, and sand
- 1 utility knife or *scissors
- Overheads of strata diagrams 1, 2, 3, and 4 (black line masters below)
- Overheads of strata puzzles 1, 2, 3, 4, 5, and 'killer' (black line masters below)

Materials for groups of 4 students

- Paper trays of clay, flour, sand, and potting mix (1 each for 4 students)
- 8 plastic spoons (2 per paper tray)
- 4 clear deli containers and lids to be glued by students and then cut by the teacher (see **Preparation** section below)
- 2 paint stirring sticks
- 4 craft sticks
- 1 glue bottle
- 1 sample strata viewing tray, set up as in Figure 2 below
- 2 copies of Photograph A
- 2 sets of Photographs B, C, D, and E

Materials for individual students

- 1 diagram set
- 1 puzzle set
- *Science notebook

Preparation

- Prepare paper trays of clay, flour, sand, and potting soil for student groups of four.

- Two days before the strata viewing trays are needed, have students glue them. Prepare enough for 1 empty tray per student, 1 sample tray per group of 4 students, and few extras for your own examples.

- Students should squeeze a bead of glue into the groove in the lid (gray area in Figure 1) and then snap the lid in place onto the bottom of the tray. The trays should be set aside to dry for at least a day.

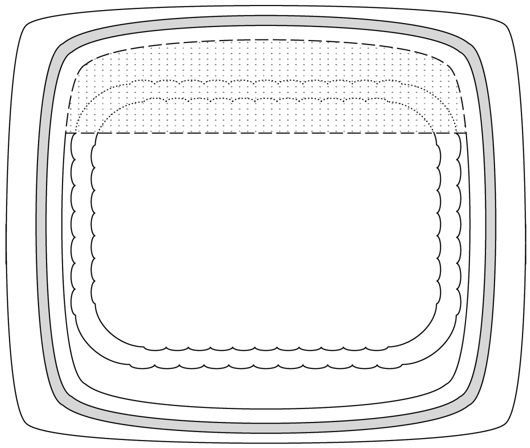


Figure 1. Preparing the strata viewing tray.

- After the glue is dry, the teacher can remove the dotted portion of the bottom piece by cutting along the dashed line with scissors or the utility knife provided.

- Set up one strata viewing tray for each group of four students as shown in Figure 2. All the trays should look fairly similar.

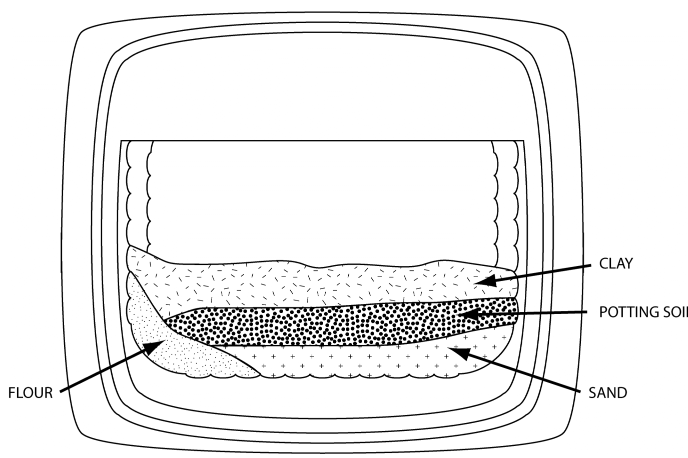


Figure 2. Sample strata viewing tray.

- Prepare a few sample trays showing examples of pressure applied with paint stirring sticks or craft sticks or create other interesting formations.

Procedure

- Distribute Photograph A and ask the students to write down 5 observations of the scene with particular attention to the rock wall. Discuss the student observations. Inform students that there are dramatic surface features all over the Earth, and people look at them and wonder how they were formed. Ask the students if they can see any evidence of how this cliff face was formed based on what they know about the Earth and rocks. Explain that this was the problem faced by early Earth scientists. What could have made that rock or layer or mountain look like that? How can one find out about things that happened long ago over very long periods of time? What kinds of evidence can one gather long after an event happened to be able to explain that event?

- Pass out the sample strata viewing trays that you have prepared (Figure 2) and ask the students to draw and label a diagram of the strata. It is appropriate to tell the students what the materials are in the strata. Ask the students to look at the strata and see if they can tell which layer came first. Ask them for their evidence and any other observations they have to support their ideas of how the strata were laid down.

- Pass around a few more examples of pre-made trays that have evidence of pressure applied with a paint stirring stick or craft stick or other interesting formations in the strata and have the students speculate on how they could have been made.

- Ask the students to make a tray of their own and to document the steps that they took to make the tray and the amounts of each material used. Have the students draw a diagram of their tray. Allow the students to start over if they are not satisfied with their first attempts at building strata. Be sure to mention that pushing or poking the strata with sticks is allowed.

- Once students have built and documented a strata tray that they like, have them trade with students at other tables. Ask the students to draw and label these new trays and to write down how they think the trays were made including an estimate of how much material was used. This activity can be repeated until the materials or enthusiasm run out.

Reflection/Discussion

- Discuss the results of the students' experiences trying to figure out how these strata layers were made. This is a good time to point out that they have just used two major laws that help in the understanding of geology. The law of *superposition* in which the oldest material is on the bottom and the law of *uniformitarianism* that states that things behave now as they always have—i.e., flour does not fall up or turn into clay.

- [Detailed descriptions of the strata diagrams and puzzles are provided at the end of this exercise.]

- Pass out the strata diagram sets and put Strata Diagram 1 on the overhead. Explain that this diagram represents a cross-sectional slice of the Earth much like the road cut photograph through the hill (Photograph A) and ask students to describe what they see. First, ask only for simple observations. Next, ask the students for possible meanings of the two types of lines at the upper and lower edges of each layer. Discuss the law of *original horizontality*, the notion that sedimentary rock layers are generally laid down in horizontal layers and that in these diagrams a straight line indicates a transition from one type of deposition to another while the materials are still under water. (Other forms of deposition also occurred—sand dunes deposited by wind or glacial till deposited by ice.) The curvy line indicates that erosion or non-deposition has taken place and something is missing or time has passed without deposition—an *unconformity*.

- Put Strata Diagram 2 on the overhead and ask for observations. After students make their observations, point out that the previous diagram supported the law of original horizontality. What is going on in this diagram and what does it indicate? Explain that there are tectonic forces that can actually lift entire sections of Earth and leave them tilted relative to how they originally formed. Also point out that deep in the Earth, perhaps miles below the surface, layers can be bent or bowed due to the intense heat and pressure deep in the crust.

- Put Strata Diagram 3 on the overhead and ask for observations. This diagram shows a fault and the results of faulting tectonic activity. The half to the right of the fault has been lifted up relative to the section to the left of the fault. This is indicated by the increased erosion of the sandstone and greater exposure of the siltstone.

- Put Strata Diagram 4 on the overhead and ask students to write their observations in their notebooks or directly on the diagram sheet. Discuss these observations. Discuss the meaning of igneous intrusion and discuss the symbol for the *zone of contact metamorphosis*. Discuss the process that causes this metamorphism.

    - Pass out the Strata Puzzles and put Puzzle 1 on the overhead. Walk the students through the puzzle and show how to answer the puzzle by using complete descriptions of the processes in order from newest (top) to oldest (bottom). Have students include complete details in their descriptions of the events. It might help students to give them the number of steps involved in each puzzle (as a check to their thinking).

- Now turn the students loose on the rest of the puzzles or go through them together as a class. If there is time, discuss and compare their results.

Assessment

- Photographs B, C, D, and E can be used for assessment. Ask the students to record their observations and analyses of what might explain the features in each of the photographs.
- Make several different strata viewing trays and ask the students to provide analyses with evidence on how the layers were formed.

Analyses and Answers for the Strata Diagrams and Puzzles

Strata Diagram 1: This Diagram Shows:
- Law of Original Horizontality
- Law of Superposition
- Uniformitarianism
- Straight lines between different layers where deposition continues to occur
- Unconformity represented by the uneven line on top that indicates erosion taking place and material missing
- Different symbols for different rock types
- Only sedimentary rocks in this cross section

Order of events–oldest at the bottom of the list to most recent at the top:
- Erosion of siltstone (most recent event)
- Siltstone deposited
- Shale deposited
- Limestone deposited
- Conglomerate deposited first (oldest event)

Strata Diagram 2: This Diagram Shows:

We must assume that the Laws of Original Horizontality, Superposition and Uniformitarianism hold true, which they do. This diagram shows that the layers can be tilted by tectonic forces (layers can also be bent and lifted). We see straight lines of deposition and boundaries between rock types and curvy lines as in Diagram 1 indicating erosion. The conglomerate is deepest down and does not reach the surface indicating that it was the first layer in the visible sequence of the diagram. Conglomerate was followed by deposition of limestone, deposition of sandstone and finally deposition of siltstone, in that order.

Once all of the layers were laid down, they were lifted and tilted and then eroded. In this diagram we can see that deposition of all of the layers occurred first. This is indicated by the parallel relationship between the layers. Deposition was followed by lifting and tilting. This was followed finally by erosion. The fact that the erosion plane is not parallel to the plane of deposition of the rock layers indicates that erosion occurred *after* the tilting.

Order of events:
[Most recent]
- Erosion
- Tilting of the layers
- Deposition of siltstone
- Deposition of sandstone
- Deposition of limestone
- Deposition of conglomerate

[Oldest]
Strata Diagram 3: This Diagram Shows:

This diagram has a few new twists. Using the aforementioned laws of geology, we can see that siltstone was deposited first, followed by deposition of limestone. Note the curvy layer between the limestone and sandstone. This indicates erosion of the limestone before the sandstone was deposited.

The fault cuts across all of the layers indicating that it is more recent than the deposition of the layers. This is referred to as the Law of Crosscutting Relationships. Note that the sandstone to the right of the fault is a thinner layer than the sandstone to the left of the fault, and that the siltstone is thicker on the right side of the fault than on the left side of the fault. These clues indicate that sandstone was deposited on the eroded limestone and that the layers on the left side of the fault dropped relative to the layers on the right. (If we could look deeper, we would probably see more siltstone on the left side of the fault, below what is visible in the diagram.) Erosion of the limestone occurred *before* the faulting and dropping, since that erosion line has been split by the fault. Erosion at the surface occurred *after* the movement at the fault.

Order of events:
[Most recent]

- Erosion of sandstone
- Faulting and dropping
- Deposition of sandstone
- Erosion of limestone
- Deposition of limestone
- Deposition of siltstone

[Oldest]

Strata Diagram 4: This Diagram Shows:

This diagram introduces the fact that igneous rocks can move through cracks in existing rock or "intrude" into existing rocks and leave material and other traces behind. Once again (as in the faulting in Diagram 3) if the intrusion cuts across a layer it is younger than that layer (the Law of Crosscutting Relationships). The zone of contact metamorphism indicates that the molten igneous rock was hot and caused some degree of metamorphosis of the rock layers that it moved through. The symbol for this zone of metamorphism is always shown in the layer that was affected by the intrusion. This is also an indication of the order of events, in that a layer must exist first before it can be metamorphosed by an intrusion. Intrusion of magma can result in different types of rock, depending on the conditions at the time of that intrusion. Two hints to remember are that granite is an igneous rock and can be the result of an intrusion and that an intrusion does not always result in straight lines.

Order of Events:
[Most recent]

- Erosion
- Igneous intrusion (accompanied by metamorphism)
- Deposition of siltstone
- Deposition of shale
- Deposition of limestone

[Oldest]

Strata Puzzle 1:

[Most recent]

- Erosion of both the limestone and the igneous intrusion (labeled Erosion 1), indicated by the curvy line on top.
- Intrusion of the black igneous rock cuts across all layers and the zone of contact metamorphism is apparent in all layers.
- Intrusion from below of igneous granite into the limestone, indicated by the zone of contact metamorphism. (This seems odd because the limestone is *above* the granite. But note that the symbol for the zone of contact is drawn in the *affected* material.)
- Deposition of limestone. It had to be there first to be acted upon by the granite.

[Oldest]

Strata Puzzle 2:

[Most recent]

- Erosion 2 of limestone *and* igneous intrusion, indicated by the curvy line on top.
- Igneous intrusion. It cuts across all layers and affects all layers with contact metamorphism.
- Deposition of limestone.
- Deposition of siltstone 2.
- Erosion 1 of both the conglomerate layer *and* the shale layer.
- Bending of sandstone, siltstone 1, shale, and conglomerate layers. This bending is indicated by the curve of the layers and the uneven amounts of conglomerate at the edges.
- Deposition of conglomerate.
- Deposition of shale.
- Deposition of siltstone 1.
- Deposition of sandstone.

[Oldest]

Strata Puzzle 3

[Most recent]

- Erosion 2 of conglomerate.
- Igneous intrusion. (This could have occurred any time *after* the deposition of the sandstone. That is, it could have happened either *before or after* the deposition of the conglomerate.)
- Deposition of conglomerate.
- Deposition of sandstone.
- Erosion 1 of limestone and granite.
- Granite intrusion of limestone and contact metamorphism.
- Deposition of limestone.

[Oldest]

Strata Puzzle 4
[Most recent]
- Erosion 4 of glacial till and formation of the river channel.
- Deposition of glacial till.
- Erosion 3 and glacial scraping of siltstone 2 and the igneous intrusion surface.
- Igneous intrusion, younger than all of the layers it cuts across.
- Deposition of siltstone 2.
- Deposition of sandstone.
- Erosion 2 of basalt layer.
- Lava flow that created the basalt layer (note the zone of metamorphism affecting all four of the sedimentary layers below).
- Erosion 1.
- Tilting of the four lower sedimentary layers.
- Deposition of conglomerate.
- Deposition of siltstone 1.
- Deposition of limestone.
- Deposition of shale.

[Oldest]

Strata Puzzle 5
[Most recent]
- Igneous intrusion 3, volcano, and basalt.
- Erosion 5 of sandstone 2.
- Deposition of sandstone 2.
- Erosion 4 of siltstone 2.
- Igneous intrusion 2.
- Deposition of siltstone 2.
- Erosion 3 of limestone 2 and igneous intrusion 1.
- Fault and uplift (affecting all the layers and igneous intrusion 1 below erosion 3).
- Igneous intrusion 1 (affecting all the layers below erosion 3).
- Deposition of limestone 2.
- Erosion 2 of siltstone1 and sandstone 1.
- Tilting of siltstone 1, sandstone 1, limestone 1, and granite.
- Deposition of siltstone 1.
- Deposition of sandstone 1.
- Deposition of limestone 1. (Note that there is no zone of metamorphism from the granite below, so the limestone must have deposited *after* erosion 5 and *after* the granite was fully formed.)
- Erosion 1 of granite.
- Granite layer formed.

[Oldest]

Killer Strata Puzzle

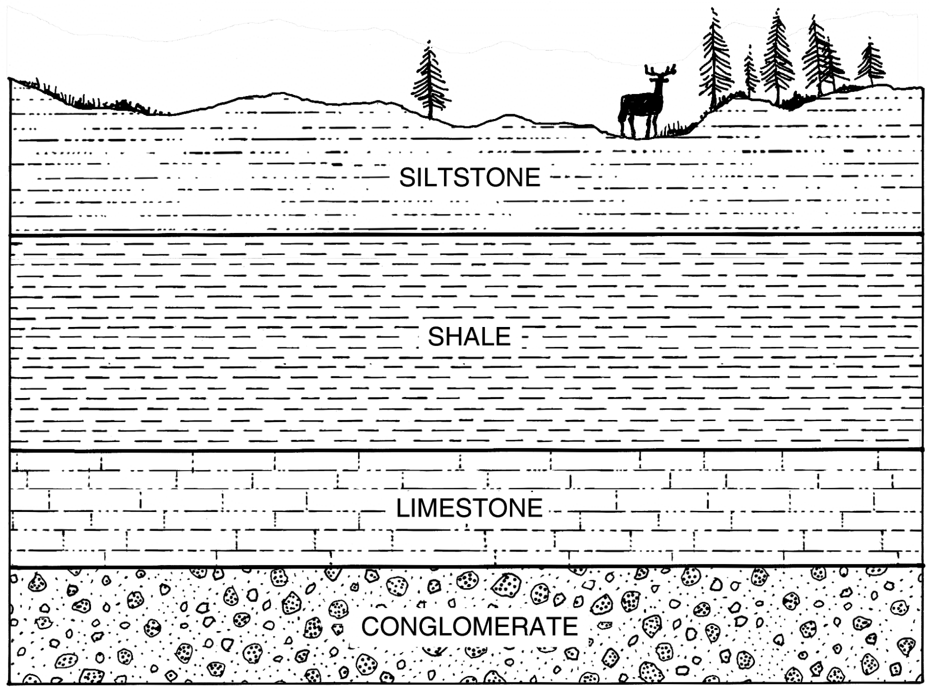
[Most recent]

- Erosion 5 and deposition of loose river sediments.
- Deposition of siltstone.
- Erosion 4 of sandstone 4.
- Fault 2 and uplift.
- Tilting of limestone, old lava flow, and sandstone 4.
- Deposition of sandstone 4.
- Erosion 3 of hardened lava flow.
- Lava flow.
- Deposition of limestone.
- Erosion 2.
- Igneous intrusion.*
- Bending of sandstone 3, sandstone 2, shale, and sandstone1 layers.
- Deposition of sandstone 3.*
- Deposition of sandstone 2.
- Deposition of shale.
- Deposition of sandstone 1.
- Erosion 1 of granite and schist.
- Fault 1 in granite.
- Intrusion of granite into schist (note the zones of metamorphism).
- Formation of schist.

[Oldest]

*In this diagram, the age relationship between the igneous intrusion and sandstone 3 is ambiguous because they are not in contact with each other. It is possible that the igneous intrusion *predates* sandstone 3.

STRATA DIAGRAM 1



OBSERVATIONS: ____

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THIS DIAGRAM SHOWS: ____

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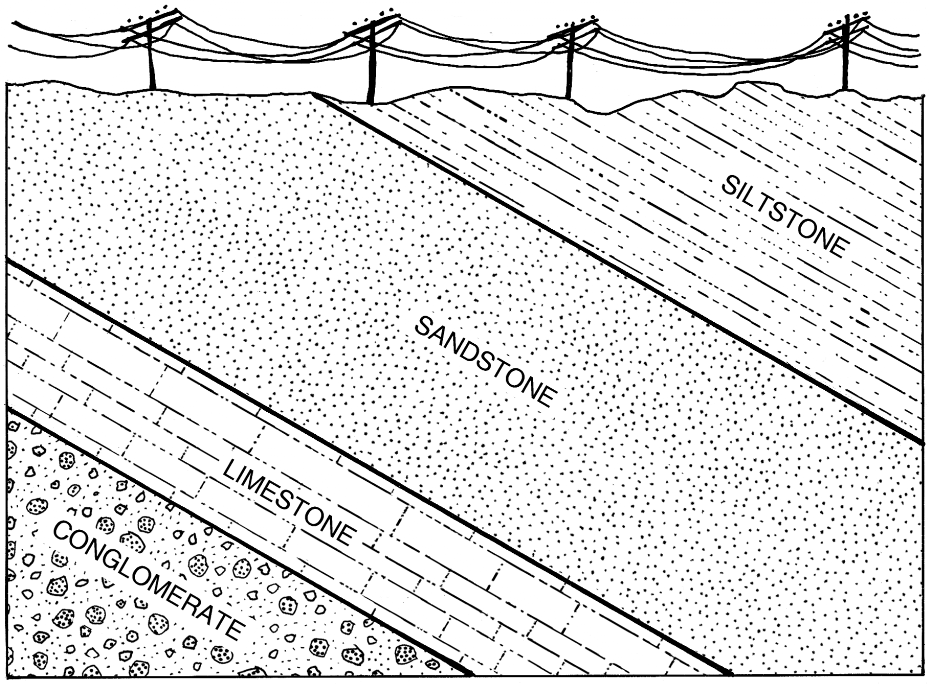
STRATA DIAGRAM 2



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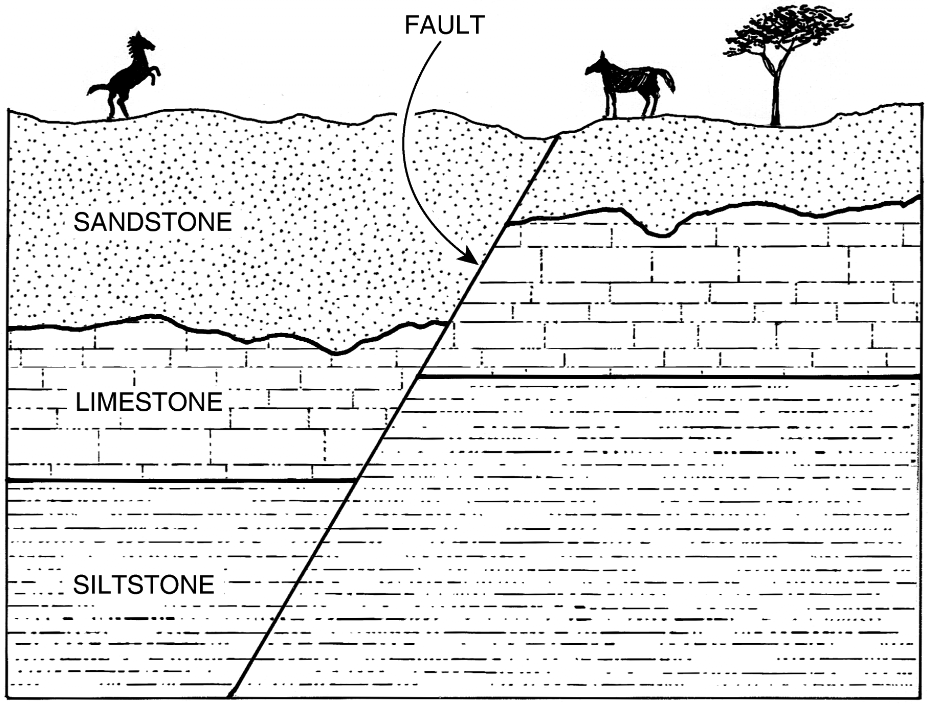
STRATA DIAGRAM 3



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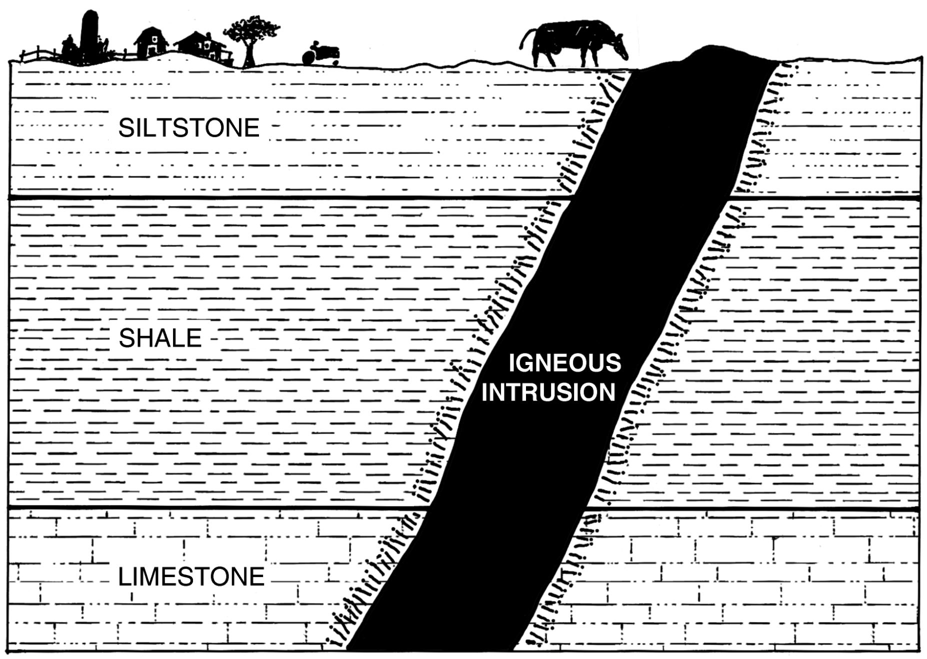
STRATA DIAGRAM 4

contact metamorphism zone



OBSERVATIONS: ______________________________

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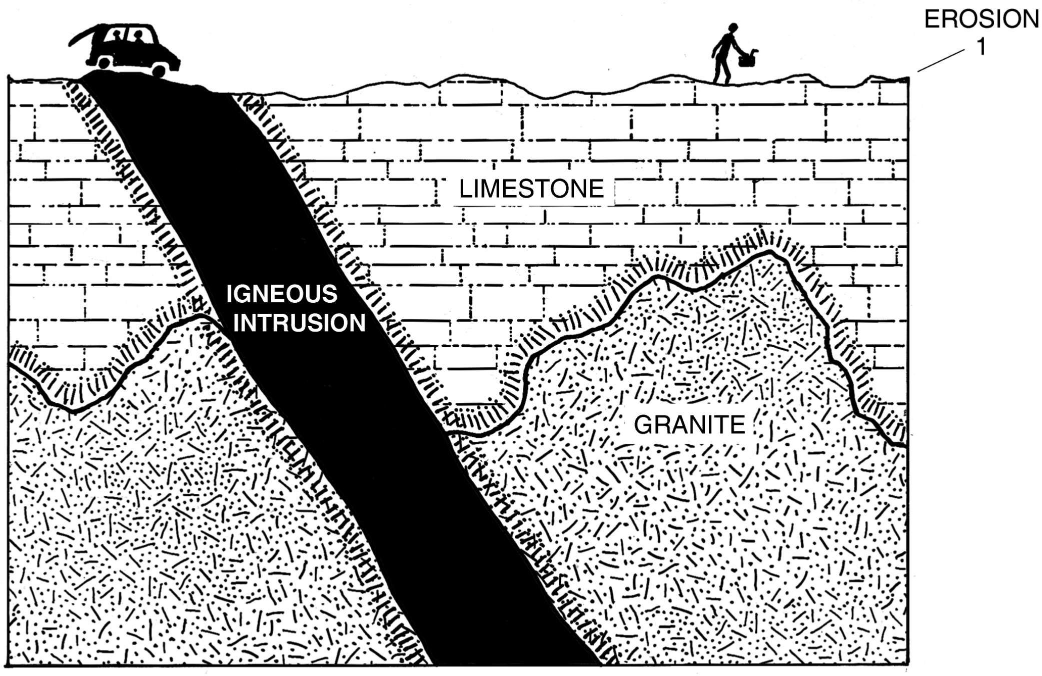
STRATA PUZZLE 1



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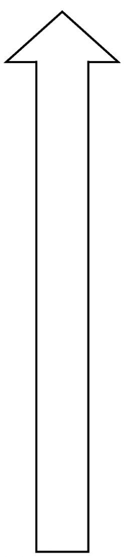
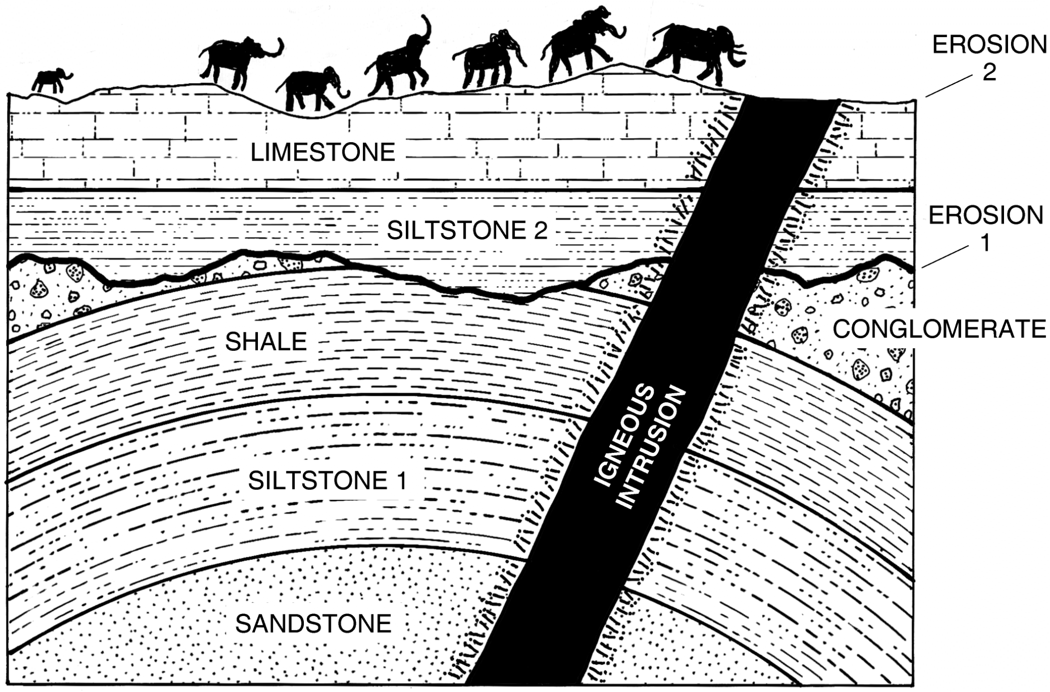


ORDER OF EVENTS

OLDEST

STRATA PUZZLE 2



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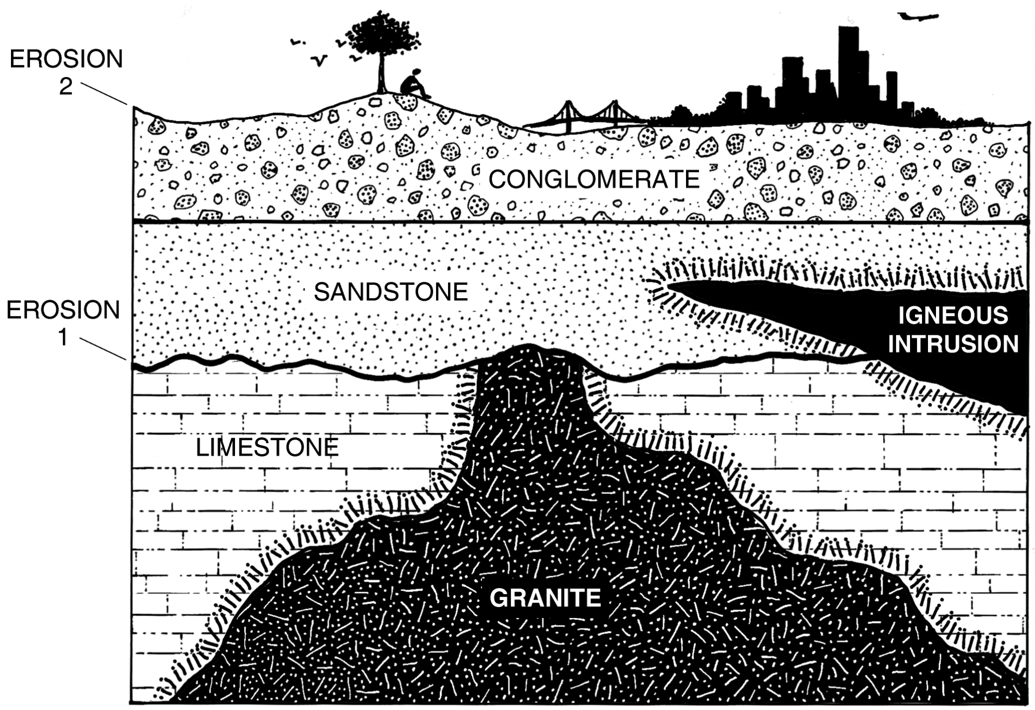
ORDER OF EVENTS

OLDEST

STRATA PUZZLE 3



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ORDER OF EVENTS

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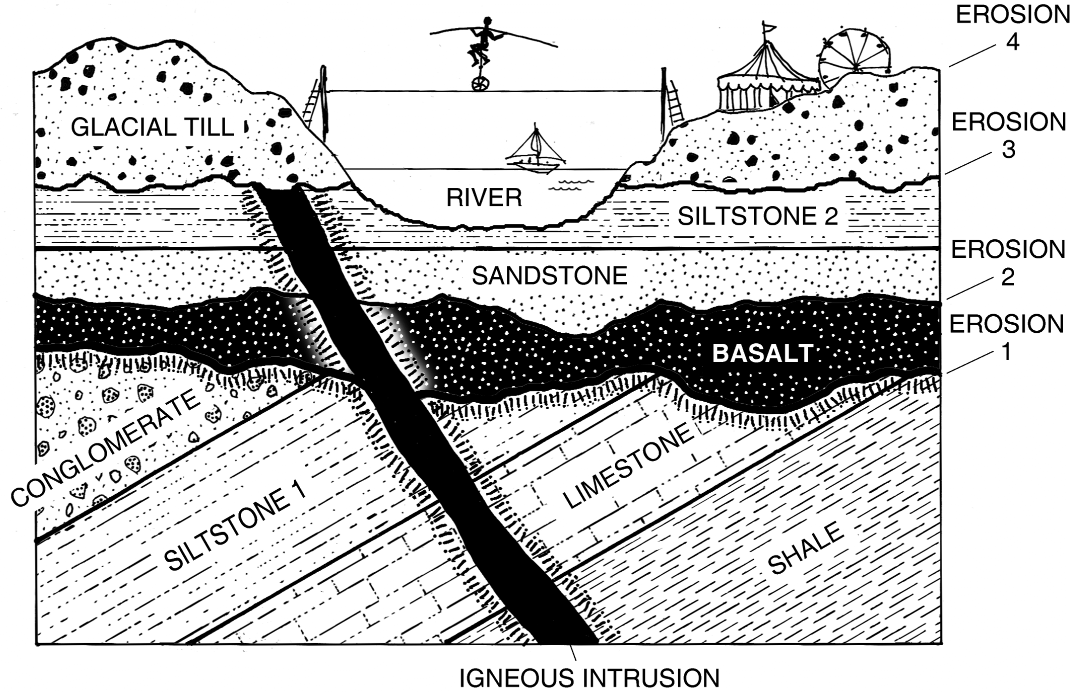
STRATA PUZZLE 4

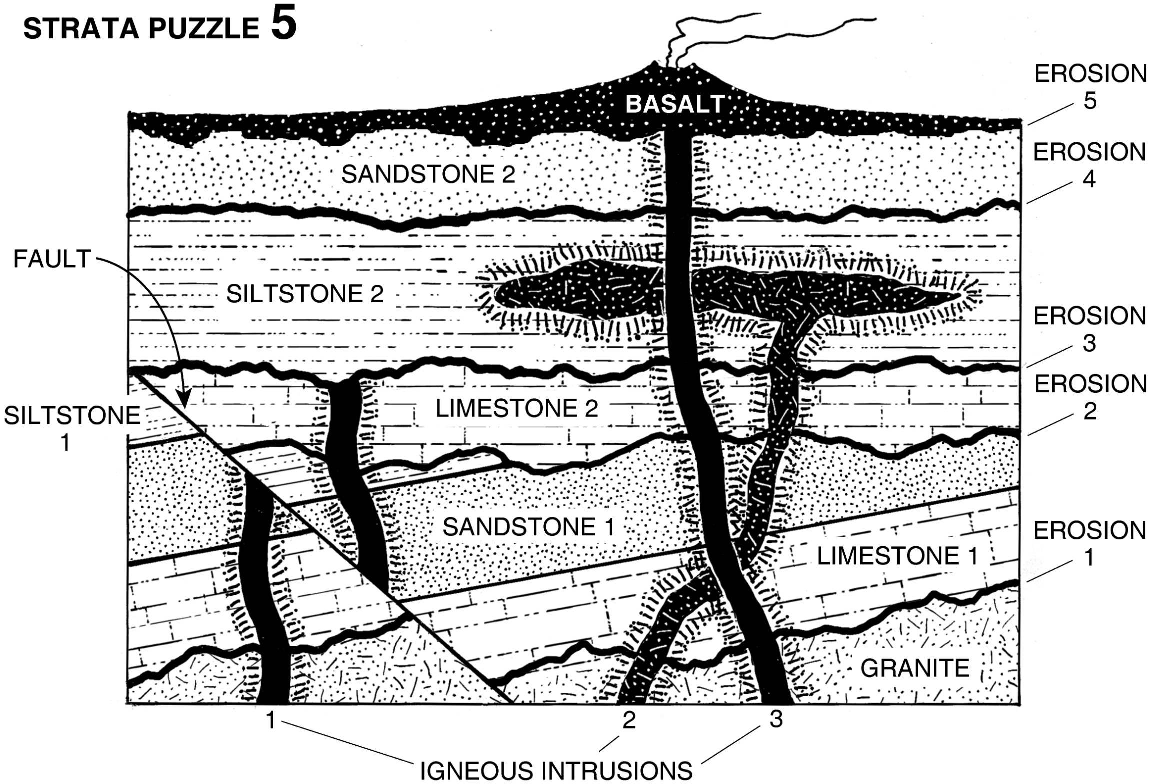


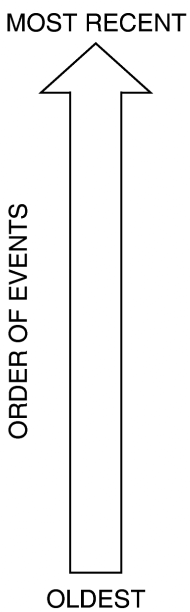
MOST RECENT

ORDER OF EVENTS

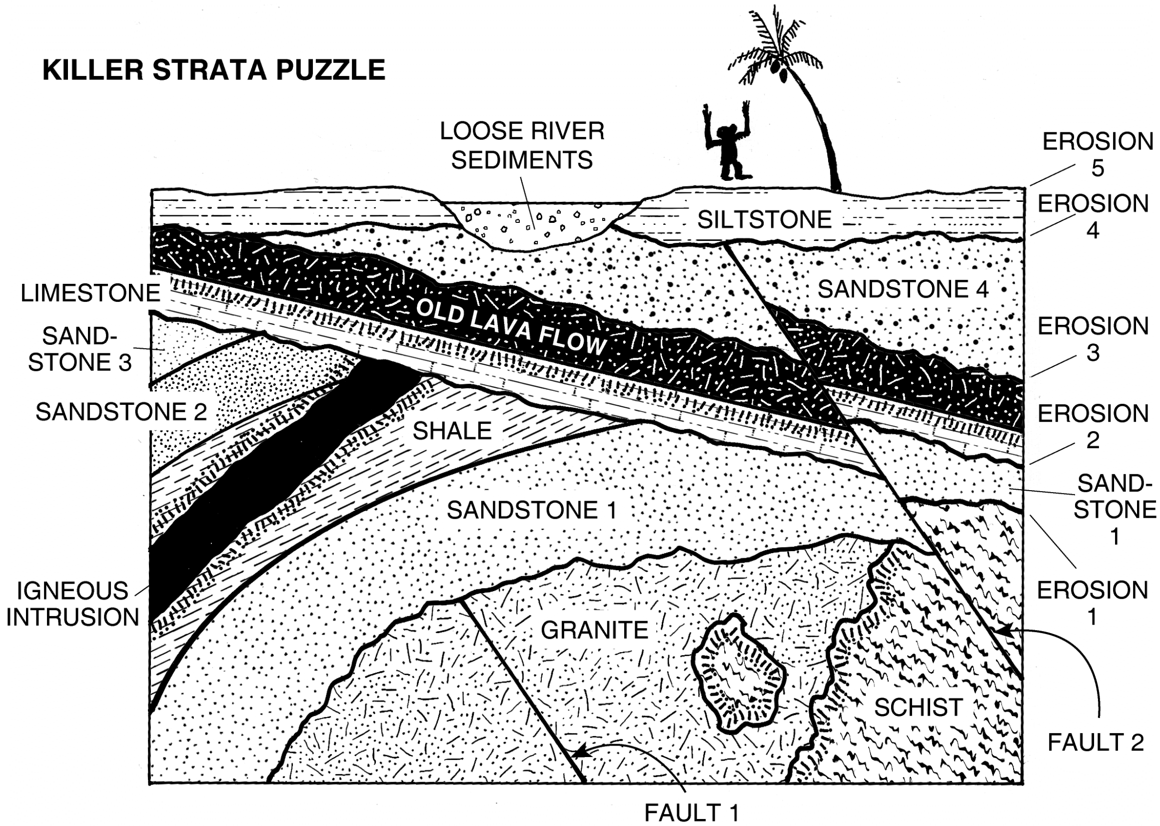
OLDEST

STRATA PUZZLE 5





KILLER STRATA PUZZLE



MOST RECENT

ORDER OF EVENTS

OLDEST

Time Capsules

Overview

Students will receive 5 bags of human-made items, representing 5 different time periods. They will arrange the bags in chronological order from oldest to newest, thus simulating the role of fossils in the study of Earth's history.

Background

When early geologists collected fossils and made detailed notes about the rock layers they came from, they noticed that certain fossils only appeared in specific rock layers (or horizons). Together with an existing understanding of the *law of superposition* (which states that in an undisturbed sequence of sedimentary rocks, the oldest layers are on the bottom and the youngest are on top), this showed that some fossils could be used as indicators of the relative age of the rock that contained them. First discussed by a British surveyor, William Smith, the *principle of fossil succession* is based on this observation. The fossils that are useful for comparing the age of rocks at different locations, even if those locations are on different continents, have become known as *index fossils.* A good index fossil comes from an organism that had hard-parts that could be easily preserved and identified, had a wide geographical distribution, and existed during a short span of geologic time.

This activity uses human-made objects instead of fossils to develop an understanding of the role played by index fossils. It should be noted that *biological evolution* is different from human-generated *technological evolution*. Things change over time in both processes, but biological evolution has no 'directed purpose.' *Random* genetic changes persist or disappear through natural selection. On the other hand, when humans purposefully set out to design something, they may discover new methods to achieve their goals. These *intentionally* developed new methods often are improvements or refinements on existing methods; thus the notion of technological evolution.

Materials

*Materials marked with an asterisk must be supplied by the teacher or the students.

Materials for the whole class

- Transparency of capsule bag contents (black line master below)

Materials for small groups

- One set of 5 different time capsule bags for each pair of students (see list of contents below)

Materials for individual students

- *Science notebook

Procedure

- Start by telling students that a worker at the Perplexed Paleontology Plant mixed up some science materials. Students will receive 5 bags of items, representing 5 different time periods. The contents of the bags are correct, but the worker lost the information about the ages of the bags. The students need to arrange the bags in chronological order from oldest to newest. They should inspect and analyze the items in the bags to provide evidence for their order. The items in each bag are items that could be found in that time period. Tell students to take only *one* time capsule bag at a time and record a detailed inventory of the items in that bag. They should then list what clues each item provides as to the relative time period of that entire bag with respect to the other bags. Once they have processed each individual time capsule bag, they should then place the bags in order based on relative time period as determined by the clues in each bag. They should be prepared to back up their order with clear evidence and reasoning.
- After students have put the bags in order, ask them for their supporting evidence. Ask them to explain the traits that made an item helpful or not helpful. If the job seems too easy, ask them which items should be removed from the bag to make the task more difficult.
- After students have completed the assignment, show them an overhead of the black line master below, and have them return the appropriate items to each bag.

Reflection/Discussion

Use the discussion of the human-made items to begin a discussion of index fossils. The overhead of the capsule bag contents can be used to aid the discussion. Be sure to include a comparison between biological and technological evolution as described in the **Background** section above.

Assessment

Have students pick ten different items that should be put in a time capsule that would help paleontologists a thousand years from now understand life in the early 21st century. Ask them to justify each selection with emphasis on how their selection might be different from a related item in the future.

Contents of Time Capsule Bags

Capsule H91	Capsule A622	Capsule X435	Capsule R183	Capsule F77
wooden match	wooden match	wooden match	wooden match	wooden match
leather shoelace			black shoelace	
wooden button			plastic button	plastic button
	metal zipper	metal zipper	plastic zipper	Velcro strip
		45 RPM record	cassette tape	CD
fabric samples w/blue flannel	fabric samples w/blue striped cotton	fabric samples w/green check pattern	fabric samples w/3 pieces	fabric samples w/fleece material
quill pen	pencil	pencil	pencil	pencil
metal spoon w/intricate design	metal spoon w/intricate design	metal spoon w/intricate design	metal spoon w/simple design	metal spoon w/simple design
		white plastic spoon	white plastic spoon	colored plastic spoon