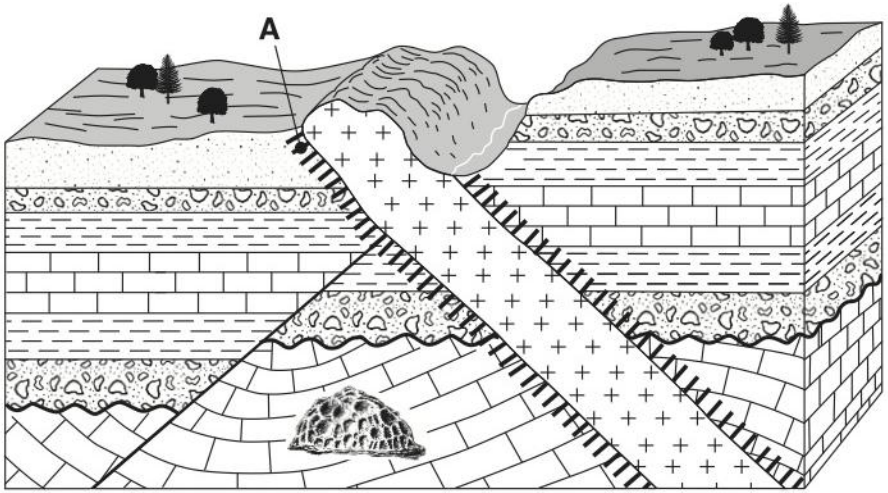
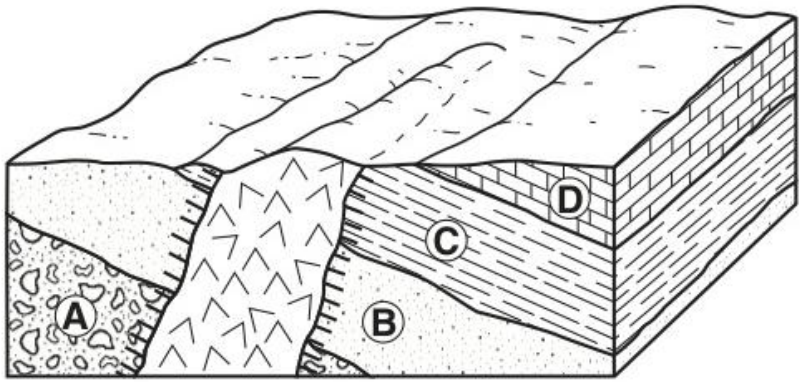
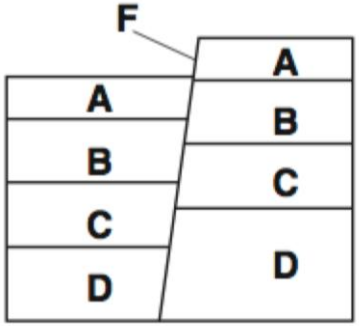
Professional Development to Improve Spatial Thinking of Earth Science Teachers & Students

Sequencing: Trading Space for Time







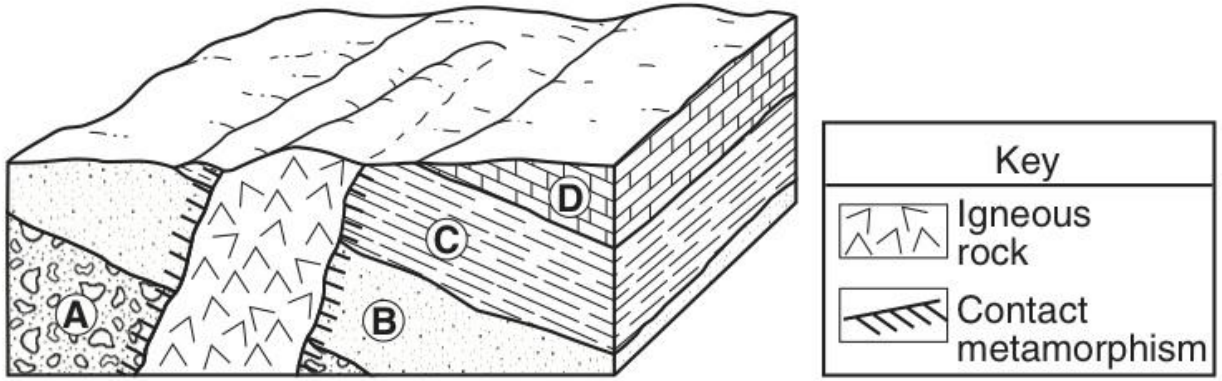
Kim Kastens

17 September 2011

Lamont-Doherty Earth Observatory

“Sequencing”: Geologist uses spatial information plus spatial reasoning to unravel or constrain the temporal sequence in which events occurred.

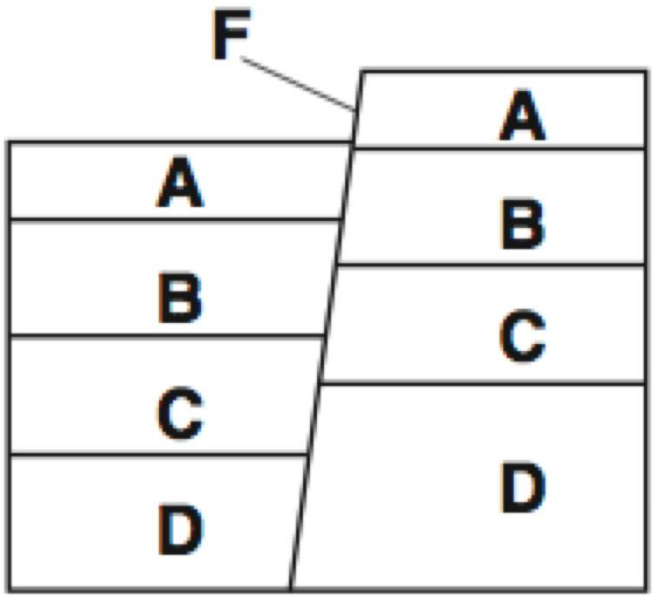
Base your answers to questions 45 through 47 on the block diagram below, which shows a portion of Earth’s crust. Letters *A*, *B*, *C*, and *D* indicate sedimentary layers.



45 Which event occurred most recently?

(1) formation of layer *A*
(2) formation of layer *D*
(3) tilting of all four sedimentary rock layers
(4) erosion of the igneous rock exposed at the surface

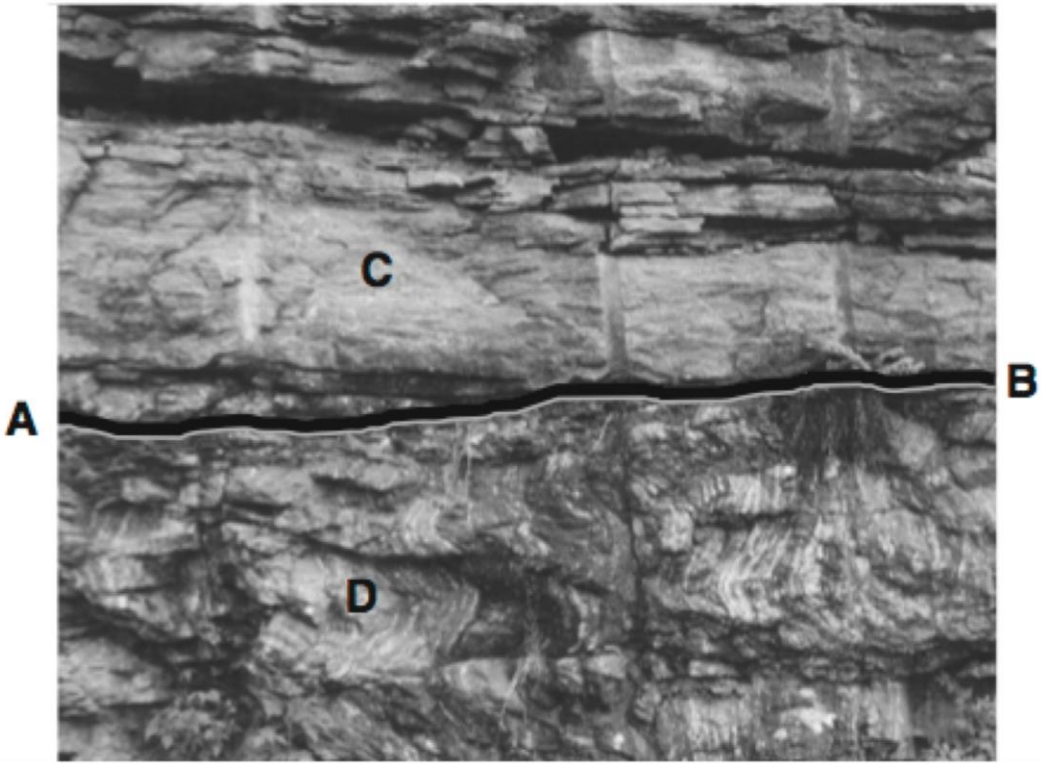
17 The cross section below shows rock layers *A*, *B*, *C*, *D*, and fault *F*. The rock layers have not been overturned.



Which sequence places the rock layers and fault in order from oldest to youngest?

(1) $D \rightarrow C \rightarrow B \rightarrow A \rightarrow F$
(2) $A \rightarrow B \rightarrow C \rightarrow D \rightarrow F$
(3) $F \rightarrow D \rightarrow C \rightarrow B \rightarrow A$
(4) $F \rightarrow A \rightarrow B \rightarrow C \rightarrow D$

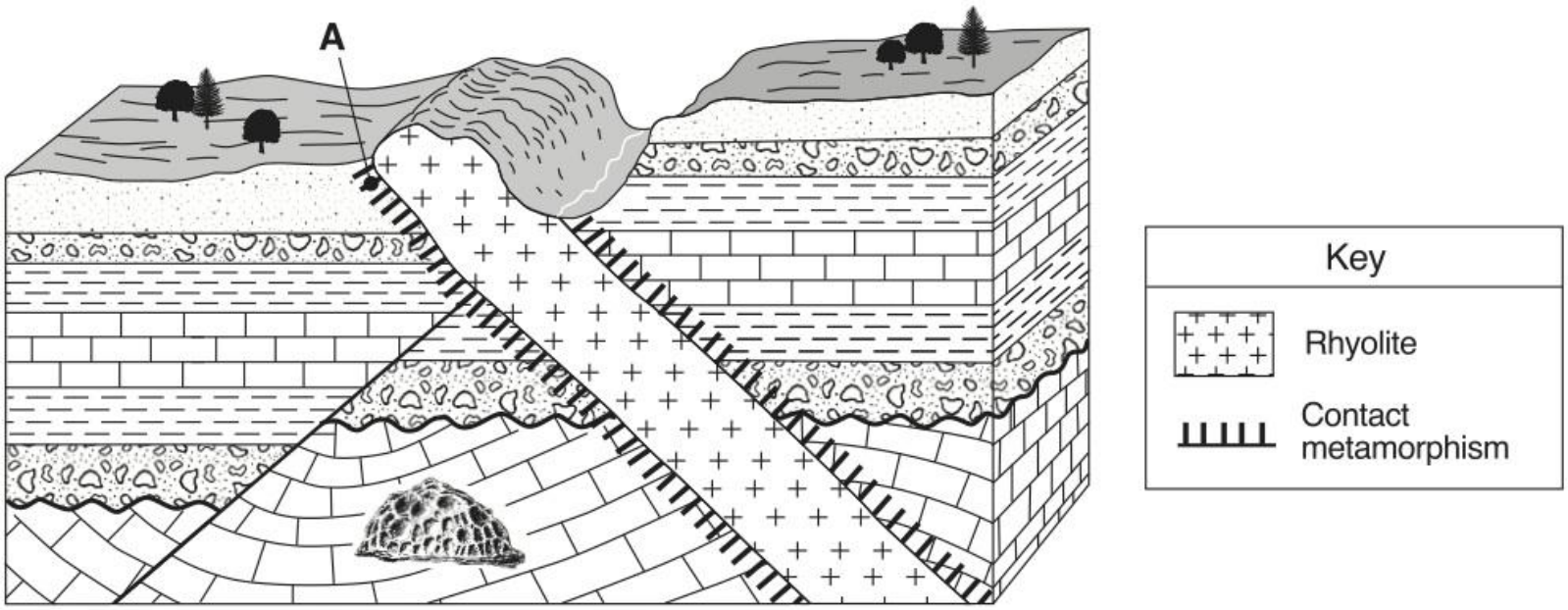
Base your answers to questions 26 and 27 on the photograph below, which shows a bedrock outcrop in northeastern New York State. Line *AB* is an unconformity between sandstone *C* and metamorphic rock *D*.



27 After the metamorphism of rock *D*, which sequence of events most probably formed unconformity *AB*?

(1) flooding → deposition → erosion → uplift
(2) uplift → erosion → flooding → deposition
(3) deposition → flooding → uplift → erosion
(4) erosion → flooding → uplift → deposition

Base your answers to questions 75 through 79 on the block diagram below, which shows rock units that have not been overturned. Point *A* is located in the zone of contact metamorphism. A New York State index fossil is shown in one of the rock units.



(Not drawn to scale)

75 State the evidence shown by the block diagram that supports the inference that the fault is older than the rhyolite. [1]

What do your students find hard about this type of question? (Group brainstorming)

- *Yes they are hard. Because they don't really understand what the question is asking for. Their experience deals only with the top*

- *the key. They don't think to use it*

- *They look at the entire picture. It is too busy, and they are overwhelmed*

- *They find the sequencing relatively easy. Provide evidence questions are harder*

- *The vocabulary is hard. They have a hard time articulating what is hard*

-

What do your students find hard about this type of question?

- *Block diagram is harder than a pure profile.*
- *They are exhausted when they get there. These questions are always at the end of the Regents.*
- *Urban kids don't have experience with mud or rocks.*
- *Block colors instead of patterns.*
-

Our suggestions:

- Motivate: why do Earth scientists care about what happened first, second, third…. most recently?

- Show students real Earth examples of the spatial relationships that are useful for making inferences about the sequence of events.

- Create a visual narrative: First…. then…. and then…. and finally…..

- Connect to great moments in history of Earth Science

- Connect to Rockland county geology

Motivate: why do Earth scientists care about what happened first, second, third…. most recently? (Teacher brainstorming)

- *Paleoseismology: how often were earthquakes in the past.*

- *Students (and also ES's) want to know how we got to where we are*

- *If we understand the past, it help us think about the future. The past is written in the rock*
- *The earth is not one solid units.*

- *There is order and sense to the world. There is a beginning, middle and end*

- *Misconception: only metal bends*

- *History of the science.*

Motivate: why do Earth scientists care about what happened first, second, third…. most recently? (teacher ideas)

- *Tangible value, e.g. mining. Where to find ores, oil, garnets. You can make money.*

- *Rocks have driven human society.*

- *Rocks, dirt, digging, is early interest.*

- *Sequence constrains causal influence: if A precedes B, then A can have caused or influenced B….*

- *Sequence & timing connects local to regional and global events.*

- *Sequence of lithologies constrains uplift, regression/ transgression*

Show students real Earth examples of the spatial relationships that are useful for making inferences about the sequence of events.

http://www.earthscienceworld.org/images/index.html

Photographer: Marli Miller University of Oregon http://www.earthscienceworld.org/images/index.html
Caption: Marine limestone of Castle Mountain in Banff National Park, Canada.

Photographer: Bruce Molnia US Geological Survey
Caption: Offset along a fault in California.

http://www.earthscienceworld.org/images/index.html

Photographer: Bruce Molnia US Geological Survey

Caption: This basaltic dike has intruded the Mount Desert Granite of Maine's Acadia National Park.

http://www.earthscienceworld.org/images/index.html

Photographer: Marli Miller University of Oregon
Caption: Turbidites in sedimentary rock layers.

http://www.earthscienceworld.org/images/index.html

Photographer: Marli Miller University of Oregon
Caption: Image of folded gneiss.

http://www.earthscienceworld.org/images/index.html

Photographer: Marli Miller University of Oregon

Caption: Image showing cross-cutting relationships. This is folded gneiss with an intrusion (younger as seen by cross-cutting).

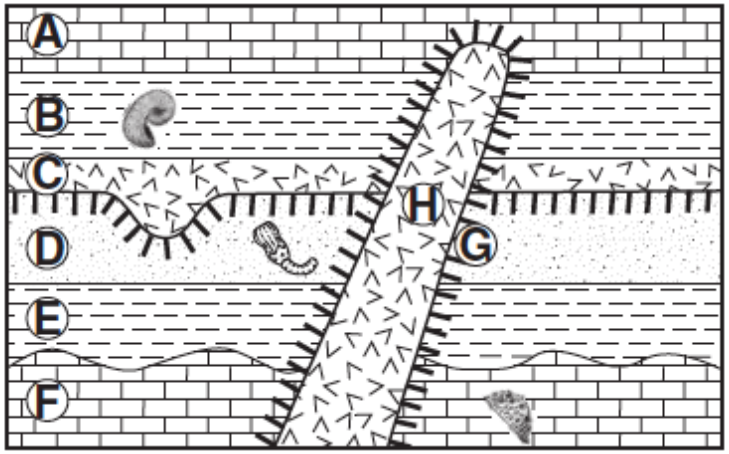
http://www.earthscienceworld.org/images/index.html

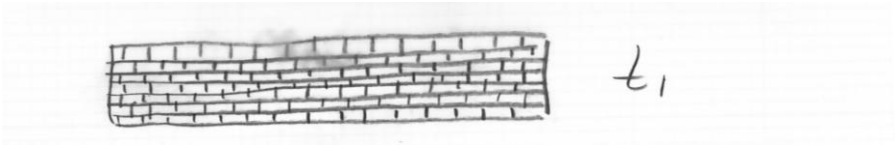
http://www.earthscienceworld.org/images/index.html

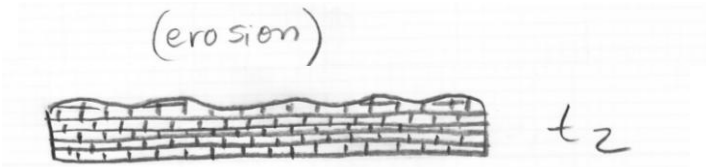
Photographer: Thomas McGuire

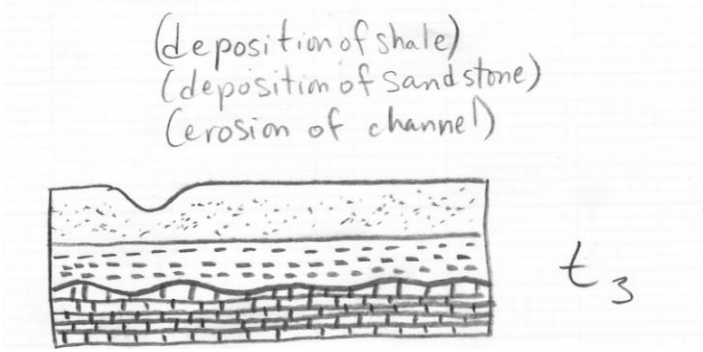
Caption: This unconformity (a buried erosional feature) formed when folded rocks of the lower formation (Entrada) had been eroded to a relatively flat surface before the sandy basal conglomerate of the Morrison formation were deposited on and buried this erosion surface.

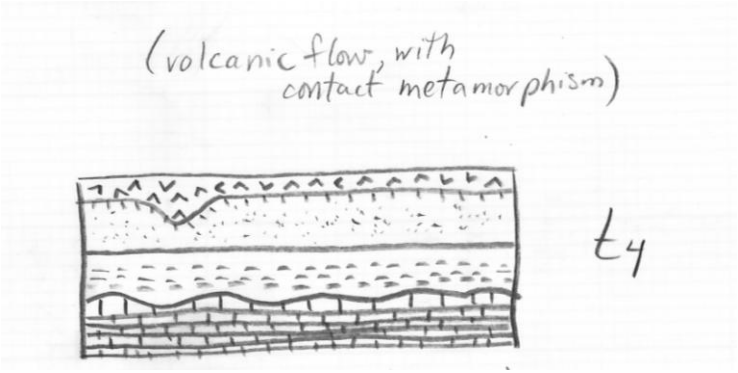
Create a visual narrative: First…. then…. and then…. and finally…..

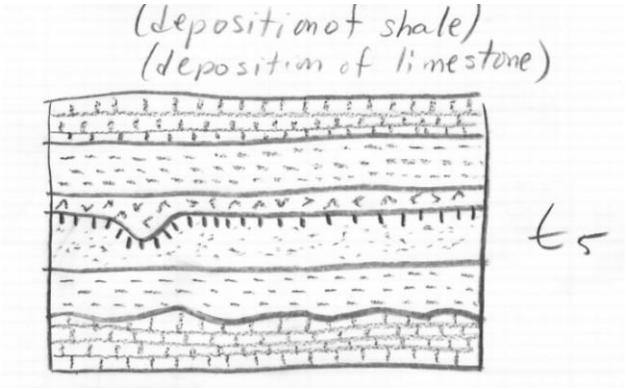


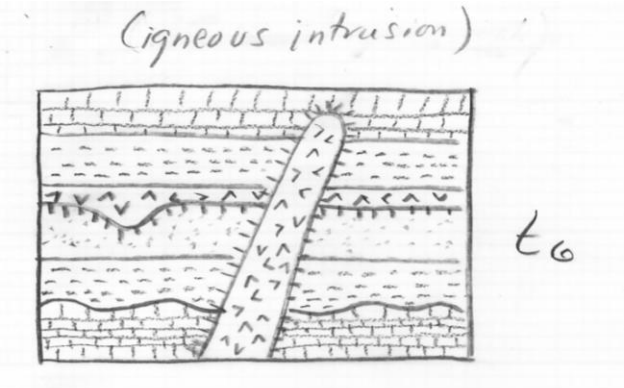












Now you try!

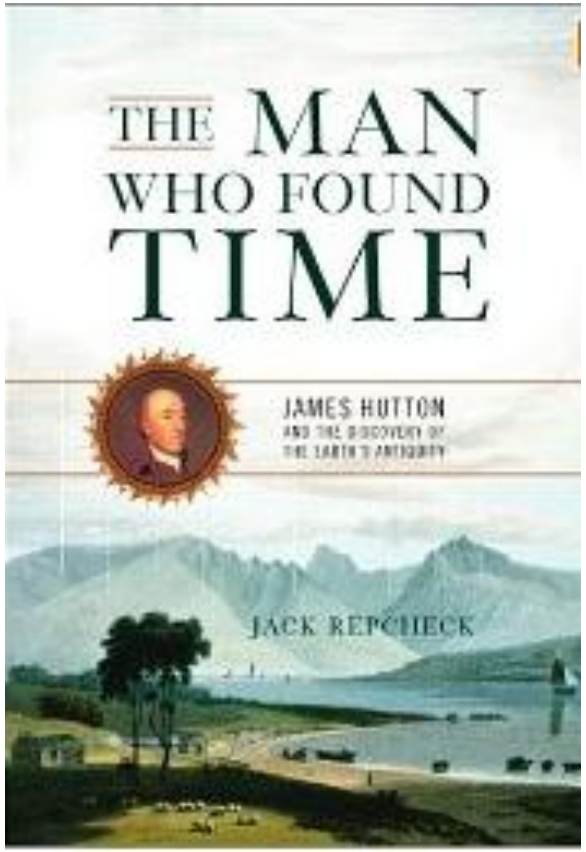
Visual Narrative (teacher ideas)

- Start with an easier diagram
- This would be culmination project, final lab.
- Write up as well (in the format of a lab report)
- Could give different groups different time slices to draw.
- Do it yourself to learn where to mess us.
- Number of panels is up to the students, that's a geologists' decision
- Use color. Rather than stipples.
- Cut and paste the layers.
- Give them boxes
- Use a 3-D physical model, like a cake, as part of the progression.
- Have the kids generate questions from the diagrams.

Connect to great moments in the history of Geology

http://commons.wikimedia.org/wiki/File:Siccar_Point_red_capstone_closeup.jpg

David Sousa



James Hutton (1726-1797)

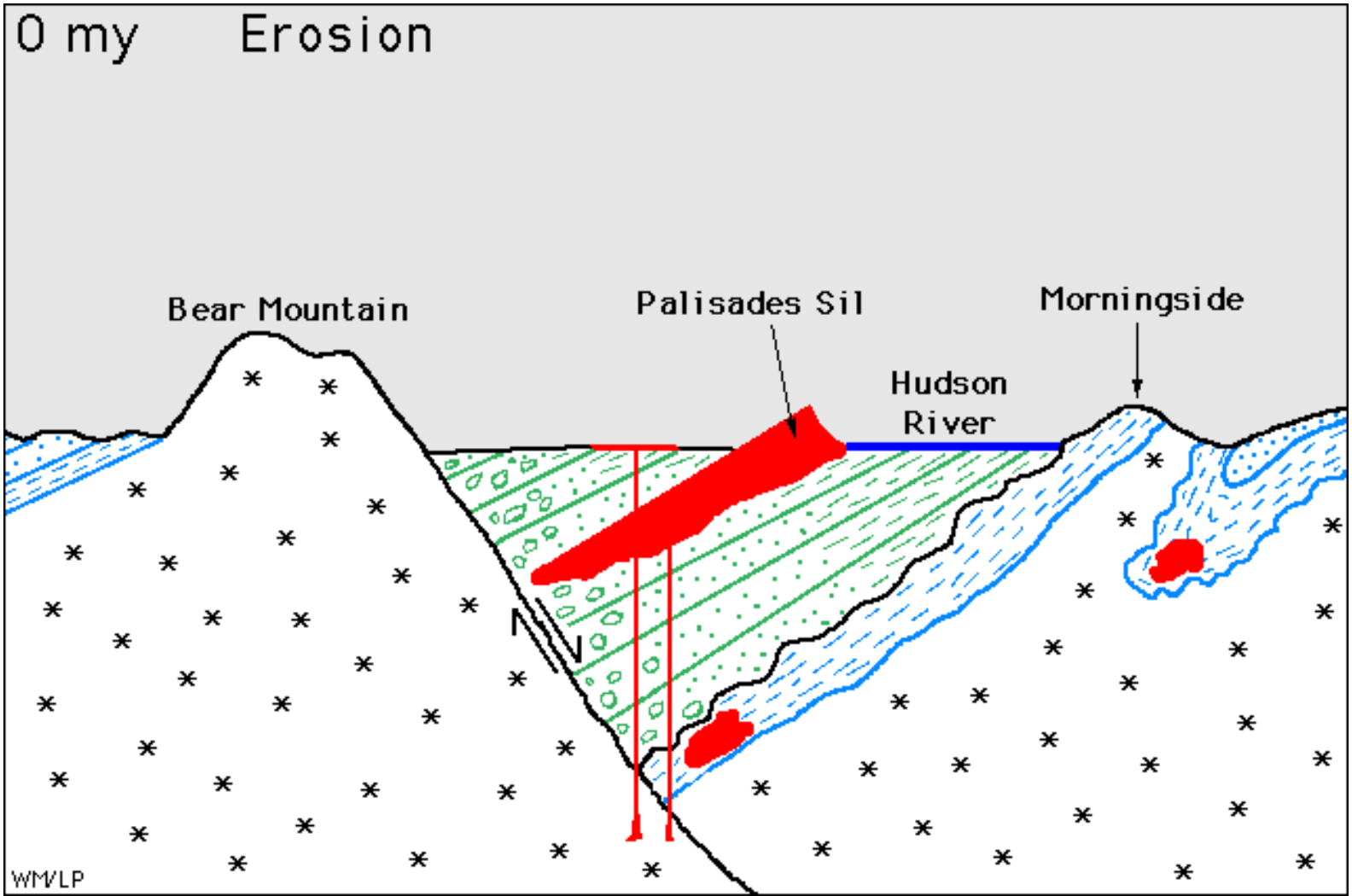
"…no vestige of a beginning, no prospect of an end…."

James Hutton

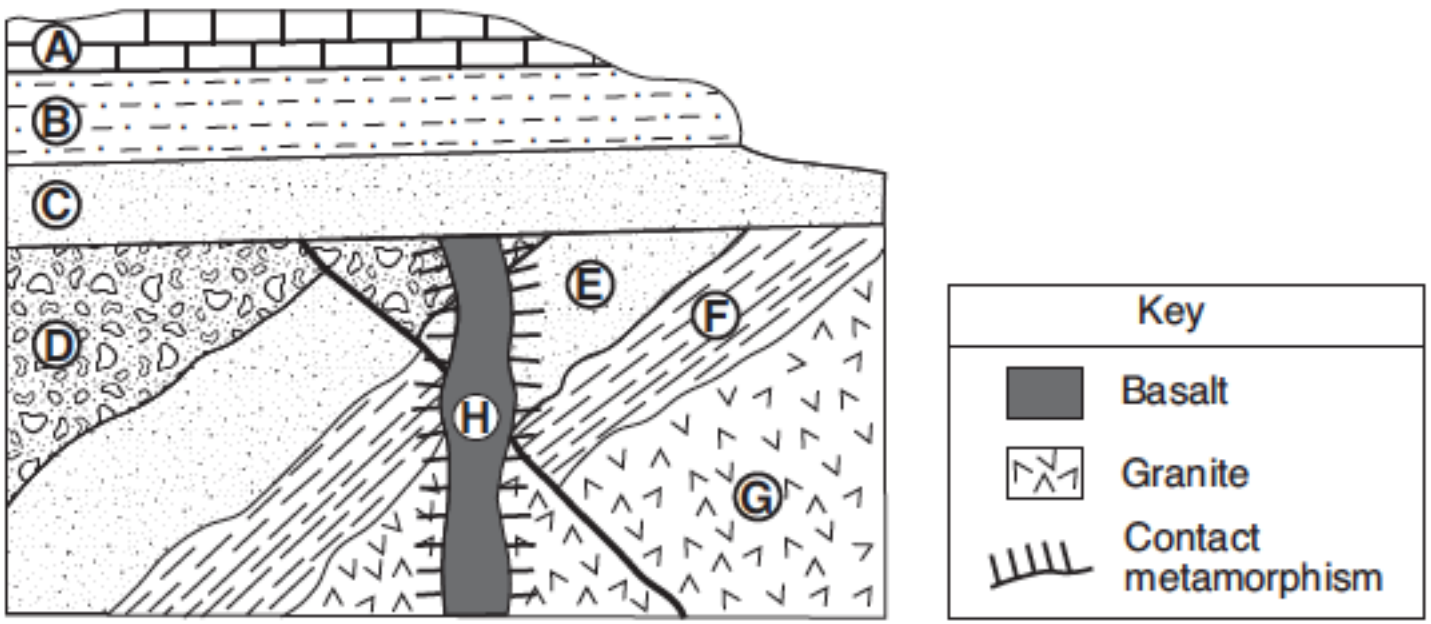
From Wikipedia, the free encyclopedia

Section called "The Search for Evidence."

Connect to Rockland County geology



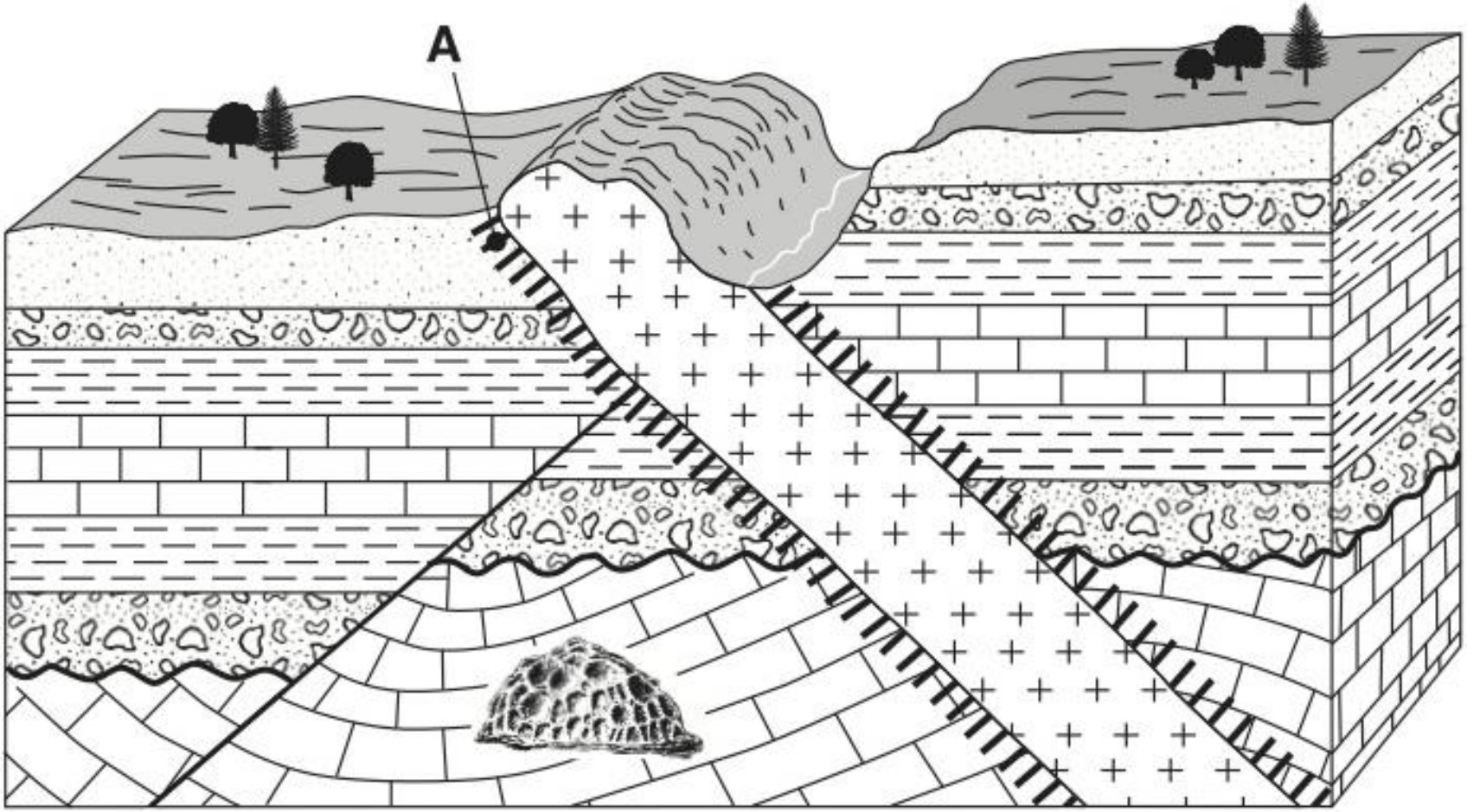
Additional figures for student activities



68 Two inferences about the cross section are listed below.

Inference 1: Rock unit *G* is older than the fault.
Inference 2: Rock unit *A* is younger than rock unit *C*.

Explain how *each* inference is supported by evidence in the cross section. [1]



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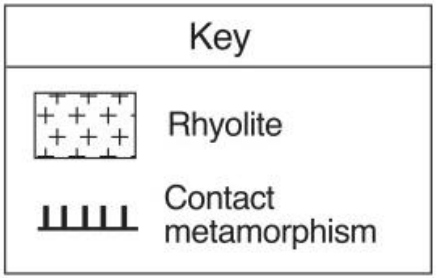
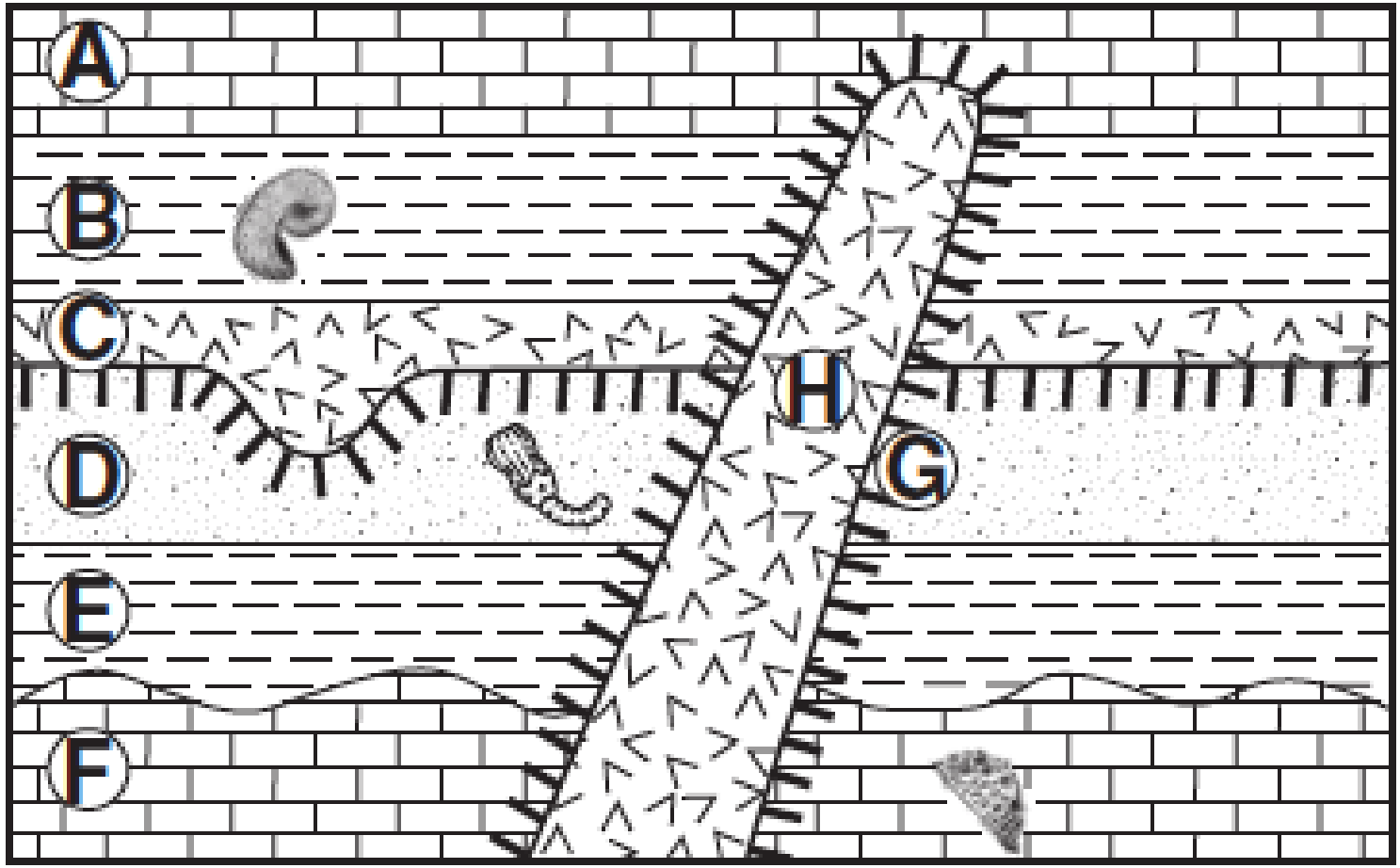
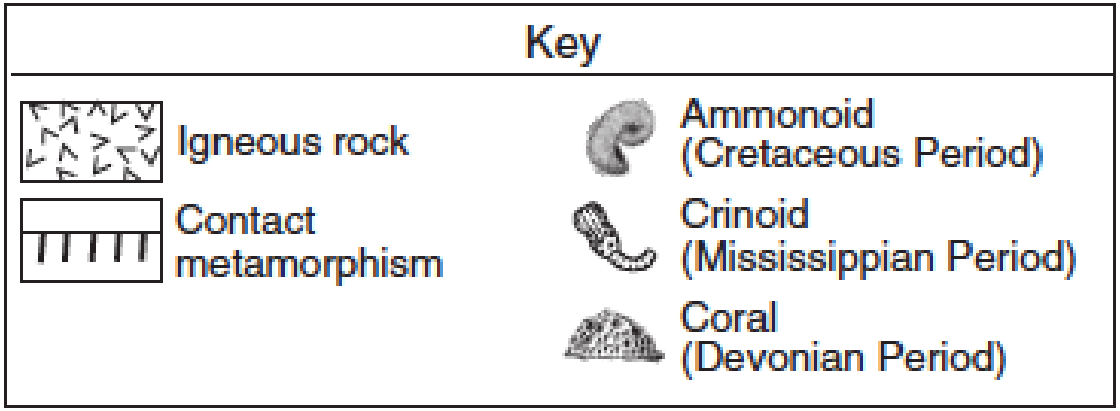


June 2010 Q75





August 2010 Q 80