Geologic Inquiry for Relative Dating

Activity 8.1

Name: _____ Course/Section: _____ Date: _____

A Analyze the piece of layer cake in Fig. A8.1.1. Each side of the block of cake is a vertical **cross-section** of the layers. Also notice the surfaces between the layers, where two different layers touch each other. Geologists refer to surfaces between layers or other bodies of rock as **contacts**.

1. Think about the process used to construct the layer cake from *depositing* the first layer to depositing the last layer. On the left edge of the cake, number the layers to show the sequence of steps in which they were deposited to make the layer cake from 1 (first step) to "n" (the number of the last step).
2. Using a pen, draw lines on the layer cake to mark all of the contacts between layers. Then place arrows along the right edge of the cake that point to each contact. Label each arrow to show its relative age from 1 for the first or oldest contact to "n"—the number corresponding to the youngest contact.

Figure A8.1.1

B Figure A8.1.2 shows an outcrop about 5 meters thick near Sedona, Arizona. The red rock in **Fig. A8.1.2** is an ancient soil called a paleosol. The brown layer in which grass is rooted near the top of the photo is modern soil. The blocky brown-gray rock with wide fractures is an ancient lava flow. This outcrop is a natural geologic cross-section of rock layers, analogous to the cake.

1. Which layer is the oldest? How do you know?

2. Using a pen, carefully draw lines on **Fig. A8.1.2** that mark the position of:
   (a) the contact between the red ancient soil and the lava flow.
   (b) the contact between the top of the lava flow and the base of the darker brown modern soil in which grass is growing.

3. Notice the fractures that cut across the lava flow layer. Are they older or younger than the lava flow? How do you know?

4. Notice that *clasts* of the lava flow are included in the brown soil. Are they older or younger than the brown soil? How do you know?

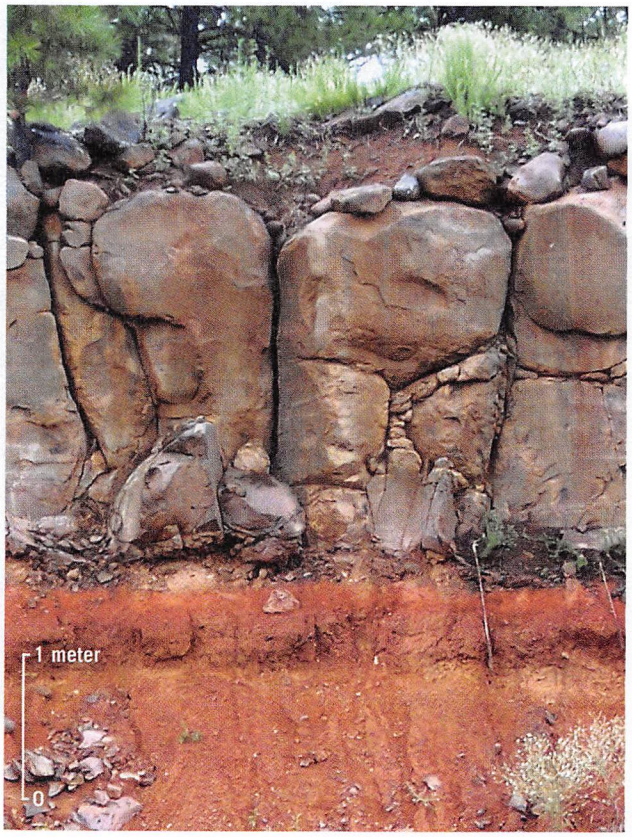


Figure A8.1.2

C Analyze the outcrop shown in **Fig. A8.1.3** photographed by geologist Thomas McGuire. It is another natural geologic cross-section with red sandstone layers on the bottom and a tan conglomerate (gravel) rock layer on top. Notice that the red rock layers are not horizontal. They are bent like a gently folded newspaper, down in the middle.

1. Using a pen on **Fig. A8.1.3**, carefully trace two of the contacts between layers within the red sandstone as well as you can. Assuming that the red sandstone layers were originally horizontal, what might have caused them to be folded in this way?

2. On both sides of **Fig. A8.1.3**, use an arrow to indicate the location of the contact between the red sandstone and the horizontal tan conglomerate above it. This surface is an unconformity like the one shown in **Fig. 8.4**. What sequence of events may have happened to form the unconformity in **Fig. A8.1.3**?

D **REFLECT & DISCUSS** In all of your work above, you had to interpret the relative ages of rock layers, fractures, folds, and clasts included in soil. Based on your work, write down three rules that a geologist could follow to tell the relative ages of rock layers, fractures, clasts, and folds in geologic cross-sections.

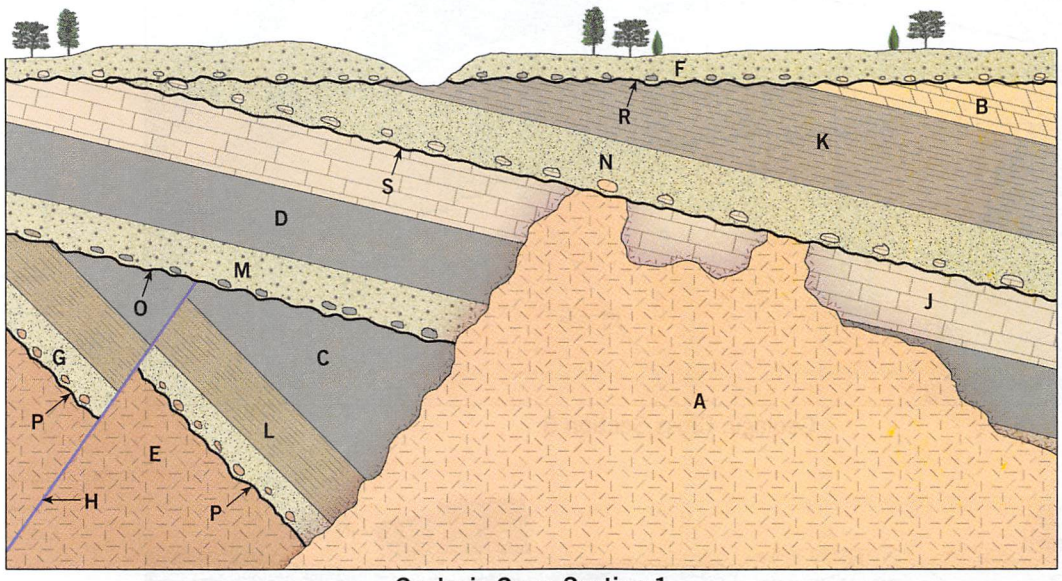
Figure A8.1.3

Determining Sequence of Events in Geologic Cross-Sections

Activity 8.2

Name: _____ **Course/Section:** _____ **Date:** _____

A Review the key to symbols at the bottom of Fig. A8.2.1. On the lines provided for each cross-section in **Figs. A8.2.1** and A8.2.2, write letters to indicate the sequence of events from oldest (first in the sequence of events) to youngest (last in the sequence of events). Refer to **Figs. 8.2–8.10** and the principles of relative dating that are explained in the text as needed.



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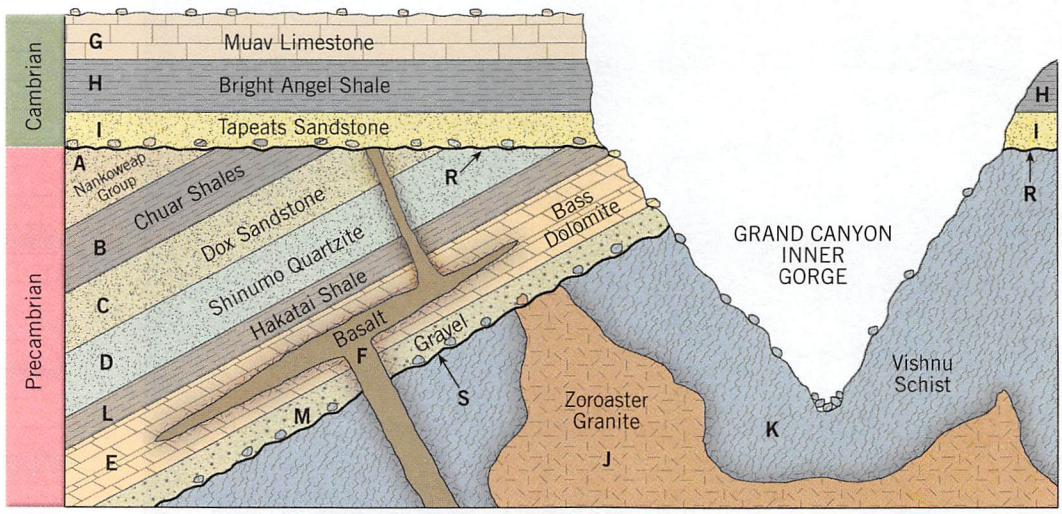
Oldest _____

Geologic Cross Section 1



Youngest _____

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Oldest _____

Geologic Cross Section 2

KEY TO SYMBOLS

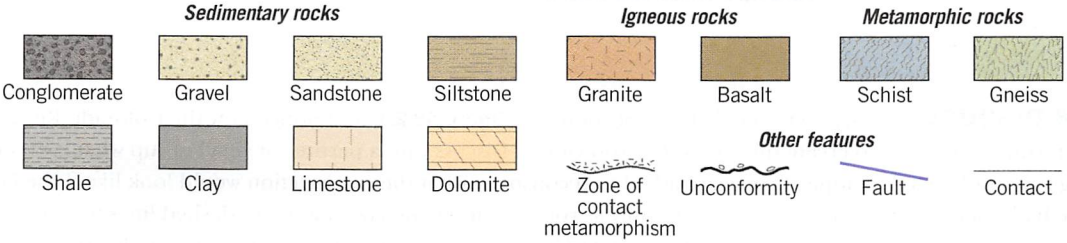
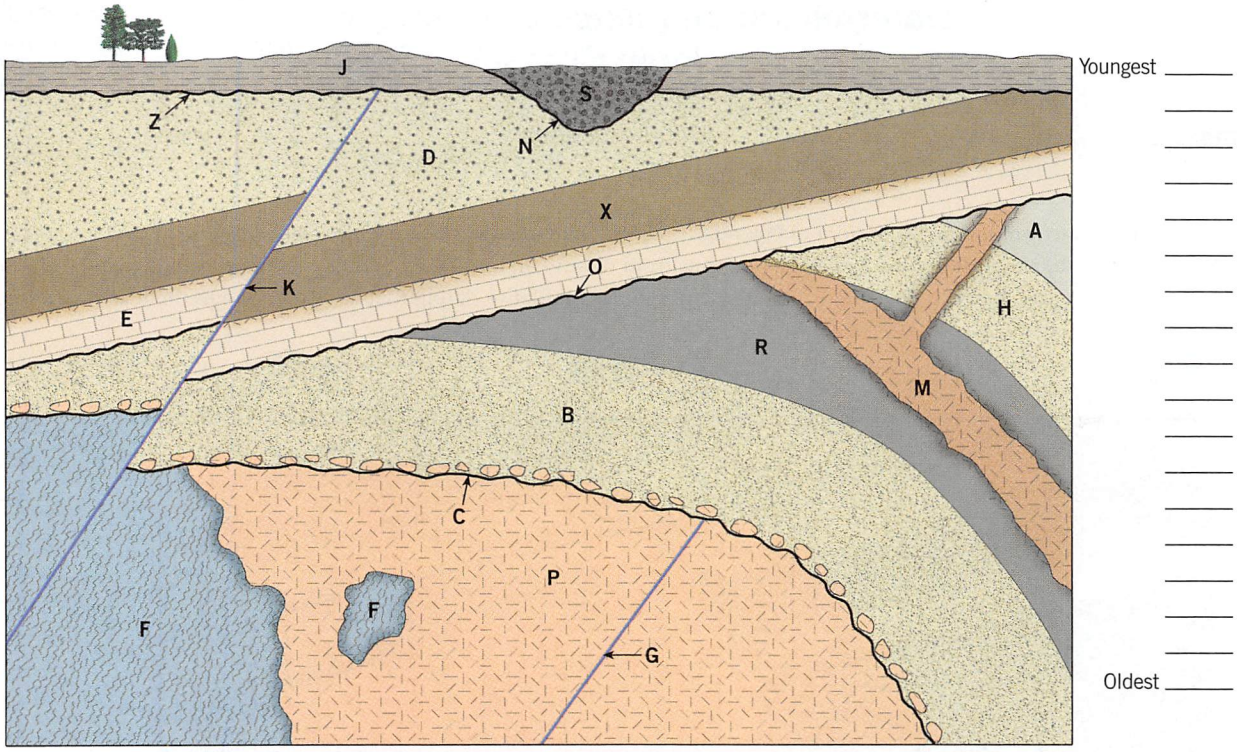
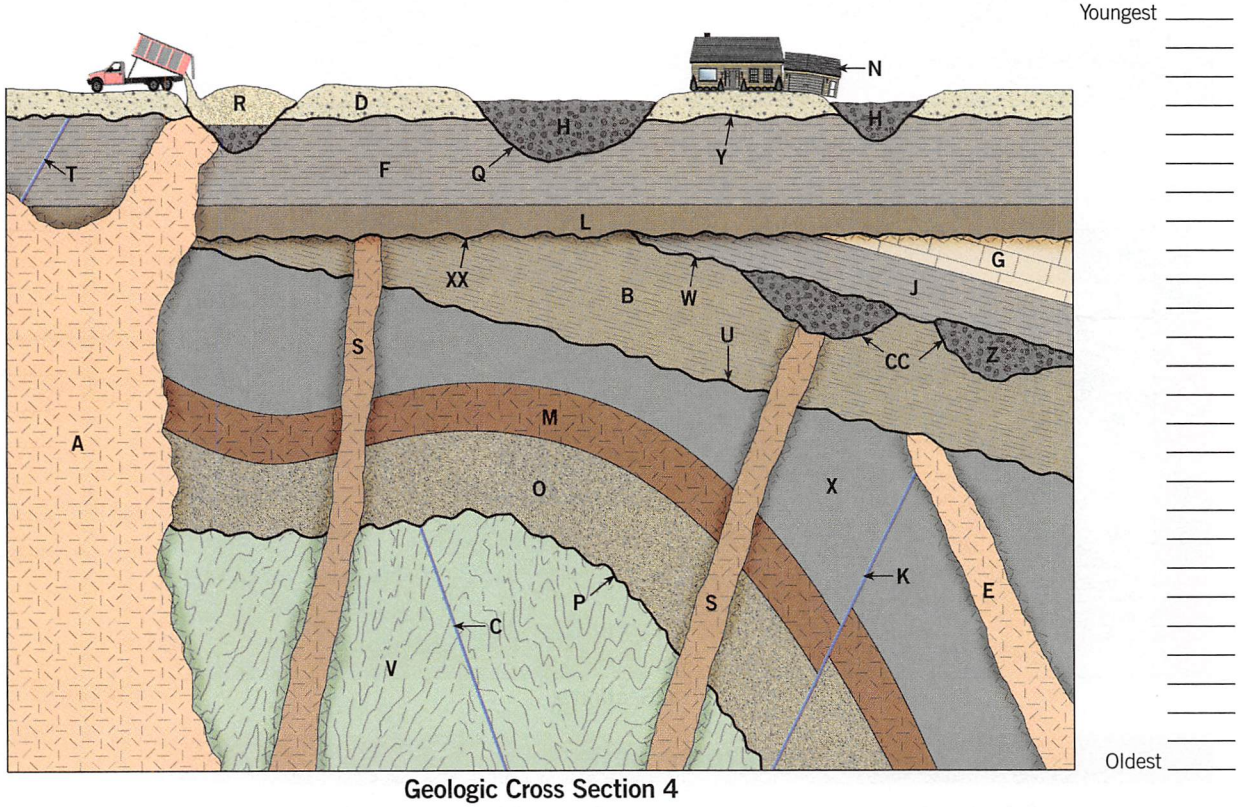


Figure A8.2.1



Geologic Cross Section 3



Geologic Cross Section 4

Figure A8.2.2

B **REFLECT & DISCUSS** Return to Geologic Cross-Section 2 in **Figure A8.2.1**, and notice how the Colorado River has cut down through the rocks to create the Grand Canyon Gorge. Discuss with a partner or small group what law(s) of relative dating you would need to apply if you were asked to reconstruct what the cross-section would look like if the Grand Canyon Gorge had not developed in this area. As carefully as you can, apply the law(s) and use dashed lines to draw in the contacts between named rock layers that were eroded away in Grand Canyon Gorge. Compare your completed drawing with those of other students.

Using Fossils to Date Rocks and Events

Activity 8.3

Name: _____ Course/Section: _____ Date: _____

A Analyze this fossiliferous rock from New York (**Fig. A8.3.1A**).

1. What index fossils from **Fig. 8.13** are present?

2. The overlap in ranges of the index fossils indicates the age of the rock. Express that age range in terms of the period(s) of the geologic time scale, using informal modifiers like "early," "middle," or "late" as appropriate. Example: late Triassic to early Jurassic.

3. Using the information in **Fig. 8.13** as your guide, how old is this rock? Express your answer as a range in millions of years.

B Analyze this fossiliferous sand from Delaware (**Fig. A8.3.1B**).

1. What index fossils from **Fig. 8.13** are present?

2. Express the age range of this sandstone in terms of the period(s) of the geologic time scale using informal modifiers like "early," "middle," or "late" as appropriate.

3. Using the information in **Fig. 8.13** as your guide, how old is this rock? Express your answer as a range in millions of years.

C Analyze this fossiliferous rock from Ohio (**Fig. A8.3.1C**).

1. What index fossils from **Fig. 8.13** are present?

2. Express the age range of this rock in terms of the period(s) of the geologic time scale, using informal modifiers like "early," "middle," or "late" as appropriate.

3. Using the information in **Fig. 8.10** as your guide, how old is this rock? Express your answer as a range in millions of years.

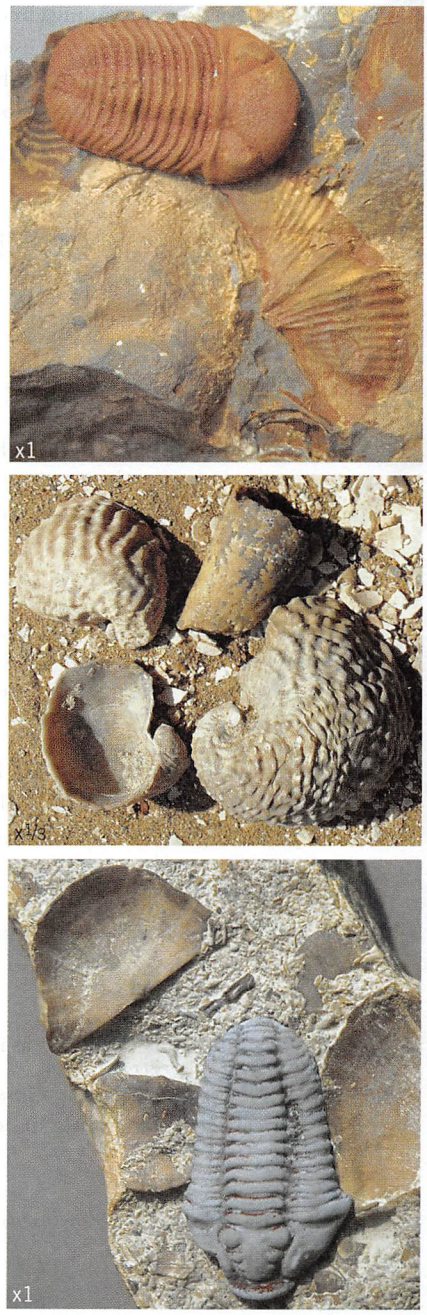


Figure A8.3.1

D Using **Fig. 8.13**, re-evaluate the geologic cross-section in **Fig. 8.2** based on its fossils.

1. Which two formations are separated by a disconformity?

2. The discontinuity indicates a gap in the rock record. What is the minimum and maximum amount of time that is not reflected in the rock record in this location?

minimum: _____ Myr maximum: _____ Myr

E **REFLECT & DISCUSS** What geologic event occurred during the Mesozoic Era in the region where **Fig. 8.6** is located? Explain.

Activity 8.4 Numerical Dating of Rocks and Fossils

Name: _____ **Course/Section:** _____ **Date:** _____

A A solidified lava flow containing zircon mineral crystals is present in a sequence of rock layers that are exposed in a hillside. A mass spectrometer analysis was used to count the atoms of uranium-235 and lead-207 isotopes in zircon samples from the lava flow. The analysis revealed that 71% of the atoms were uranium-235, and 29% of the atoms were lead-207. Refer to **Fig. 8.14** to help you answer the following questions.

1. About how many half-lives of the uranium-235 to lead-207 decay pair have elapsed in the zircon crystals?
   _____
2. What is the numerical age of the lava flow based on its zircon crystals? Explain how you arrived at your answer.

3. What is the age of the rock layers above the lava flow? _____
4. What is the age of the rock layers beneath the lava flow? _____

B Astronomers think that Earth probably formed at the same time as all of the other rocky materials in our solar system, including the oldest meteorites. The oldest meteorites ever found on Earth contain nearly equal amounts of both uranium-238 and lead-206. Based on **Fig. 8.14**, what is Earth's approximate age? Explain your reasoning.

C The radioactive isotope carbon-14 (C-14) is continuously replenished in organisms while they are alive. When an organism dies, it is no longer able to take in new C-14, and so the amount of C-14 decreases as it decays to its stable daughter product: nitrogen-14 (N-14).

1. The carbon in a buried peat bed has about 6% of the C-14 of modern shells. When the plants that now form the buried peat were alive, they absorbed C-14 and probably had about the same amount of C-14 as modern shells, so about 94% of the peat's original C-14 has decayed. What is a reasonable initial estimate of the age of the peat bed? Explain.

2. In sampling the peat bed, you must be careful to avoid any young plant roots or old limestone. Why?

D Zircon ($ZrSiO_4$) forms in magma as it cools into igneous rock. It is also useful for numerical dating (**Fig. 8.14**).

1. If you walk on a modern New Jersey beach, then you will walk on some zircon sand grains. Yet if you determine the numerical age of the zircons, it does not indicate a modern age (zero years) for the beach. Why?

2. Suggest a rule that geologists should follow when they date rocks based on the radiometric ages of mineral grains inside the rocks.

E **REFLECT & DISCUSS** An "authentic dinosaur bone" is being offered for sale on the Internet. The seller claims that he had it analyzed by scientists who confirmed that it is a dinosaur bone and used carbon dating to determine that it is 400 million years old. Discuss the seller's claims with a partner or in a small group. Should you be suspicious of this bone's authenticity? Explain. (See **Figs. 8.13** and **8.14**.)

Infer Geologic History from a New Mexico Outcrop

Activity 8.5

Name: _____ **Course/Section:** _____ **Date:** _____

A Refer to **Fig. A8.5.1**, which shows an outcrop in a surface coal mine in northern New Mexico. Note the sill, sedimentary rocks, fault, and places where a fossil leaf was found and isotope data for zircon crystals in the sill.

1. What is the relative age of the sedimentary rocks in this rock exposure? Explain your reasoning.

2. What is the numerical age of the sill? Use the information in **Fig. 8.14**, and show how you calculated the answer.

3. Locate the fault. Approximately how much displacement has occurred along this fault? _____ m
What additional information would you like to have to make a better estimate of fault displacement?

Figure A8.5.1

B Make a numbered list of the geologic events that contributed to the development of the geological features in this outcrop, starting with deposition of the sandstone (oldest event: 1) and ending with the time this picture was taken. Include the name(s) of relevant period(s) from the geologic time scale as well as the isotopic age of the sill in your writing. *Your reasoning and number of events may differ from those of other students.*

1.

2.

3.

4.

5.

6.

7.

8.

C **REFLECT & DISCUSS** Write a question that you have about the geologic history of this location. What geologic evidence would you need to answer the question?

Investigating a Natural Cross-Section in the Grand Canyon

Activity 8.6

Name: _____ Course/Section: _____ Date: _____

A Figure A8.6.1A is a photograph of part of the bottom of the Grand Canyon, which extends east to west across northern Arizona. The photo was taken west of Grand Canyon Village on the south rim of the Canyon, looking at the north side of the bottom of the canyon.

Carefully analyze the photograph for rock layering. The very bottom rock layers in the foreground are folded Precambrian metamorphic rock called the Vishnu Schist, which contains narrow white bodies of igneous rock. The Vishnu Schist is overlain here by relatively horizontal layers of sedimentary rock.

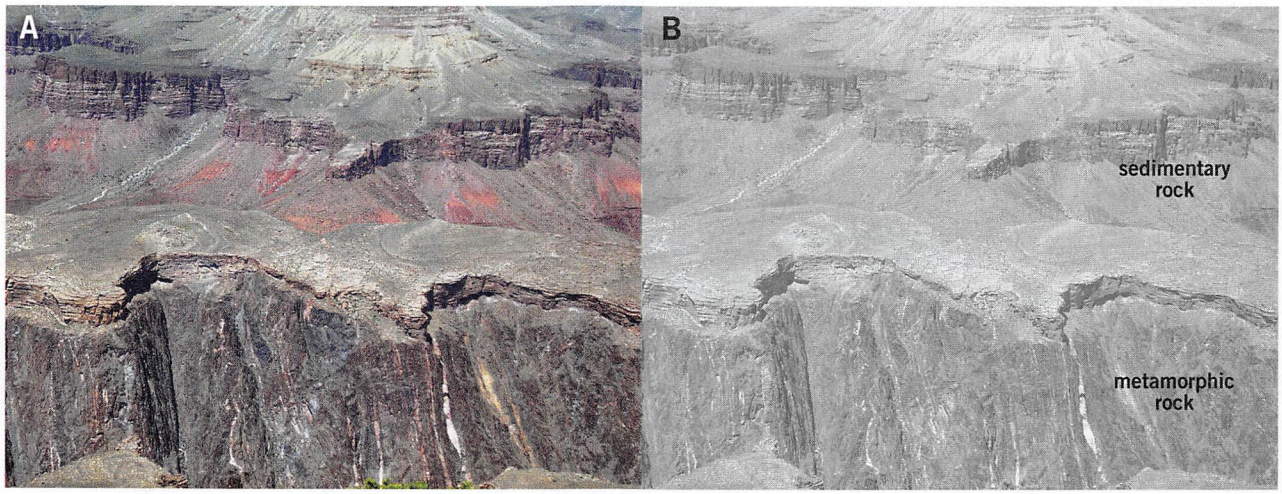


Figure A8.6.1

1. Using a pen or colored pencil on **Fig. A8.6.1B**, carefully trace the contact between the Vishnu Schist and the relatively horizontal sedimentary rocks above it.

2. Based on **Figs. 8.2–8.10**, what specific kind of unconformity occurs along the contact you just traced on **Fig. A8.6.1B**?

B **REFLECT & DISCUSS** The Vishnu Schist has a numerical age of about 1700 million years. The Lower Cambrian Tapeats Sandstone was deposited on top of the unconformity that you considered in part **A**. Imagine that you find reliable information indicating that the Tapeats Sandstone was deposited at the very start of the Cambrian Period and then how about much time is represented by the rock record that is "missing" across this unconformity—missing in the sense of erosion, nondeposition, or both prior to deposition of the Tapeats Sandstone on the erosional surface at the top of the Vishnu Schist?

C Figure A8.6.2A is another photograph of part of the bottom of the Grand Canyon. The photo was taken east of Grand Canyon Village on the south rim of the Canyon, looking at the north side of the canyon. All of the rocks in this scene are sedimentary rocks.

1. Analyze this canyon scene. Then, using a pen or colored pencil on **Fig. A8.6.2B**, carefully trace the contact that marks a significant unconformity in the photo.
2. What kind of unconformity did you identify?

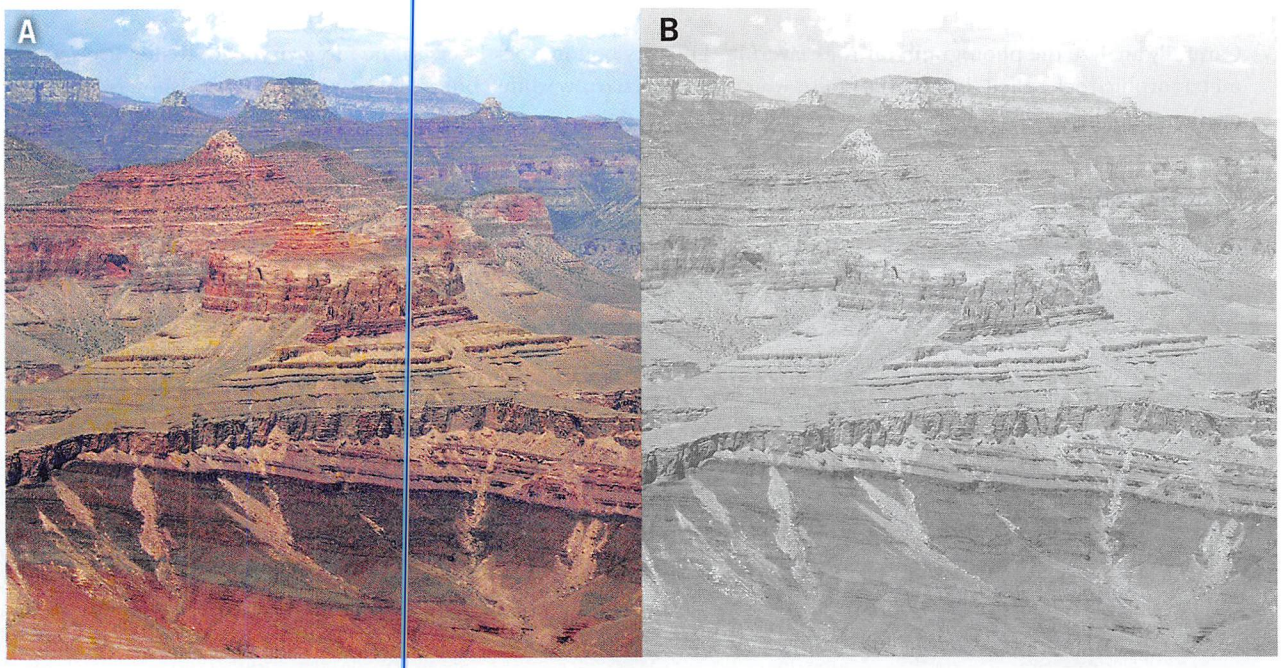


Figure A8.6.2

D **REFLECT & DISCUSS** What evidence did you apply to justify drawing an unconformity where you did on **Fig. A8.6.2B**?