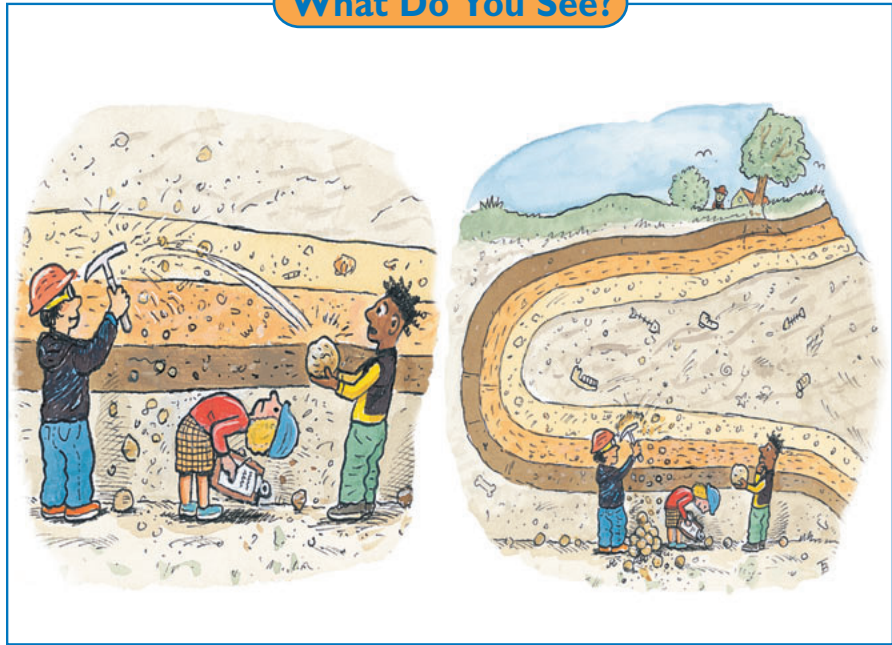




Section 7

Reading the Geologic History of Your Community

What Do You See?



Learning Outcomes

In this section, you will

- **Understand** the basic principles used to determine the relative ages of rock units.
- **Understand** the nature and significance of unconformities and their role in deciphering geologic history.
- **Interpret** the geologic history of an area using the basic geologic principles.

Think About It

Figuring out the ages of rock units relative to one another is, in a sense, similar to solving a puzzle.

- **When you are studying rocks at an outcrop in your community, and you identify two different rock units, how can you tell which is older and which is younger?**

Record your ideas about this question in your *Geo* log. Include a quick sketch. Be prepared to discuss your responses with your small group and the class.

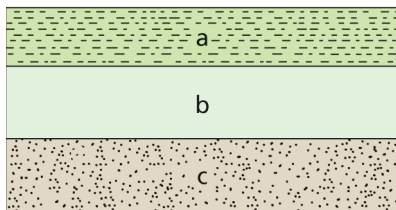
Investigate

In this *Investigate*, you will use models and cross sections to study the ages of rock layers.

Part A: Basic Geologic Principles

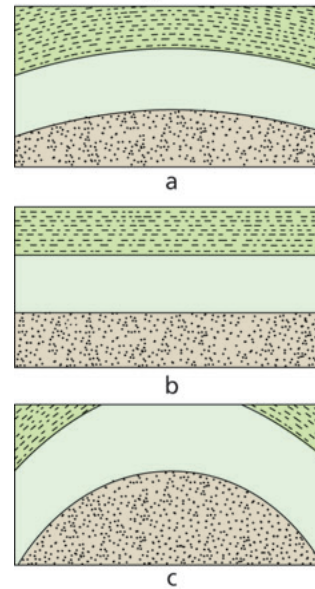
- Roll out three different colors of soft modeling clay: red, yellow, and blue. Place the red layer flat on the table. Place the yellow layer on top of it, followed by the blue layer.
- Which layer is the “oldest” (that is, has been there the longest)? Which layer is the “youngest”?
- The geologic cross section in *Figure A* shows a series of layers of sedimentary units. As you read, sedimentary rocks are laid down in layers, much like the layers of clay in *Step 1*.
- Which of the units in the cross section do you think is the oldest? Which unit do you think is the youngest? How do you know?

Figure A



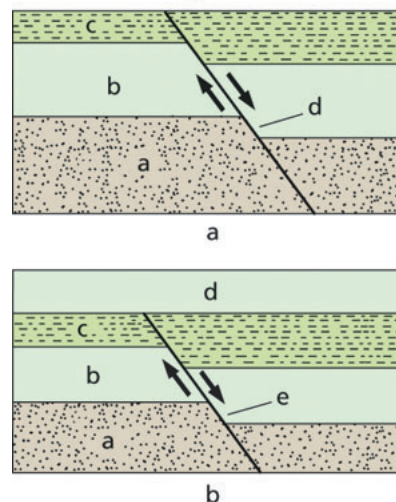
- Examine the clay layers from *Step 1*.
- Sketch a side view of what you see.
 - Now form the layers into folds, as you did in the previous section. Sketch a side view of what you see now.
 - Sedimentary and extrusive igneous rocks are originally laid down in nearly horizontal layers. Why do you think that the layers are not horizontal? Number the cross sections in *Figure B* in the order in which they would occur.

Figure B



- Flatten out the clay layers and again stack them into a block. Make a slanting cut through the block. Lift the lower side up relative to the upper side so that the red layer on the left matches up with the yellow layer on the right. Recall from *Section 6* that you have produced a normal fault.
- Sketch what you see.
 - Now, look at the two cross sections shown in *Figure C*. What is the youngest feature in each of the two cross sections? How do you know?

Figure C

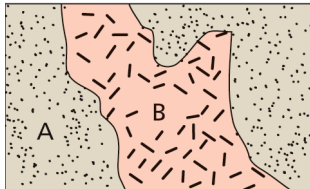




5. The geologic cross section shown in *Figure D* shows a sedimentary rock unit A and an intrusive igneous rock unit B.

- a) From what you know about how intrusive igneous rock units form, which of these units do you think is older? How do you know?

Figure D



6. The rock units in the cross section shown in *Figure E* have been assigned approximate age ranges.

- a) Are the ages continuous, or do you see any time gaps?
- b) Assume that these are sedimentary rocks that were formed as sediment was slowly deposited, layer upon layer. Can you think of an explanation for why there is a time gap in the record?

Figure E

D: 0–5 million
C: 20–35 million
B: 35–50 million
A: 50–60 million

Part B: Using the Principles to Interpret Geologic History

1. The following cross section shows several rock units in an area that has had a long and varied geologic history.

- a) Put the rock units and other geologic features marked with letters in the cross section in order of occurrence from earliest to latest. Start by asking yourself what was there first, and then work your way forward through time. You can think of this as a “geologic puzzle.”

Sedimentary Rocks

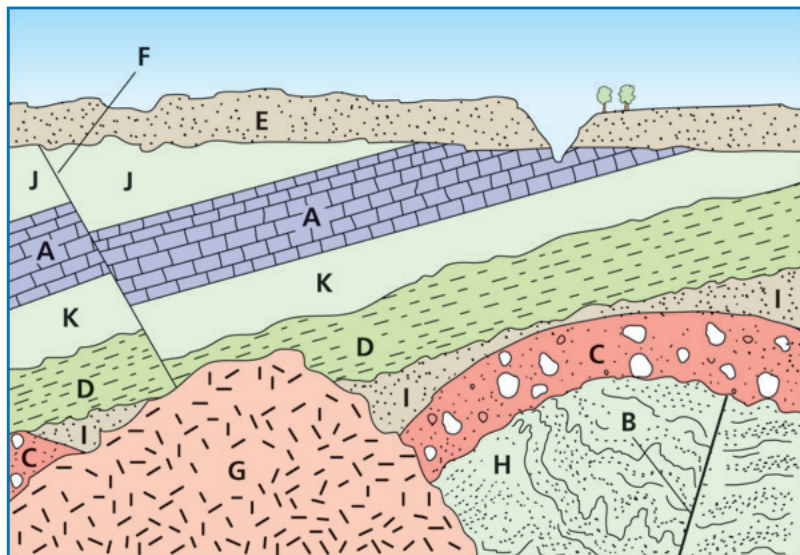
sandstone	limestone	shale
shale	conglomerate	

Igneous Rocks

granite

Metamorphic Rocks

gneiss



A simplified cross section of strata.

Digging Deeper

INTERPRETING GEOLOGIC HISTORY

Geologic Events and Processes

In the *Investigate*, you studied how scientists determine the ages of rock layers. You did this by using models and cross sections. It is important for geologists to know the age of the rock layers. Most areas of Earth's crust have a long and often complex geologic history. Many kinds of geologic events can occur. Many kinds of geologic processes can shape the geologic history of an area. You have read about many of these in previous sections. Here are some important ones: deposition, erosion, folding, faulting, uplift, subsidence, igneous intrusion, volcanism, metamorphism, changes in sea level, and climate change.

The only processes in the list above that you have not yet looked at in detail are **uplift** and **subsidence**. Local areas of Earth's crust can be slowly raised (uplift) by large-scale forces acting within Earth. They can also be lowered (subsidence). Vertical changes in elevation can range from meters to kilometers. Much of uplift and subsidence is caused by the movement of Earth's lithospheric plates. However, it can also be caused just by changes in the temperature of the rocks. When rocks cool, they contract. That causes subsidence. When rocks are heated, they expand. That causes uplift. The degree of contraction and expansion is small. However, great thicknesses of rock are affected (kilometers to tens of kilometers). As a result, uplift and subsidence of Earth's surface caused in this way can amount to hundreds of meters.

Basic Geologic Principles

Geologists make geologic maps of areas of bedrock. The surface geology shown in these maps comes from data gathered from a variety of sources. These include topographic maps, satellite images, and bore holes. Rocks in the field also provide data. A geologic map contains one or more cross sections. These are constructed by projecting the rock units and other geologic features seen at the surface downward into Earth. To do this, geologists must measure the angles that rock units and structures dip into Earth. The geologic map is a description of the bedrock. Geologists then use the map to interpret the area's geologic history.



Figure 1 In a series of rock layers, the oldest rocks are usually found on the bottom while the youngest rocks are on the top.

Geo Words

uplift: the process by which local areas of Earth's crust can be slowly raised by large-scale forces acting within Earth or the heating of rocks.

subsidence: the process by which local areas of Earth's crust can be slowly lowered by large-scale forces acting within Earth or the cooling of rocks.





Geo Words

stratigraphy: the scientific study of rock layers (called strata).

The scientific study of rock layers is called **stratigraphy**. This involves the application of several basic principles, which follow. Some of these principles might seem like “common sense” to you. In a way, they are. However, when they were first developed long ago, they were revolutionary. They advanced how early geologists thought about the geologic record. They provide powerful tools for analyzing the relative ages of rock layers and structures.

- **Principle of Superposition:** Younger sedimentary and volcanic rocks are deposited on top of older rocks, as shown in *Figure 1* on the previous page.
- **Principle of Original Horizontality:** Sedimentary and volcanic rocks are laid down in nearly horizontal layers.
- **Principle of Lateral Continuity:** Sedimentary and volcanic rocks are laid down in layers that are usually much greater in lateral extent than in thickness.
- **Principle of Crosscutting Relationships:** If one rock unit or geologic feature cuts across another rock unit or geologic feature, it was formed later in geologic time. Here are two examples of this principle. If you see a rock unit cut by an igneous intrusion, such as a dike, you can be sure that the dike is younger than the rock unit. (See *Figure 2*.) If you see one or more rock units cut by a fault, then you know that the fault is younger than the rock units. (See *Figure 3*.)

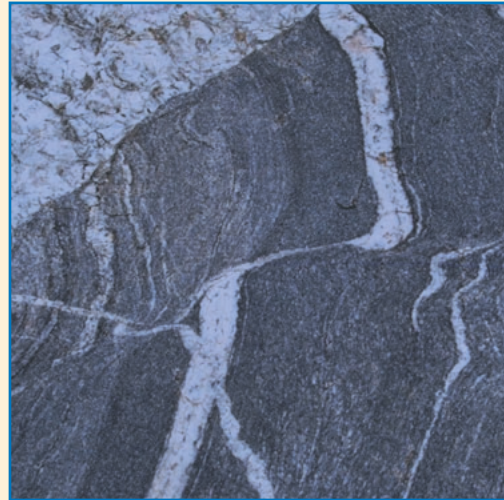


Figure 2 Which rock unit shown in the photograph is the youngest?

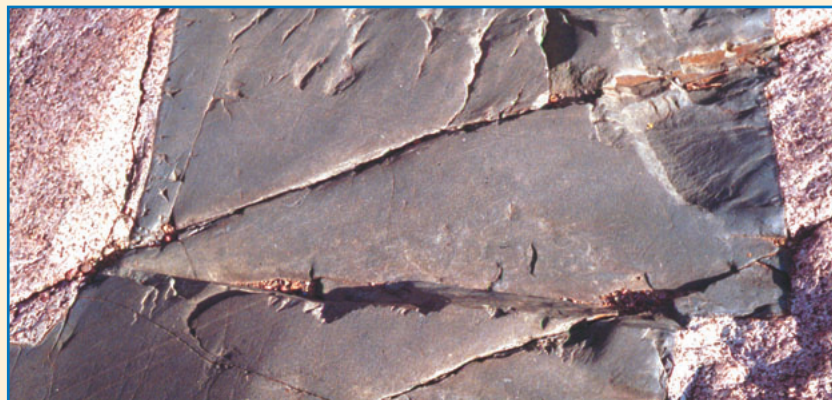


Figure 3 After intruding into the surrounding granite, this dike was offset by a fault.

Unconformities

There is another important concept to think about when trying to interpret the geologic history of an area. **Successions** of sedimentary and volcanic rocks are deposited on an earlier rock surface. The contact between that earlier rock and the younger layers is called an **unconformity**. It is important to note that for some period time, nothing except perhaps erosion was occurring on this surface. Some period of geologic time was not recorded at the surface. The “missing” time might be as short as thousands of years. However, it is usually much longer. It can be hundreds of thousands to many millions of years long. At some unconformities, more than a billion years of Earth history is not recorded.

Figures 4a–b show two common kinds of unconformity. In *Figure 4a*, younger sedimentary rock is resting on an older one. The older one was folded. Then it eroded down. This occurred before conditions changed and more sediment was deposited. In *Figure 4b*, a younger sedimentary succession is resting on an intrusive body of granite. The granite was placed deep in Earth. Erosion later wore down the land surface to the level of the granite intrusion. Then conditions changed for some reason. Sediment was deposited on the previously eroded surface. These examples show that an unconformity can be very helpful in interpreting geologic history.



Figure 4a An unconformity in which the older, underlying rocks are at a different angle than the younger, overlying rocks is called an angular unconformity.



Figure 4b An unconformity developed when older igneous rocks were exposed to erosion before sedimentary rocks covered them is called a nonconformity.

Geo Words

succession: a number of rock units or a mass of strata that succeed one another in chronological order; the chronological order of rock units.

unconformity: the contact between an earlier rock and younger sedimentary and/or volcanic layers.



Geo Words

principle of faunal succession: the kinds of animals and plants found as fossils change through time. When the same kinds of fossils in rocks are found from different places, the rocks are the same age.

The Use of Fossils in Dating Geologic Successions

As you have read, fossils represent the remains of once-living organisms. Most fossils are the remains of organisms that are extinct. This means that they are no longer living anywhere on Earth. Fossil records help to mark the divisions within the geologic time scale. These divisions are largely based on the appearance and disappearance of specific species of fossils.

Scientists use fossils to find information about the ages of rocks. To help them do this, they have developed the **principle of faunal succession**. This states that because life on Earth has changed through time, the kinds of fossils found in rocks of different ages will also differ. This means that when the same kinds of fossils are found in rocks from different places, then those rocks are the same age. Therefore, if the age range of fossils contained in a rock are known then the age of that rock can be determined.

Cenozoic Era (Age of Recent Life)	Quaternary Period	<i>Pecten gibbus</i>		<i>Neptunea tabulata</i>	
	Tertiary Period	<i>Calyptrophorus velatus</i>		<i>Venericardia planicosta</i>	
Mesozoic Era (Age of Medieval Life)	Cretaceous Period	<i>Scaphites hippocrepis</i>		<i>Inoceramus labiatus</i>	
	Jurassic Period	<i>Perisphinctes tiziani</i>		<i>Nerinea trinodosa</i>	
	Triassic Period	<i>Trophites subbullatus</i>		<i>Monotis subcircularis</i>	
Paleozoic Era (Age of Ancient Life)	Permian Period	<i>Leptodus americanus</i>		<i>Parafusulina bosei</i>	
	Pennsylvanian Period	<i>Dictyoclostus americanus</i>		<i>Lophophyllidium proliferum</i>	
	Mississippian Period	<i>Cactocrinus multibrachiatus</i>		<i>Prolecanites gurleyi</i>	
	Devonian Period	<i>Mucrospirifer mucronatus</i>		<i>Palmatolepus unicornis</i>	
	Silurian Period	<i>Cystiphyllum niagarensis</i>		<i>Hexamoceras hertzeri</i>	
	Ordovician Period	<i>Bathyrus extans</i>		<i>Tetragraptus fruticosus</i>	
	Cambrian Period	<i>Paradoxides pinus</i>		<i>Billingsella corrugata</i>	
Precambrian	-----				

Figure 5 Species of mollusks used as index fossils to identify specific periods of geologic time.

Fossils that lived for narrow time spans are very important. They can be used to indicate very specific periods in geologic time. These are known as **index fossils**. Examples of index fossils are shown in *Figure 5*. The presence of a key index fossil in a rock reveals the date of the rock. For example, the trilobite *Paradoxides pinus* indicates that a rock was deposited between the Ordovician and Cambrian Periods.

Most often, rocks contain several fossils without an index fossil. In that case, scientists look at the overlap in the age ranges of the fossils. They try to find the period when all the fossils existed at the same time. In this way, they are able to narrow down the ages of these rocks. This approach to finding the relative ages of rocks is called **biostratigraphy**. *Figure 6* shows the history of five fossils. It illustrates how biostratigraphy is used to determine the age ranges of three fossil-bearing rocks.

Geo Words

index fossil: a fossil with narrow age range and a wide distribution that can be used to date rocks.

biostratigraphy: the study of and differentiation of rock units based on the fossils they contain.

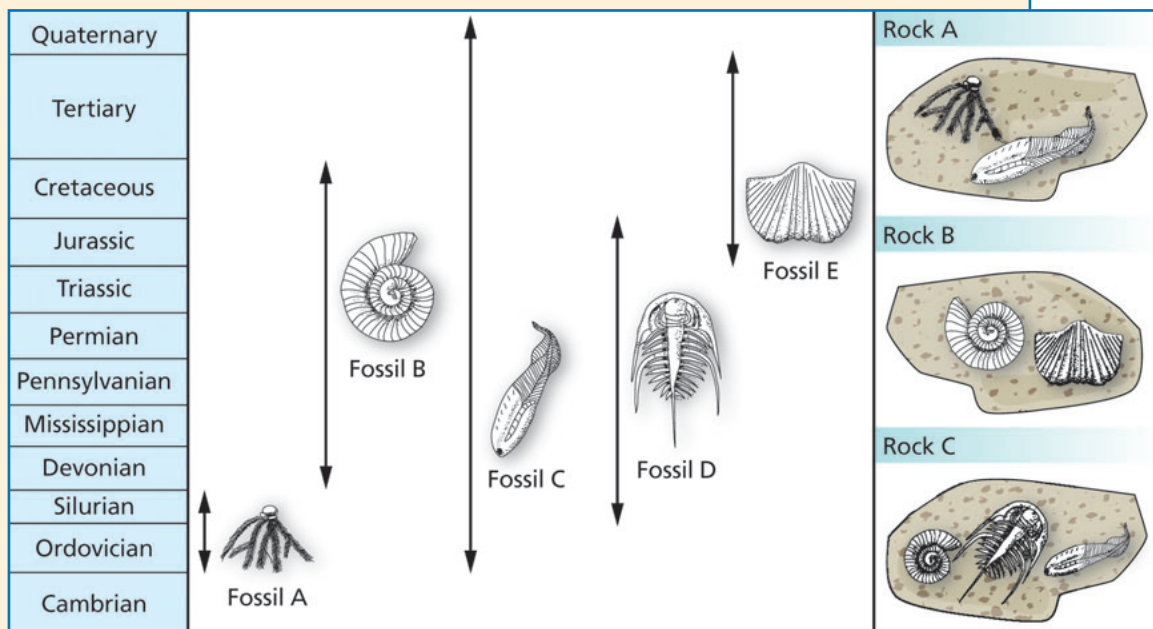


Figure 6 A hypothetical example of the age ranges of five fossils. The ranges are: Fossil A is Silurian to Ordovician; Fossil B is Cretaceous to Devonian; Fossil C is Quaternary to Ordovician; Fossil D is Jurassic to Silurian; and Fossil E is Tertiary to Jurassic. The age ranges of the rocks are: Rock A is Silurian to Ordovician; Rock B is Cretaceous to Jurassic; and Rock C is Jurassic to Devonian.

Species that make good index fossils have the following characteristics:

- well preserved so they are easy to find
- distinctive body shapes that make them easy to recognize
- large populations so they are abundant
- a widespread distribution that allows for distant locations to be compared
- existing for relatively short periods of time that indicate precise ages





Index fossils are often from animal species that had hard, exterior bodies. Also, the best index fossils are from animals that lived mainly on or near the seafloor. The water would also need to be quite calm. For these reasons, the most common index fossils are marine mollusks. *Figure 5* shows many of the different kinds of mollusks used to identify the ages of rock layers. For example, in sedimentary rocks from the Jurassic and Triassic Periods, the flat spiraled shells of ammonites are common. They evolved very rapidly. They could also be found throughout the oceans during these periods. As a result, they are very useful for comparing the ages of rocks on all the continents. Earlier than the Paleozoic Era, the trilobites achieved similar success. They are an index fossil for sedimentary layers dating back to 520 million years.

Fossils can be used to find the relative age of the rock layers in which they occur. Then the age can be correlated to other sequences containing similar layers. Following this approach, a longer sequence can be constructed from many smaller sequences. Look at *Figure 7*. The oldest rocks in Outcrop B appear at its base. The mollusks they contain are the same age as those at the top of Outcrop A. Therefore, the lower layers in Outcrop A may provide insight into the geologic history below the oldest layer of Outcrop B. On the other hand, Outcrop C can be correlated to the top of Outcrop B. It reveals a younger part of the stratigraphic column.

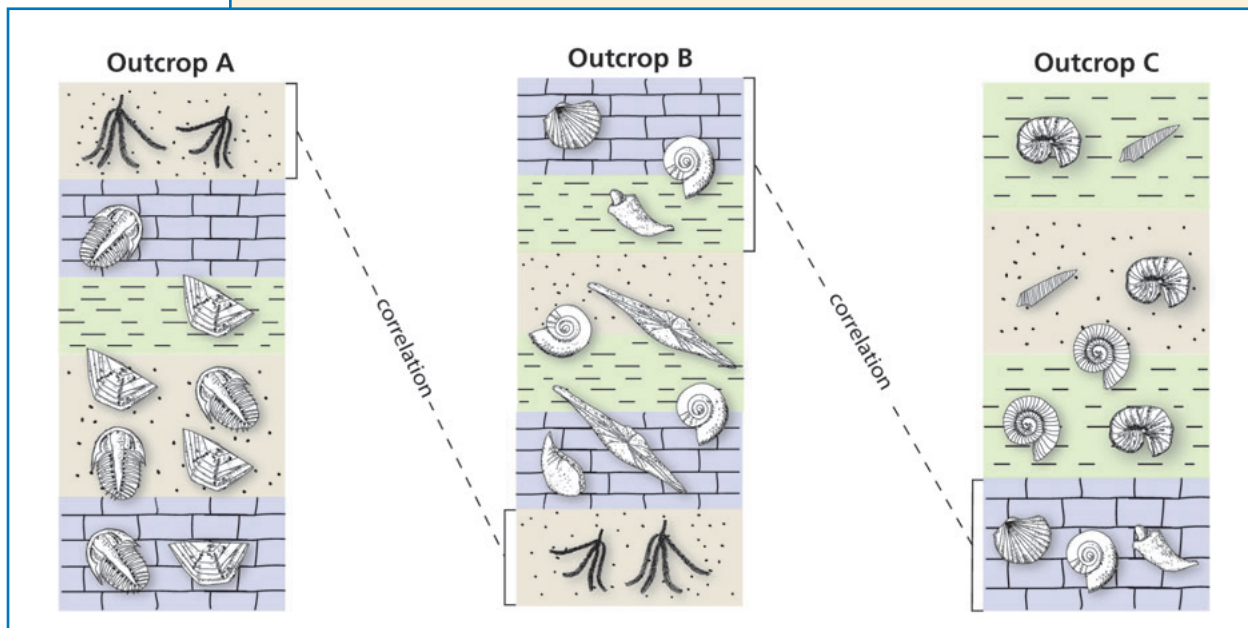


Figure 7 Biostratigraphic correlation of rock layers from different places using the ages of fossils found within the layers.

There are a number of different reasons scientists want to know the age of rocks. For instance, this information is used to predict the locations of coal and minerals. It is also used to reconstruct the geologic history of an area. For example, scientists have correlated rock layers in Chesapeake Bay on the mid-Atlantic coast. This has helped them determine how this bay was formed. They determined that 35 million years ago a meteorite hit the area. (See *Figure 8*.) It created a massive impact crater. They found that before the impact, sedimentary layers extended laterally for long distances. After the impact, these sedimentary layers were disrupted. (See *Figure 9*.) They were disrupted by several faults along the rim of the crater. Using index fossils, they observed that along these faults, younger layers were moved against older layers in the sequence. The main impact structure is now buried beneath sediments in the bay.



Figure 8 The meteorite impact site that formed the Chesapeake Bay.

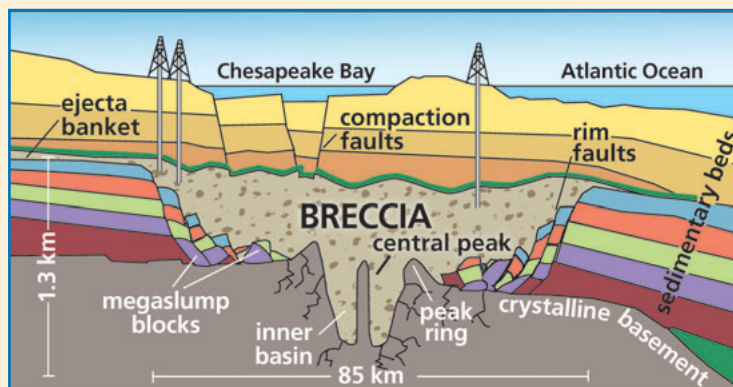


Figure 9 Faults along the rim of the crater disrupted the sedimentary beds. The original stratigraphic sequence was reconstructed using fossils.

Checking Up

1. What causes uplift and subsidence?
2. How do unconformities form?
3. Define and explain two of the major principles used by geologists to interpret the rock record.
4. What is an index fossil?



Think About It Again

At the beginning of this section, you were asked the following:

- When you are studying rocks at an outcrop in your community, and you identify two different rock units, how can you tell which is older and which is younger?

Record your ideas about this question now. Be sure your answer includes the basic principles used to determine the relative ages of rock units.

Reflecting on the Section and the Challenge

In the *Investigate* and in the *Digging Deeper*, you read about how geologists can use the relationships of rock units and geologic features, such as folds or faults, to interpret an area's geologic history. You then applied basic principles to interpret the history of a geologically complex cross section. These are important concepts and skills to communicate in your museum exhibit. You will need to help your exhibit visitors apply the basic principles of relative geologic time so that they can understand the geologic history of your local area and region.

Understanding and Applying

1. Can you think of a situation in which the Principle of Superposition does not work (that is, when the oldest rocks are on top)?
2. Can the Principle of Original Horizontality be applied to metamorphic rocks? Explain your answer.
3. Examine your state geologic map and geologic cross sections.
 - a) Which rock unit near your community is the oldest? Use the legend on the map and the geologic time scale on the next page to estimate an age range for this rock.
 - b) Which rock unit near your community is the youngest? Use the legend and the geologic time scale to estimate an age range for this rock.
 - c) If there are any faults or folds in your area, when did they occur relative to the surrounding rocks?
 - d) Is there evidence for any unconformities near your community? If so, use the legend and geologic time scale to estimate the length of time that is not recorded.
4. Why are index fossils useful for the study of sedimentary layers of the same rock type on either side of a suspected fault or unconformity?
5. Examine *Figure 6* from the *Digging Deeper*. Give a relative age range for a rock that contains fossils B, C, D, and E.
6. *Preparing for the Chapter Challenge*

To help prepare your museum exhibit, use the techniques that you have learned to prepare a chronological list (oldest to youngest) of geologic events that have occurred in your local area and in your region. Be sure to include the order in which rocks formed, as well as when events such as folding or faulting may have occurred.

Remember to ask yourself the question: “What was there first?” Think about how you could display this graphically in your exhibit so that it catches visitors’ eyes and makes them want to know more.

Eon	Era	Period	Epoch	Million Years Ago	
Phanerozoic	Cenozoic	Quaternary	Holocene	0.01	
			Pleistocene	Late 0.8 Early 1.8	
		Tertiary	Neogene	Pliocene	Late 3.6 Early 5.3
				Miocene	Late 11.2 Middle 16.4 Early 23.0
					Oligocene
				Paleogene	
			Paleocene		Late 61.0 Early 65.5
				Mesozoic	Cretaceous
			Jurassic		
					Triassic
		Permian	Late 256 Early 299		
			Pennsylvanian		318
		Mississippian	359		
		Paleozoic	Devonian		Late 370 Middle 391 Early 416
	Silurian				Late 423 Early 444
					Ordovician
	Cambrian		D 488 C 500 B 512 A 520		
			542		
			Precambrian	Late 900	
				Middle 1600	
	Early 2500				
	Archean		Late 3000		
			Middle 3400		
		Early 3800?			

Inquiring Further

1. Dating techniques

In this section, you have read about how to tell the relative age of rocks from their relationships to each other. Geologists also use other techniques to determine the ages of rocks. Research radiometric dating and describe how it is used and how it differs from the techniques that you learned in this section. Be sure to cite the sources you used in your research and discuss how you evaluated their reliability.