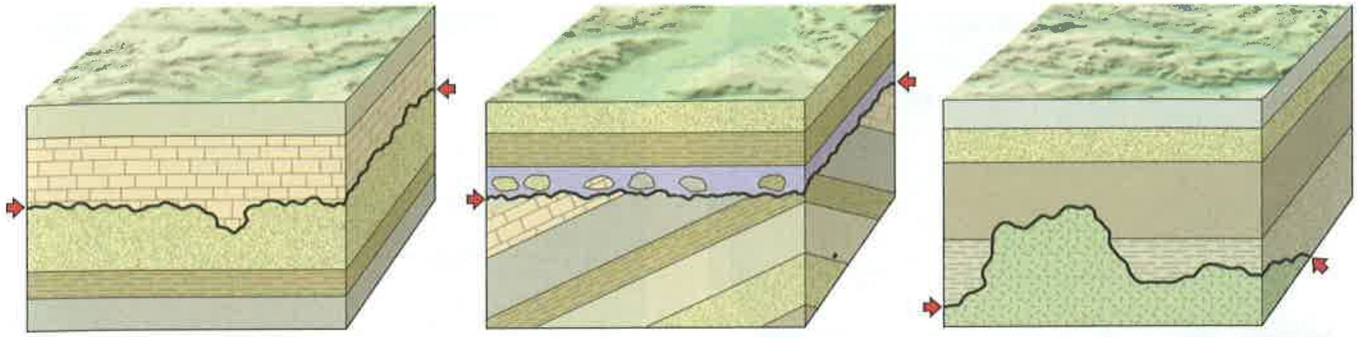


Disconformity
In a succession of rock layers (sedimentary strata or lava flows) parallel to one another, the disconformity surface is a gap in the layering. The gap may be a non-depositional surface where some layers never formed for a while, or the gap may be an erosional surface where some layers were removed before younger layers covered up the surface.

Angular unconformity
An angular unconformity is an erosional surface between two bodies of layered sedimentary strata or lava flows that are not parallel. The gap is because the older body of layered rock was tilted and partly eroded (rock was removed) before a younger body of horizontal rock layers covered the eroded surface.

Nonconformity
A nonconformity is an erosional surface between older igneous and/or metamorphic rocks and younger rock layers (sedimentary strata or lava flows). The gap is because some of the older igneous and/or metamorphic rocks were partly eroded (rock was removed) before the younger rock layers covered the eroded surface.

FIGURE 8.1 Three kinds of unconformities. Unconformities are surfaces that represent gaps (missing layers) in the geologic record; analogous to a gap (place where pages are missing) in a book. Red arrows point to the unconformity surface (bold black line) in each block diagram.

Laws for Determining Relative Age

Geologists use six basic laws for determining relative age relationships among bodies of rock based on their physical relationships. They are as follows:

- **Law of Original Horizontality**—*Sedimentary layers (**strata**) and lava flows were originally deposited as relatively horizontal sheets, like a layer cake.* If they are no longer horizontal or flat, it is because they have been displaced by subsequent movements of Earth's crust.
- **Law of Lateral Continuity**—*Lava flows and strata extend laterally in all directions until they thin to nothing (pinch out) or reach the edge of their basin of deposition.*
- **Law of Superposition**—*In an undisturbed sequence of strata or lava flows, the oldest layer is at the bottom of the sequence and the youngest is at the top.*
- **Law of Inclusions**—*Any piece of rock (clast) that has become included in another rock or body of sediment must be older than the rock or sediment into which it has been incorporated.* Such a clast (usually a rock fragment, crystal, or fossil) is called an **inclusion.** The surrounding body of rock is called the **matrix** (or groundmass). Thus, an inclusion is older than its surrounding matrix.
- **Law of Cross Cutting**—*Any feature that cuts across a rock or body of sediment must be younger than the rock or sediment that it cuts across.* Such cross cutting features include fractures (cracks in rock), faults (fractures along which movement has occurred), or masses of magma (*igneous intrusions*) that cut across preexisting rocks before they cooled. When a body of magma intrudes preexisting rocks, a narrow *zone of contact metamorphism* usually forms in the preexisting rocks adjacent to the intrusion.

Unconformities

Surfaces called **unconformities** represent gaps in the geologic record that formed wherever layers were not deposited for a time or else layers were removed by erosion. Most contacts between adjacent strata or formations are *conformities*, meaning that rocks on both sides of them formed at about the same time. An unconformity is a rock surface that represents a gap in the geologic record. It is like the place where pages are missing from a book. An unconformity can be a buried surface where there was a pause in sedimentation, a time between two lava flows, or a surface that was eroded before more sediment was deposited on top of it.

There are three kinds (FIGURE 8.1). A **disconformity** is an unconformity between *parallel* strata or lava flows. Most disconformities are very irregular surfaces, and pieces of the underlying rock are often included in the strata above them. An **angular unconformity** is an unconformity between two sets of strata that are not parallel to one another. It forms when new horizontal layers cover up older layers folded by mountain-building processes and eroded down to a nearly level surface. A **nonconformity** is an unconformity between younger sedimentary rocks and subjacent metamorphic or igneous rocks. It forms when stratified sedimentary rocks or lava flows are deposited on eroded igneous or metamorphic rocks.

Relative Age Dating Examples

Analyze and evaluate FIGURES 8.2–8.9 to learn how the above laws of relative age dating are applied in cross sections of Earth's crust. These are the kinds of two-dimensional cross sections of Earth's crust that are exposed in road cuts, quarry walls, and mountain sides. *Be sure that you consider all of these examples before proceeding.*

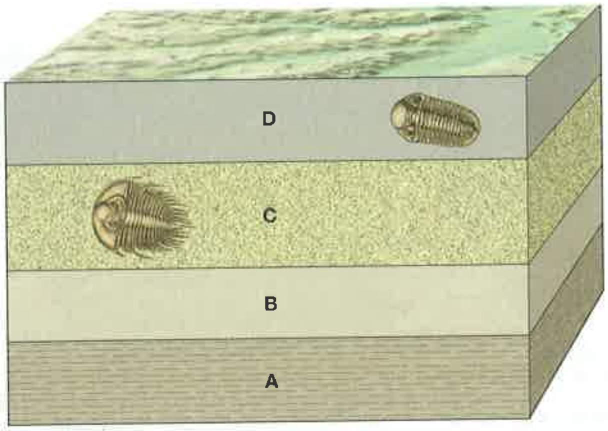


FIGURE 8.2 Law of superposition in horizontal strata. This is a sequence of strata that has maintained its original horizontality and does not seem to be disturbed. Therefore, Formation **A** is the oldest, because it is on the bottom of a sedimentary sequence of rocks. **D** is the youngest, because it is at the top of the sedimentary sequence. The sequence of events was deposition of **A, B, C,** and **D,** in that order and stacked one atop the other.

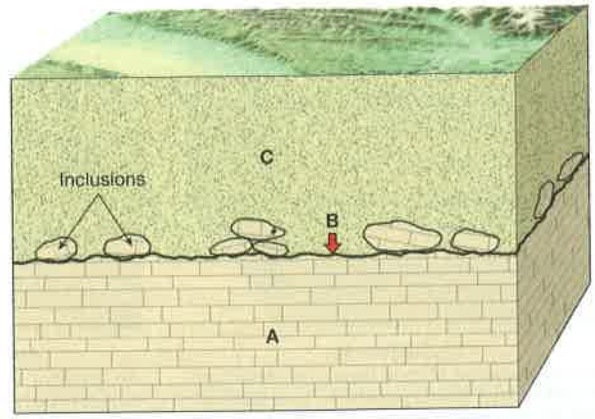


FIGURE 8.3 Inclusions on a disconformity. These strata are all horizontal. Limestone **A** is older, because it is on the bottom of a sequence of strata. Sandstone **C** is younger, because it is on top of the limestone and has inclusions (fragments of older rock) of the older limestone. Contact **C** is unconformable, because some of the limestone layers were eroded (making a gap in the rock layers) and became inclusions in the overlying sandstone. An unconformity between parallel strata, like this one, is a disconformity.

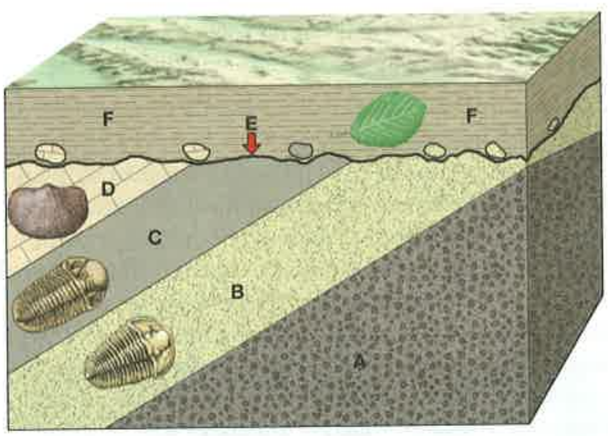


FIGURE 8.4 Angular unconformity. This is another sequence of strata, some of which do not have their original horizontality. Formation **A** is the oldest, because it is at the bottom of the sedimentary sequence. Formation **F** is youngest, because it forms the top of the sequence. Tilting and erosion of the sequence occurred after **D** but before deposition of Formation **F. E** is an angular unconformity.

The sequence of events began with deposition of **A, B, C,** and **D,** in that order and stacked one atop the other. The sequence of **A–D** was then tilted, and its top was eroded **(E)**. Siltstone **F** was deposited horizontally on top of the erosional surface **(E),** which is now an angular unconformity.

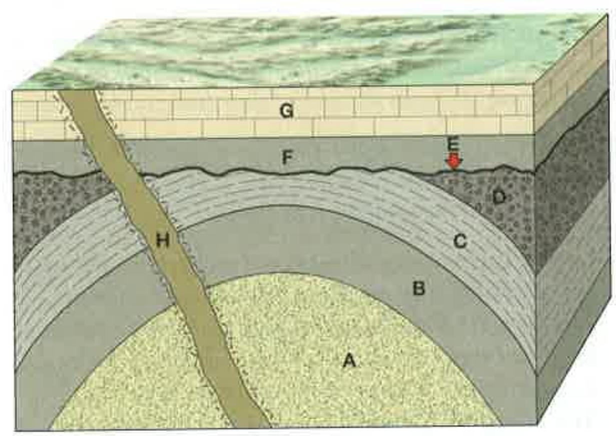
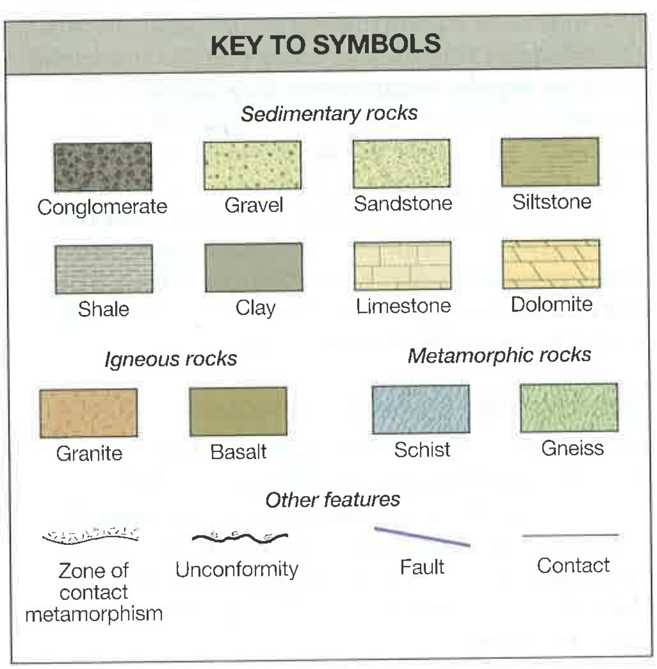


FIGURE 8.5 Law of cross-cutting. The body of igneous rock **H** is the youngest rock unit, because it cuts across all of the others. (When a narrow body of igneous rock cuts across strata in this way, it is called a **dike.**) **A** is the oldest formation because it is at the bottom of the sedimentary rock sequence that is cut by **H.** Folding and erosion occurred after **D** was deposited, but before **F** was deposited. **E** is an angular unconformity.

The sequence of events began with deposition of formations **A** through **D** in alphabetical order and one atop the other. That sequence was folded, and the top of the fold was eroded. Formation **F** was deposited horizontally atop the folded sequence and the erosional surface, which became angular unconformity **E. G** was deposited atop **F.** Lastly, a magma intruded across all of the strata and cooled to form basalt dike **H.**



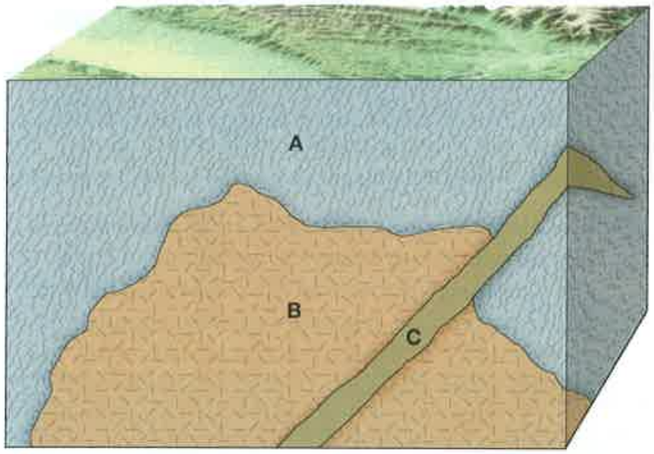


FIGURE 8.6 Igneous intrusions and cross-cutting. The body of granite **B** must have formed from the cooling of a body of magma that intruded the preexisting rock **A,** called **country rock.** The country rock is schist **A** containing a zone of contact metamorphism adjacent to the granite. Therefore, the sequence of events began with a body of country rock **A.** The country rock was intruded by a body of magma, which caused development of a zone of contact metamorphism and cooled to form granite **B.** Lastly, another body of magma intruded across both **A** and **B.** It caused development of a second zone of contact metamorphism and cooled to form basalt dike **C.**

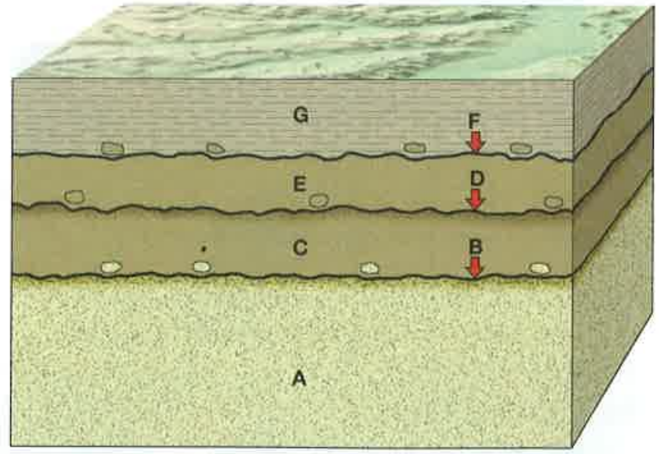


FIGURE 8.8 Disconformities. Notice that this is a sequence of strata and basalt lava flows (that have cooled to form the basalt). There are zones of contact metamorphism beneath both of the basalt lava flows **(C, E).** The sequence of events must have begun with deposition of sandstone **A,** because it is on the bottom. A lava flow was deposited atop **A** and cooled to form basalt **C.** This first lava flow caused development of the zone of contact metamorphism in **A** and the development of disconformity **B.** A second lava flow was deposited atop **C** and cooled to form basalt **E.** This lava flow caused the development of a zone of contact metamorphism and a disconformity **D.** An erosional surface developed atop **E,** and the surface became a disconformity **F** when shale **G** was deposited on top of it.

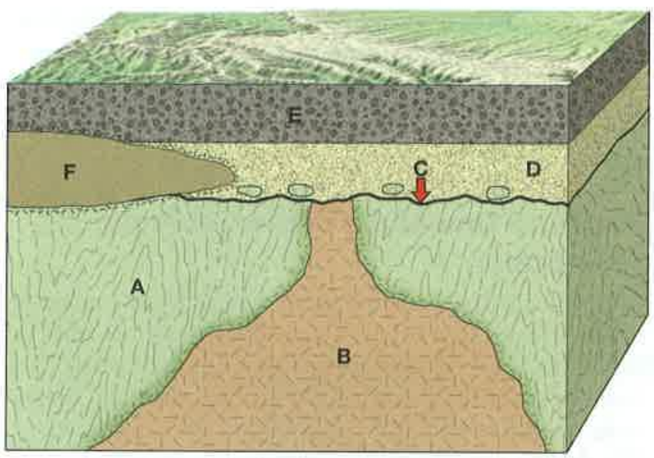


FIGURE 8.7 Nonconformity. At the base of this rock sequence there is gneiss **A,** which is separated from granite **B** by a zone of contact metamorphism. This suggests that a body of magma intruded **A,** then cooled to form the contact zone and granite **B.** There must have been erosion of both **A** and **B** *after* this intrusion (to form surface **C**), because there is no contact metamorphism between **B** and **D.** Formation **D** was deposited horizontally atop the eroded igneous and metamorphic rocks, forming nonconformity **C.** After **E** was deposited, a second body of magma **F** intruded across **A, C, D,** and **E.** Such an intrusive igneous body that is intruded along (parallel to) the strata is called a **sill (F).**

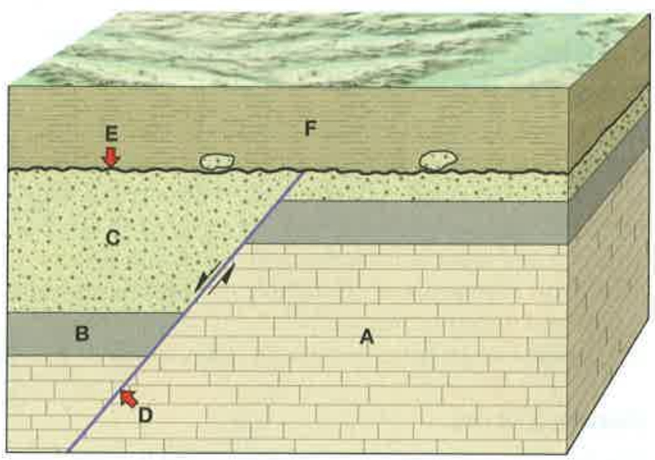


FIGURE 8.9 Cross-cutting by a fault. This is a sequence of relatively horizontal strata: **A, B, C,** and **F. A** must be the oldest of these formations because it is on the bottom. **F** is the youngest of these formations because it is on top. Formations **A, B,** and **C** are cut by a fault, which does not cut **F.** This means that the fault **D** must be younger than **C** and older than **F. E** is a disconformity. The sequence of events began with deposition of formations **A, B,** and **C,** in that order and one atop the other. This sequence was then cut by fault **D.** After faulting, the land surface was eroded. When siltstone **F** was deposited on the erosional surface, it became disconformity **E.**

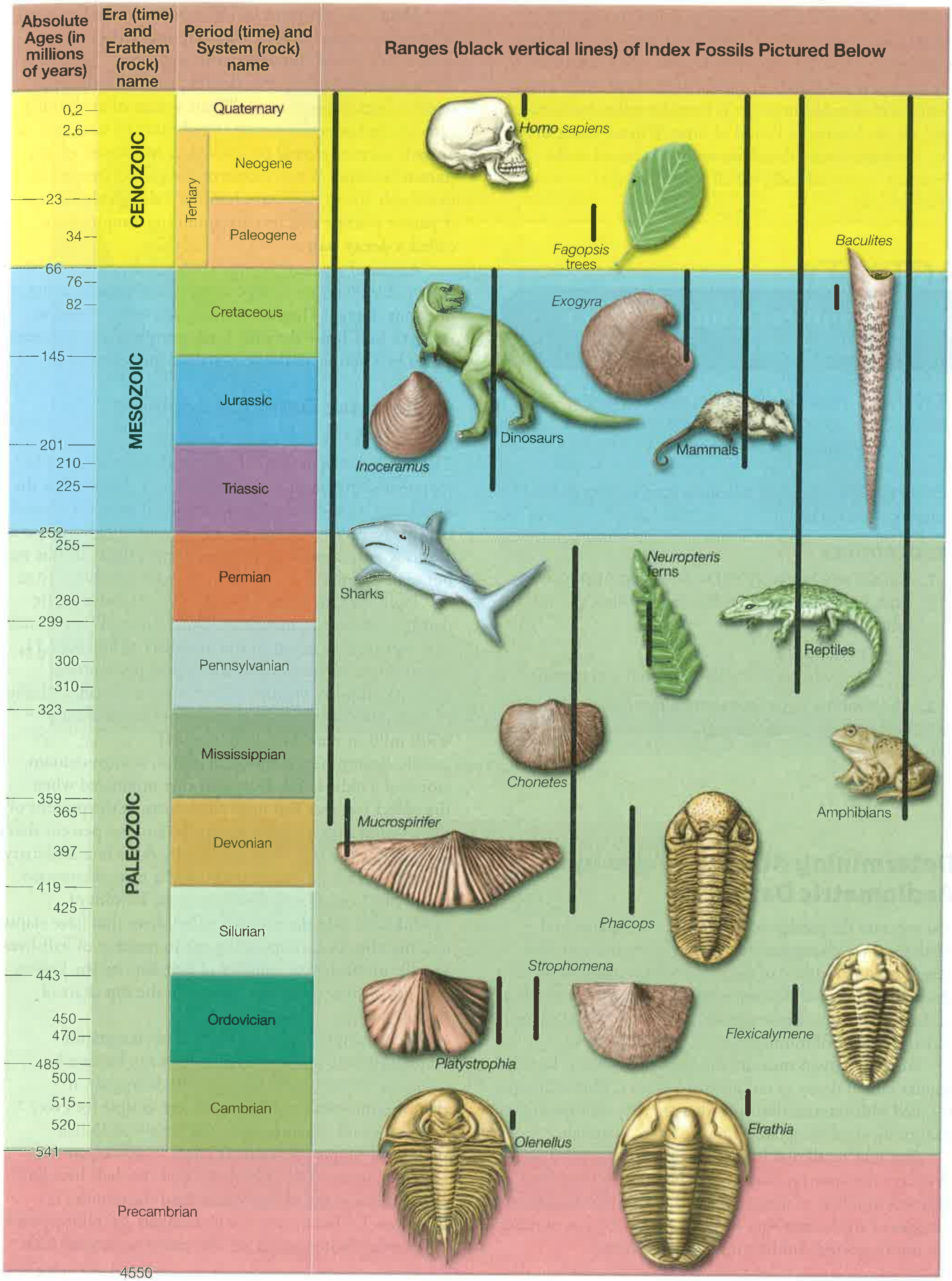
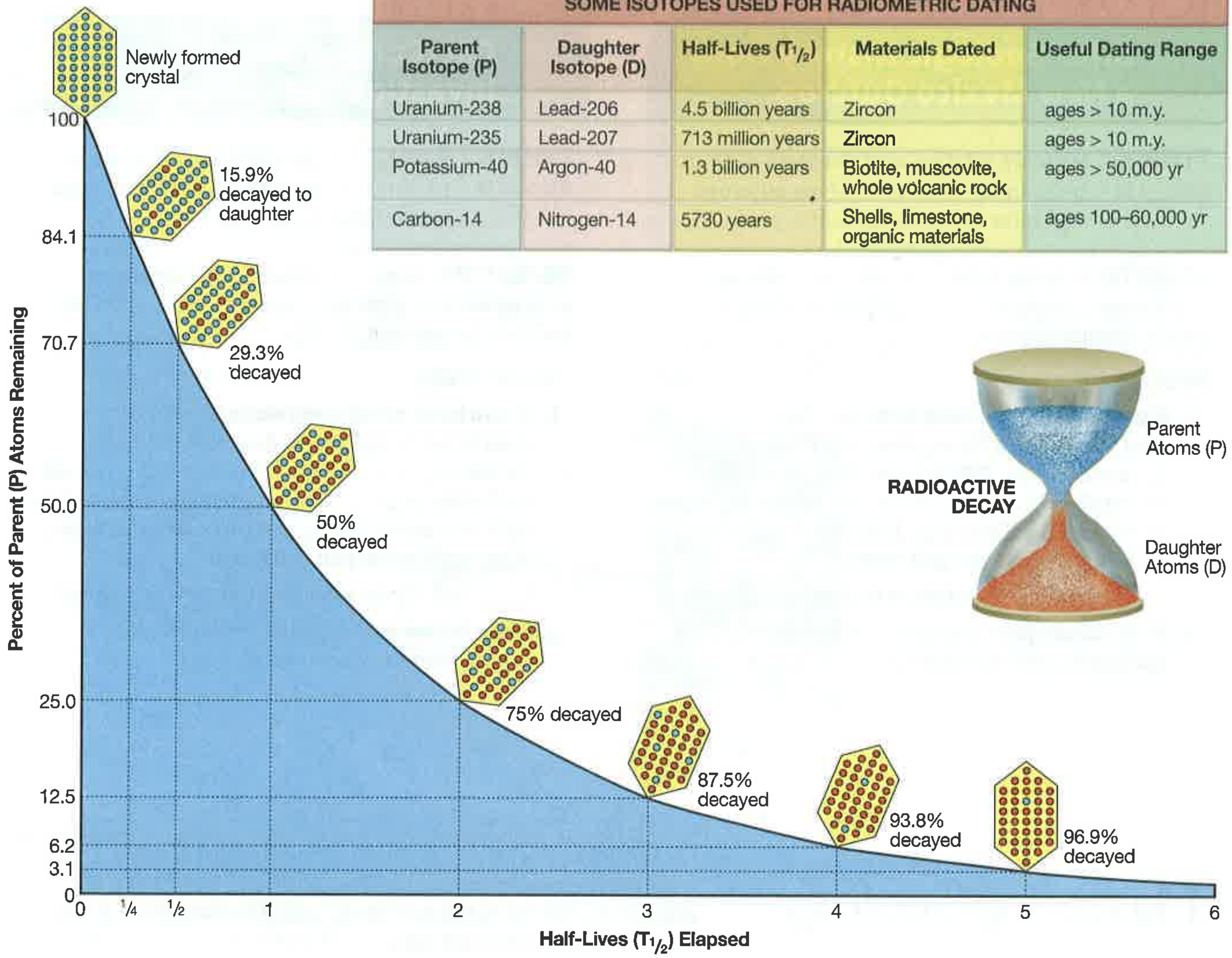


FIGURE 8.10 Range zones. Range zones (vertical bold black lines) of some well-known index fossils relative to named divisions of the geologic time scale.

SOME ISOTOPES USED FOR RADIOMETRIC DATING				
Parent Isotope (P)	**Daughter Isotope (D)**	**Half-Lives ($T_{1/2}$)**	**Materials Dated**	**Useful Dating Range**
Uranium-238	Lead-206	4.5 billion years	Zircon	ages > 10 m.y.
Uranium-235	Lead-207	713 million years	Zircon	ages > 10 m.y.
Potassium-40	Argon-40	1.3 billion years	Biotite, muscovite, whole volcanic rock	ages > 50,000 yr
Carbon-14	Nitrogen-14	5730 years	Shells, limestone, organic materials	ages 100–60,000 yr



DECAY PARAMETERS FOR ALL RADIOACTIVE DECAY PAIRS			
Percent of Parent Atoms (P)	**Percent of Daughter Atoms (D)**	**Half-Lives Elapsed**	**Age**
100.0	0.0	0	$0.000 \times T_{1/2}$
98.9	1.1	1/64	$0.015 \times T_{1/2}$
97.9	2.1	1/32	$0.031 \times T_{1/2}$
95.8	4.2	1/16	$0.062 \times T_{1/2}$
91.7	8.3	1/8	$0.125 \times T_{1/2}$
84.1	15.9	1/4	$0.250 \times T_{1/2}$
70.7	29.3	1/2	$0.500 \times T_{1/2}$
50.0	50.0	1	$1.000 \times T_{1/2}$
35.4	64.6	1½	$1.500 \times T_{1/2}$
25.0	75.0	2	$2.000 \times T_{1/2}$
12.5	87.5	3	$3.000 \times T_{1/2}$
6.2	93.8	4	$4.000 \times T_{1/2}$
3.1	96.9	5	$5.000 \times T_{1/2}$

FIGURE 8.11 Radiometric dating. Some isotopes useful for radiometric dating, their decay parameters, and their useful ranges for dating. The half-life of each decay pair is different (top chart), but the graph and decay parameters (bottom charts) are the same for all decay pairs.