# Chapter 19

# Geological Time

In 1788, after many years of geological study, James Hutton, one of the great pioneers of geology, wrote the following about the age of Earth: *The result, therefore, of our present enquiry is, that we find no vestige of a beginning — no prospect of an end*.1 Of course he wasn’t exactly correct, there was a beginning and there will be an end to Earth, but what he was trying to express is that geological time is so vast that we humans, who typically live for less than a century, have no means of appreciating how much geological time there is. Hutton didn’t even try to assign an age to Earth, but we now know that it is approximately 4,570 million years old. Using the scientific notation for geological time, that is 4,570 **Ma** (for *mega annum* or “millions of years”) or 4.57 **Ga** (for *giga annum* or billions of years). More recent dates can be expressed in **ka** (*kilo annum*); for example, the last cycle of glaciation ended at approximately 11.7 ka or 11,700 years ago. This notation will be used for geological dates throughout this book.

Unfortunately, knowing how to express geological time doesn’t really help us understand or appreciate its extent. A version of the geological time scale is included as Figure 19.1. Unlike time scales you’ll see in other places, or even later in this book, this time scale is linear throughout its length, meaning that 50 Ma during the **Cenozoic** is the same thickness as 50 Ma during the **Hadean**—in each case about the height of the “M” in Ma. The Pleistocene glacial epoch began at about 2.6 Ma, which is equivalent to half the thickness of the thin grey line at the top of the yellow bar marked “Cenozoic.” Most other time scales have earlier parts of Earth’s history compressed so that more detail can be shown for the more recent parts. That makes it difficult to appreciate the extent of geological time.

To create some context, the **Phanerozoic** Eon (the last 542 million years) is named for the time during which visible (*phaneros*) life (*zoi*) is present in the geological record. In fact, large organisms — those that leave fossils visible to the naked eye — have existed for a little longer than that, first appearing around 600 Ma, or a span of just over 13% of geological time. Animals have been on land for 360 million years, or 8% of geological time. Mammals have

* + 1. Hutton, J, 1788. Theory of the Earth; or an investigation of the laws observable in the composition, dissolution, and restoration of land upon the Globe. Transactions of the Royal Society of Edinburgh.

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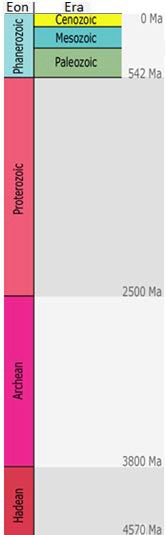
[](http://opentextbc.ca/geology/wp-content/uploads/sites/110/2015/08/The-geological-time-scale.png)

Figure 19.1 The geological time scale [SE]

dominated since the demise of the dinosaurs around 65 Ma, or 1.5% of geological time, and the genus *Homo* has existed since approximately 2.2 Ma, or 0.05% (1/2,000th) of geological time.

Geologists (and geology students) need to understand geological time. That doesn’t mean simply memorizing the geological time scale; instead, it means getting your mind around the concept that although most geological processes are extremely slow, very large and important things can happen if such processes continue for enough time.

For example, the Atlantic Ocean between Nova Scotia and northwestern Africa has been getting wider at a rate of about 2.5 cm per year. Imagine yourself taking a journey at that rate — it would be impossibly and ridiculously slow. And yet, since it started to form around 200 Ma (just 4% of geological time), the Atlantic Ocean has grown to a width of over 5,000 km!

A useful mechanism for understanding geological time is to scale it all down into one year. The origin of the solar system and Earth at 4.57 Ga would be represented by January 1, and the present year would be represented by the last tiny fraction of a second on New Year’s Eve. At this scale, each day of the year represents 12.5 million

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years; each hour represents about 500,000 years; each minute represents 8,694 years; and each second represents 145 years. Some significant events in Earth’s history, as expressed on this time scale, are summarized on Table 19.1.

|  |  |  |
| --- | --- | --- |
| **Event** | **Approximate Date** | **Calendar Equivalent** |
| Formation of oceans and continents | 4.5 – 4.4 Ga | January |
| Evolution of the first primitive life forms | 3.8 Ga | early March |
| Formation of British Columbia’s oldest rocks | 2.0 Ga | July |
| Evolution of the first multi-celled animals | 0.6 Ga or 600 Ma | November 15 |
| Animals first crawled onto land | 360 Ma | December 1 |
| Vancouver Island reached North America and the Rocky Mountains were formed | 90 Ma | December 25 |
| Extinction of the non-avian dinosaurs | 65 Ma | December 26 |
| Beginning of the Pleistocene ice age | 2 Ma or 2000 ka | 8 p.m., December, 31 |
| Retreat of the most recent glacial ice from southern Canada | 14 ka | 11:58 p.m., December 31 |
| Arrival of the first people in British Columbia | 10 ka | 11:59 p.m., December 31 |
| Arrival of the first Europeans on the west coast of what is now Canada | 250 years ago | 2 seconds before midnight, December 31 |

Table 19.1 A summary of some important geological dates expressed as if all of geological time was condensed into one year [SE]

The geological time scale is currently maintained by the International Commission on Stratigraphy (ICS), which is part of the International Union of Geological Sciences. The time scale is continuously being updated

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as we learn more about the timing and nature of past geological events. You can view the ICS time scale at https://stratigraphy.org/chart#latest-version It would be a good idea to print a copy (in colour) to put on your wall while you are studying geology.

Geological time has been divided into four eons: Hadean, Archean, Proterozoic, and Phanerozoic, and as shown in Figure 19.2, the first three of these represent almost 90% of Earth’s history. The last one, the Phanerozoic (meaning “visible life”), is the time that we are most familiar with because Phanerozoic rocks are the most common on Earth, and they contain evidence of the life forms that we are all somewhat familiar with.

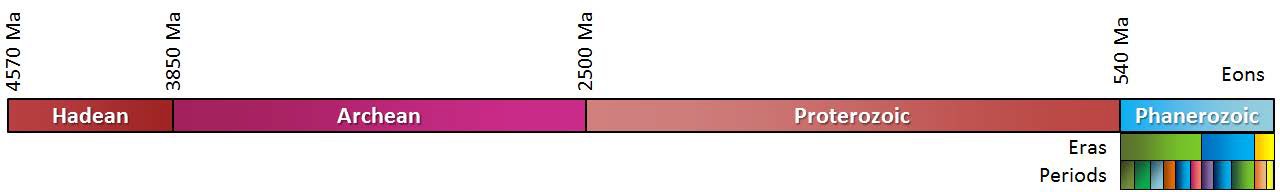
[](http://opentextbc.ca/geology/wp-content/uploads/sites/110/2015/07/eons-of-Earth.png)

Figure 19.2 The eons of Earth’s history [SE]

The Phanerozoic — the past 540 Ma of Earth’s history — is divided into three eras: the Paleozoic (“early life”), the Mesozoic (“middle life”), and the Cenozoic (“new life”), and each of these is divided into a number of periods (Figure 19.3). Most of the organisms that we share Earth with evolved at various times during the Phanerozoic.

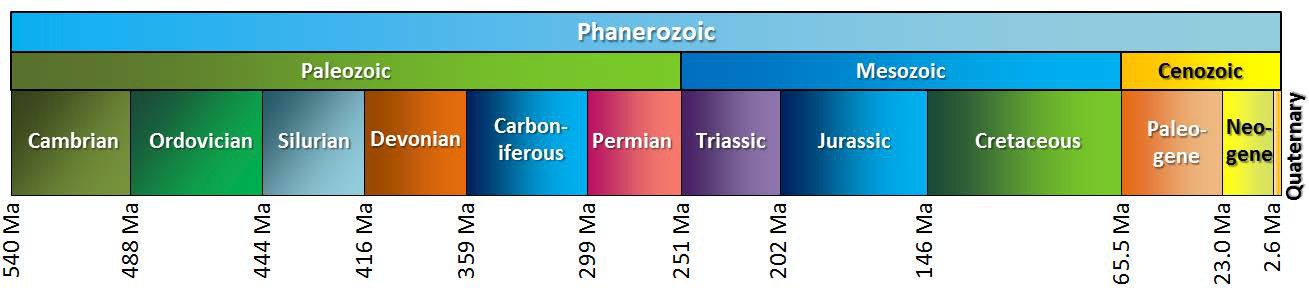
[](http://opentextbc.ca/geology/wp-content/uploads/sites/110/2015/07/Phanerozoic.png)

Figure 19.3 The eras (middle row) and periods (bottom row) of the Phanerozoic [SE]

The Cenozoic, which represents the past 65.5 Ma, is divided into three periods: Paleogene, Neogene, and Quaternary, and seven epochs (Figure 19.4). Dinosaurs became extinct at the start of the Cenozoic, after which birds and mammals radiated to fill the available habitats. Earth was very warm during the early Eocene and has steadily cooled ever since. Glaciers first appeared on Antarctica in the Oligocene and then on Greenland in the Miocene, and covered much of North America and Europe by the Pleistocene. The most recent of the Pleistocene glaciations ended around 11,700 years ago. The current epoch is known as the Holocene. Epochs are further divided into ages (a.k.a. stages), but we won’t be going into that level of detail here.

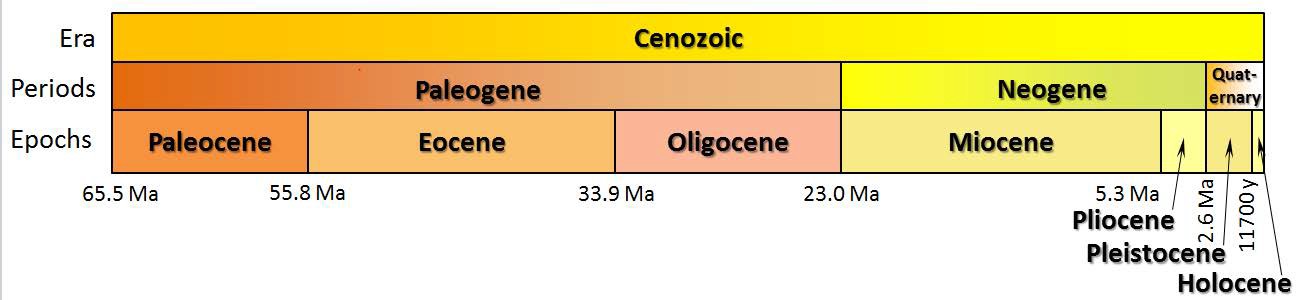
[](http://opentextbc.ca/geology/wp-content/uploads/sites/110/2015/07/Cenozoic.png)

Figure 19.4 The periods (middle row) and epochs (bottom row) of the Cenozoic [SE]

Most of the boundaries between the periods and epochs of the geological time scale have been fixed on the basis

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of significant changes in the fossil record. For example, as already noted, the boundary between the Cretaceous and the Paleogene coincides exactly with the extinction of the dinosaurs. That’s not a coincidence. Many other types of organisms went extinct at this time, and the boundary between the two periods marks the division between sedimentary rocks with Cretaceous organisms below, and Paleogene organisms above.

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# Relative Dating Methods

The simplest and most intuitive way of dating geological features is to look at the relationships between them. There are a few simple rules for doing this. For example, the principle of superposition states that sedimentary layers are deposited in sequence, and, unless the entire sequence has been turned over by tectonic processes or disrupted by faulting, the layers at the bottom are older than those at the top. The **principle of inclusions** states that any rock fragments that are included in rock must be older than the rock in which they are included. For example, a **xenolith** in an igneous rock or a clast in sedimentary rock must be older than the rock that includes it (Figure 19.5a).

[](http://opentextbc.ca/geology/wp-content/uploads/sites/110/2015/07/xenolith-of-diorite.jpg)

Figure 19.5a A xenolith of diorite incorporated into a basalt lava flow, Mauna Kea volcano, Hawaii. The lava flow took place some time after the diorite cooled, was uplifted, and then eroded. (Hammerhead for scale) [SE]

The **principle of cross-cutting relationships** states that any geological feature that cuts across, or disrupts another feature must be younger than the feature that is disrupted. An example of this is given in Figure 19.5b, which shows three different sedimentary layers. The lower sandstone layer is disrupted by two **faults**, so we can infer that the faults are younger than that layer. But the faults do not appear to continue into the coal seam, and they certainly do not continue into the upper sandstone. So we can infer that coal seam is younger than the faults (because it disrupts them), and of course the upper sandstone is youngest of all, because it lies on top of the coal seam.

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[](http://opentextbc.ca/geology/wp-content/uploads/sites/110/2015/07/sandstone.jpg)

Figure 19.5b Rip-up clasts of shale embedded in Gabriola Formation sandstone, Gabriola Island,

B.C. The pieces of shale were eroded as the sandstone was deposited, so the shale is older than the sandstone. [SE]

[](https://opentextbc.ca/physicalgeologyearle/wp-content/uploads/sites/145/2016/03/cavan-2.png)

Figure 19.6 Superposition and cross-cutting relationships in Cretaceous Nanaimo Group rocks in Nanaimo, B.C. The coal seam is about 50 cm thick. [SE ]

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An **unconformity** represents an interruption in the process of deposition of sedimentary rocks. Recognizing unconformities is important for understanding time relationships in sedimentary sequences. An example of an unconformity is shown in Figure 19.7. The Proterozoic rocks of the Grand Canyon Group have been tilted and then eroded to a flat surface prior to deposition of the younger Paleozoic rocks. The difference in time between the youngest of the Proterozoic rocks and the oldest of the Paleozoic rocks is close to 300 million years. Tilting and erosion of the older rocks took place during this time, and if there was any deposition going on in this area, the evidence of it is now gone.

There are four types of unconformities, as summarized in Table 8.1, and illustrated in Figure 19.8.

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[](http://opentextbc.ca/geology/wp-content/uploads/sites/110/2015/07/Grand-Canyon.jpg)

Figure 19.7 The great angular unconformity in the Grand Canyon, Arizona. The tilted rocks at the bottom are part of the Proterozoic Grand Canyon Group (aged 825 to 1,250 Ma). The flat-lying rocks at the top are Paleozoic (540 to 250 Ma). The boundary between the two represents a time gap of nearly 300 million years. [SE ]

|  |  |
| --- | --- |
| **Unconformity Type** | **Description** |
| Nonconformity | A boundary between non-sedimentary rocks (below) and sedimentary rocks (above) |
| Angular unconformity | A boundary between two sequences of sedimentary rocks where the underlying ones have been tilted (or folded) and eroded prior to the deposition of the younger ones (as in Figure 8.8) |
| Disconformity | A boundary between two sequences of sedimentary rocks where the underlying ones have been eroded (but not tilted) prior to the deposition of the younger ones (as in Figure 8.7) |
| Paraconformity | A time gap in a sequence of sedimentary rocks that does not show up as an angular unconformity or a disconformity |

Table 19.1 The characteristics of the four types of unconformities

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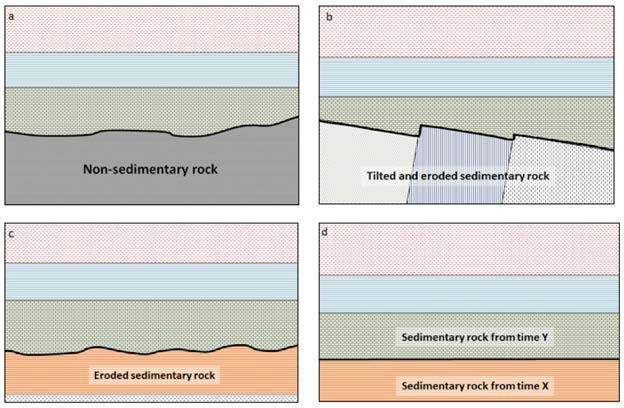
[](http://opentextbc.ca/geology/wp-content/uploads/sites/110/2015/07/unconformities.png)

Figure 19.8 The four types of unconformities: (a) a nonconformity between non-sedimentary rock and sedimentary rock, (b) an angular unconformity, (c) a disconformity between layers of sedimentary rock, where the older rock has been eroded but not tilted, and (d) a paraconformity where there is a long period (millions of years) of non-deposition between two parallel layers. [SE

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# Dating Rocks Using Fossils

Geologists get a wide range of information from fossils. They help us to understand evolution and life in general; they provide critical information for understanding depositional environments and changes in Earth’s climate; and, of course, they can be used to date rocks.

Although the recognition of fossils goes back hundreds of years, the systematic cataloguing and assignment of relative ages to different organisms from the distant past — paleontology — only dates back to the earliest part of the 19th century. The oldest undisputed fossils are from rocks dated around 3.5 Ga, and although fossils this old are typically poorly preserved and are not useful for dating rocks, they can still provide important information about conditions at the time. The oldest well-understood fossils are from rocks dating back to around 600 Ma, and the sedimentary record from that time forward is rich in fossil remains that provide a detailed record of the history of life. However, as anyone who has gone hunting for fossils knows, that does not mean that all sedimentary rocks have visible fossils or that they are easy to find. Fossils alone cannot provide us with numerical ages of rocks, but over the past century geologists have acquired enough isotopic dates from rocks associated with fossil-bearing rocks (such as igneous dykes cutting through sedimentary layers) to be able to put specific time limits on most fossils.

A very selective history of life on Earth over the past 600 million years is provided in Figure 19.9. The major groups of organisms that we are familiar with evolved between the late Proterozoic and the Cambrian (~600 Ma to

~520 Ma). Plants, which evolved in the oceans as green algae, came onto land during the Ordovician (~450 Ma). Insects, which evolved from marine arthropods, came onto land during the Devonian (400 Ma), and amphibians (i.e., vertebrates) came onto land about 50 million years later. By the late Carboniferous, trees had evolved from earlier plants, and reptiles had evolved from amphibians. By the mid-Triassic, dinosaurs and mammals had evolved from very different branches of the reptiles; birds evolved from dinosaurs during the Jurassic. Flowering plants evolved in the late Jurassic or early Cretaceous. The earliest primates evolved from other mammals in the early Paleogene, and the genus *Homo* evolved during the late Neogene (~2.8 Ma).

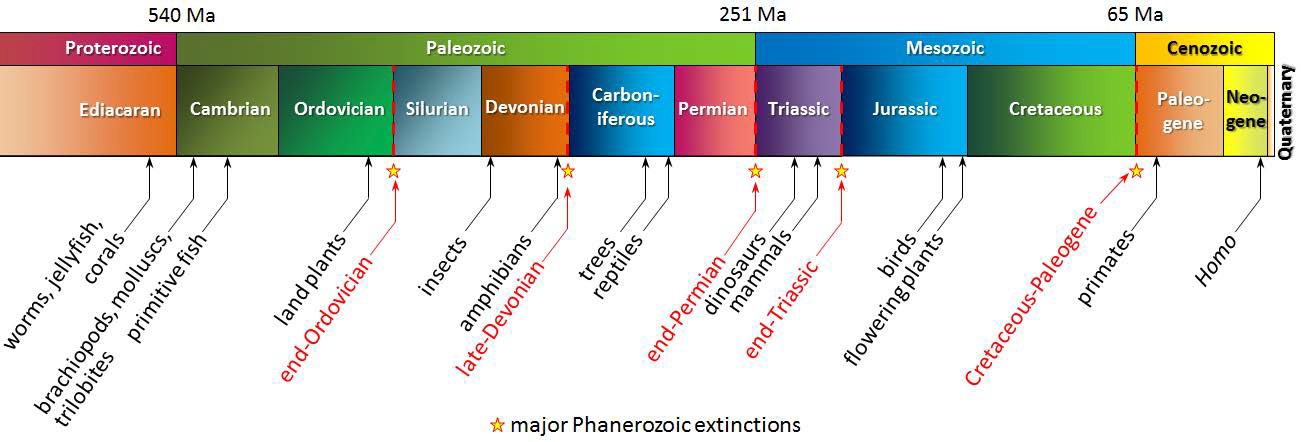
[](http://opentextbc.ca/geology/wp-content/uploads/sites/110/2015/07/Proterozoic-and-the-Phanerozoic.png)

Figure 19.9 A summary of life on Earth during the late Proterozoic and the Phanerozoic. The top row shows geological eras, and the lower row shows the periods. [SE]

If we understand the sequence of evolution on Earth, we can apply knowledge to determining the relative ages of rocks. This is William Smith’s principle of faunal succession, although of course it doesn’t just apply to “fauna” (animals); it can also apply to fossils of plants and those of simple organisms.

The Phanerozoic has seen five major extinctions, as indicated in Figure 19.9. The most significant of these was at the end of the Permian, which saw the extinction of over 80% of all species and over 90% of all marine

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species. Most well-known types of organisms were decimated by this event, but only a few became completely extinct, including trilobites. The second most significant extinction was at the Cretaceous-Paleogene boundary (K- Pg, a.k.a. the K-T extinction). At that time, about 75% of marine species disappeared. Again, a few well-known types of organisms disappeared altogether, including dinosaurs (but not birds) and the pterosaurs. Other types were badly decimated but survived, and then flourished in the Paleogene. The K-Pg extinction is thought to have been caused by the impact of a large extraterrestrial body (10 km to 15 km across), but it is generally agreed that the other four Phanerozoic extinctions had other causes, although their exact nature is not clearly understood.

As already stated, it is no coincidence that the major extinctions all coincide with boundaries of geological periods and even eras. Paleontologists have placed most of the divisions of the geological time scale at points in the fossil record where there are major changes in the type of organisms observed.

If we can identify a fossil to the species level, or at least to the genus level, and we know the time period when the organism lived, we can assign a range of time to the rock. That range might be several million years because some organisms survived for a very long time. If the rock we are studying has several types of fossils in it, and we can assign time ranges to those fossils, we might be able to narrow the time range for the age of the rock considerably. An example of this is given in Figure 19.10.

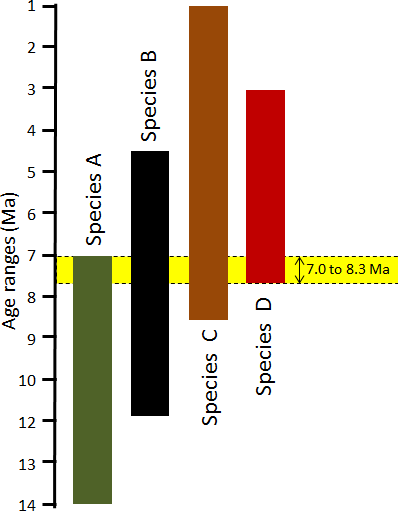
[](http://opentextbc.ca/geology/wp-content/uploads/sites/110/2015/07/age-of-a-rock.png)

Figure 19.10 The application of bracketing to constrain the age of a rock based on several fossils. In this diagram, the coloured bar represents the time range during which each of the four species (A – D) existed on Earth. Although each species lived for several million years, we can narrow down the likely age of the rock to just 0.7 Ma during which all four species coexisted. [SE]

Some organisms survived for a very long time, and are not particularly useful for dating rocks. Sharks, for example, have been around for over 400 million years, and the great white shark has survived for 16 million years, so far. Organisms that lived for relatively short time periods are particularly useful for dating rocks, especially if they were distributed over a wide geographic area and so can be used to compare rocks from different regions. These are

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known as **index fossils**. There is no specific limit on how short the time span has to be to qualify as an index fossil. Some lived for millions of years, and others for much less than a million years.

Some well-studied groups of organisms qualify as **biozone** fossils because, although the genera and families lived over a long time, each species lived for a relatively short time and can be easily distinguished from others on the basis of specific features. For example, ammonites have a distinctive feature known as the **suture** line — where the internal shell layers that separate the individual chambers (**septae**) meet the outer shell wall, as shown in Figure 19.11. These suture lines are sufficiently variable to identify species that can be used to estimate the relative or absolute ages of the rocks in which they are found.

[](http://opentextbc.ca/geology/wp-content/uploads/sites/110/2015/07/septum-of-an-ammonite.png)

Figure 19.11 The septum of an ammonite (white part, left), and the suture lines where the septae meet the outer shell (right). [SE]

Foraminifera (small, carbonate-shelled marine organisms that originated during the Triassic and are still around today) are also useful biozone fossils. As shown in Figure 19.12, numerous different foraminifera lived during the Cretaceous. Some lasted for over 10 million years, but others for less than 1 million years. If the foraminifera in a rock can be identified to the species level, we can get a good idea of its age.

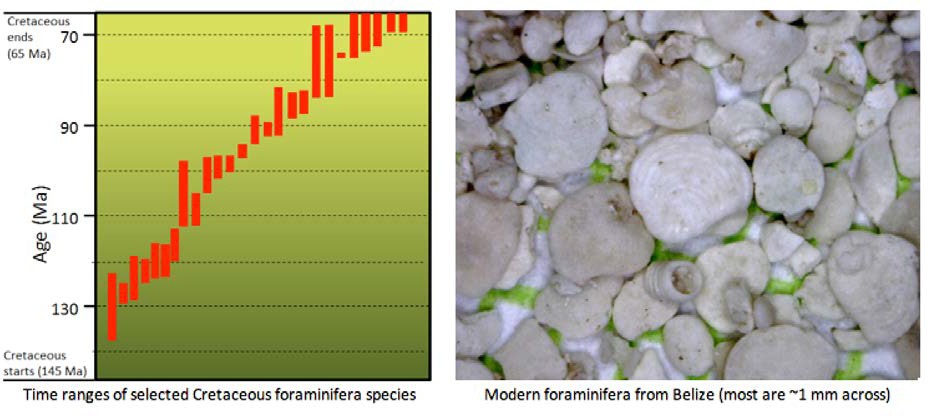
[](http://opentextbc.ca/geology/wp-content/uploads/sites/110/2015/07/foraminifera.png)

Figure 19.12 Time ranges for Cretaceous foraminifera (left) and modern foraminifera from the Ambergris area of Belize (right) [left: SE, from data in Scott, R, 2014, A Cretaceous chronostratigraphic database: construction and applications, Carnets de Géologie, Vol. 14., right : SE

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# Isotopic Dating Methods

Originally fossils only provided us with relative ages because, although early paleontologists understood biological succession, they did not know the absolute ages of the different organisms. It was only in the early part of the 20th century, when isotopic dating methods were first applied, that it became possible to discover the absolute ages of the rocks containing fossils. In most cases, we cannot use isotopic techniques to directly date fossils or the sedimentary rocks they are found in, but we can constrain their ages by dating igneous rocks that cut across sedimentary rocks, or volcanic ash layers that lie within sedimentary layers.

Isotopic dating of rocks, or the minerals in them, is based on the fact that we know the decay rates of certain unstable **isotopes** of elements and that these rates have been constant over geological time. It is also based on the

premise that when the atoms of an element decay within a mineral or a rock, they stay there and don’t escape to the surrounding rock, water, or air. One of the isotope pairs widely used in geology is the decay of 40K to 40Ar (potassium-40 to argon-40). 40K is a radioactive isotope of potassium that is present in very small amounts in all

minerals that have potassium in them. It has a half-life of 1.3 billion years, meaning that over a period of 1.3 Ga one-half of the 40K atoms in a mineral or rock will decay to 40Ar, and over the next 1.3 Ga one-half of the remaining atoms will decay, and so on (Figure 19.13).

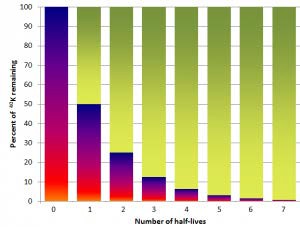
[](https://opentextbc.ca/physicalgeologyearle/wp-content/uploads/sites/145/2016/03/decay-of-40K.png)

Figure 19.13 The decay of 40K over time. Each half-life is 1.3 billion years, so after 3.9 billion years (three half-lives) 12.5% of the original 40K will remain. The red-blue bars represent 40K and the green-yellow bars represent 40Ar. [SE]

In order to use the K-Ar dating technique, we need to have an igneous or metamorphic rock that includes a potassium-bearing mineral. One good example is granite, which normally has some potassium feldspar (Figure 19.14). Feldspar does not have any argon in it when it forms. Over time, the 40K in the feldspar decays to 40Ar. Argon is a gas and the atoms of 40Ar remain embedded within the crystal, unless the rock is subjected to high temperatures after it forms. The sample must be analyzed using a very sensitive mass-spectrometer, which can detect the differences between the masses of atoms, and can therefore distinguish between 40K and the much more abundant 39K. Biotite and hornblende are also commonly used for K-Ar dating.

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[](http://opentextbc.ca/geology/wp-content/uploads/sites/110/2015/07/Crystals-of-potassium-feldspar.jpg)

Figure 19.14 Crystals of potassium feldspar (pink) in a granitic rock are candidates for isotopic dating using the K-Ar method because they contained potassium and no argon when they formed. [SE]

#### Why can’t we use isotopic dating techniques with sedimentary rocks?

[](http://opentextbc.ca/geology/wp-content/uploads/sites/110/2015/07/sedimentary-rocks.jpg)

An important assumption that we have to be able to make when using isotopic dating is that when the rock formed none of the daughter isotope was present (e.g., 40Ar in the case of the K-Ar method). A clastic sedimentary rock is made up of older rock and mineral fragments, and when the rock forms it is almost certain that all of the fragments already have daughter isotopes in them. Furthermore, in almost all cases, the fragments have come from a range of source rocks that all formed at different times. If we dated a number of individual grains in the sedimentary rock, we would likely get a range of different dates, all older than the age of the rock. It might be possible to date some chemical sedimentary rocks isotopically, but there are no useful isotopes that can be used on old chemical sedimentary rocks. Radiocarbon dating can be used on sediments or sedimentary rocks that contain carbon, but it cannot be used on materials older than about 60 ka.

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K-Ar is just one of many isotope-pairs that are useful for dating geological materials. Some of the other important pairs are listed in Table 19.2, along with the age ranges that they apply to and some comments on their applications. When radiometric techniques are applied to metamorphic rocks, the results normally tell us the date of metamorphism, not the date when the parent rock formed.

|  |  |  |  |
| --- | --- | --- | --- |
| **Isotope System** | **Half- Life** | **Useful Range** | **Comments** |
| Potassium-argon | 1.3 Ga | 10 Ka –  4.57 Ga | Widely applicable because most rocks have some potassium |
| Uranium-lead | 4.5 Ga | 1 Ma – 4.57  Ga | The rock must have uranium-bearing minerals |
| Rubidium-strontium | 47 Ga | 10 Ma –  4.57 Ga | Less precision than other methods at old dates |
| Carbon-nitrogen (a.k.a. radiocarbon dating) | 5,730  y | 100 y to  60,000 y | Sample must contain wood, bone, or carbonate minerals; can be applied to young sediments |

Table 19.2 A few of the isotope systems that are widely used for dating geological materials

Radiocarbon dating (using 14C) can be applied to many geological materials, including sediments and sedimentary rocks, but the materials in question must be younger than 60 ka. Fragments of wood incorporated into young sediments are good candidates for carbon dating, and this technique has been used widely in studies involving late Pleistocene glaciers and glacial sediments. An example is shown in Figure 19.15; radiocarbon dates from wood

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fragments in glacial sediments have been used to estimate the time of the last glacial advance along the Strait of Georgia.

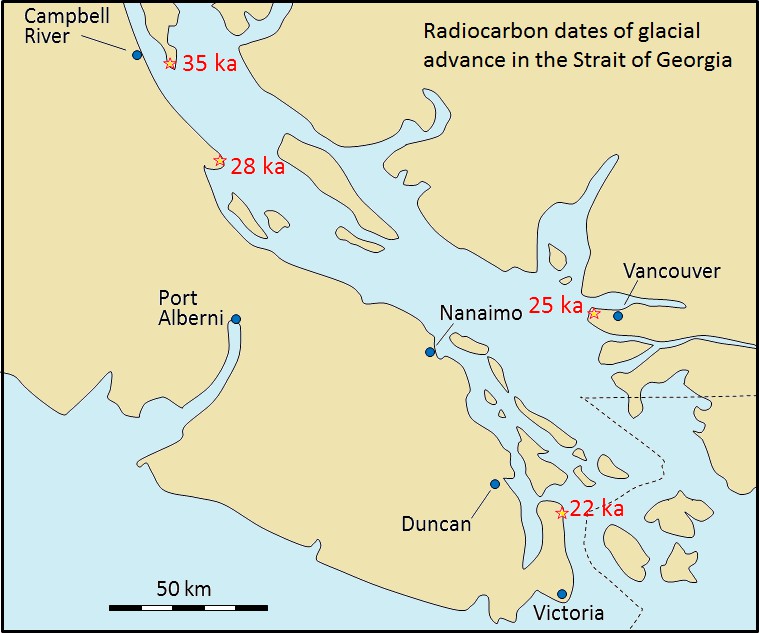
[](http://opentextbc.ca/geology/wp-content/uploads/sites/110/2015/07/Radiocarbon.png)

Figure 19.15 Radiocarbon dates on wood fragments in glacial sediments in the Strait of Georgia [SE after Clague, J, 1976, Quadra Sand and its relation to late Wisconsin glaciation of southeast British Columbia, Can. J. Earth Sciences

Understanding Geologic time

It’s one thing to know the facts about geological time — how long it is, how we measure it, how we divide it up, and what we call the various periods and epochs — but it is quite another to really understand geological time. The problem is that our lives are short and our memories are even shorter. Our experiences span only a few decades, so we really don’t have a way of knowing what 11,700 years means. What’s more, it’s hard for us to understand how 11,700 years differs from 65.5 Ma, or even from 1.8 Ga. It’s not that we can’t comprehend what the numbers mean

— we can all get that figured out with a bit of practice — but even if we do know the numerical meaning of 65.5 Ma, we can’t really appreciate how long ago it was.

You may be wondering why it’s so important to really “understand” geological time. There are some very good reasons. One is so that we can fully understand how geological processes that seem impossibly slow can produce anything of consequence. For example, we are familiar with the concept of driving from one major city to another: a journey of several hours at around 100 km/h. Continents move toward each other at rates of a fraction of a millimetre per day, or something in the order of 0.00000001 km/h, and yet, at this impossibly slow rate (try walking at that speed!), they can move thousands of kilometres. Sediments typically accumulate at even slower rates — less than a millimetre per year — but still they are thick enough to be thrust up into monumental mountains and carved into breathtaking canyons.

Another reason is that for our survival on this planet, we need to understand issues like extinction of endangered species and **anthropogenic** (human-caused) climate change. Some people, who don’t understand geological time, are quick to say that the climate has changed in the past, and that what is happening now is no different. And it certainly has changed in the past. For example, from the Eocene (50 Ma) to the present day, Earth’s climate cooled by about 12°C. That’s a huge change that ranks up there with many of the important climate changes of the distant past, and yet the rate of change over that time was only 0.000024°C/century. Anthropogenic climate change has been

1.1°C over the past 100 years,1 and that is 45,800 times faster than the rate of natural climate change since the Eocene!

One way to wrap your mind around geological time is to put it into the perspective of single year, because we all know how long it is from one birthday to the next. At that rate, each hour of the year is equivalent to approximately 500,000 years, and each day is equivalent to 12.5 million years.

If all of geological time is compressed down to a single year, Earth formed on January 1, and the first life forms evolved in late March (~3,500 Ma). The first large life forms appeared on November 13 (~600 Ma), plants appeared on land around November 24, and amphibians on December 3. Reptiles evolved from amphibians during the first week of December and dinosaurs and early mammals evolved from reptiles by December 13, but the dinosaurs, which survived for 160 million years, were gone by Boxing Day (December 26). The Pleistocene Glaciation got started at around 6:30 p.m. on New Year’s Eve, and the last glacial ice left southern Canada by 11:59 p.m.

It’s worth repeating: on this time scale, the earliest ancestors of the animals and plants with which we are familiar did not appear on Earth until mid-November, the dinosaurs disappeared after Christmas, and most of Canada was periodically locked in ice from 6:30 to 11:59 p.m. on New Year’s Eve. As for people, the first to inhabit

B.C. got here about one minute before midnight, and the first Europeans arrived about two seconds before midnight.

It is common for the popular press to refer to distant past events as being “prehistoric.” For example, dinosaurs are reported as being “prehistoric creatures,” even by the esteemed National Geographic Society.2 The written records of our history date back to about 6,000 years ago, so anything prior to that is considered “prehistoric.” But to call the dinosaurs prehistoric is equivalent to — and about as useful as — saying that Singapore is beyond the

1. Climate change data from NASA Goddard Institute for Space Studies: <http://data.giss.nasa.gov/gistemp/tabledata_v3/GLB.Ts.txt>
2. <http://science.nationalgeographic.com/science/prehistoric-world/>

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city limits of Kamloops! If we are going to become literate about geological time, we have to do better than calling dinosaurs, or early horses (54 Ma), or even early humans (2.8 Ma), “prehistoric.”

**Summary**

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| --- | --- | --- | --- |
| The Geological Time Scale | | The work of William Smith was critical to the establishment of the first geological time scale early in the 19th century, but it wasn’t until the 20th century that geologists were able to assign reliable dates to the various time periods. The geological time scale is now maintained by the International Commission on Stratigraphy. Geological time is divided into eons, eras, periods, and epochs. | |
| Relative Dating Methods | | We can determine the relative ages of different rocks by observing and interpreting relationships among them, such as superposition, cross-cutting, and inclusions. Gaps in the geological record are represented by various types of unconformities. | |
| Dating Rocks Using Fossils | | Fossils are useful for dating rocks date back to about 600 Ma. If we know the age range of a fossil, we can date the rock, but some organisms lived for many millions of years. Index fossils represent shorter geological times, and if a rock has several different fossils with known age ranges, we can normally narrow the time during which the rock formed. | |
| Isotopic Dating Methods | | Radioactive isotopes decay at predictable and known rates, and can be used to date igneous and metamorphic rocks. Some of the more useful isotope systems are potassium-argon, rubidium- strontium, uranium-lead, and carbon-nitrogen. Radiocarbon dating can be applied to sediments and sedimentary rocks, but only if they are younger than 60 ka. | |
|  | | Understanding Geological Time | | While knowing about geological time is relatively easy, actually comprehending the significance of the vast amounts of geological time is a great challenge. To be able to solve important geological problems and critical societal challenges, like climate change, we need to really understand geological time. | |

Review Question

What are the features of a useful index fossil?

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