7.1: Relative Dating

Relative dating is the process of determining if one rock or geologic event is older or younger than another, without knowing their specific ages—i.e., how many years ago the object was formed. The principles of relative time are simple, even obvious now, but were not generally accepted by scholars until the scientific revolution of the 17th and 18th centuries [3]. James Hutton (see Chapter 1) realized geologic processes are slow and his ideas on uniformitarianism (i.e., “the present is the key to the past”) provided a basis for interpreting rocks of the Earth using scientific principles.
Relative Dating Principles

Stratigraphy is the study of layered sedimentary rocks. This section discusses principles of relative time used in all of geology, but are especially useful in stratigraphy.

Figure `\(\PageIndex{1}\)`: A Geologic Time Scale

Figure `\(\PageIndex{1}\)`: Lower strata are older than those lying on top of them.
**Principle of Superposition:** In an otherwise undisturbed sequence of sedimentary strata, or rock layers, the layers on the bottom are the oldest and layers above them are younger.

**Principle of Original Horizontality:** Layers of rocks deposited from above, such as sediments and lava flows, are originally laid down horizontally. The exception to this principle is at the margins of basins, where the strata can slope slightly downward into the basin.

**Principle of Lateral Continuity:** Within the depositional basin, strata are continuous in all directions until they thin out at the edge of that basin. Of course, all strata eventually end, either by hitting a geographic barrier, such as a ridge, or when the depositional process extends too far from its source, either a sediment source or a volcano. Strata that are cut by a canyon later remain continuous on either side of the canyon.

**Principle of Cross-Cutting Relationships:** Deformation events like folds, faults and igneous intrusions that cut across rocks are younger than the rocks they cut across.

**Principle of Inclusions:** When one rock formation contains pieces or inclusions of another rock, the included rock is older than the host rock.
Principle of Fossil Succession: Evolution has produced a succession of unique fossils that correlate to the units of the geologic time scale. Assemblages of fossils contained in strata are unique to the time they lived and can be used to correlate rocks of the same age across a wide geographic distribution. Assemblages of fossils refer to groups of several unique fossils occurring together.

Grand Canyon Example

The Grand Canyon of Arizona illustrates the stratigraphic principles. The photo shows layers of rock on top of one another in order, from the oldest at the bottom to the youngest at the top, based on the principle of superposition. The predominant white layer just below the canyon rim is the Coconino Sandstone. This layer is laterally continuous, even though the intervening canyon separates its outcrops. The rock layers exhibit the principle of lateral continuity, as they are found on both sides of the Grand Canyon which has been carved by the Colorado River.
The diagram called “Grand Canyon’s Three Sets of Rocks” shows a cross-section of the rocks exposed on the walls of the Grand Canyon, illustrating the principle of cross-cutting relationships, superposition, and original horizontality. In the lowest parts of the Grand Canyon are the oldest sedimentary formations, with igneous and metamorphic rocks at the bottom. The principle of cross-cutting relationships shows the sequence of these events. The metamorphic schist (#16) is the oldest rock formation and the cross-cutting granite intrusion (#17) is younger. As seen in the figure, the other layers on the walls of the Grand Canyon are numbered in reverse order with #15 being the oldest and #1 the youngest [4]. This illustrates the principle of superposition. The Grand Canyon region lies in Colorado Plateau, which is characterized by horizontal or nearly horizontal strata, which follows the principle of original horizontality. These rock strata have been barely disturbed from their original deposition, except by a broad regional uplift.
The photo of the Grand Canyon here show strata that were originally deposited in a flat layer on top of older igneous and metamorphic “basement” rocks, per the original horizontality principle. Because the formation of the basement rocks and the deposition of the overlying strata is not continuous but broken by events of metamorphism, intrusion, and erosion, the contact between the strata and the older basement is termed an **unconformity**. An unconformity represents a period during which deposition did not occur or erosion removed rock that had been deposited, so there are no rocks that represent events of Earth history during that span of time at that place. Unconformities appear in cross-sections and stratigraphic columns as wavy lines between formations. Unconformities are discussed in the next section.

### Unconformities

The red, layered rocks of the Grand Canyon Supergroup overlying the dark-colored rocks of the Vishnu schist represents a type of unconformity called a nonconformity.

There are three types of unconformities, nonconformity, disconformity, and angular unconformity. A nonconformity occurs...
when sedimentary rock is deposited on top of igneous and metamorphic rocks as is the case with the contact between the strata and basement rocks at the bottom of the Grand Canyon.

The strata in the Grand Canyon represent alternating marine transgressions and regressions where sea level rose and fell over millions of years. When the sea level was high marine strata formed. When sea-level fell, the land was exposed to erosion creating an unconformity. In the Grand Canyon cross-section, this erosion is shown as heavy wavy lines between the various numbered strata. This is a type of unconformity called a disconformity, where either non-deposition or erosion took place. In other words, layers of rock that could have been present, are absent. The time that could have been represented by such layers is instead represented by the disconformity. Disconformities are unconformities that occur between parallel layers of strata indicating either a period of no deposition or erosion.

![Figure 1: Angular unconformity in the Grand Canyon](https://example.com/angular-unconformity.jpg)

Figure 1: In the lower part of the picture is an angular unconformity in the Grand Canyon known as the Great Unconformity. Notice the flat-lying strata over dipping strata (Source: Doug Dolde).

The Phanerozoic strata in most of the Grand Canyon are horizontal. However, near the bottom horizontal strata overlie tilted strata. This is known as the Great Unconformity and is an example of an angular unconformity. The lower strata were tilted by tectonic processes that disturbed their original horizontality and caused the strata to be eroded. Later, horizontal strata were deposited on top of the tilted strata creating an angular unconformity.

Here are three graphical illustrations of the three types of unconformity.

![Disconformity](https://example.com/disconformity.png)

Disconformity, where is a break or stratigraphic absence between strata in an otherwise parallel sequence of strata.
Nonconformity, where sedimentary strata are deposited on crystalline (igneous or metamorphic) rocks.

Angular unconformity, where sedimentary strata are deposited on a terrain developed on sedimentary strata that have been deformed by tilting, folding, and/or faulting, so that they are no longer horizontal.

**Applying Relative Dating Principles**

In the block diagram, the sequence of geological events can be determined by using the relative-dating principles and known properties of igneous, sedimentary, metamorphic rock (see Chapter 4, Chapter 5, and Chapter 6). The sequence begins with the folded metamorphic gneiss on the bottom. Next, the gneiss is cut and displaced by the fault labeled A. Both the gneiss and fault A are cut by the igneous granitic intrusion called batholith B; its irregular outline suggests it is an igneous granitic intrusion emplaced as magma into the gneiss. Since batholith B cuts both the gneiss and fault A, batholith B is younger than the other two rock formations. Next, the gneiss, fault A, and batholith B were eroded forming a nonconformity as shown with the wavy line. This unconformity was actually an ancient landscape surface on which sedimentary rock C was subsequently deposited perhaps by a marine transgression. Next, igneous basaltic dike D cut through all rocks except sedimentary rock E.
This shows that there is a disconformity between sedimentary rocks C and E. The top of dike D is level with the top of layer C, which establishes that erosion flattened the landscape prior to the deposition of layer E, creating a disconformity between rocks D and E. Fault F cuts across all of the older rocks B, C and E, producing a fault scarp, which is the low ridge on the upper-left side of the diagram. The final events affecting this area are current erosion processes working on the land surface, rounding off the edge of the fault scarp, and producing the modern landscape at the top of the diagram.

References
