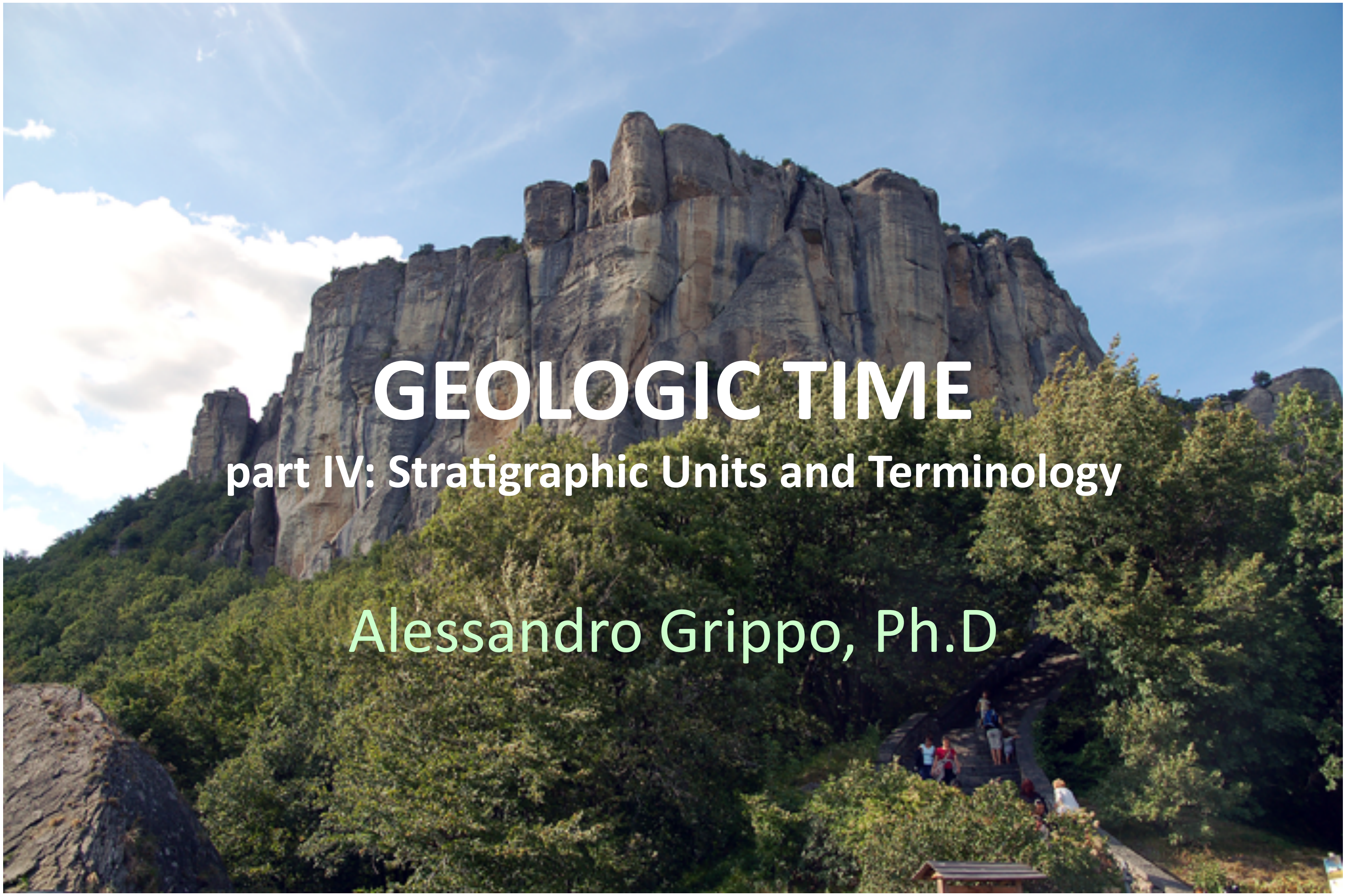


GEOLOGIC TIME

part IV: Stratigraphic Units and Terminology

Alessandro Grippo, Ph.D

Calcarenites of the Bismantova Rock, Middle Miocene
Reggio Emilia, Italy

Stratigraphic Terminology

- Our stratigraphic record is made of rocks
- The first thing we see when out in the field is rocks
- Rocks need to be distinguished one from the other
- The concept of stratigraphic unit is born:
  - a stratigraphic unit is any subdivision of the record based on certain rock characteristics

Geochronologic and Chronostratigraphic Units

- Starting in the XIX century, geologists began subdividing the rock record in intervals
- These intervals indicated different relative times but were rock-based

- These were called **systems** of rocks
- Systems of rocks from during time **periods**

- Systems were given names based on places (e.g. Cambrian, Permian) or other characteristics (e.g. Silurian, Carboniferous, etc.)

- So, the Cambrian System of rocks was deposited during the Cambrian Period of time.

- Systems can be touched, seen, described
- Periods are abstract units of time

- A System represents a **Chronostratigraphic Unit**
- A Period represents a **Geochronologic Unit**

- Systems and Period have the same names, but represent different concepts

- Both System and Periods are part of hierarchy of Units

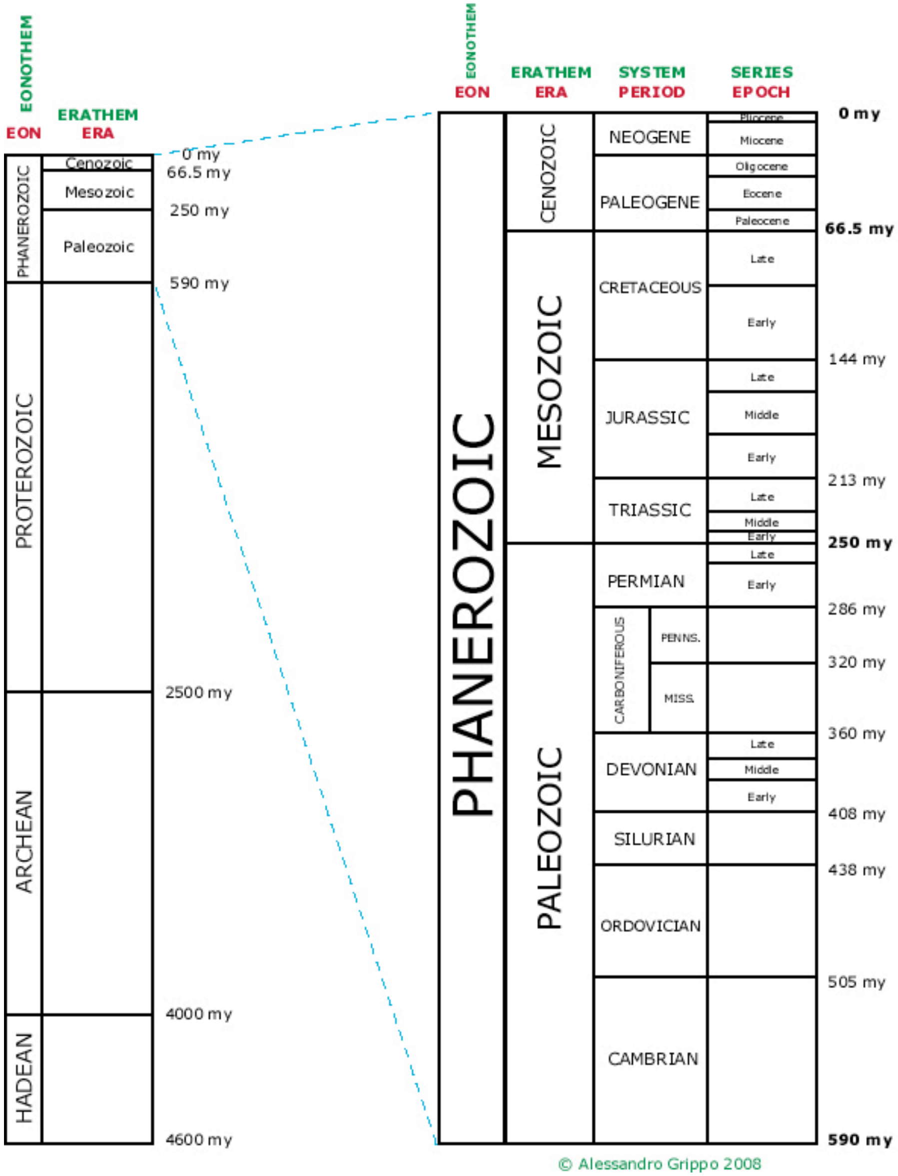
Conventional hierarchy of formal Chronostratigraphic and Geochronologic terms.

CHRONOSTRATIGRAPHIC	GEOCHRONOLOGIC
Eonothem	Eon
Erathem	Era
System*	Period*
Series*	Epoch*
Stage^	Age
Substage	Subage, or age

* If additional ranks are needed, the prefixes sub and super may be used with these terms.
^ Several adjacent stages may be grouped into a superstage

In the end:

- A Chronostratigraphic Units is a body of rock that was deposited during a certain time interval (a Geochronologic Unit)
  - Chronostratigraphic units are bounded by **synchronous horizons** (boundaries)
  - A **chronostratigraphic horizon** is a stratigraphic surface or interface that is synchronous



- **Cenozoic** comes from the Greek *kainos* (new) and *zoikos* (animal), *zoion* (living being). It thus means "(period of) new life".
- **Mesozoic** comes from the Greek *meso* (in between, middle) and *zoikos* (animal), *zoion* (living being). It thus means "(period of) middle life".
- **Paleozoic** comes from the Greek *palaios* (old) and *zoikos* (animal), *zoion* (living being). It thus means "(period of) old life”

- **Cretaceous** (d'Halloy, 1822) comes from the Latin *creta*, or chalk. It means thus "the time of the chalk", and it originated because of the abundance of chalk of this age in the Paris Basin, in France
- **Jurassic** (Von Humboldt, 1795) originates from the Jura Mountains, a mountain chain located between Switzerland and France
- **Triassic** (Von Alberti, 1834) comes from the Latin *Trias*, meaning a System organized in three parts named, from the bottom to the top, Buntsandstein (German for New Red Sandstone), Muschelkalk (German for mussel limestone, or shell limestone) and Keuper (an old German miner name for "iridiscent marls", a marl being a mixture between shale and limestone).

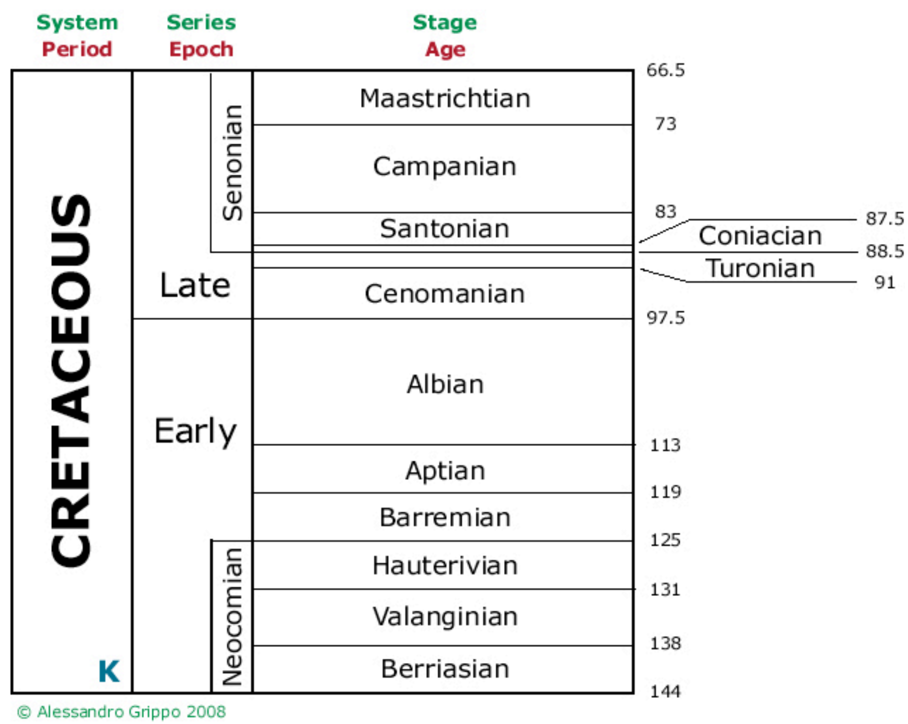
- The **Permian** (Murchison, 1841) was named after rocks from the Perm Basin, in Russia. Some sources maintain that Murchison wanted to make a reference to the ancient kingdom of Permia, rather than the city of Perm itself; in any case, that lost kingdom is today part of a Russian federal republic whose capital is the city of Perm
- The Pennsylvanian (Williams, 1891) is named after the state of Pennsylvania, in the USA* The Mississippian (Williams, 1891) owes its name to the fact that rocks of this age crop out in the Mississippi valley in the USA*
  *please note that the names Pennsylvanian and the Mississippian are only used in the United States in place of the Carboniferous
- The **Carboniferous** (Phillips, 1835) was so named because of the abundance of coal (carbon) identified in rocks of this age in western Europe
- The name for the **Devonian** (Murchison and Sedgwick, 1840) comes from the region of Devon, in England, UK
- The term **Silurian** (Murchison, 1835) comes from the Latin *Silures* (an ancient Celt population of Wales, in the UK)
- The term **Ordovician** (Lapworth, 1879) comes from the Latin *Ordovices* (an ancient Celt population of Wales, in the UK)
- The term **Cambrian** (Sedgwick, 1835) comes from the Latin word *Cambria* (the ancient name of Wales, in the UK)

Ages and Stages

- A stage (and its time equivalent, the age) is a small-rank chronostratigraphic unit (geochronologic unit). In the picture below is an example of stages (and ages) relative to the Cretaceous System (Period):

- The **stage** has been called the basic working unit of chronostratigraphy

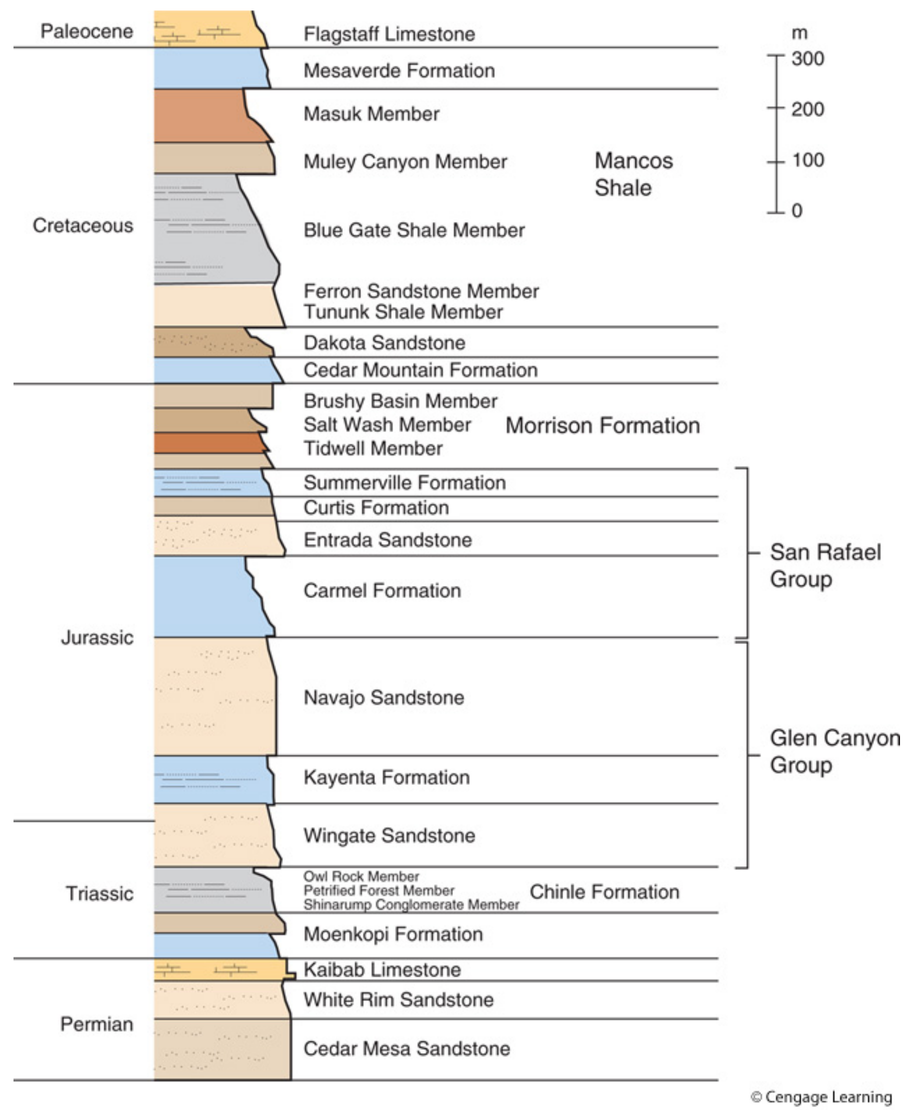
- A stage is defined by its **boundary stratotypes**

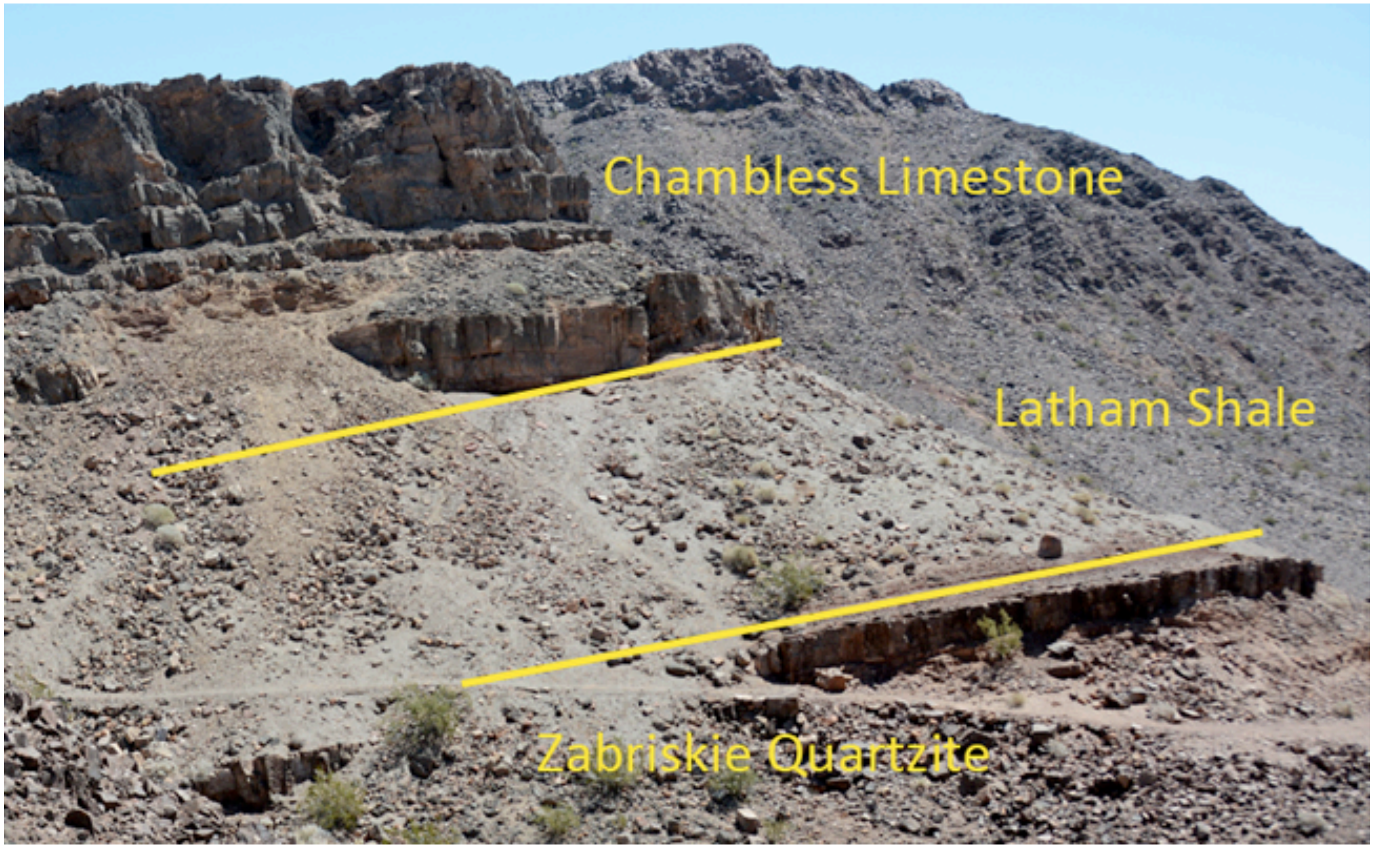


Lithostratigraphic Units

- Still, when we go in the field, we just see rocks, not time
- So, stratigraphic units based on rocks are the most common units
- These are defined as Lithostratographic Units

- The basic lithostratigraphic unit is the **Formation**
  - A Formation is a physical body of rocks that is distinct from surrounding ones, and thick enough to be mappable
  - Formations are named after a local name or a characteristic of the rock, accompanied by either the name of the rock itself or, if more than one lithology, the name "Formation"
    - Examples
      - the Santa Monica Shale
      - the Green River Formation





This image shows three units, from bottom to top: a quartzite (slightly metamorphosed sandstone), a shale, a limestone. Each one is distinct form the other based on their lithological characteristics. As a consequence, each unit is a **Formation**. Notice that the limestone includes within its boundaries a few levels of shale. The trail at the base of the cliff works as scale.

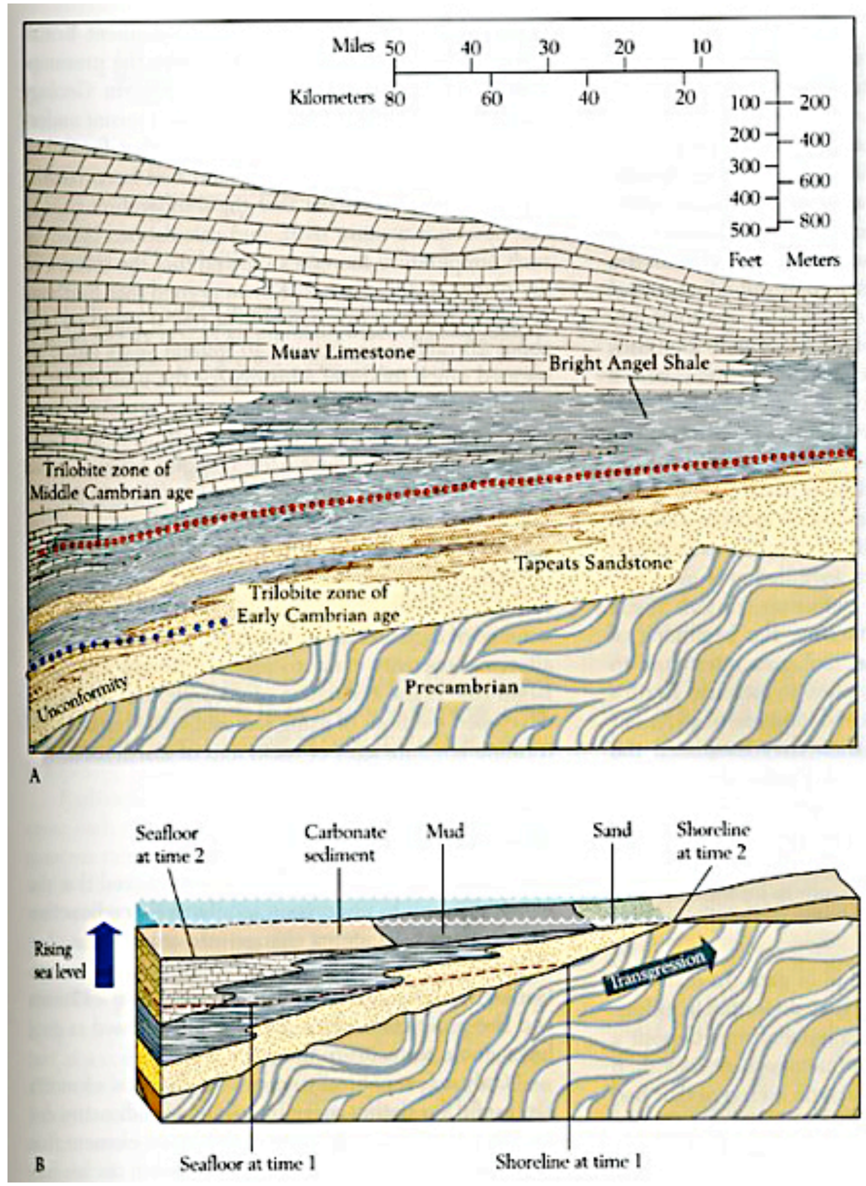
Mojave Desert, San Bernardino County, California

Formations (lithostratigraphic units)

- Formations can be part of Groups, or can be subdivided into Members
- As you remember from before, **bodies of rock do not represent time**
- So, a Formation is not the same of a Chronostratigraphic Unit

- For instance the Bright Angel Shale of the American Southwest is Lower Cambrian in age in California and Nevada, but is Middle Cambrian in age in Utah and Arizona

- Formations are a very practical tool in the field but bear no time significance



Biostratigraphy

- The use of fossils for stratigraphic correlation is called **biostratigraphy**.

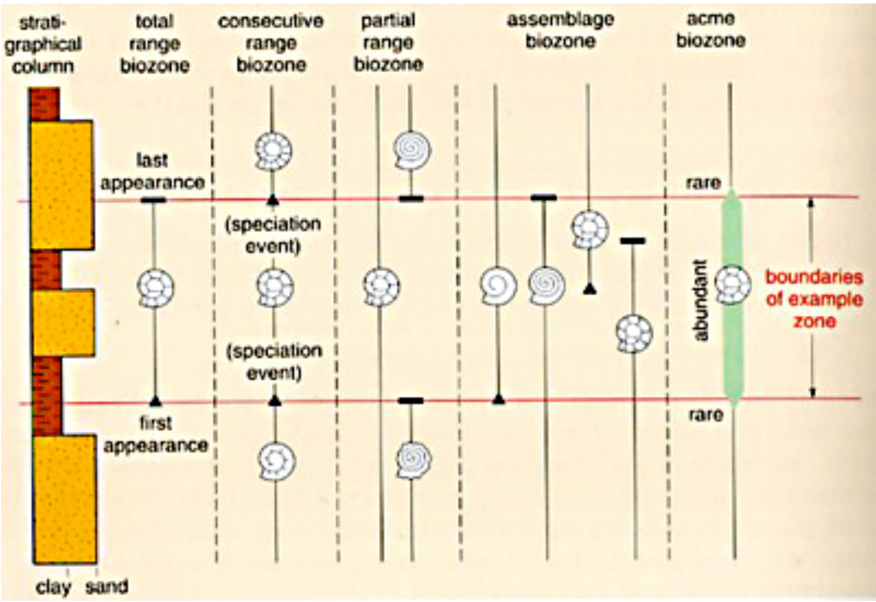
- Biostratigraphy is based on William Smith's **Principle of Faunal and Floral Succession**.

- Biostratigraphic units are based on the stratigraphic range of fossil taxa.

- The **stratigraphic range of a taxon** is the total vertical interval through which that taxon occurs in the rock record, from its lowermost to its uppermost occurrence.

Biozones (biostratigraphic units)

- The most fundamental biostratigraphic unit is the zone or, more formally, the biozone. A **zone** is a physical body of rock whose boundaries, lower and upper, are based on the ranges of one or more taxa.



Chemical Stratigraphy

- Chemical stratigraphy, or **chemostratigraphy**, refers to the study of the **fractionation** of stable isotopes in nature
- Fractionation is simply the separation of isotopes according to their different atomic weights
- Fractionation can occur, for instance, as a consequence of oceanographic and climatic changes

- The most important fractionation processes we are going to discuss refer to the isotopes of
  - oxygen ($^{18}O/^{16}O$)
    - studies about climate change
  - carbon ($^{13}C/^{12}C$)
    - studies about oxygenation of the ocean bottom
  - strontium ($^{87}Sr/^{86}Sr$)
    - studies about the age of certain fossils

Strontium isotopes studies ($^{87}Sr/^{86}Sr$)

- ^{86}Sr is abundant and constant in nature
- ^{87}Sr instead is increasing over time, because it derives from radioactive decay of ^{87}Rb

- As a consequence, the ratio $^{87}Sr/^{86}Sr$ is increasing over time
- The smallest this value, the older the rock

Where do we find ^{87}Sr and ^{86}Sr?

- ^{87}Sr and ^{86}Sr can replace Ca ions in calcite and aragonite

- Marine animals use calcite and/or aragonite to build shells or other parts of their structure

- Any calcite or aragonite skeleton will contain some traces of Sr in its $CaCO_3$ mineral structure

- By knowing the relation between the ratio value and time, we can establish when the organism lived

- Sr isotopes work as stratigraphic clocks.

- This method is actually not reliable for samples older than the Eocene

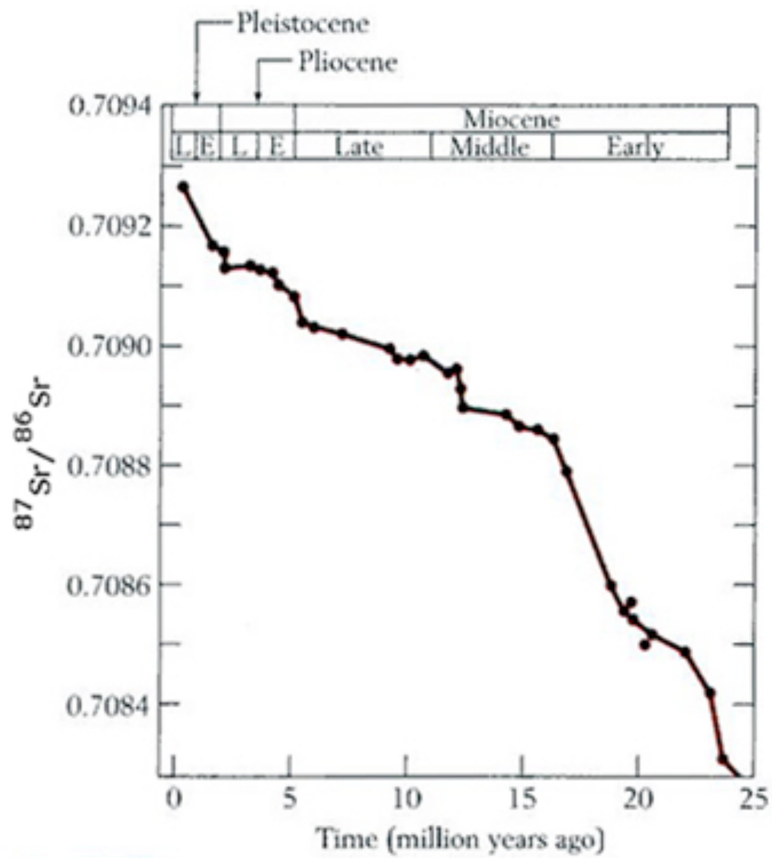


FIGURE 6-12 **The changing ratio of strontium isotopes in marine fossils composed of calcium carbonate during the past 25 million years.** (After D. J. DePaolo, *Geology* 14:103–106, 1986.)

Stratigraphy

END of part IV