Geology and Art, Fall 2004
Introduction & Geologic Time, Lecture 1
Dynamic Earth, Chapter

Skinner, B. J., Porter, S. C., and Park, J., 2004, *Dynamic Earth, An Introduction to Physical Geology*: John Wiley & Sons. (ISBN 0-471-15228-5)

Objectives of the Geology Component:

- The "rock record" contains an incomplete story describing the evolution of the earth and our objective is to gain literacy so that you can start "reading" this record and understand the story. Understand the existence and importance of the rock record.
- The rock record is incomplete due to erosion, burial, subsequent deformation or melting, or other destructive processes. Understand the geologic process that produce the rock record and modify it.
- It takes a lot of expertise and fancy equipment to discern parts of the story. Learn to do literature research and use some analytical equipment.
- The story is always changing and not everyone agrees with all aspects of the story – people may read the rock record in two or more ways. Understand that geology, like all the sciences, is a very dynamic field of study and this is the result of the scientific method.

> Scientific Method (page 8-9):
> 1. **Observe** and describe a phenomenon
> 2. Form a **hypothesis** to explain the phenomenon
> 3. Use the hypothesis to **predict** the existence of another phenomena, or to predict quantitatively the results of new observations
> 4. Perform an experiment or experiments to **test** the predictions.

- Recording observations (field and lab notebooks) is key to understanding the rock record. You will improve your skills at observation and recording.

Relationship between Geologic Time and "Human Time"

In 1650, Roman Catholic Archbishop Usher reviewed the Old Testament and using genealogies and generations calculated the age of the earth (creation of Adam) at 9:00 AM on October 26, 4004 BC, making the earth about 6000 years old. This age was adopted by the church and widely accepted for the next several hundred years.

James Hutton was the first to articulate that geologic processes occur very slowly and change can not usually be observed over the span of a human life. He stated the rock record has "*no vestige of a beginning, no prospects of an end*".

> James Hutton (1726-1797) is considered to be the founder of modern Geology. His studies of the rock formations of his native Scotland helped him to formulate his most famous work, "Theory of the Earth". This work was interpreted and used by many as the basis for geological theory. Hutton made many observations about rock formations and how they were effected by erosion. His terminology and rock formation theories became known as "Huttonian" Geology. Several of the watercolors on this page are reproductions of works that he did while in the field. This portrait of him was done by Abner Lowe in the 1920s.
> http://www.usgs.gov/museum/575005.html

The Rock Record

Layers of sedimentary and/or volcanic rocks have been deposited in basins in the past and some of these layers have been preserved and are exposed today.
Stratum: one distinct layer of rock
Strata: more than one layer of rock
Stratigraphy: the study of strata

Law of Original Horizontality: sediment is generally deposited by water and when originally deposited the layers are horizontal or nearly horizontal.

Principle of Stratigraphic Superposition: strata are deposited in sequence, on above the other, and the chronologic order in which strata were deposited is from the bottom to the top.

Subsequent geologic process can change the orientation and superposition of the strata. Examples of tilted strata and overturned strata.

Missing "pages" or time: there are gaps in the rock record
Conformity: strata have been deposited without any interruption
Unconformity: an substantial interruption in the deposition of strata

- **Angular Unconformity:** marked by an angular discontinuity between two strata. This feature implies that the older strata was tilted and eroded prior to deposition of the younger strata.
- **Disconformity:** an erosional surface parallel to the bedding plain (strata). This feature implies a cessation of deposition and possibly erosion, but no tilting of the strata. These features can be very difficult to identify in the field.
- **Nonconformity:** strata that overlie crystalline rocks (igneous or metamorphic). There is significant time missing between the uplift and erosion of the crystalline rocks and deposition of the strata.

There are two different ways of grouping rock units:

Rock-Stratigraphic Record: classification based on distinction between rock units. This is any distinctive rock unit that differs from the strata above and below. The basic rock-stratigraphic unit is the formation

- **Formation**: a collection of similar strata that are sufficiently different from adjacent collection of strata so that on the basis of physical properties (appearance) they constitute a distinctive, recognizable unit that can be used for geologic mapping over a wide area.

Time-Stratigraphic Record: classification based on geologic time intervals and not rock character. As you move laterally, different rock types (sediment) can be deposited at the same time. On either boundary of a time-stratigraphic unit (lower and older, or upper and younger), age is everywhere equal, that is, the boundaries are isochrons (equal age surfaces).

- **System**: The basic time-stratigraphic unit is the system which includes enough strata that the time interval it represents is sufficiently long to be useful over a wide geographic region

Geologic Time Intervals: intervals of geologic time that

Names of the time intervals originated in the nineteenth-century (Europe) and are usually based on a geographic location that contained examples of rocks of the specific age.

Need to transfer this information into your field notebook (back cover) for easy reference.

Geologic Time Scale

Eon	Era	Period	Epoch	Time (millions of years)
Phanerozoic	Cenozoic	Quaternary	Holocene	0 - 0.01
			Pleistocene	0.01 - 1.8
		Tertiary	Pliocene	1.8 - 5.3
			Miocene	5.3 - 23.8
			Oligocene	23.8 – 33.7
			Eocene	33.7 – 54.8
			Paleocene	54.8 - 65
	Mesozoic	Cretaceous		65 - 144
		Jurassic		144 - 206
		Triassic		206 - 248
	Paleozoic	Permian		248 - 290
		Pennsylvanian		290 - 323
		Mississippian		323 - 354
		Devonian		354 - 417
		Silurian		417 - 443
		Ordovician		443 - 490
		Cambrian		490 - 542
Proterozoic				543 - 2500
Archean				2500 - 3800
Hadean				3800 - 4500

Time Scale from Geological Society of America (1999) http://www.geosociety.org/science/timescale/timescl.pdf

Standard names have been given to the time scale and this is the standard time divisions that geologists use worldwide.

Eons: Largest interval of geologic time but they are not of equal length. The length of time is a result of historic definitions of significant geologic events that bound the intervals.

Eras: The Phanerozoic Eon is divided into “old life” (Paleozoic), “middle life” (Mesozoic), and “recent life” (Cenozoic). The Precambrian is not divided into Eras.

Periods: The Eras are divided into Periods based on paleontology (fossils). The names of the Periods are based on type localities.

Epochs: Periods are divided into Epochs based on a subdivision of the fossil record The Pleistocene refers to the latest ice age and the Holocene represents the time since the glacial retreat.

Geologic Time in Perspective

Age of the Earth = 4.6 Ga

Age of the oldest known rock = 3.96 Ga (Yellowknife region, NWT)

Age of the oldest known life = 3.77 Ga (blue-green algae in NW Australia)

Time-transgressive sequences must be identified - the rocks may correlate but their ages do not

Geologic Time

- Time is probably the most important dimension in geology
- The scale of time is inconceivable, extremely long intervals
- Time hinders development of the “story” because the evidence is slowly lost due to erosion - the older the rock, the less remains

Relationship between rates and time - slow rates over long intervals results in significant events.

William “Strata” Smith was a surveyor for the English canal system that was developed during the industrial revolution (1969-1839). He identified a systematic succession of fossils in strata (principle of faunal succession) and created maps that used fossils to correlate geologic units. This work was the result of keen observation and interpreting those observations.

Correlation: the means of determining the equivalence of rock units (time- or rock-stratigraphic units) between two or more different places.

Rocks linked by continuous exposure are easily correlated but the further apart exposures are, and the more rapid the lateral changes in the rock type (lithology), the increasingly difficult correlation is; similar rock layers may suggest the rock originated at the same time but the equivalency must be ascertained by correlation

Key Bed: a distinctive thin and widespread stratigraphic unit that is easily recognized in the field and can be used for correlation. A volcanic ash or iridium layer is an excellent example of a key bed.

Index Fossil: a fossil with a common occurrence, widespread distribution and very restricted age that can be used for correlation.

William Smith (1769-1839)

Fossils have been long studied as great curiosities, collected with great pains, treasured with great care and at a great expense, and shown and admired with as much pleasure as a child's hobby-horse is shown and admired by himself and his playfellows, because it is pretty; and this has been done by thousands who have never paid the least regard to that wonderful order and regularity with which nature has disposed of these singular productions, and assigned to each class its peculiar stratum.

William Smith, notes written January 5, 1796

William Smith was born on March 23, 1769, into a family of small farmers. He received little formal education, but from an early age took an interest in exploring and collecting fossils in his native Oxfordshire in England. At the same time, he learned geometry, surveying, and mapping; at the age of eighteen he became an assistant surveyor, learning his trade from the master surveyor Edward Webb. Surveying required Smith to travel all over England; in 1794 he toured the entire country, and then he began to supervise the digging of the Somerset Canal in southwestern England, a job that lasted six years. The job of surveying canal routes required detailed knowledge of the rocks through which the canal was to be dug. This led Smith to examine the local rocks very carefully. While doing this, Smith observed that the fossils found in a section of sedimentary rock were always in a certain order from the bottom to the top of the section. This order of appearance could also be seen in other rock sections, even those on the other side of England. As Smith described it,

. . . each stratum contained organized fossils peculiar to itself, and might, in cases otherwise doubtful, be recognised and discriminated from others like it, but in a different part of the series, by examination of them.

This is a statement of the "principle of faunal succession." The layers of sedimentary rocks in any given location contain fossils in a definite sequence; the same sequence can be found in rocks elsewhere, and hence strata can be correlated between locations. The principle is still used today, albeit with some alterations; for example, some fossil species may not be distributed over a wide area and therefore not be useful for long-range correlation.

In 1796, Smith was elected to the agricultural society at Bath, and began to discuss his ideas with others who were interested in rocks and fossils. He began to write notes and draw up local geologic maps. Smith was not the first to make geologic maps, but he was the first to use fossils as a tool for mapping rocks by their stratigraphic order, and not necessarily by their composition. Previous mapmakers had attempted to use the composition of rocks as indicators of their position in the stratigraphic column.

In 1799, Smith's employment with the canal-building firm came to an end. Smith then took a series of engineering jobs in several parts of Britain, and made a number of side trips all over England and Wales. His goal was to produce a complete geologic map of England and Wales, using the principles of fossil succession. Progress was slow, and money to finance the publication of such a map was hard to find. Finally, with the aid of 400 subscribers underwriting the project, production of the completed map began in 1812, and in 1815 the map was finally published.

Unfortunately, Smith's map was overlooked at first by the scientific community of the time; his humble origins and limited education were an obstacle to success in learned society. Not until the later part of his life was his contribution to geology appreciated in full. His contribution may best be summed up this way: In 1831, the Geological Society of London instituted the Wollaston Medal, its highest honor, awarded each year for outstanding achievement in geology. Smith received the first Wollaston Medal that same year. The geologist Adam Sedgwick, then President of the Society, presented the award to Smith with these words:

If, in the pride of our present strength, we were disposed to forget our origin, our very speech betrays us: for we use the language which he taught us in the infancy of our science. If we, by our united efforts, are chiselling the ornaments and slowly raising up the pinnacles of one of the temples of nature, it was he that gave the plan, and laid the foundations, and erected a portion of the solid walls, by the unassisted labour of his hands. http://www.ucmp.berkeley.edu/history/smith.html

See: The Map That Changed the World : William Smith and the Birth of Modern Geology by Simon Winchester

Geologic Ages (Dating)