Geological Time and the Fossil Record

BI 201 Natural History of Guam

Class Presentation 12

- Geological time
  - Geological time began with the formation of Earth some 4.5 Bybp
  - Because of the magnitude of this time span, Earth’s history is subdivided into categories to help us in discussing events during various periods

GEOLOGIC TIME SCALE

EON	GEOLOGICAL TIME (Mybp)	ERA	DURATION (My)	PERIOD
PHANEROZOIC	1.6	CENOZOIC		QUATERNARY
	65		63.4	TERTIARY
	140	MESOZOIC	75	CRETACEOUS
	210		70	JURASSIC
	245		35	TRIASSIC
	290	PALEOZOIC	45	PERMIAN
	365		75	CARBONIFEROUS
	413		48	DEVONIAN
	441		28	SILURIAN
	504		63	ORDOVICIAN
	545		66	CAMBRIAN
PROTEROZOIC	2500			ALGONKIAN
ARCHAEAN	4000			
PRISCOAN	~4500			

GEOLOGICAL TIME (Mybp)	ERA	DURATION (My)	PERIOD	EPOCH
0.01	CENOZOIC	0.01	QUATERNARY	HOLOCENE (RECENT)
1.6		1.59		PLEISTOCENE

GEOLOGICAL TIME (Mybp)	ERA	DURATION (My)	PERIOD		EPOCH
1.6	CENOZOIC				
5		3.4	TERTIARY	NEOGENE	PLIOCENE
26		21			MIOCENE
38		12		PALEOGENE	OLIGOCENE
54		16			EOCENE
65		11			PALAEOCENE

- Earth time is subdivided into four categories:
  - Eons
  - Eras
  - Periods
  - Epochs

- Eons
  - An eon is the largest geological time unit, spanning hundreds of millions to billions of years
  - There are four eons:
    - Priscoan [L. *priscus* = of former times, ancient]; >4 Bybp
    - Archaean [Gr. *archae* = beginning, from the beginning]; 4–2½ Bybp
    - Proterozoic [Gr. *proteros* = earlier]; 2,500–560 Mybp
    - Phanerozoic [Gr. *phaneros* = visible; *zoion* = animal]; time of visible life; <560 Mybp
  - Many geologists refer to the first three eons collectively as the Precambrian Eon
  - Each eon is subdivided into a number of eras

- Era
  - An era is a first-order geologic time unit
  - Eras often span tens to hundreds of millions of years of Earth’s history

- Because this class is concerned primarily with the Phanerozoic Eon, there are three eras for study
  - Paleozoic [Gr. *palaios* = ancient, old]; 540-245 Mybp
  - Mesozoic [Gr. *mesos* = middle]; 245-65 Mybp
  - Cenozoic [Gr. *kainos* = recent, new] 65 Mybp to present
- Guam's geological history falls within the Cenozoic Era
- Each era is composed of several periods

- Period
  - A period is a second-order geologic time unit Periods span millions to tens of millions of years of Earth history
  - The Palaeozoic Era is subdivided into six periods (or seven in America); the Mesozoic Era is subdivided into three periods; and the Cenozoic Era is subdivided into two periods
  - The geological history of Guam spans most of the two periods of the Cenozoic Era, the Tertiary and Quaternary Periods
  - Geological periods are further subdivided into epochs

- Epoch
  - An epoch is a third-order time unit
  - Guam's geological history began in the Eocene Epoch and spans the five subsequent epochs to the present, which is called the Holocene Epoch or Recent Epoch
  - Each epoch may be further subdivided into geological ages

- Absolute Time
  - Absolute time is the age of rock in years
  - Absolute time is difficult to ascertain, but it is best determined by radiometric dating
    - Radiometric dating is the most precise method of dating rocks, wherein the age of the rock is calculated from the relative percentages of 'parent' and 'daughter' isotopes of a particular radioactive element in the rock

- Radiometric dating make use of the fact that ‘heavy’ isotopes of elements tend to be unstable and undergo spontaneous nuclear disintegration, called radioactive decay
  - Radioactive decay occurs when protons or neutrons are lost from the nucleus of an unstable isotope
  - When protons or neutrons leave the nucleus, energy (i.e., radiation) is emitted
  - When protons are lost from the nucleus during radioactive decay, the resulting atom becomes a different element, called a daughter product

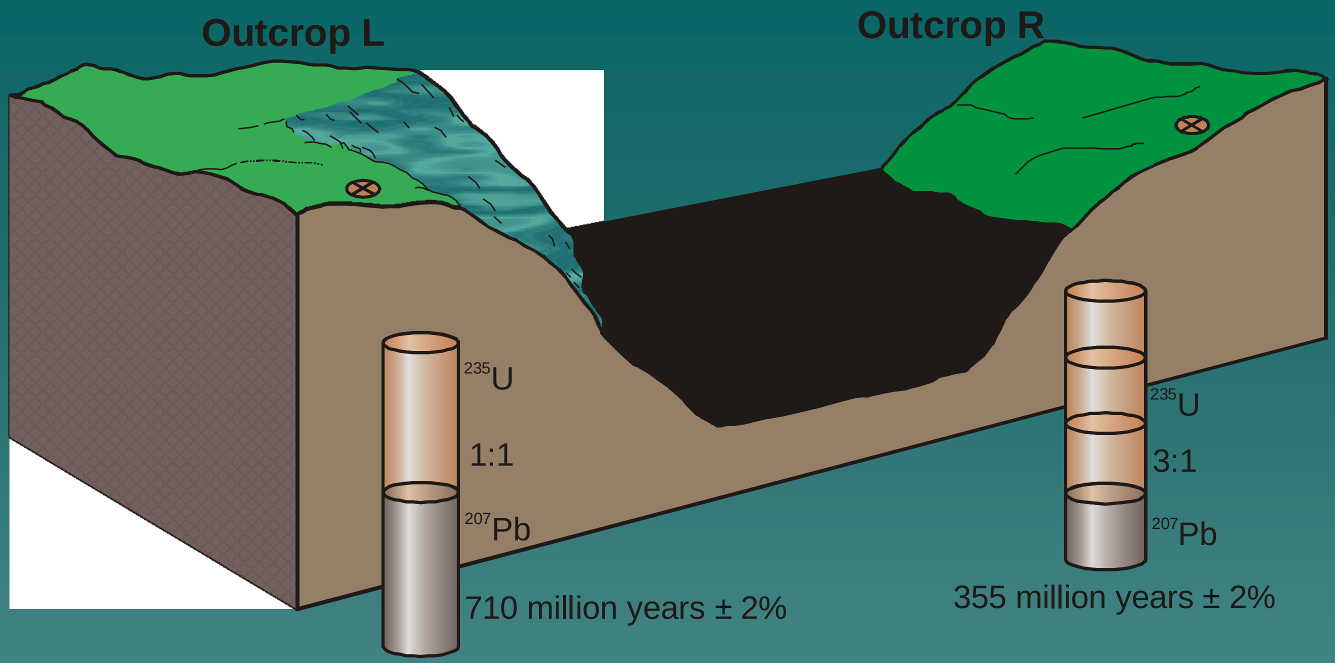
- For example, when ^{238}U decays, 10 protons and 22 neutrons are lost from the nucleus
  - Therefore, the resulting daughter element is lead: ^{206}Pb, which contains 82 protons + 124 neutrons in its nucleus
- The rate of radioactive decay is constant; it is not affected by temperature or pressure or any change in the physical environment
  - Therefore, radioactive decay of heavy elements is a very precise clock that is useful for determining the age of rock
- The rate of radioactive decay is given as a **half-life**
  - A half-life is the time it takes for a given amount of a radioactive isotope to be reduced by one-half

- Some radioactive isotopes for dating rocks include:

Isotope	Daughter Product	Half-life
Potassium 40 (^{40}K)	Argon 40 (^{40}Ar)	1.3 By
Uranium 238 (^{238}U)	Lead 206 (^{206}Pb)	4.5 By
Uranium 235 (^{235}U)	Lead 207 (^{207}Pb)	713 My
Thorium 232 (^{232}Th)	Lead 208 (^{208}Pb)	14.1 By
Rubidium 87 (^{87}Rb)	Strontium 87 (^{87}Sr)	49 By
Carbon 14 (^{14}C)	Nitrogen 14 (^{14}N)	5,730 yr

- The steps that are taken to determine the age of rock containing ^{40}K would be as follows:
  1. First, the amount of ^{40}K present in the sample must be determined by chemical analysis
  2. Next, the amount of ^{40}Ar present in the sample must be determined by chemical analysis
  3. Then, we use the data from (2.) to calculate the amount of ^{40}K present when the rock was formed
  4. Finally, using the ratio of (3.) : (2.), we can calculate the age of the rock

- For illustrative purposes, let's say that our rock sample has 0.25 g ^{40}K and 0.75 g ^{40}Ar at the present time
  - Based on these data, we would estimate that there was 1.0 g ^{40}K at the origin of the rock
  - Therefore, the age of the rock is 2.6 By
    - That is, 1.0 g ^{40}K decays to 0.5 g ^{40}K in 1 half-life, or 1.3 By, and
    - 0.5 g ^{40}K decays 0.25 g ^{40}K in 1 half-life, or 1.3 By
    - Therefore, the sample has decayed by two half-lives, or 2 x 1.3 By = 2.6 By



Absolute Dating. Outcrops L and R contain the radioisotope uranium 235. It has a half-life of 710 million years and decays to lead 207. Dating with radioisotopes is possible for many types of rocks but is more broadly possible with igneous rocks like the basalt and granite that make up most of the oceanic and continental components, respectively, of Earth's crust. At out crop L, the ratio of ^{235}U to ^{207}Pb of 1:1 means that one-half of the ^{235}U atoms have decayed to ^{207}Pb, so the rocks are one half-life of ^{235}U old, or 710 million years. In Outcrop R, the ratio of ^{235}U to ^{207}Pb is 3:1. This means that one-fourth of the original ^{235}U atoms have decayed to ^{207}Pb, so the is rock is one-half of a half-life old, or 355 million years.

- There is one significant limitation to radiometric dating
  - Geologists can date only igneous rock with this method, because sedimentary rock may be contaminated with previously formed daughter products and isotopes from more than one igneous rock formation
- Therefore, geologists must use relative age for dating sedimentary rock

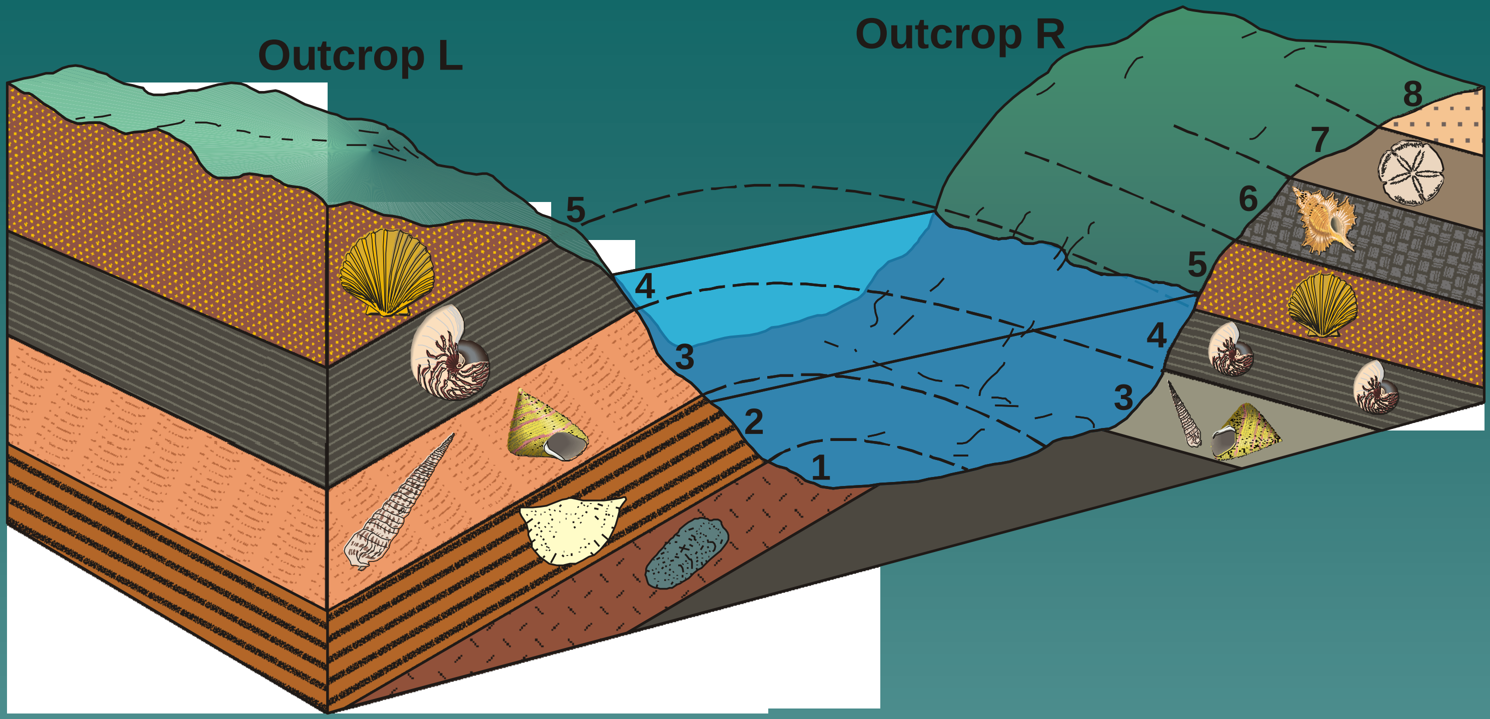
- Relative Time
  - Geologists use four basic principles to determine the relationship of geologic events to one another
    1) Principle of original horizontality
    2) Principle of suprapostion
    3) Principle of lateral continuity
    4) Principle of cross-cutting relationships

- Original Horizontality
  - The principle of original horizontality states that beds of sediment deposited in water formed as horizontal or nearly horizontal layers
- Superposition
  - The principle of superposition states that within a sequence of undisturbed sedimentary or volcanic rocks, the layers are younger going from bottom to top

- Lateral continuity
  - The principle of lateral continuity states that an original sedimentary layer extends laterally until it tapers or thins at its edges
- Cross-cutting relationships
  - The principle of cross-cutting relationships states that a disrupted pattern is older is older than the cause of the disruption

- Fossils
  - Fossils are traces of plants or animals preserved in rock
    - Plants and animals that lived at the time the sedimentary rock was forming were buried by sediment, and their fossil remains are preserved in the rock

- Fossils are common in sedimentary rock, and their presence is important for correlation
  - Correlation is the determination of the age relationships between rock units or geological events in separate areas
  - Fossils in one layer of sedimentary rock often differ markedly from fossils in the layer above or below them
  - No matter where on Earth they are found, individual fossil species always occur in the same sequence relative to one another



Relative Dating. Fossil assemblages used in relative dating can be found in Outcrops L and R. Assemblages 3, 4 and 5 may be matched, telling us the rocks in segments of the outcrops formed at the same time. We could not, however, tell how many years ago this formation occurred when fossil evidence was the only dating tool we had. The concept of superposition states that younger sediments are laid down on older deposits.

- Some fossils are restricted in geographic distribution, representing organisms adapted to special environments
- Other fossils are distributed globally, indicating that they lived over vast areas of Earth
  - Fossil assemblages from these widely distributed species may be used for worldwide correlation