G202 Class Notes - Introduction to Stratigraphy and Geologic Time

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I. Introduction

A. Stratigraphy: the study of the geologic rock record in the context of geologic time.

1. Geologic Rock Record: analogous to a tape recording in which some historical events are preserved and recorded, others have been erased, and still others were not taped at all

a. Referred to as "Stratigraphic Record": originally involved the study of "layered" sedimentary rocks and the fossil record.

2. Geologic Time: abstract concept of continuous linear time from earth's origins to present day (portions of which are preserved in the rock record, and portions of which are not)

a. Time Record vs. Rock Record

Time is recorded in the rock record, but not all rocks or all time are preserved.

3. The study of Stratigraphy represents an attempt to correlate the relative sequence of observations from the rock record, with that of historical/linear time.

B. Historical Geology: Use of the stratigraphic record to derive historical time record and physical/biological evolution of the earth.

1. Examining the rock record to deduce the natural history of the time record.
2. Goal: to place Earth history events in the proper chronological order

C. Sedimentology: study of the processes and products of the near-surface environment of the earth

1. Sedimentology outgrowth of stratigraphy, historical geology

a. Stratigraphy originally based on layered sedimentary rocks and the fossils contained within.

b. Sediments accumulate as horizontal layers of particles under the force of gravity, "layer cake" approach to geology and interpretation of the rock record.

II. Basic Principles of Stratigraphy

A. Law of Uniformitarianism: geological processes operating today, are similar to those that have operated in the past

1. Present is the key to the past, the observable processes operating today are the key to interpreting the geologic record

2. Original Opposing View to Uniformitarianism: "Catastrophism"

   a. Catastrophist View: large-scale catastrophic processes are responsible for most of the changes and evolution of the earth (floods, quakes, eruptions, storms)

      (1) Short bursts of violent (high energy) processes, followed by slow process cycles

      (2) Although originally proposed in the spirit of scientific thought, catastrophism was embraced by the church and biblical fundamentalists in terms of Noah's flood, fire and brimstone, etc.

   b. Modern Resurgence of Catastrophism among Stratigraphers

   c. More recently, sedimentologists and stratigraphers have recognized the importance of catastrophic events in shaping the rock record
      (1) the volcanic eruption
      (2) hurricane/storm deposits
      (3) 100 year fluvial flood deposits

   d. "Catastrophic Uniformitarianism": combination of slow incremental process-response, punctuated by catastrophic events, repetitively in a cyclical pattern throughout earth history.

B. Relative Dating - determining the relative chronological order of Earth history events

   1. Law of original horizonatality: no matter what the current bedding orientation, sedimentary strata were deposited as horizontal beds under the influence of gravity. Steeply inclined strata have therefore suffered structural disturbance.

   2. Law of lateral continuity: sedimentary strata were generally deposited in more or less continuous blankets or sheets (may have since be subjected to erosion and cross-cutting)

   3. Law of Superposition: sedimentary strata are such that deposition occurs in chronological succession with the oldest bed on the bottom and the youngest at top.

   4. Law of Cross-cutting Relationships- " a disrupted pattern is older than the cause of the disruption".
      a. E.g. when a fault cross-cuts a sequence of sedimentary rocks, the rocks were deposited first, then cross-cut by the fault, otherwise they would have been undisturbed by the faulting event.

      b. Cross-cutting geologic phenomena include: faults, volcanic intrusions, and erosional unconformities.

   5. Law of Inclusions: if a pre-existing rock type is included as a fragment within a magma intrusive or lava flow, the the pre-existing rock must be older than the igneous body.

6. Law of Faunal Succession: in a succession of strata containing fossils, the fossils found in the lowest beds are the oldest
    a. Formed basis of Darwin's Theory of Evolution

7. Principle of Fossil Correlation: assemblages of fossils found in a given rock layer or unit are of like age; therefore strata containing like fossils are of similar age

    a. Index Fossils: a given fossil species that is particularly useful for correlation of strata
        (1) it is unique in its stratigraphic occurrence,
        (2) of limited vertical distribution
        (3) geographically widespread.

            (a) e.g. trilobites found only in Cambrian and lower Ordovician,
                e.g. sharks found throughout geo-history since Devonian

8. Principles of Relative Rock Correlation:
    a. Physical continuity of rock bedding.
    b. Similarity of Rock types
    c. Correlation/similarity of fossils: based on theory of evolution and distinct periods of life forms on earth.

C. Absolute (Numerical) Dating

1. Basic Premise
    a. uses radioactive elements contained within rock sequences to chemically and quantitatively determine the absolute age of that rock within the framework of statistical and/or experimental error.

2. Radiometric Dating- chemical/analytical method for determing the amount of radioactive decay that has occurred to a radioactive isotope (contained in a rock or mineral).

    a. Radioactive Decay Series: process that occurs whereby unstable radioactive elements (e.g. Uranium) decay or breakdown into subatomic particles in order to attain a more stable atomic structure.

        (1) "Parent" = initial radioactive isotope (e.g. U-238)
        (2) "Daughter" = final end product that results from decay process (e.g. Pb 206)

For e.g. U-238 loses 32 protons during the decay process, resulting in an atomic no. of 206, defining the element lead.

        (3) For a given radioactive element, it has been experimentally determined that the rate of radioactive decay is constant.

        (4) Half Life
            (a) Amount of time it takes 1/2 the amount of a given quantity of

Parent isotope to decay into Daughter product.

(b) e.g. $T_{1/2}$ for U238 to Pb206 = 4.5 billion years; i.e. it takes 4.5 billion years for one/half of a given amount of U238 to decay into PB206.

(5) Radiometric Dating Technique

(a) Given the rate of decay for a given radioactive isotope: it is possible to measure the amount of parent isotope and amount of daughter isotope in a given rock specimen, and work back to the age of that rock.

D. Subdisciplines of Stratigraphy

1. Lithostratigraphy: correlation and organization of rock strata based on physical lithologic properties.

2. Biostratigraphy: correlation and organization of rock strata based on fossil content

3. Chronostratigraphy: Age dating of stratigraphic rock units in the context a absolute geologic time

4. Magnetostratigraphy: correlation and organization of rock strata on the basis of magnetic properties of sedimentary and igneous rock sequences
   a. Remnant Magnetism Preserved in the rock at the time of formation.

5. Seismic Stratigraphy: correlation and organization of rock strata on the basis of seismic character.

III. Geologic Time and the Geologic Record

1. Gaps in the Rock Record:

a. Its clear that in any given stratigraphic section for a given geographic region, only a certain portion of the stratigraphic rock record is present. In the record that is present, many lengths of time may be unrecorded, missing or unaccounted for.

b. Causes of Gaps in the Record (Hiatus)

(1) Non-deposition: i.e. geologic processes did not result in a sedimentary or igneous product

(a) Sedimentation processes are episodic: a function of energy in sedimentary system and sediment available for transport/deposition.

(b) There may be long or short periods in which net sediment accumulation or aggradation = 0.

(c) Diastem: a small-scale gap or break in the sedimentary-stratigraphic record

(2) Post-depositional Erosion: the geologic process did result in a sedimentary or igneous product, however this product was later stripped by weathering/erosion.

(a) Causes of Post-depositional Erosion

i) Broad "epeirogenic" upwarping of continental areas with subsequent weathering, erosion and stripping of sedimentary rock cover as land area is elevated relative to erosional base level

ii) Active Tectonic Erosion and Alteration
a) Tectonic Uplift, Erosion
b) Subduction--- return to mantle
c) Metamorphism

iii) Erosion in conjunction with sedimentary processes

a) Fall of Sea Level: exposes coastal sediments, subject to subsequent erosion

b) Channel cutting and erosion by fluvial systems

c) Ocean current/wave base erosion

(3) The sedimentary and tectonic process is such that much of the time record is missing from the stratigraphic rock record.

(a) Much of absolute geologic time may be unaccounted for in the rock record
i) Completeness of rock record controlled by nature of sedimentary/igneous processes and erosion cycle processes

2. Unconformable and conformable sequences

a. Conformable sedimentary sequences: parallel beds of rock lying above and below one another with no evidence of erosive or structural discontinuities

b. Unconformities: sequences of rock which show evidence for erosive or structural breaks in the record. Unconformities are defined by surfaces of erosion.

(1) Marked by erosive, cross-cutting contacts, basal gravel lags, rip-up clasts.

c. Classification of Unconformities

(1) Angular Unconformity: angular discordance of bedding between older and younger sequences of rock, discordance marked by surface of erosion

(a) imply period of deposition, horizontal sediment accumulation, lithification, structural deformation/tilting of rock beds, subaerial exposure/erosion, renewed deposition on top of erosion surface.

(b) Hutton's unconformity at Siccar Point, Scotland (tilted sed rocks overlain by horizontal sed rocks):

i) Slow rates of modern processes, implied that enormous amounts of geologic time are required to account for the relationships observed in the rock record.

(2) Nonconformity: sedimentary strata overlying crystalline rocks (igneous and/or metamorphic), separated by erosion surface

(3) Disconformity: major stratigraphic breaks in the sedimentologic record (erosionally or nondepositionally), with no angular discordance of strata

(a) Parallel beds with observable surface of erosion separating sequences

(4) Paraconformity: similar to disconformity but with no observable erosive break in the sequence

(a) often identified by fossil record or other stratigraphic technique

(5) Lacuna: refers to missing stratigraphic/time interval within the unconformity

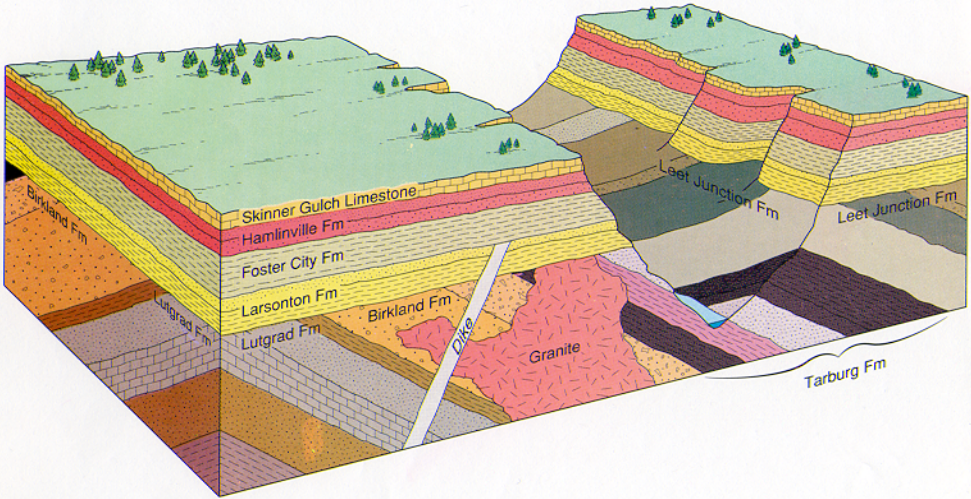
IV. Geologic Time Scale

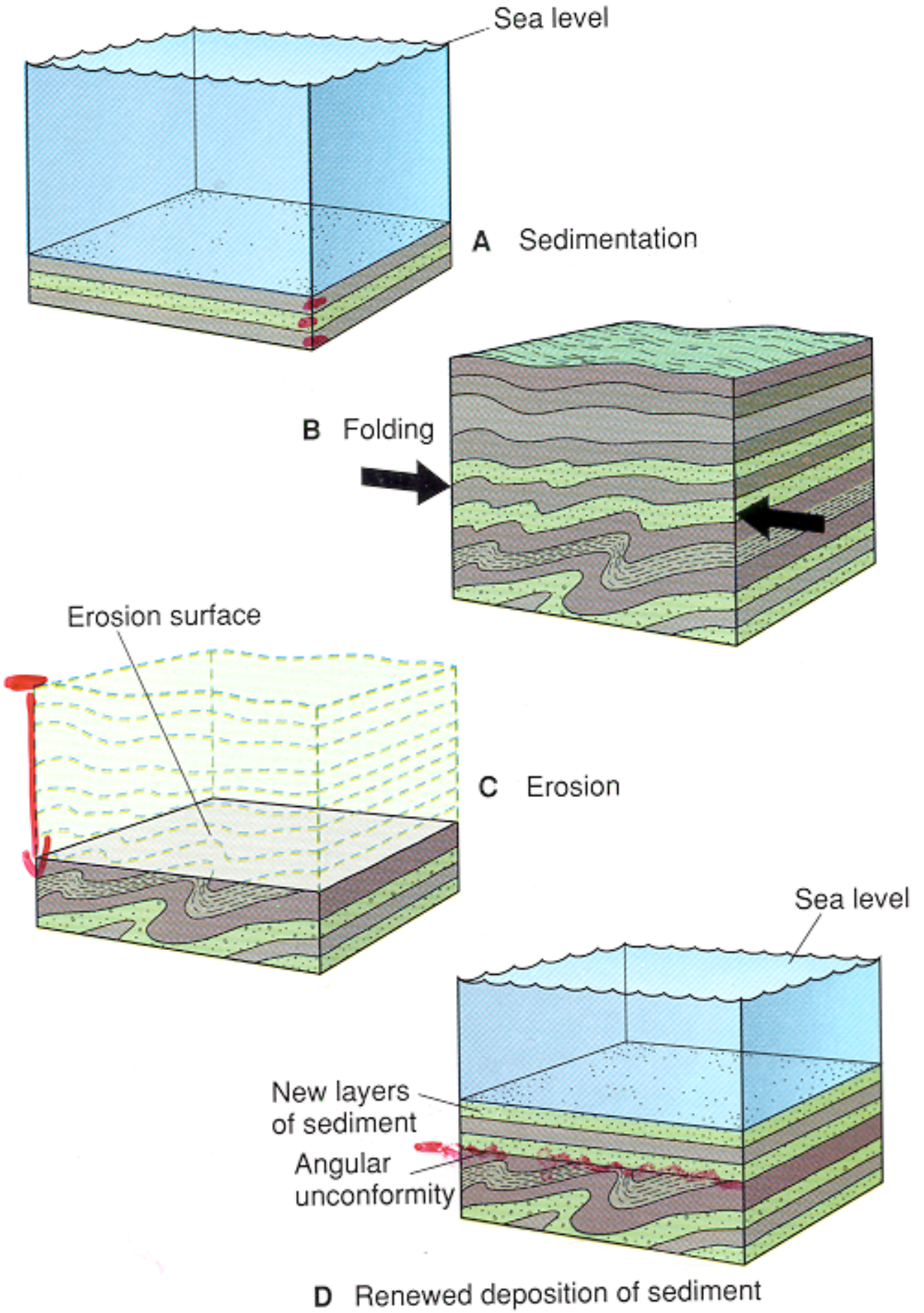
A. A work of art in progress for the past 200 years

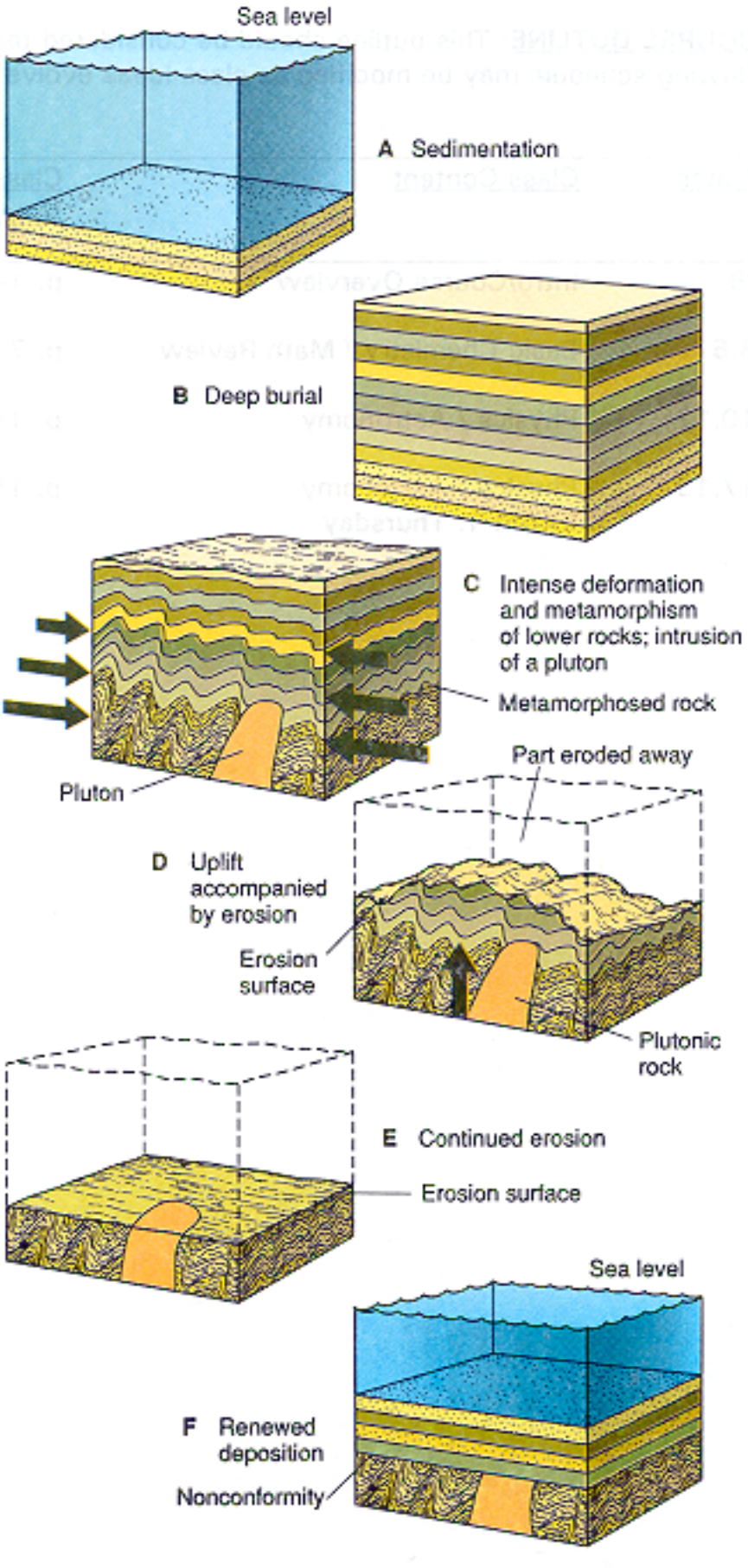
1. The result of the work of a great number of geologists and stratigraphers for many years and in many different places around the globe

2. Modern Geologic Time Scale Based On:
   a. Fossil Record / Fossil Correlation
   b. Paleomagnetic Record
   c. Geochemical / Radiometric Dating

B. Geologic Time Scale: broken into Eras, Periods, Epochs in decreasing time interval
1. Eras: Precambrian, Paleozoic, Mesozoic, Cenozoic
2. Periods:
   a. Paleozoic: Cambrian, Ordovician, Devonian, Mississippian, Pennsylvania, Permian
   b. Mesozoic: Triassic, Jurassic, Cretaceous
   c. Cenozoic: Tertiary, Quaternary
3. Epochs:
   a. Tertiary: Paleocene, Eocene, Oligocene, Miocene, Pliocene
   b. Quaternay: Pleistocene, Holocene

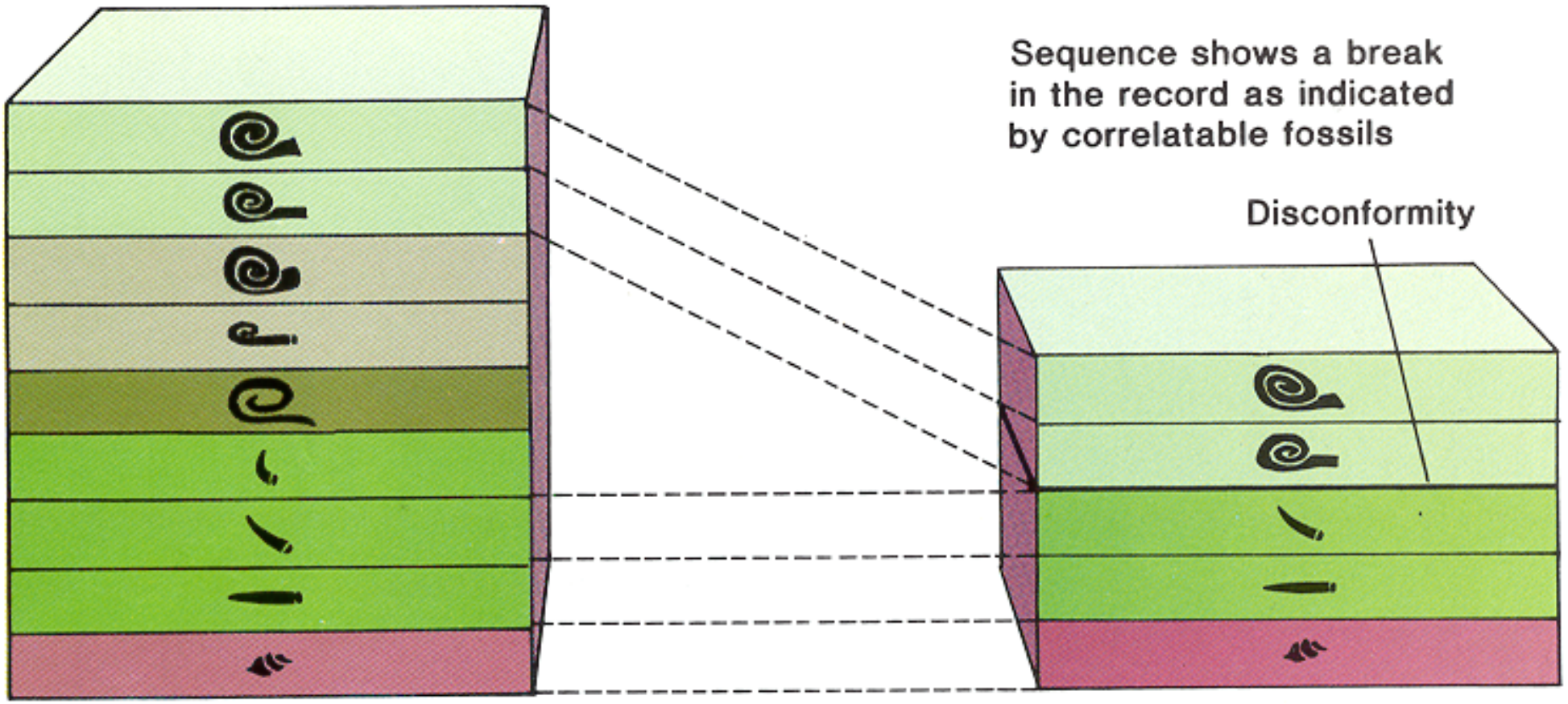

Skinner Gulch Limestone
Hamlinville Fm
Foster City Fm
Larsonton Fm
Lutgrad Fm
Birkland Fm
Lutgrad Fm
Birkland Fm
Dike
Granite
Leet Junction Fm
Leet Junction Fm
Tarburg Fm

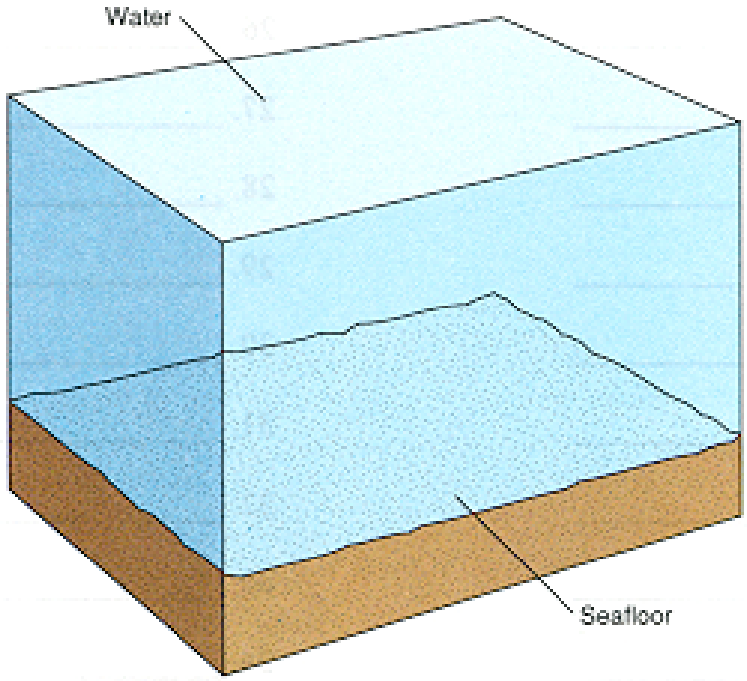


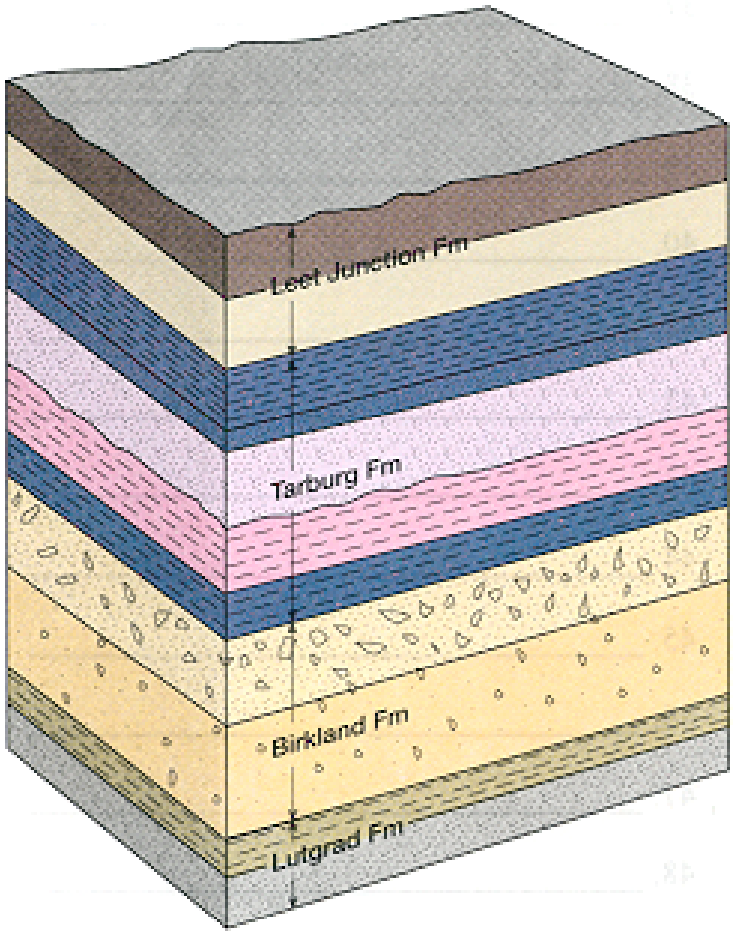


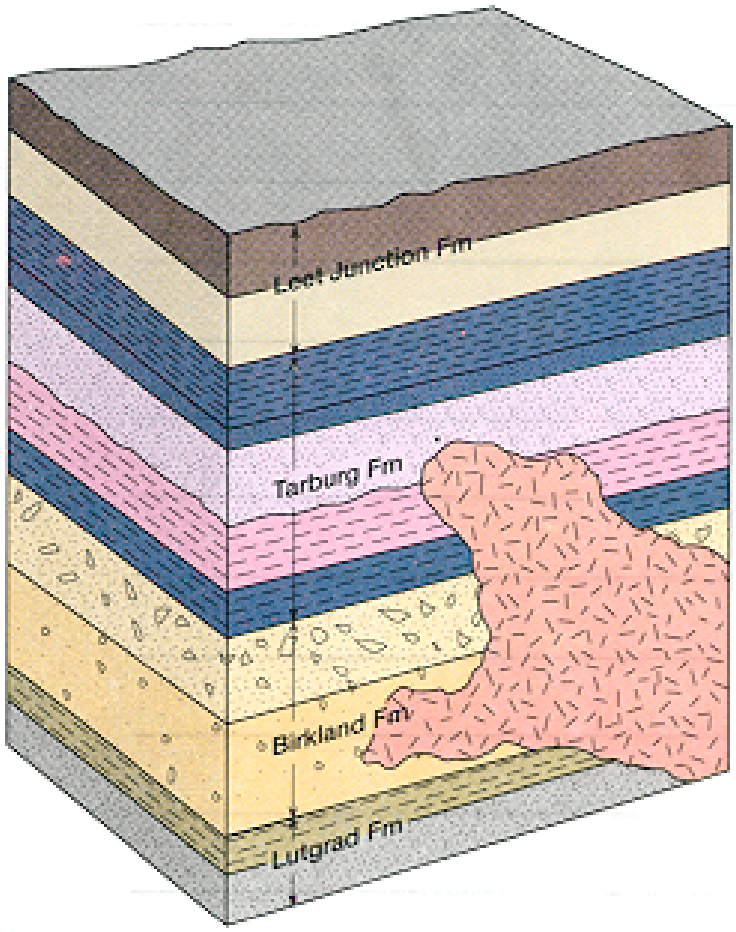
Nonconformity

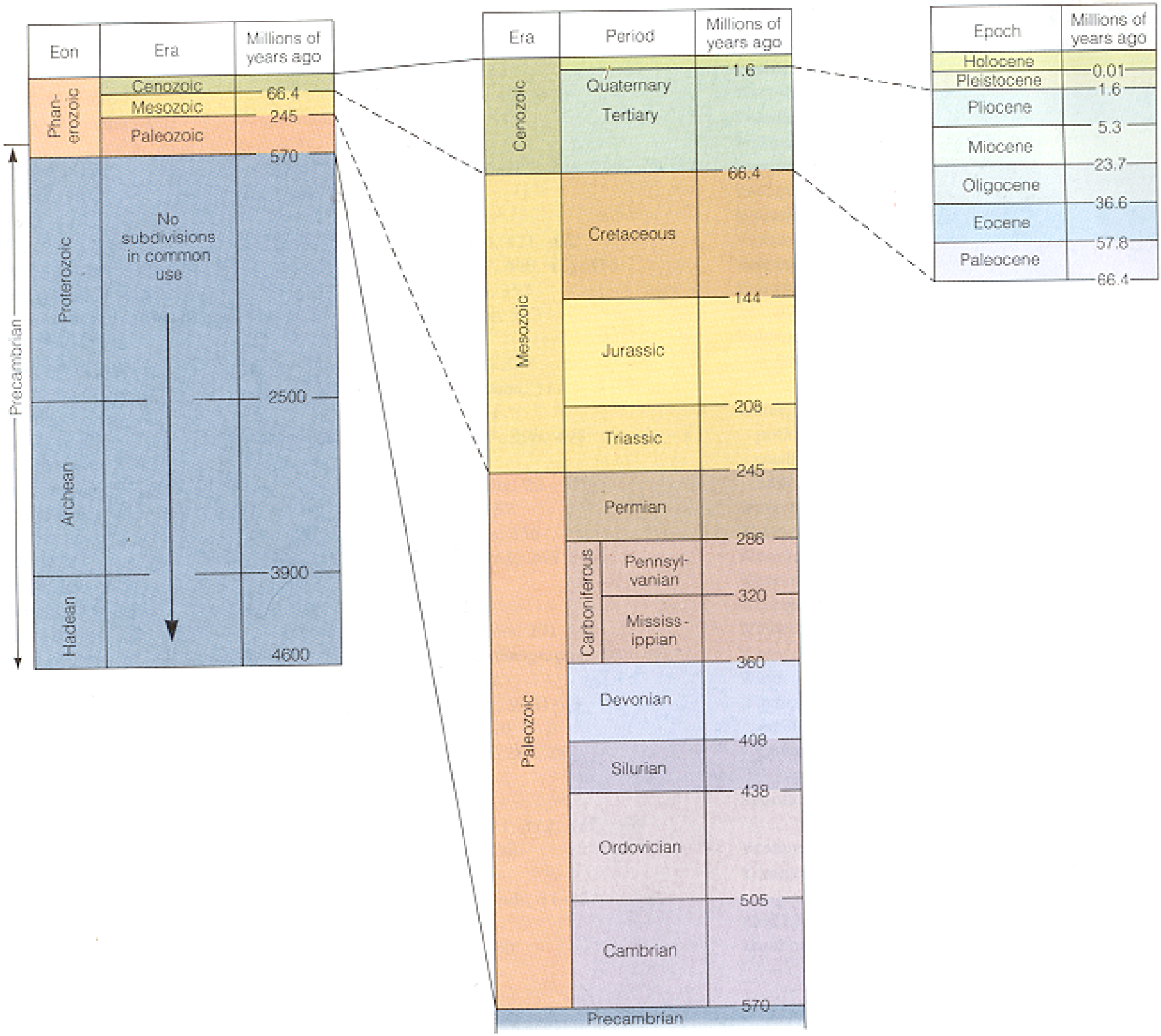
Plummer, Charles C., and David McGeary, *Physical Geology*, 6/


Sequence of sedimentary rock with complete record of deposition
Sequence shows a break in the record as indicated by correlatable fossils
Disconformity
Dashed lines indicate correlation of rock units between the two areas


Water
Seafloor


Leet Junction Fm
Tarburg Fm
Birkland Fm
Lutgrad Fm


Leet Junction Fm
Tarburg Fm
Birkland Fm
Lutgrad Fm


Eon
Era
Millions of years ago
Phanerozoic
Cenozoic
Mesozoic
Paleozoic
66.4
245
570
Proterozoic
Archean
Hadean
Precambrian
No subdivisions in common use
2500
3900
4600
Era
Period
Millions of years ago
Cenozoic
Quaternary
Tertiary
1.6
66.4
Mesozoic
Cretaceous
Jurassic
Triassic
144
206
245
Paleozoic
Permian
Carboniferous
Pennsylvanian
Mississippian
286
320
360
Devonian
408
Silurian
438
Ordovician
505
Cambrian
570
Precambrian
Epoch
Millions of years ago
Holocene
Pleistocene
Pliocene
Miocene
Oligocene
Eocene
Paleocene
0.01
1.6
5.3
23.7
36.6
57.8
66.4