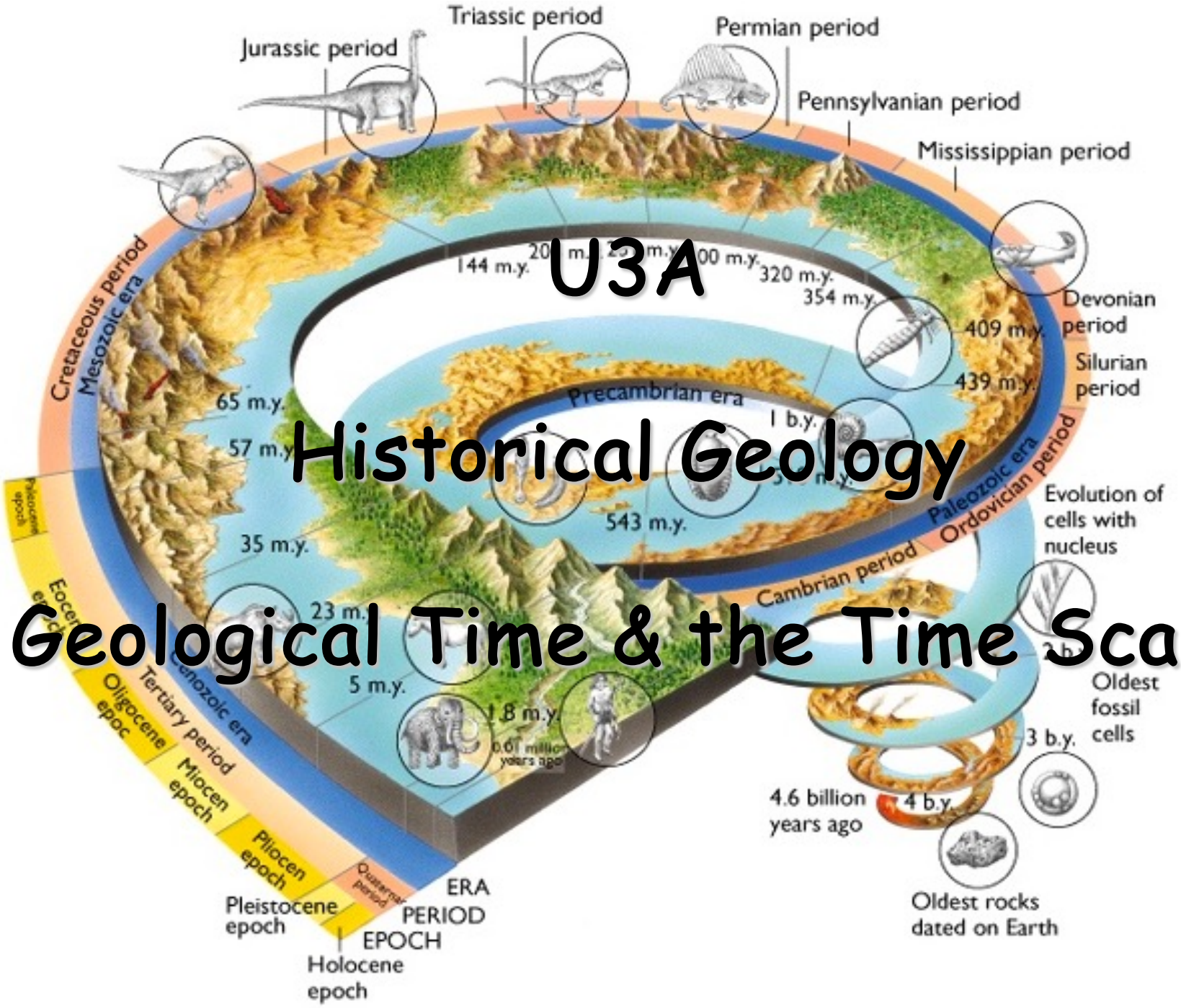


U3A

Historical Geology

Geological Time & the Time Scale

The nature of geological time

- History of Earth covers an immense span of geological time over which geological events have occurred
- historical aspect to geology → understanding how the Earth and planetary bodies evolved with time
- knowledge and nature of geological time → unique contribution geology has made to science
- only geologists and astronomers have to deal with time on such an immense scale
- acceptance of immensity of geological time was very slow

Grand Canyon Arizona

Grand Canyon

- Rocks at base of Grand Canyon → fundamentally different to overlying rocks
- metamorphic rocks at base of canyon → ~1800myr overlying are mainly marine sedimentary rocks → 525-270myr
- each layer was deposited over a period of time
- a layered sequence records history of processes operating at the time that layers were depositing (read like a book)
- Colorado Plateau uplifted ~3km by flat slab subduction
- understanding the immensity of geological time requires an understanding of events that have occurred over time

Rhythmites

Rythmites are sedimentary rocks formed in cyclic depositional environments

Tidal rhythmites from Pichi Richi pass, Flinders Ranges, South Aust.

Varve deposits, Glacial Lake Missoula, Montana

Grand Canyon and relative time

Developments of concepts of time

- Early concepts of time and the Earth

- Few hundred years ago → age of Earth was constructed from oral records of history → Earth thought to have formed at the same time as people first appeared
- ancient times → Earth was generally thought to be young ~6000yrs according to interpretation of biblical records, considered useful
- belief persisted in Mediaeval and Renaissance Europe

- Central idea

- short period of time required (thousands of years) required to form the entire record of the history of the Earth

James Ussher (1581-1656)

- James Ussher, Calvinist archbishop of Armagh → spent 20years reconstructing the history of the Earth from the Bible and ancient writings
- he proposed that the creation of the Earth occurred on October 22nd 4004BC
- Ussher's calculations were widely accepted for several generations

James Ussher

Catastrophism

- Catastrophism → Renaissance concept proposed to explain the geological features e.g. deformation structures in mountain ranges, volcanoes
- catastrophists believed Earth's landscape had been modelled by a series of short term events e.g. Noachian flood
- the concept survived until the 19th century (and even today?)
- certain neo-catastrophism creeping back into modern Earth Science → does not follow same lines as past catastrophism
- concept of catastrophism vs gradualism (gradual change) led to alignment of opposing scientific groups in Europe in the late 18th and early 19th centuries

Georges (Baron) Cuvier (1769 - 1832)

- Supported catastrophism to explain extinction and faunal succession
- proposed that 6 catastrophes had occurred in the past history of Earth
- conveniently corresponded to the 6 days of biblical creation the last being the deluge

Werner and catastropism

- Abraham Werner → German geologist working in the late 18th and early 19th centuries → influential advocate of catastrophism
- Werner observed → crystalline rocks commonly occur at the base of a rock sequence and are overlain by sedimentary rocks with surficial deposits of silt, sand and gravel occurring at the top of the sequence
- Werner proposed → Earth's history characterised by a series of eras in which certain rock types formed
- he concluded that the basal crystalline rocks precipitated from an ancient ocean that once covered the Earth "Theory of Neptunism"

Werner's Rock series

1st Series	(a) Granites (b) Schists, gneisses	Universal, embracing Earth
2nd Series	Slates, limestones	Ocean sediments
3rd Series (Tertiary)	Limestone, salt, gypsum, basalt	Deposited after oceans had receded, discontinuous
4th Series (Quaternary)	sands, clays, gravels	Surficial deposits

Origin of modern ideas of time

- Seventeenth Century

  - Nicolaus Steno (1669) originally Niels Stensen

  - interest in natural world → very important contributions

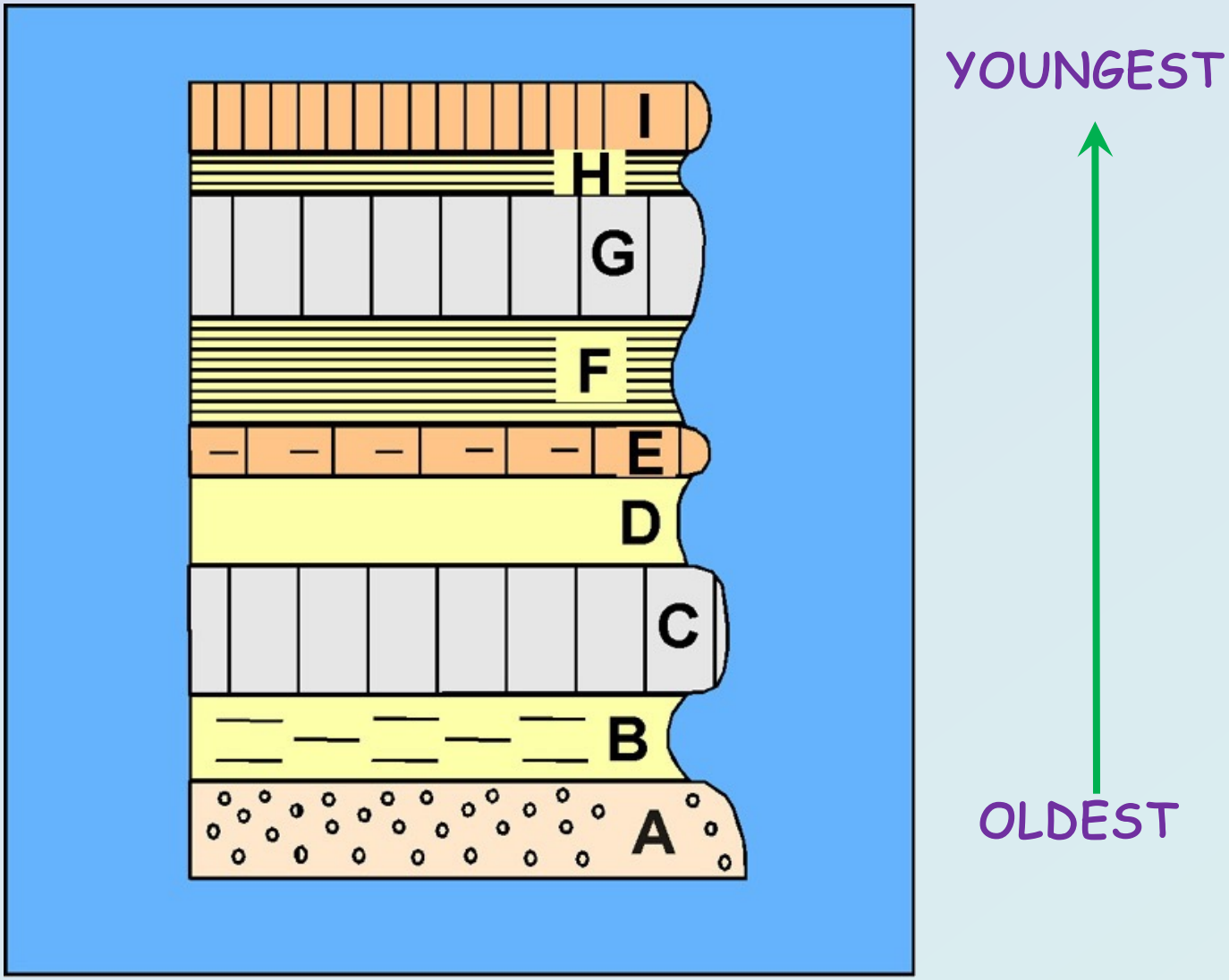
  - studied the nature of layered sedimentary rocks

  - Principle of Original Horizontality → "sedimentary rocks are deposited in the sea as more or less horizontal sheets"

  - Law of Superposition → "any layer superimposed on another, must be younger than it"

Superposition

"Any layer that is superimposed on another is younger than it"



James Hutton (late 1700s)

- Late Eighteenth Century

- James Hutton (1780s) → Scottish physician

- made remarkable observations and interpretations sailing around Scottish coast where outcrops were well exposed

- considered Father of modern geology

- dismissed the concept of catastrophism

- convoluted writing style difficult to decipher

- biography of James Hutton (good read) " The man who found time" Author Jack Repcheck

James Hutton (late 1700s)

- Principle of Uniformitarianism

" The natural processes operating on Earth today producing geological features, are the same natural processes that have operated throughout the Earth's history"

- he interpreted that processes that he observed occurring over a long period of time could account for thicknesses of sedimentary rocks observed in ancient sequences
- he recognised that it took a vast period of time (tens or even 100s of millions of years) for these to form
- Hutton thought that geological time was infinite with

" no vestige of a beginning, no vestige of an end"

Stack, Port Campbell, Victoria

James Hutton - other contributions

James Hutton compiled a series of other principles that are still applicable today → useful in establishing relative ages of rocks in an area

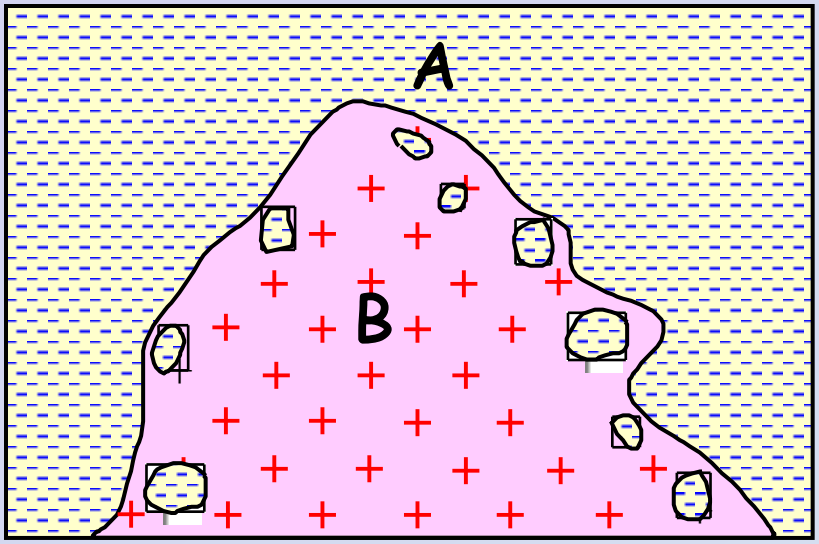
(1) Principle of inclusions

(2) Principle of cross-cutting relationships

(3) significance and recognition of unconformities

(4) Theory of plutonism

Principle of inclusions



- if one rock is found as an inclusion in another then it must be older than the one that encloses it.

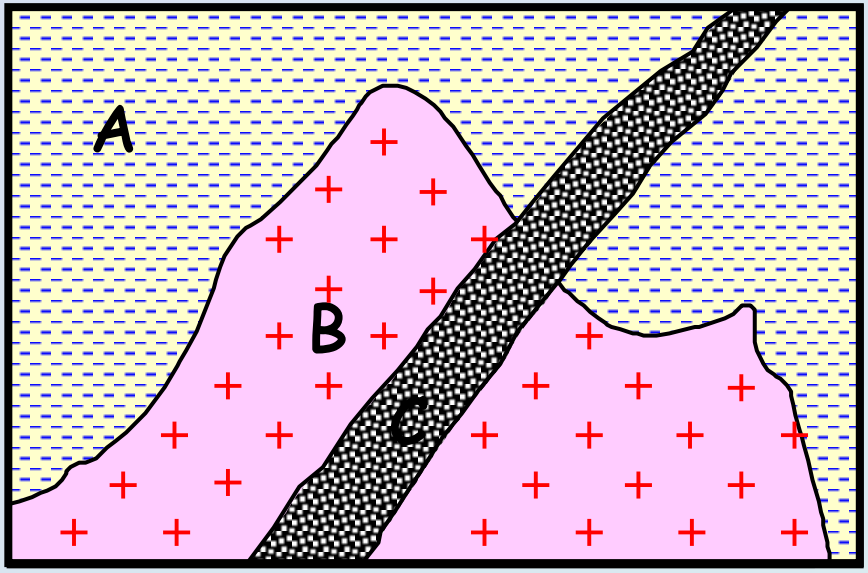
Rock A older than rock B

Inclusion of shale boulder in conglomerate, NZ

Principle of cross-cutting relationships

- any rock body that cuts across another

  is younger than the one that it cuts



Basalt dyke intruding granite

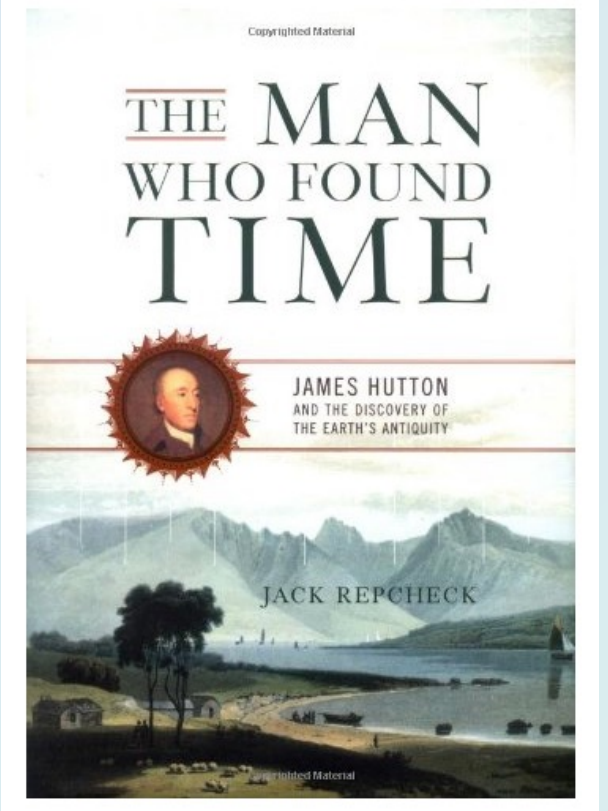
James Hutton - other contributions

- Unconformities

Surfaces that represent major time breaks in the geological record marking periods of erosion or non-deposition

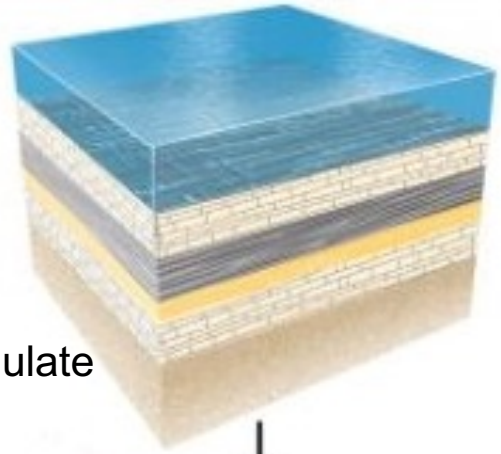
e.g. Siccar Point in Berwickshire, Scotland

- Siccar Point is where Hutton first recognised an unconformity

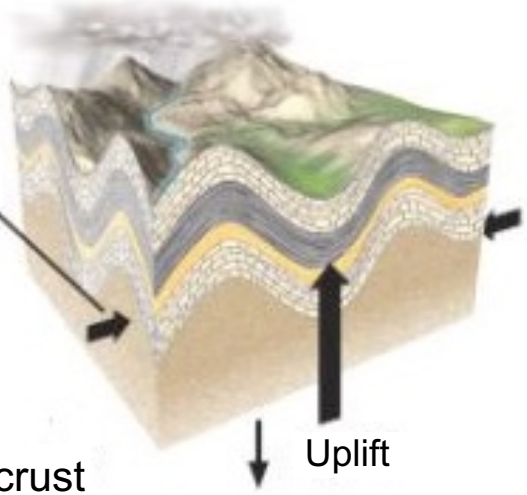


Unconformity, Siccar Point, Scotland

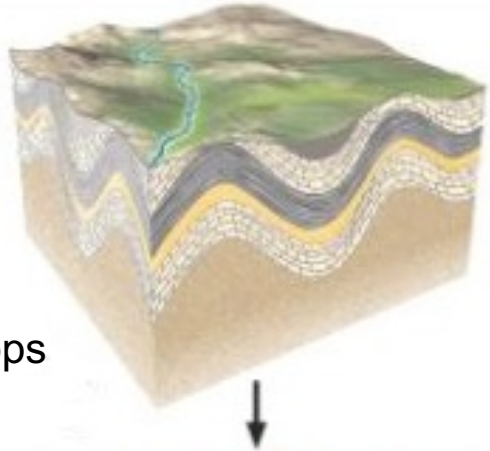
Sequence in formation of angular unconformity



Time 1
Sediments accumulate beneath the sea



Time 2
Compression in crust causes uplift and folding of strata



Time 3
Erosion removes tops of folded layers

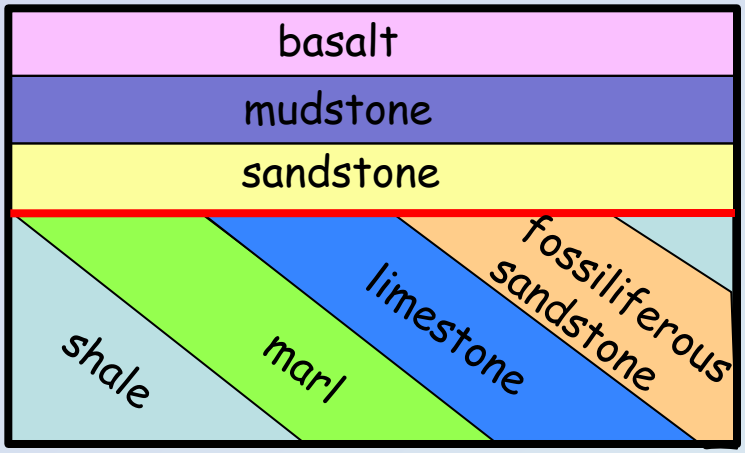
Time 4
Subsidence below sea allows new sediments to be deposited

Angular unconformity, Atacama Desert, Chile

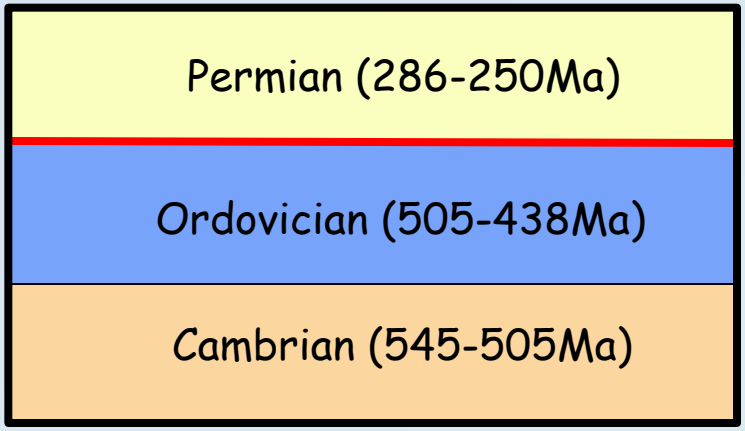
Local unconformity between older Silurian marine sedimentary rocks and much younger gravels, Ivanhoe, Vic.

Unconformities

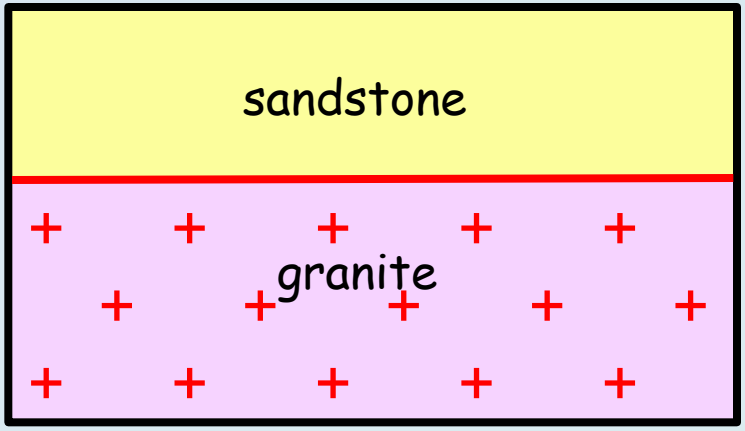
Unconformity – major time break in deposition



Angular unconformity



Disconformity



Nonconformity

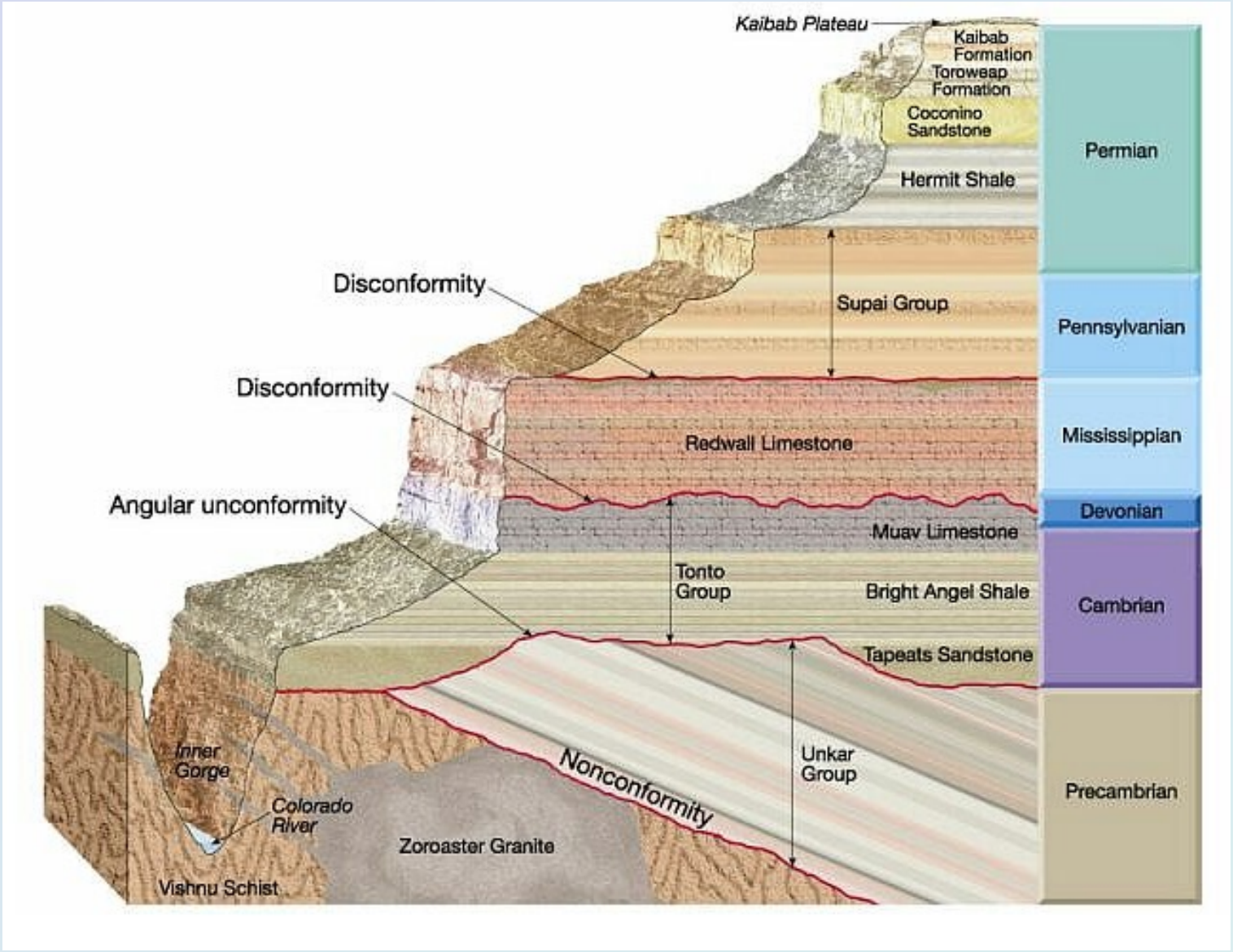
Disconformity

Disconformity between sandstone overlying bedded shale, Grand Canyon

Nonconformity

Nonconformity between sandstone overlying weathered granite, Colorado, USA

Grand Canyon geology



James Hutton - other contributions

Theory of plutonism

- crystalline rocks such as granite were of igneous origin

  → formed by solidification from the molten state

- feud between Neptunists (Werner and his supporters) and Plutonists persisted for some time

- Hutton was eventually proven correct

Stratigraphy

- Stratigraphy – branch of geology concerned with composition, origin, age relationships and geographical extent of layered rocks
- mainly concerns sedimentary rocks but can involve any sequence of stratified rocks
- Conformable sequence – no depositional breaks of any consequence
- Unconformity – hiatus in formation separating younger rocks from older rocks

Early nineteenth century

William Smith

- British canal builder Late 18th to Early 19th century recognised → same types of rocks occurred in the same stratigraphic sequence at scattered localities in southern England
- became important for him to understand the rocks he was cutting through → became an acute observer of the natural world
- he identified features in rocks e.g. fossils that could establish equivalence of rocks at different localities
- Smith mapped the distribution of different rock units in southern England → first geological map produced

Faunal succession

Principle of faunal succession

- William Smith recognised that fossils are the remains of once -living animals and plants commonly preserved in sedimentary rocks
- Smith realised that similar rock types in a sequence could be differentiated on the basis of fossil assemblages

* rocks of a particular age contain the same assemblage of fossils and these succeed each other in a specific, reliable order that can be identified over a long distance

- in general, the older the rocks, the more the fossils that they contain will differ from modern organisms

"The map that changed the world"

- Smith produced the first geological map of southern England

"The Map that changed the World" by Simon Winchester

Correlation

Correlation → process of demonstrating equivalence of rock units from different localities based on distinctive units or fossil and mineral assemblages

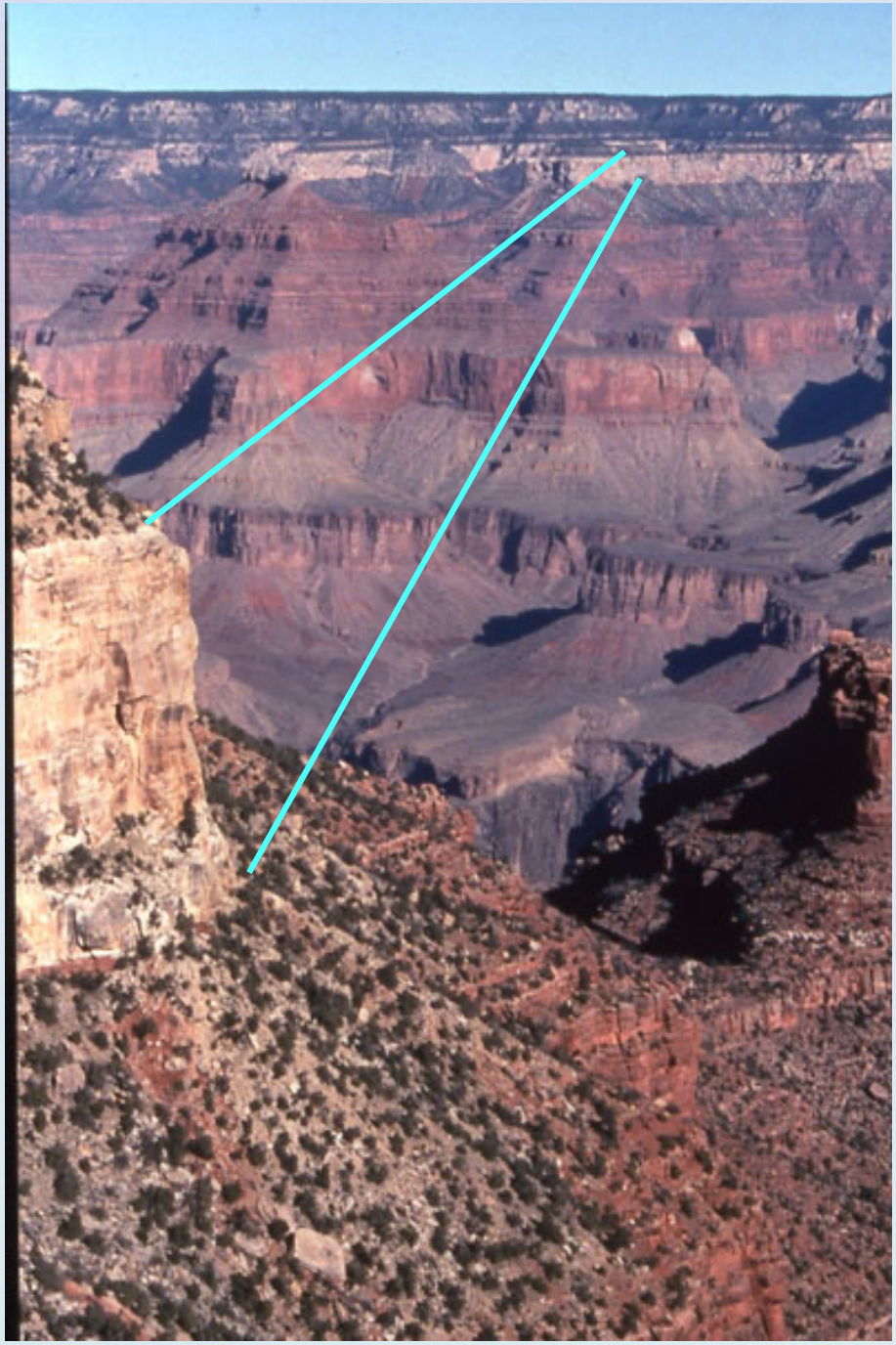
- correlation of rock sequences enabled William Smith to produce maps showing distribution of rock types

Correlation

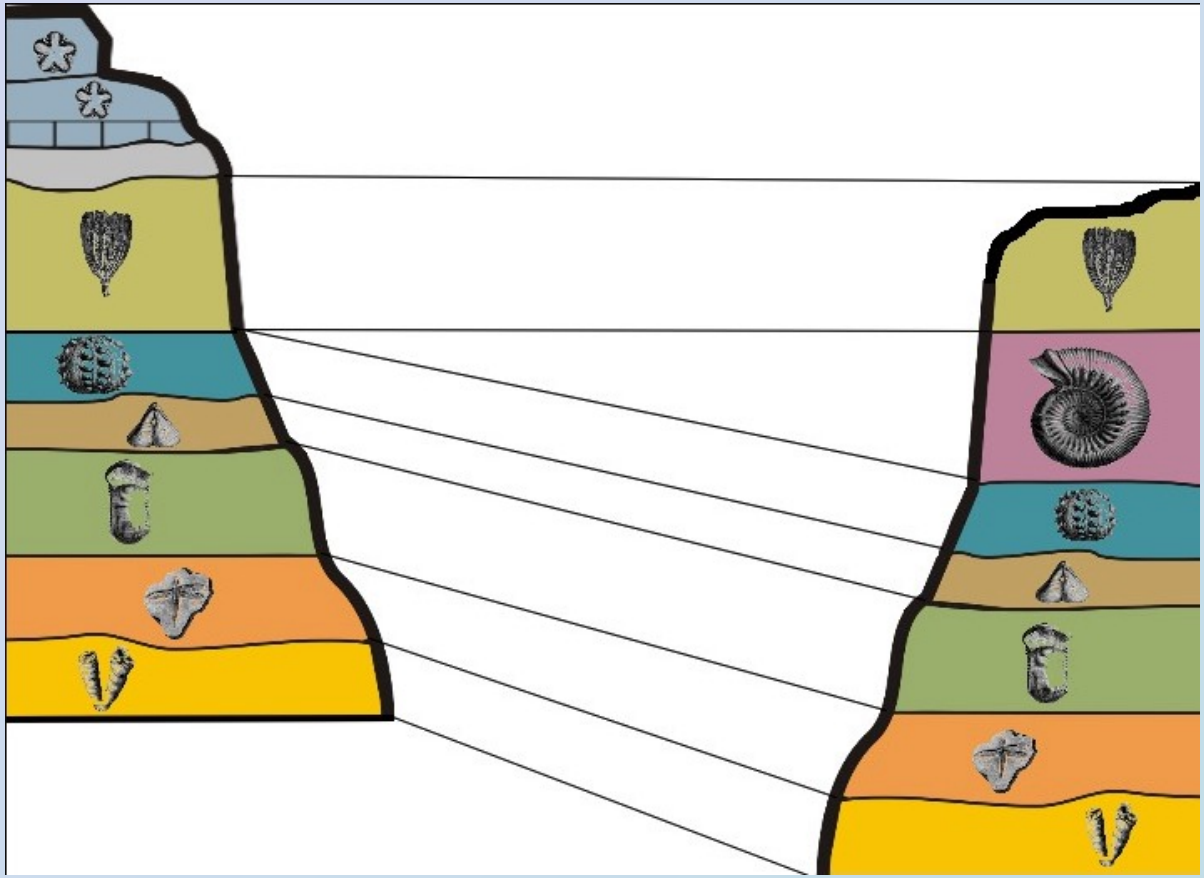
Correlation of layers

on opposite sides of the

Grand Canyon



Correlation from faunal succession



Faunal succession showing correlation of strata

Nineteenth century

Sir Charles Lyell (1797-1875)

- Published "Principles of Geology" in 1830
- based on uniformitarianism principles
- highly influential e.g. Charles Darwin (1809-1882)
- presented Hutton's concepts in intelligible form
- "the present is the key to the past" became the catchphrase of late 19th century Geology
- this meant that if you want to understand the past record of geological history, you need to understand present day processes

Determination of relative age

For any group of rocks, we can determine the relative ages using the following principles:

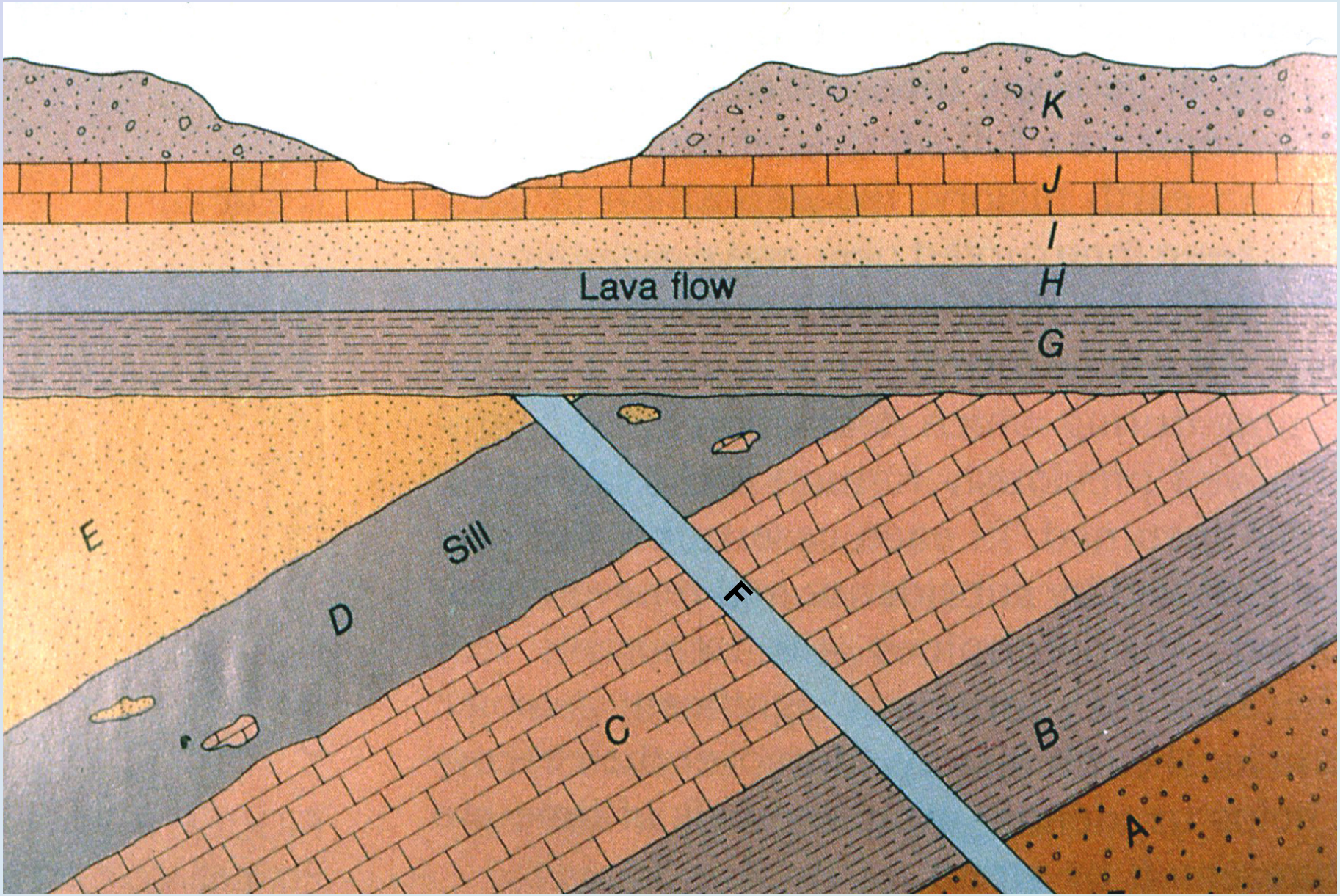
(1) The principle of original horizontality
(2) The law of uniformitarianism
(3) The principle of crosscutting relationships
(4) The principle of inclusions

Collectively known as the "Laws of stratigraphy"

Determining relative age

- Principles of stratigraphy
  - Original horizontality
  - superposition
  - cross cutting relationships
  - inclusions
- Correlation
  - establishing equivalency of rocks from different localities based on similarity of rock types and faunal succession
- The relative geological time scale
  - constructed using these principles
  - particular periods → given names and were identified by fossil assemblages
  - largely 19th century

Relative age determination



The relative Geological time scale

Eon	Era	Period
PHANEROZOIC	Cainozoic	Quaternary Tertiary
	Mesozoic	Cretaceous Jurassic Triassic
	Palaeozoic	Permian Carboniferous Devonian Silurian Ordovician Cambrian
PRECAMBRIAN		