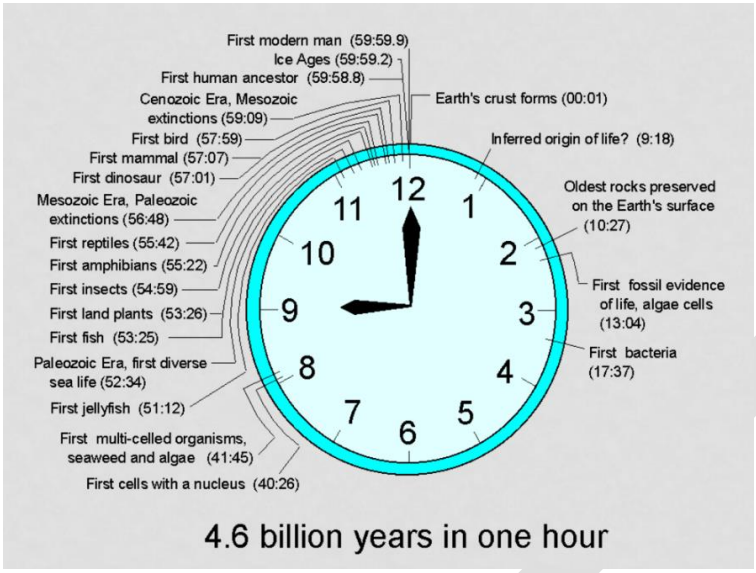
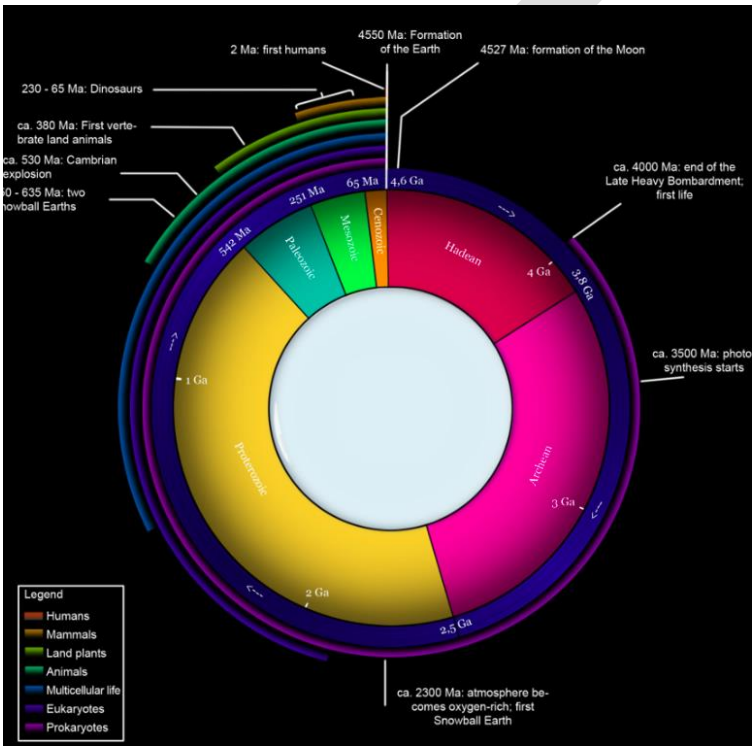
Geography – History of Earth

Distinguish Eon, Era, Period and Epoch

They divide the time scale. Eon are the biggest time interval and they are divided into Eras. Eras are the Paleozoic, the Mesozoic and Cenozoic. The eras are subdivided into periods. And periods are subdivided into Epochs.

We will get a list of the names, time interval and division.





What's typical for each Eon

Typical Climate typical life forms typical marks

The Big Bang and the birth of our solar system

The beginning of our universe, where time and space appeared. There were protons, neutrons and other smaller pieces. The temperature raised, and neutrons and protons fused together, to Hydrogen 1 Proton 1 Neutron. Hydrogen fused to Helium. (Fusion → 1+1=0.8 and 0.2 = E = mc^2) It happened 13,8 Billion years ago. The milky way galaxy was than formed. Stars formed transmuted elements in nuclear fire and ended their lives in supernovae explosions.

The birth of the solar system happened 4.6 Billion years ago. After the star explosions. A large cloud of the interstellar dust rotated and started to condense, because of gravitation. The central mass started to condense first and to increase its mass. More mass equals faster condensation. The central mass formed our sun. Around the sun, along the Accretion Disk, more atoms also started to condense. They formed planetoids which created had their own gravity and attracted more and more material. Like this they formed planets. The Energy that the sun released by the fusion of Hydrogen to Helium (mass defection law) is very high. Jupiter was the planet that was first formed. It consists of helium and hydrogen like the sun because the stellar wind blew it outwards. Near the sun the later elements couldn't bind because they evaporated. Further away, where it was cooler, they could condensate. The heavier elements only melt, they didn't evaporate, and they didn't get blown away. That's why the inner planets, like the earth, are made out of heavier elements. Central of gravity is the central of the earth. Over time the heavier metals move towards the center when the earth still was liquid. The fact that heavier elements sink toward the center is called gravity differentiation.

Eon: Hadeon 4.5-3.8 billion years ago - Precambrian

- Formation of our moon (4.5 billion years ago)
    - A Mars sized body hit the earth and scratched away a part. This part then became the moon – Explanation why the moon is less dense, and the moon is almost formed with the same material as the earth crust.
    - The moon is further away today than it was before. The friction from the tides released kinetic energy which causes the earth to rotate slower and release the energy to the moon. Because Earth and moon are connected the moon starts to rotate faster and faster. This acceleration causes the moon to go further away. This stops when earth and moon take the time for one rotation.
- At the start was very hot and not survivable for any creatures.
- Many asteroids hit the earth.
- There were massive volcanoes and lava fields.
- The Earth's atmosphere was a toxic mix of methane, carbon dioxide and ammonia. It had thick and turbulent clouds.
- As long as 4.2 billion years ago liquid water and the perquisite (Grundvorausseztung) for life was present. Water came on Earth…
    - … In form from ice as asteroids
    - … It was inside the earth already but because of the heat only in form of gas. When the earth cooled down it was able to condensate and rained down.

- Since 4 billion years first life has been present. At that time there were relatively simple single celled life. The early life forms weren't visible with the eye and less complex. They only did photosynthesis and didn't need oxygen, anaerobe. Main disadvantage: risky, one hole they die, very sensitive membrane.

Eon: Archeon 3.85 – 2.5 billion years ago – Precambrian

- Atmosphere was a mixture of methane, carbon dioxide and ammonia
- Volcanic eruption, asteroid impacts (could cause a tsunami), shifting tectonic plates, radiation, changes in climate (ice age, dryness) made living very difficult
- First primitive life forms that lived in an oxygen free environment for example stromatolites (look like rocks) and cyanobacteria that had oxygen as metabolic waste (!O was always on the planet but O_2 as gas wasn't!)
- The oxygen from the life forms was first in the ocean and later in the atmosphere
- 2.8 billion years ago first ice ages. Evidence found in rock

Eon: Proterozoic 2500mya – 542 mya – Precambrian

- 2.3 billion years ago the *Oxygen Catastrophe* happened. In this event every living-being died as a result of this massive bacteria-induced climate change. The cause for the climate change was the high and now consistent level of oxygen that this cyanobacteria releases. Due to the minerals in the rock record that it had extensive deposits of pyrite and uranium oxide in the sediments between 2.5-2.3 years ago. They require low level of oxygen. After 2.3 Billion years ago iron rust was found, this indicates the presence of free oxygen.
- 2.3 billion years ago first snowball earth
- The oxygen would also solve the radiation problem – molecules of ozone formed the protective *ozone layer*
- 1'100 mya land belonged to the super-continent Rodinia
- 800mya earth underwent a monstrous ice age. (Evidence of glacial ice in tropical latitudes.) Earth was completely, it looked like a snowball. The ice blocked all the sunlight. It was very cold and that killed most ocean life. It was a time with very small number of creatures.

Eon: Phanerozoic 542mya – today

PALEOZOIC

During this era High temperature and humidity (Plants grew at much higher latitudes and represent plants that live in tropical and mild temperature.) → Ice age (locked up large amount of water causing sea levels to drop, an increase in dry land, decrease of swamps and mass extinction of marine life)
The conditions weren't stable – always cyclic flooding and drying → lots pf changes in the natural environment. The rock formations occur as a pattern of stripes

Cambrian

- Cambrian Explosion marks the start of this era. Multicellular organism popped up in great prefusion. It resulted in an explosion of multicellular life forms. It marked the beginning of visible life. Living beings could now be seen with the eye, there were more complex. Evidence was fossils.
- Trilobite, organism with shell, sponges, jelly fish, algae

Ordovician

- Trilobite, organism with shell, squid-like orthoceratites

Silurian

- First life forms (primitive plants) outside the sea
- Land fauna had no major impact on the earth
- Moss forest, primitive fish, sharks, primitive plants

Devonian

- Horsetail, first trees e.g. conifer, palms, first vertebrate e.g. bony fish, first amphibians, tetrapod (Quastenflosser), shark, fish, first arthropods
- Late Devonian Extinction – Trilobites almost extinct.
- Drop in sea level at the end

Carboniferous

- Plants lacked growth rings indicating a uniform climate
- In the middle ice age
- Large amount of oxygen due to the trees led to the largest insects
- The great amount of plant was buried forming the great coal deposits
- Lots of trees – first forests and fern, swamps, largest insects (dragon flies, arthopleura, centipede), amphibian ancestor of the reptiles, plants that live in tropical and mild temperate areas today
- Large shallow seas and huge deposit of carbonate material that would later form beds of limestone

Permian

- First large reptiles, reptile ancestor of the mammals, modern plants, conifers
- Reptiles had legs at the side that was very inefficient because it needs a lot of muscle force
- At the end life had just survived Permo-Carboniferous Ice Age
- Permian-Triassic-Extinction (PTE) marks the end of the Paleozoic – 95% of all life became extinct. The cause is still not clear

MESOZOIC

The climate is considerate warm and arid (ferns were found at higher latitudes), but there are some conflicting signs → Coral reefs did not have that an extended range. The earth had during most of the era no polar ice cap.

Triassic

- Slow recovery of life forms → new and more dynamic life-forms
- First primitive mammals, new form of reptilian life, at the end first dinosaurs, forests with giant ferns and unusual plants, modern trees – conifer, reptiles in the water
- First Mammals (warm blooded → always faster and readier but they have to eat more)
- Closed with an extinction event that primary effected marine life

Jurassic

- Age of reptiles, dinosaurs, later the first true birds, more modern mammals
- Time of the dinosaurs – leg started to be below the body → more efficient you need less muscle

Cretaceous

- Sea level rose
- Warmer temperature in higher latitudes
- CO_2 level was very high
- Dinosaur, flowering plants, ants, primitive coniferous forest, Tyrannosaurus Rex
- Ended with a mass extinction – Cretaceous-Paleogene extinction event (KT-Boundary). Cretaceous-Teritiary (KT) boundary contained high level of the rare iridium caused by an asteroid colliding with the Earth. Droplets of basalt rock in the KT boundary layer indicates that rock from the crust had been melted and catapulted into the air by a violent impact. Presence of shocked quartz indicate that it was an asteroid.

CENOZOIC

Age of mammals.

PALEOGENE

- Animal evolved from small simple animals to larger forms
- Mammals also returned to the sea
- Earth's climate cooled

PALEOCENE

- Mammals and bird adapt and occupied new habitats and ecological niches

EOCENE

- Paleocene-Eocene Thermal Maximum (PETM) most rapid and extreme periods of global warming. This led to significant changes in the animal life. The PETM was caused by a volcanic outbreak or a massive release of methane from the deep-sea floor. This warm period lasted 150'000 years
- Oxygen levels in the ocean dropped because warm water can contain less oxygen– 40% of marine life died
- Animals became smaller
- Brontotheres (looks like a rhino), trees everywhere, strange creatures – wolves like animal with hooves
- Most constant climate, rainy tropical climate extend to 45° latitude
- After PETM larger animals began to appear
- At the end – Grand Coupure extinction event appeared. Cause could had been cooling climate, large asteroids or swings in sea level

OLIGOCENE

- First Elephants with trunks, early horses, modern grasses
- Climate still supports tropical greenery but hint of dryer and cooler times, climate stabilized, temperature cooled
- First Antarctica

Neogene

MIOCENE

- Climate got dryer, colder and much harsher
- Continental forest was replaced by grassland and savannas, deserts formed
- Mountains and the alps were created
- Animals had to adapt. The prayers got better eyesight and longer legs. Predator also had to adapt
- Horses, bison, sheep, giraffes, camels

PLIOCENE

- Human evolution starts
- 2° warmer than today
- Midway the Pleistocene Ice Age began. Sea levels dropped, and land bridges appeared allowing man and animal to migrate. 1 Theory: Winds brought cold, deep ocean water to the surface in low latitudes. Other theories range from long-term cyclical variation of solar energy to massive Vulcanic eruptions. Vulcanic eruptions could have caused ash to form a cloud all over the world blocking out the sunlight.

PLEISTOCENE

- Pleistocene Ice age
- Wolves, Mammoths

HOLOCENE

- Recent epoch
- Begins with retreating ice
- There seems to be a glacial cycle of 20'000 years interglacial separating 100'000 years glacial periods (could be cause by change of the earth's axis)
- We are creatures of the Ice Age. Without the challenge mankind would never have developed the survival skills that have brought us to dominance. Mankind's first evidence is 130'000 years old. The entire recorded history of our species is contained within the Holocene.

Evolution during the history of earth

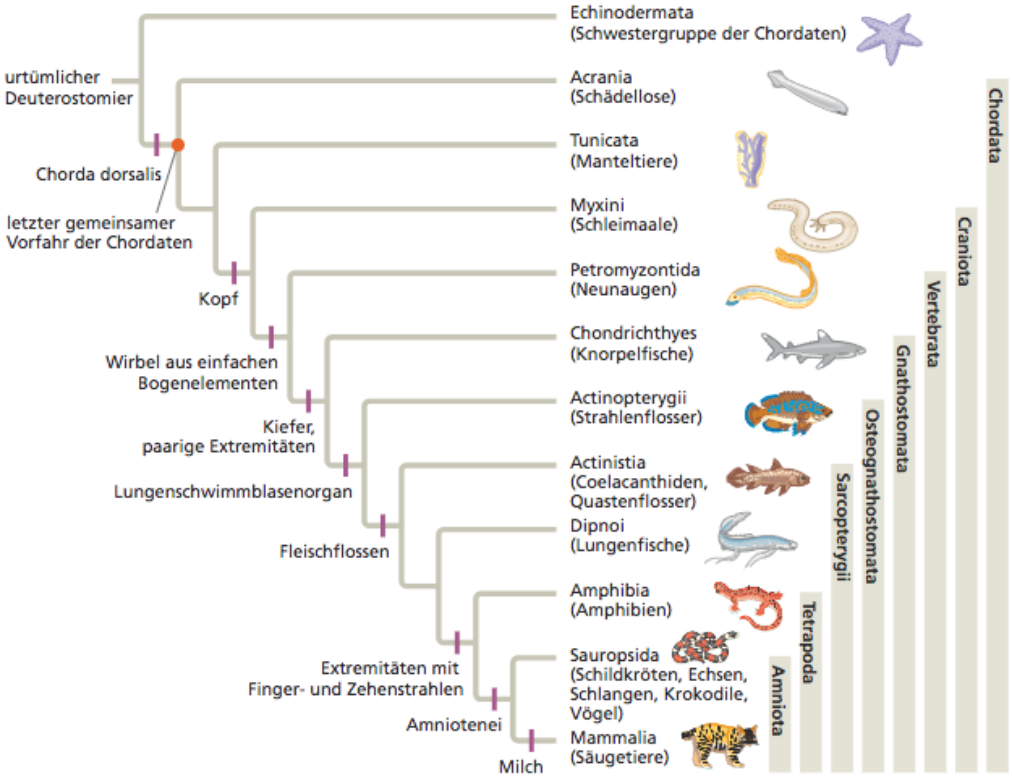


Abbildung 34.2: Phylogenie der heute lebenden Chordaten.

Methods of absolute and relative age determination

Stratigraphy – The study of strata in rocks

Determining Age with rock.

Principles of Stratigraphy

1. The **principle of original horizontality** – Sediments are deposited under the influence of gravity as horizontal beds. Folded or faulted strata has been deformed by tectonic forces after the deposition.
2. The **principle of superposition** – Each layer of sedimentary sequence is younger than the one beneath and older than the one above. A new layer cannot be deposited beneath an existing

layer. A set of strata can be ordered chronologically. This set is known as a *stratigraphic succession*.

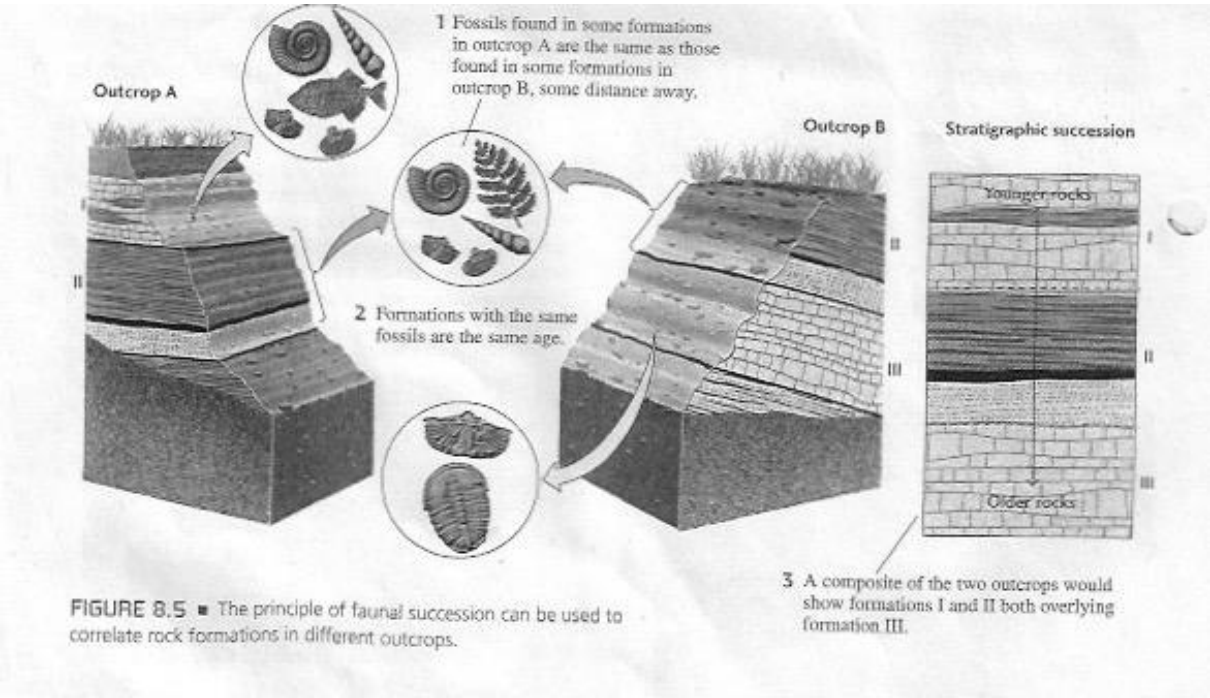


FIGURE 8.5 ■ The principle of faunal succession can be used to correlate rock formations in different outcrops.

With these principles we can determine whether one sedimentary formation (Bodenformation) is older than another. By piecing together, the formations exposed in different outcrops, we can sort them into chronical order and construct the stratigraphic succession of a region.

Problem

1. Always found gaps in a stratigraphic succession indicating intervals that had gone entirely unrecorded
2. Difficult to determine the relative ages of two formations that were widely separated in space

Fossils

Different layers contain different fossils. We can make general order for the sequences of fossils and strata from lowest to uppermost. By stratigraphically ordering the fossils of an animal species (fauna) we can make a sequence known as *faunal succession*. You specify the age by looking at the fossil sets contained. We can order different strata and match it with different locations. We are able to identify formations of the same age in different outcrops. It isn't possible to use the faunal succession in the Precambrian because the rocks melted and that would destroy any biological material or distorted beyond recognition.

Principle of faunal succession

Sedimentary strata contain fossils in a definite sequence (bestimmte Reihenfolge). The same sequence can be found in different outcrops at other locations.

Isotopic Clocks/Dating

For a given element the number of neutrons can vary among different isotopes. A nucleus of a radioactive Isotope can spontaneously decay (zerfallen) by emitting particles and transforming the atom – parent – into an atom of a different element – daughter. The decay at constant rate is measured by the isotope's half-life. The time required for one half of the original number of parents to transform into daughter atoms. One half-life is when the parents have decreased by factor of two. After two half-life's the parents have decreased by the factor 4. With a mass spectrometer – instrument that can detect quantities of isotopes – we can measure the ratio of parent to daughter atoms in a rock. Knowing the half-life, we can then calculate the time elapsed since the isotopic clock began to tick.

The age corresponds to the time when the clock was "reset" when the isotopes were locked into the minerals of the rock. For example, when a mineral crystallizes from magma or recrystallizes during metamorphosis. The number of daughters doesn't always reset to zero. A mineral could also lose daughter isotopes by weathering or contamination by fluid circulating. There also have to be a measurable number of parents and daughters.

C14-Dating method

How it works

Carbon-14 (half-life 5700 years) has a fast decay and can only be used to date younger rocks. It is especially useful for dating bone, shell, wood and other organic material. Carbon is an essential element in the living cells. When a plant dies Carbon-14 decays to Nitrogen-14 which is a gas and leaks. To estimate the absolute age of a plant you have to calculate the Carbon-14/Carbon-12 ratio measured in the material to match the ratio in the atmosphere at the time the plant died (ratio of Carbon-14 to Carbon-12 in the plant is the same as the ratio of Carbon-14 Carbon-12 in the atmosphere).

Field of Application

- Rock formations in the search for minerals and petroleum
- Water samples to understand oceanic circulation
- Ice cores to chart climate variations
- Bubbles of air trapped in rock and ice to measure changes in the composition of the atmosphere
- *To date younger and organic*

More terms of geological science

Relative and Absolute Age

The absolute age means that the years are clear. When we refer to the relative age, we can only say whether an event was before or after the other.

Fossil

An artifact of life preserved in the geologic record. They are the remains of ancient life deposited with sediment. A fossil can be a dead organism (just dead body (and younger)) preserved and buried but also foot prints or poo, basically any trace from and of life forms. (at least 10'000 years old)

PALEONTOLOGY

The historical study of ancient life-forms. Fossils of each sedimentary bed must represent the organisms living at the time that bed was deposited.

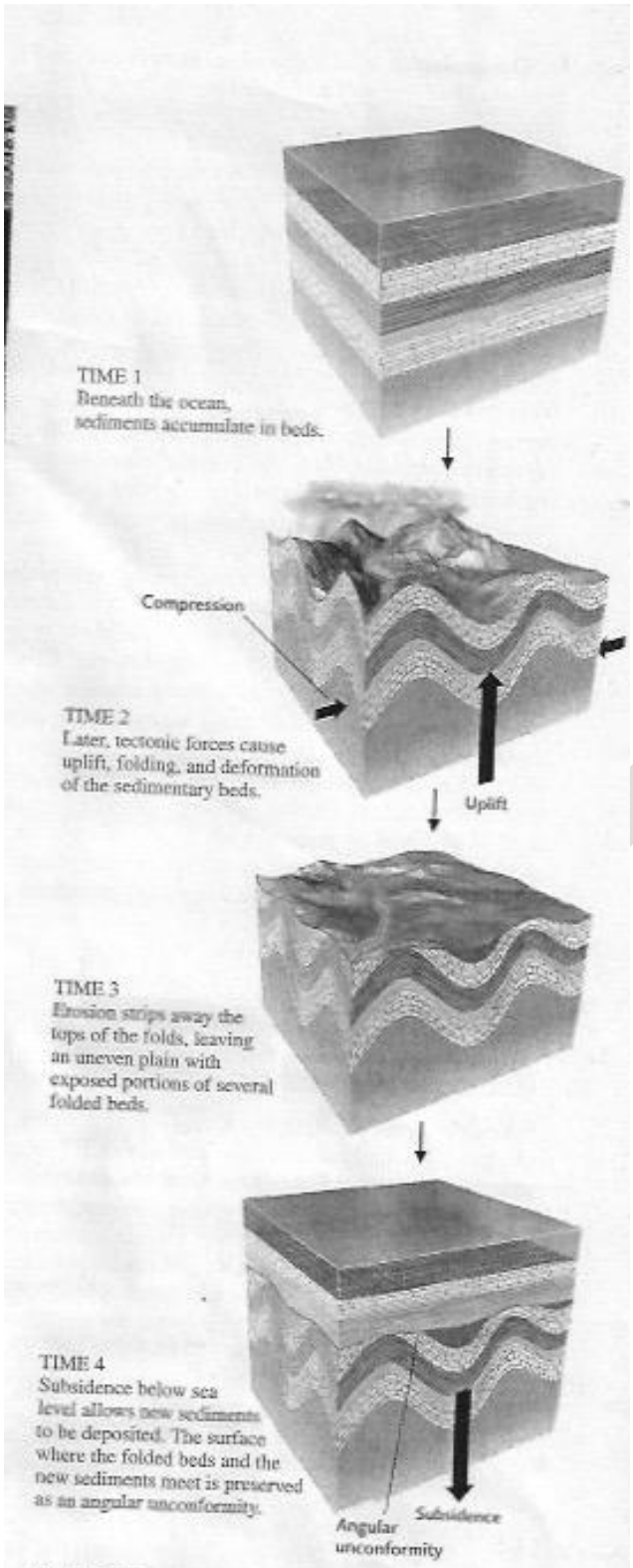


FIGURE 8.8 ■ An angular unconformity is a surface that separates two sedimentary sequences whose bedding planes are not parallel. This series of drawings shows how an angular unconformity can form.

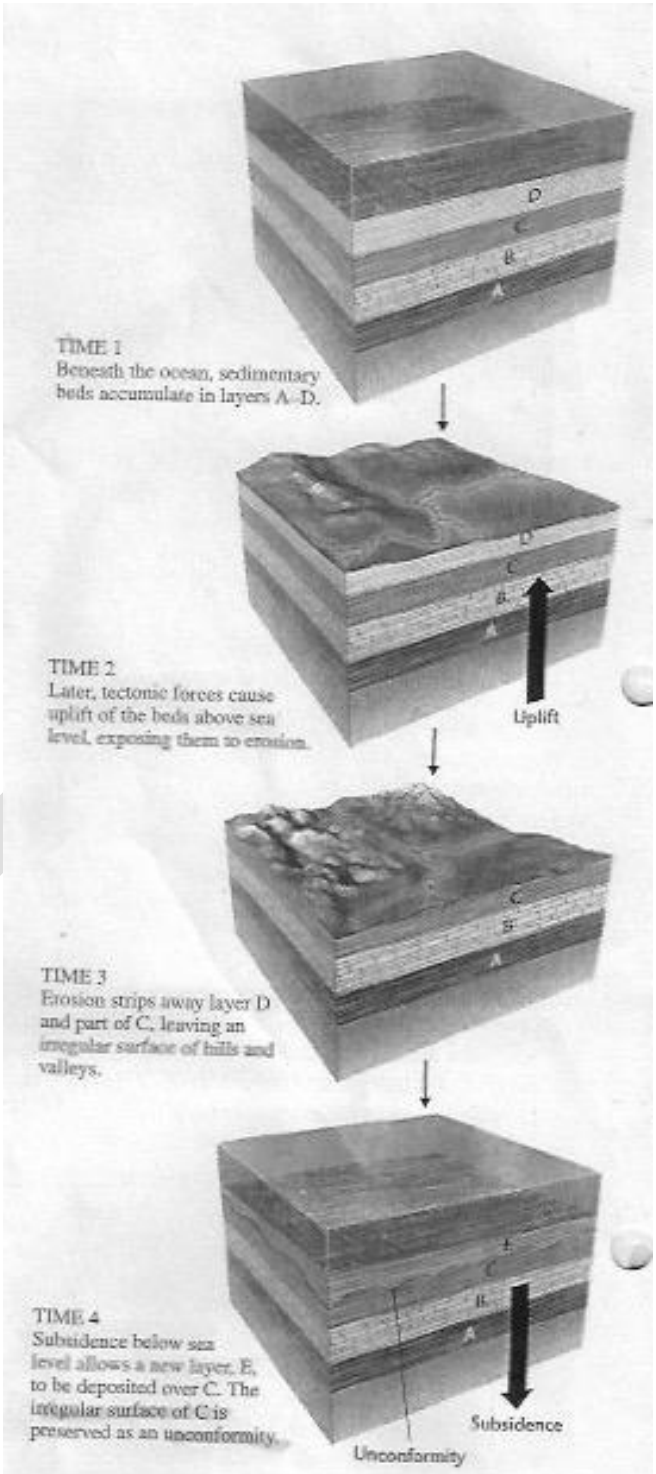


FIGURE 8.6 ■ An unconformity is a surface between two rock layers representing a layer that never formed or was eroded away. The type of unconformity shown here, created through uplift and erosion followed by subsidence and another round of sedimentation on top of an undeformed surface, is called a disconformity.

Sediment

Material deposited by water, wind or glaciers

Isotopic Dating

The identification of Age of a Rock Sample by determining the proportional content of certain radioactive Isotopes.

Unconformities

There are places where formation is missing. Either no rock was ever deposited, or it was eroded (with tectonic forces or erosion) away before the next strata could deposit. The boundary where to beds with time gap meet is called unconformity. Series of beds bounded by unconformities is referred to as a *sedimentary sequence*. It presents the passage of time (Ablauf der Zeit).

Disconformity

The upper sedimentary sequence overlies a undeformed, still-horizontal sedimentary sequence which witnessed erosion.

Nonconformity

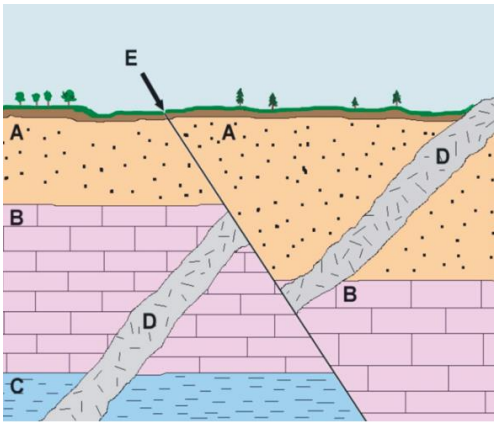
Upper sedimentary beds overlie metamorphic or igneous (magmatisch) rocks.

Angular conformity

Upper sedimentary beds overlie beds that have been folded by tectonic processes and then eroded to an even plane. The sequences have bedding planes that are not parallel.

Cross-Cutting Relationships

Dikes can cut through sedimentary beds and faults can displace bedding plane, dikes, sills as they shift blocks of rock. These cross-cutting relationships can be used to determine the relative ages of igneous intrusion or faults within the stratigraphic succession. Intrusion or deformation events must take place after the sedimentary beds were deposited.



Intrusion

The forcible entry of molten rock or magma into or between other rock formation.

Faulting

A fracture (e.g. crack in layer by tectonic forces - Dikes cut in certain angle into layer and sills horizontally.) in the crust of the earth accompanied by a displacement of one side of the fracture, usually in a direction parallel to the fracture. You need to have a faulting before an Intrusion. Else the magma wouldn't have a space to entry.

Geologic time scale

A worldwide history of geologic events.

Intervals of Geologic Time

Faunal succession from different continents often displayed the same changes in fossils. Intervals of time are marked by distinct sets of fossils. The boundaries are when this sets changed abruptly. The basic divi,

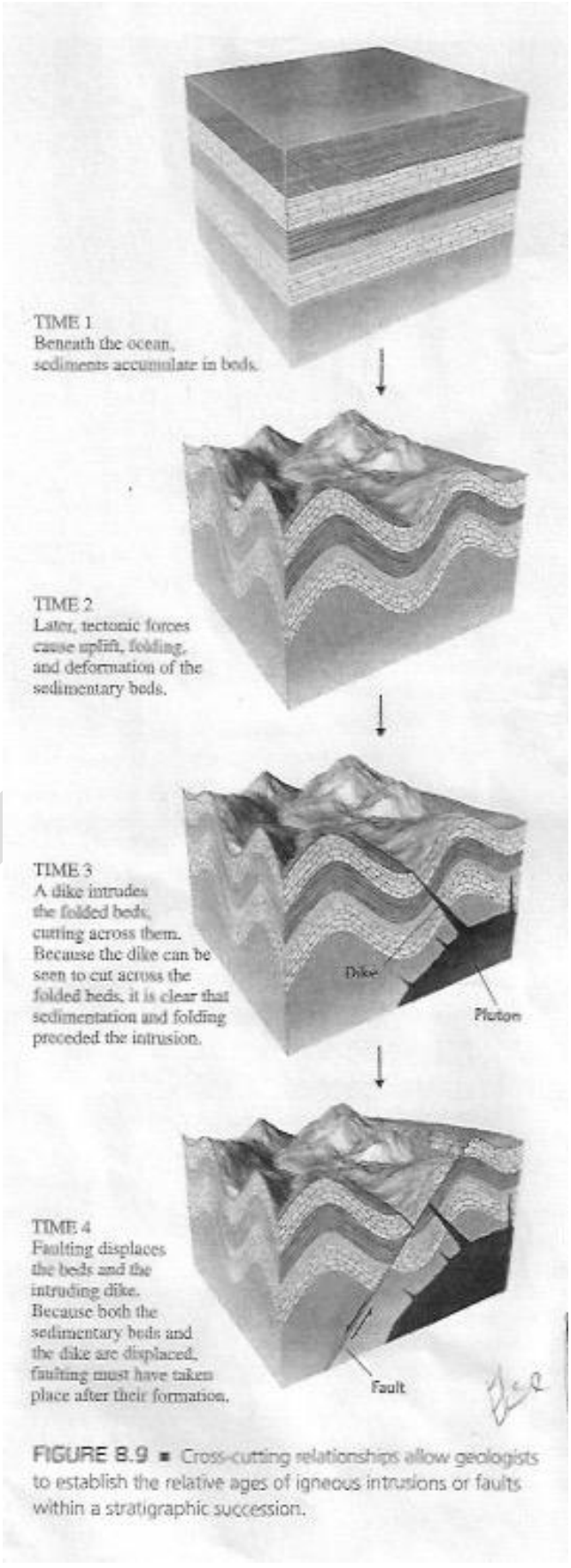


FIGURE 8.9 ■ Cross-cutting relationships allow geologists to establish the relative ages of igneous intrusions or faults within a stratigraphic succession.

Interval Boundaries Mark Mass Extinction

Interval boundaries in the geologic time scale often represent *mass extinctions*: short intervals during which a large proportion of the species living at the time simply disappeared from the fossil record, followed by the blossoming of many new species

Addition

The Rock Formation of Grand Canyon

Sheet!

Continental Drift

…