Chronostratigraphy

Chronostratigraphy

- Chronostratigraphy. The element of stratigraphy that deals with the relative time relations and ages of rock bodies
- Chronostratigraphic classification. The organization of rocks into units on the basis of their age or time of origin.
- Correlating rocks from different areas on earth
- Forming a uniform systematic geochronological sequence

Chronostratigraphy

- The purpose of chronostratigraphic classification is to organize systematically the rocks forming the Earth's crust into named units (chronostratigraphic units) corresponding to intervals of geologic time (geochronologic units) to serve as a basis for time-correlation and a reference system for recording events of geologic history.
- Therefore two types of units:

1. Chronostratigraphic units
2. Geochronologic units

Chronostratigraphic units

- A body of rocks that includes all rocks formed or deposited during a specific interval of geologic time, and only those rocks formed during that time span.
- Chronostratigraphic units are bounded by synchronous horizons.
- They are used as well to define the intervals of geologic time for the respective geochronologic units

Geochronologic units

- The interval of geologic time during which the respective chronostratigraphic unit was formed or deposited.
- A clearly defined time period in years
- Basic measuring unit: 1 year

Chronostratigraphic units

- Based on intervals of geologic time represented by lithostratigraphic units, biostratigraphic units and magnetostratigraphic units
- Their boundaries (stratotype boundaries) are defined by a certain stratotype based on the palaeontological and physical features of the rocks
- Usually the lower boundary of a unit is defined. The upper boundary consists the lower boundary of the next unit.
- Normally they should be indpendent of lithology or fossils, practically though correlation and geographic range of the boundaries is based on such criteria.

Global boundary Stratotype Section and Point (GSSP)

Stratotype boundary Selandian – Thanetian (Palaeocene), Zumaia Basque Country

Chronostratigraphic units

1. Correlation of rocks between different regions.
2. Placing all rocks of the crust in a systematic sequence indicating their relative position and age in respect to the age of the earth
3. Creating the International Chronostratigraphic Scale

Geochronologic units

- The geologic time is separated into smaller and larger units
- The time intervals of these units are not equal.
- Defined on the meetings of the International Commission on Stratigraphy Bolonia (1881), Paris (1900), Copenhagen (1960)

1. **Eons**
2. **Eras**
3. **Periods**
4. **Epochs**
5. **Ages**
6. **Chrons**

Chronostratigraphic units

1. Eonothem
2. Erathem
3. System
4. Series
5. Stage
6. Chronozone

1. **Eons**
2. **Eras**
3. **Periods**
4. **Epochs**
5. **Ages**
6. **Chrons**

1. Eonothem
2. Erathem
3. System
4. Series
5. Stage
6. Chronozone

- **Eonothem and Eon**. global scale. Related with the main periods of life development on earth
- **Erathem and Era**. global scale. An erathem consists of a group of systems. The names of erathems were chosen to reflect major changes of the development of life on the Earth.
- **System and Period.** global scale. A system is a unit of major rank in the conventional chronostratigraphic hierarchy. The boundaries of a system are defined by boundary-stratotypes . The time span of the currently accepted Phanerozoic systems ranges from 30 to 80 million years, except for the Quaternary System that has a time span of only about 2.56 million years.
- **Series and Epoch**. global scale . A unit of major rank at the continent level . Series are defined by boundary stratotypes. Time span ~15 my.

- **Stage and Age.** The stage has been called the basic working unit of chronostratigraphy because it is suited in scope and rank to the practical needs and purposes of intraregional chronostratigraphic classification. The stage includes all rocks formed during an age. A stage is normally the lowest ranking unit in the chronostratigraphic hierarchy that can be recognized on a global scale.
- A stage is defined by its boundary stratotypes, sections that contain a designated point in a stratigraphic sequence of essentially continuous deposition, preferably marine, chosen for its correlation potential. Currently recognized stages vary in time span, but most range between 2 and 10 million years

- Chronozones and Chrons. Localised units of short time span, based on a local biostratigraphic or lithostratigraphic Unit

Example

- Neogene is very widespread in France

Meaning: The Neogene System (all the rocks that consist this system) is widespread

- Neogene mammals are widespread in France

Meaning: The mammals that lived during the Neogene Period (time span) are widespread

Naming

- Composite name
- First letters always capitalised
- Unique names
- Higher rank units names come from:
  - reflect major changes in the development of life on the Earth
  - Geographic localities
  - Tribe names
  - chronologic position

Naming

- For Series (Epochs) and lower ranks:
  - geographic feature in the vicinity of its stratotype
  - For Series the words Lower, Middle, Upper
  - For Epochs the words Early, Middle, Late

- For Chronozones (Chrons) they come from the respective units used to define them

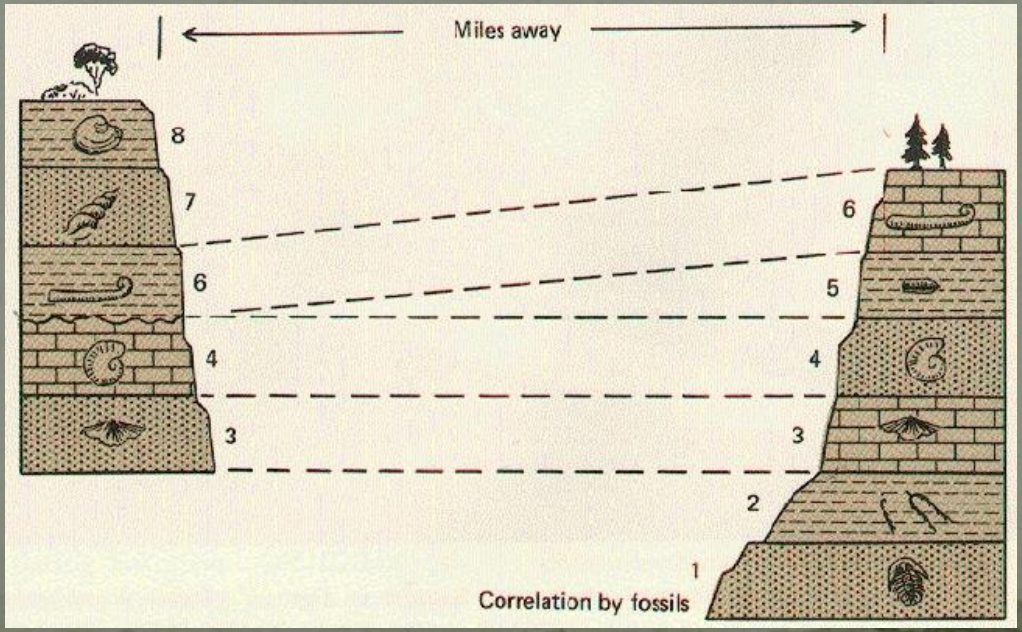
Geological time

- Age of the earth 4.600.000.000 years
- The history of earth and life on earth have been stigmatised by several severe crises and dramatic changes
- It is possible to trace these characteristic “marks” in the rocks all over the earth
- The geological time unit boundaries are placed where such changes appear (eg mass extinction events)

- Identifying repeated fossil appearances
- Identifying Index fossils
- Relative dating by placing events the one after the other
- Geologists use this to correlate rocks and in doing so they were able to create piece by piece a commonly accepted dating of geological events back in time

Index fossils

Typical fossils with large geographical range which though lived for short and specific time periods (short time spans). Finding them help us date the rocks in a relative way.



Geochronology

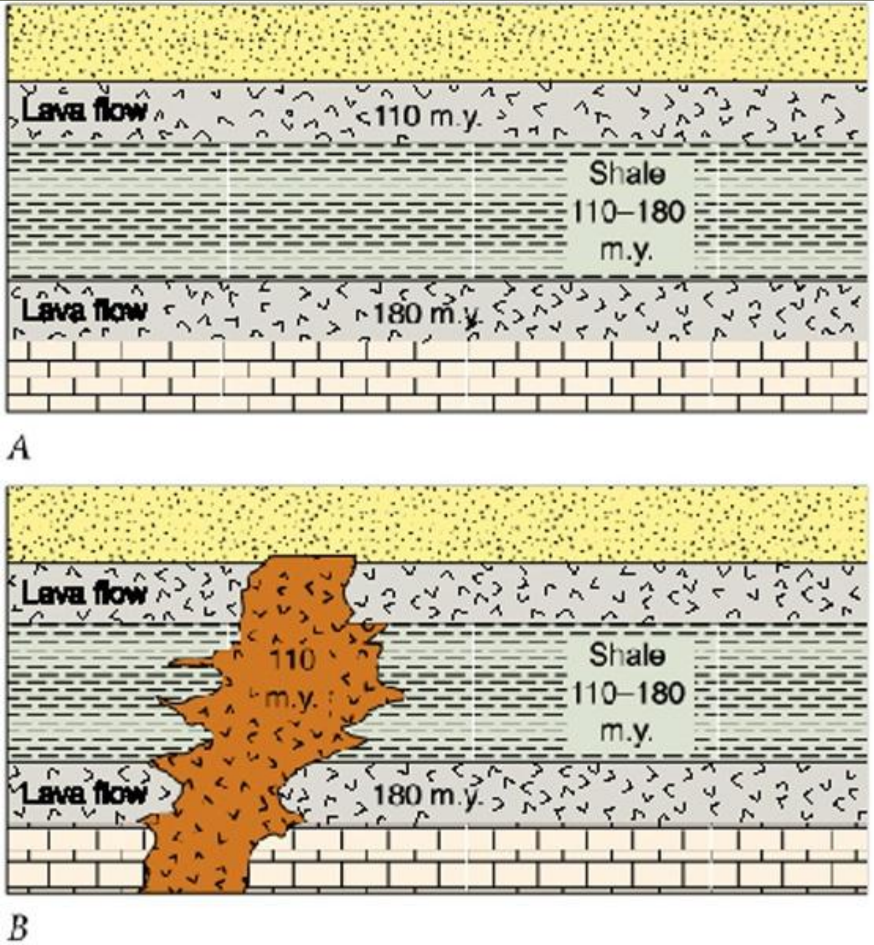
The earth science that is involved with the dating of the rocks

Dating Methods

1. Relative dating– Using principles of stratigraphy and fossils.

2. Absolute dating– Determining the age of rocks in years

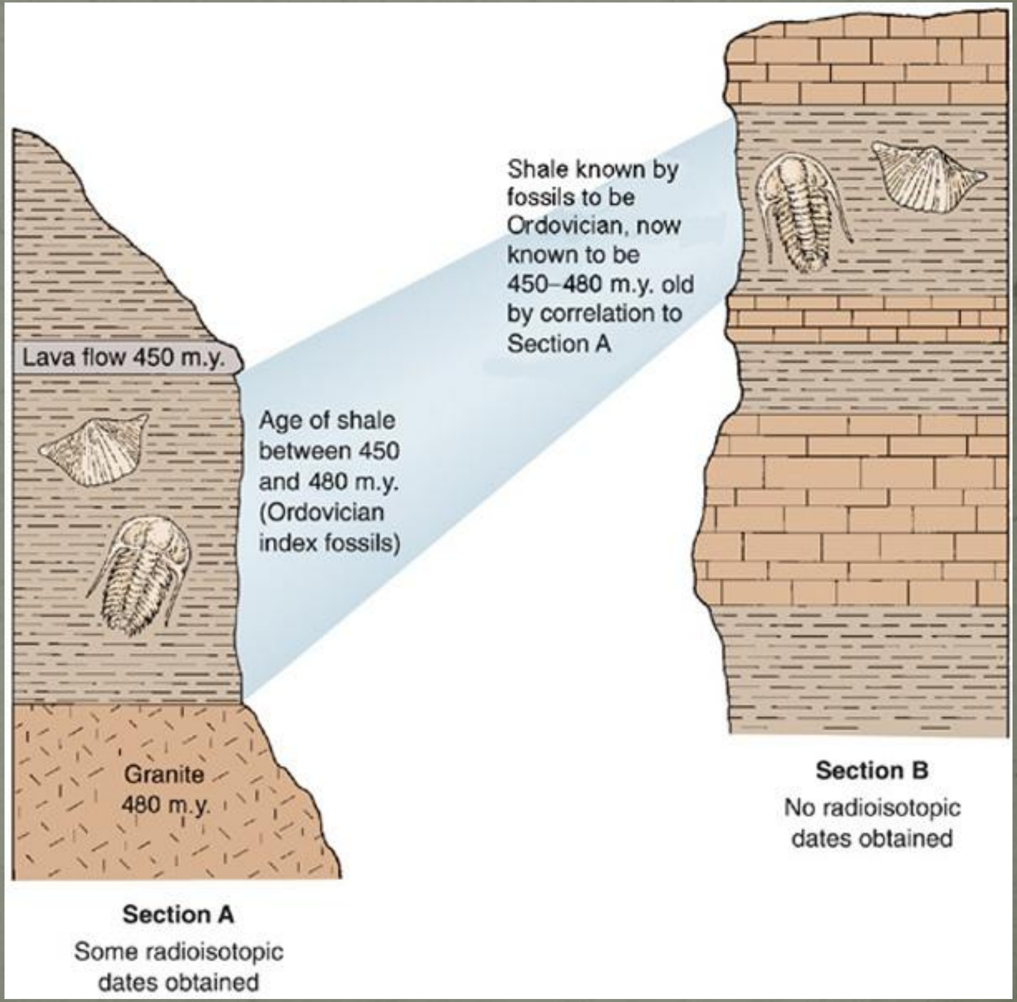
Dating Stratified rocks



The ages come both from absolute as well as relative dating.

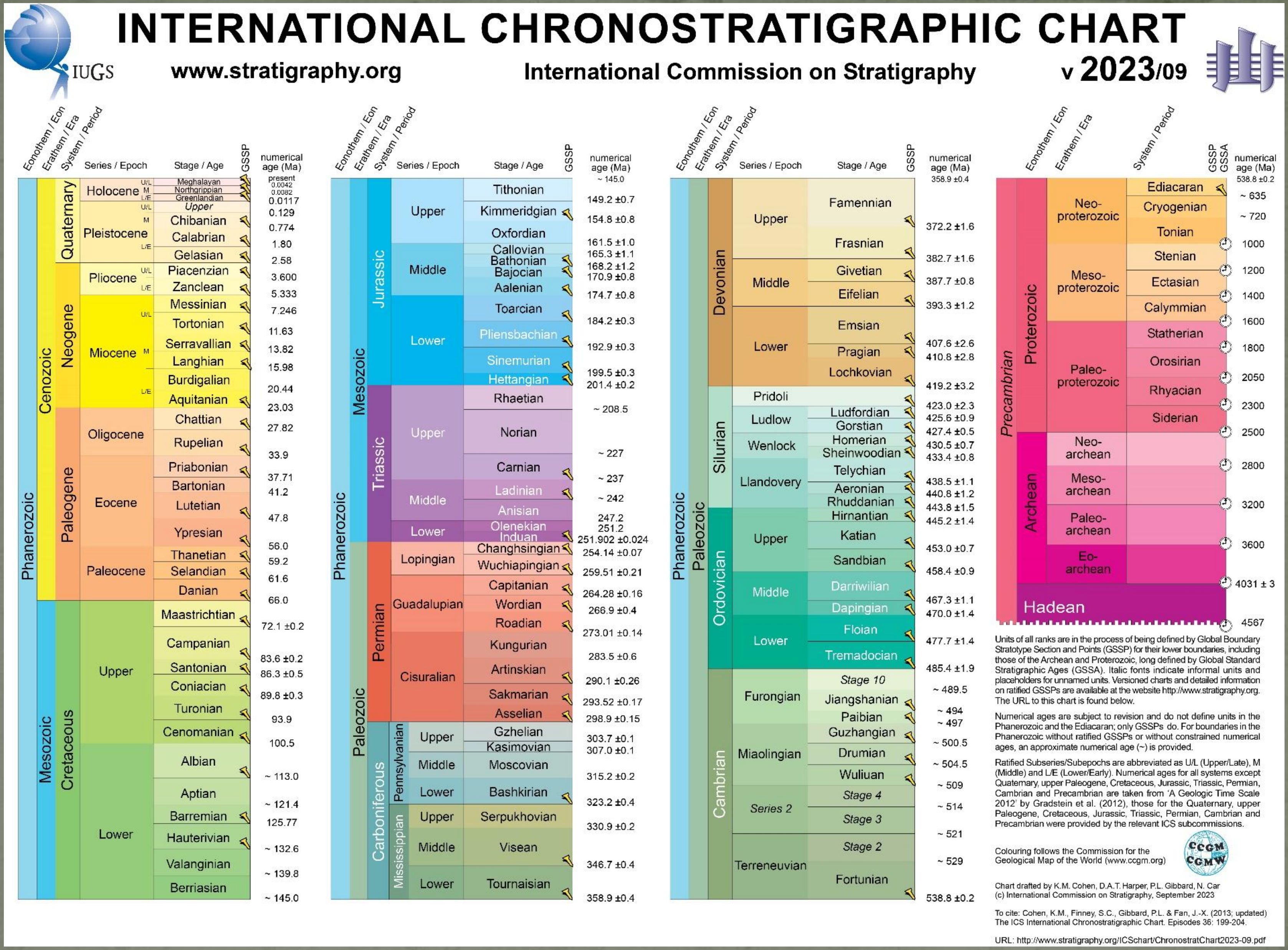
Dating of fossils

pretty much the same principle.



Geochronologic time scale

- Was made piece by piece through the years using relative dating, correlation, fossils, radiometric dating or other dating methods


INTERNATIONAL CHRONOSTRATIGRAPHIC CHART
IUGS
www.stratigraphy.org
International Commission on Stratigraphy
v 2023/09
Eonothem / Eon
Erathem / Era
System / Period
Series / Epoch
Stage / Age
GSSP
numerical age (Ma)
Phanerozoic
Cenozoic
Quaternary
Holocene
Meghalayan
Northgrippian
Greenlandian
Pleistocene
Upper
Chibanian
Calabrian
Gelasian
Neogene
Pliocene
Piacenzian
Zanclean
Miocene
Messinian
Tortonian
Serravallian
Langhian
Burdigalian
Aquitanian
Paleogene
Oligocene
Chattian
Rupelian
Eocene
Priabonian
Bartonian
Lutetian
Ypresian
Paleocene
Thanetian
Selandian
Danian
present
0.0042
0.0082
0.0117
0.129
0.774
1.80
2.58
3.600
5.333
7.246
11.63
13.82
15.98
20.44
23.03
27.82
33.9
37.71
41.2
47.8
56.0
59.2
61.6
66.0
Mesozoic
Cretaceous
Upper
Maastrichtian
Campanian
Santonian
Coniacian
Turonian
Cenomanian
Lower
Albian
Aptian
Barremian
Hauterivian
Valanginian
Berriasian
72.1 ±0.2
83.6 ±0.2
86.3 ±0.5
89.8 ±0.3
93.9
100.5
~ 113.0
~ 121.4
125.77
~ 132.6
~ 139.8
~ 145.0
Jurassic
Upper
Tithonian
Kimmeridgian
Oxfordian
Middle
Callovian
Bathonian
Bajocian
Aalenian
Lower
Toarcian
Pliensbachian
Sinemurian
Hettangian
~ 145.0
149.2 ±0.7
154.8 ±0.8
161.5 ±1.0
165.3 ±1.1
168.2 ±1.2
170.9 ±0.8
174.7 ±0.8
184.2 ±0.3
192.9 ±0.3
199.5 ±0.3
201.4 ±0.2
Triassic
Upper
Rhaetian
Norian
Carnian
Middle
Ladinian
Anisian
Lower
Olenekian
Induan
~ 208.5
~ 227
~ 237
~ 242
247.2
251.2
251.902 ±0.024
Paleozoic
Permian
Lopingian
Changhsingian
Wuchiapingian
Guadalupian
Capitanian
Wordian
Roadian
Cisuralian
Kungurian
Artinskian
Sakmarian
Asselian
254.14 ±0.07
259.51 ±0.21
264.28 ±0.16
266.9 ±0.4
273.01 ±0.14
283.5 ±0.6
290.1 ±0.26
293.52 ±0.17
298.9 ±0.15
Carboniferous
Pennsylvanian
Upper
Gzhelian
Kasimovian
Middle
Moscovian
Lower
Bashkirian
Mississippian
Upper
Serpukhovian
Middle
Visean
Lower
Tournaisian
303.7 ±0.1
307.0 ±0.1
315.2 ±0.2
323.2 ±0.4
330.9 ±0.2
346.7 ±0.4
358.9 ±0.4
Devonian
Upper
Famennian
Frasnian
Middle
Givetian
Eifelian
Lower
Emsian
Pragian
Lochkovian
358.9 ±0.4
372.2 ±1.6
382.7 ±1.6
387.7 ±0.8
393.3 ±1.2
407.6 ±2.6
410.8 ±2.8
419.2 ±3.2
Silurian
Pridoli
Ludlow
Ludfordian
Gorstian
Wenlock
Homerian
Sheinwoodian
Llandovery
Telychian
Aeronian
Rhuddanian
423.0 ±2.3
425.6 ±0.9
427.4 ±0.5
430.5 ±0.7
433.4 ±0.8
438.5 ±1.1
440.8 ±1.2
443.8 ±1.5
Ordovician
Upper
Hirnantian
Katian
Sandbian
Middle
Darriwilian
Dapingian
Lower
Floian
Tremadocian
445.2 ±1.4
453.0 ±0.7
458.4 ±0.9
467.3 ±1.1
470.0 ±1.4
477.7 ±1.4
485.4 ±1.9
Cambrian
Furongian
Stage 10
Jiangshanian
Paibian
Miaolingian
Guzhangian
Drumian
Wuliuan
Series 2
Stage 4
Stage 3
Terreneuvian
Stage 2
Fortunian
~ 489.5
~ 494
~ 497
~ 500.5
~ 504.5
~ 509
~ 514
~ 521
~ 529
538.8 ±0.2
GSSA
Precambrian
Proterozoic
Neoproterozoic
Ediacaran
Cryogenian
Tonian
Mesoproterozoic
Stenian
Ectasian
Calymmian
Paleoproterozoic
Statherian
Orosirian
Rhyacian
Siderian
Archean
Neoarchean
Mesoarchean
Paleoarchean
Eoarchean
Hadean
538.8 ±0.2
~ 635
~ 720
1000
1200
1400
1600
1800
2050
2300
2500
2800
3200
3600
4031 ± 3
4567
Units of all ranks are in the process of being defined by Global Boundary Stratotype Section and Points (GSSP) for their lower boundaries, including those of the Archean and Proterozoic, long defined by Global Standard Stratigraphic Ages (GSSA). Italic fonts indicate informal units and placeholders for unnamed units. Versioned charts and detailed information on ratified GSSPs are available at the website http://www.stratigraphy.org. The URL to this chart is found below.
Numerical ages are subject to revision and do not define units in the Phanerozoic and the Ediacaran; only GSSPs do. For boundaries in the Phanerozoic without ratified GSSPs or without constrained numerical ages, an approximate numerical age (~) is provided.
Ratified Subseries/Subepochs are abbreviated as U/L (Upper/Late), M (Middle) and L/E (Lower/Early). Numerical ages for all systems except Quaternary, upper Paleogene, Cretaceous, Jurassic, Triassic, Permian, Cambrian and Precambrian are taken from 'A Geologic Time Scale 2012' by Gradstein et al. (2012), those for the Quaternary, upper Paleogene, Cretaceous, Jurassic, Triassic, Permian, Cambrian and Precambrian were provided by the relevant ICS subcommissions.
Colouring follows the Commission for the Geological Map of the World (www.ccgm.org)
CCGM CGMW
Chart drafted by K.M. Cohen, D.A.T. Harper, P.L. Gibbard, N. Car
(c) International Commission on Stratigraphy, September 2023
To cite: Cohen, K.M., Finney, S.C., Gibbard, P.L. & Fan, J.-X. (2013; updated) The ICS International Chronostratigraphic Chart. Episodes 36: 199-204.
URL: http://www.stratigraphy.org/ICSchart/ChronostratChart2023-09.pdf

4.56 by of the age of the earth are separated into:

a. Precambrian Eon 4600-541 my
b. Phanerozoic Eon 541-0 my

Precambrian Eon

- Hadean Era (4560-4000 my)
- Archean Era (4000-2500 my)
- Proterozoic Era (2500-541 my)

Precambrian covers 87% of geological history.

Archean Era is separated into EoArchean, PaleoArchean, MesoArchean, NeoArchean

Proterozoic Era is separated into PaleoProterozoic, MesoProterozoic, NeoProterozoic

Phanerozoic Eon

- Paleozoic Era (541-252 my)
- Mesozoic Era (252-66 my)
- Cenozoic Era (66-0 my)

The Plant History

- The major evolution steps of the animal and plant regimes do not match therefore paleobotanists use their own era names:

Ζωικός κόσμος	Φυτικός κόσμος
Archean	Archaeophytic
Proterozoic	Proterophytic
Paleozoic	Paleophytic
Mesozoic	Mesophytic
Cenozoic	Cenophytic or Neophytic

Paleozoic Era (541-252 my)

Six periods

Cambrian (541-485 my)

Ordovician (485-444 my)

Silurian (444-419 my)

Devonian (419-359 my)

Carboniferous (359-299 my)

Permian (299-252 my)

Mesozoic Era (252-66 my)

In three periods

- Triassic (252-201 my)
- Jurassic (201-145 my)
- Cretaceous (145-66 my)

Cenozoic Era (66-0 my)

In two periods

- Tertiary (66-2.6my)
- Quaternary (2.6-0 my)

Tertiary **(66-2.6my)**

In two subperiods

- Paleogene (66-23my)
- Neogene (23-2.6my)

Paleogene **(66-23my)**

In three Epochs

- Paleocene (66-56my)
- Eocene (56-35my)
- Oligocene (35-23my)

Neogene **(23-2.6my)**

In two Epochs

- Miocene (23-5.3 my)
- Pliocene (5.3-2.6 my)

Quaternary **(2.6-0 my)**

In two epochs (or three as recently assumed)

- Pleistocene (2.6-0.0117my)
- Holocene (0.0117-today [or0.0003my])
- Anthropocene (0.0003-today)

Epochs are separated into ages

Ages are separated into chrons

Geochronology

1. Chronography or Geochronography (using geological, biological, astronomical or climatic methods)
2. Chronometry or Geochronometry (using physics methods)

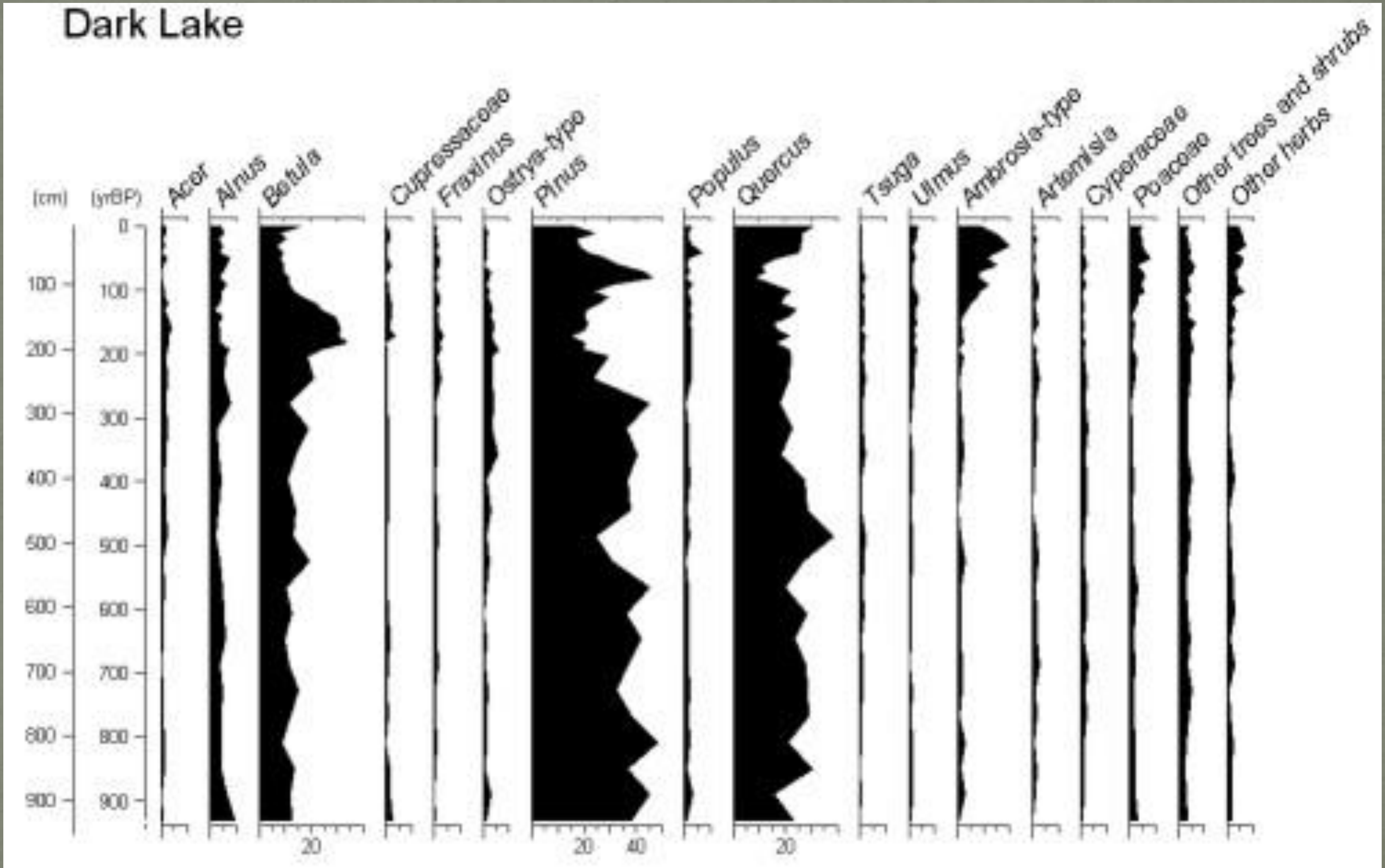
Chronography

1. Annual bedding
2. Palynology
3. Dentrochronography (Tree rings)
4. Zoochronography (animal shell increments)
5. Lichenometry (for recent glacial deposits)
6. Astronomical methods (changes in the earth's orbital oscillations)

Annual bedding

Annual pair of black (winter) and white (summer) deposits

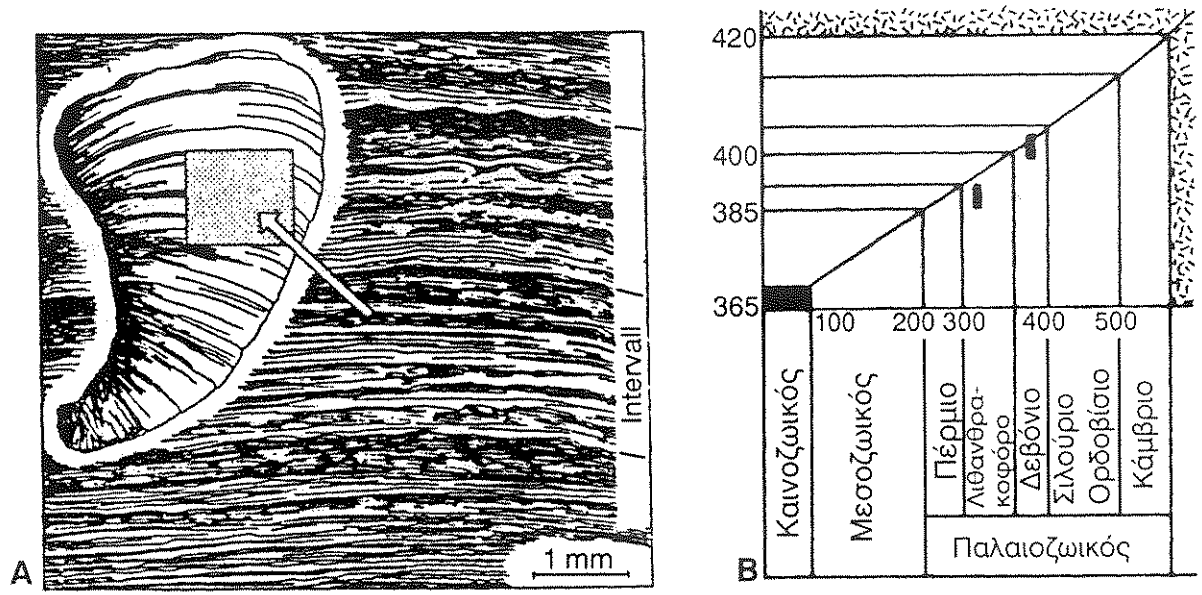
Palynology



Plants produce pollen annually

Dentrochronography

Zoochronography



Σχήμα Γ-12. *Α. Ζώνες αύξησης του Heliophyllum σε σχέση με τις φάσεις της Σελήνης. Β. Ελάττωση του χρόνου περιστροφής της Γης με βάση τη μελέτη των ταινιών αύξησης σε κοράλλια του Δεβόνιου και Λιθανθρακοφόρου.*

(GEYER, 1973)

Duration of days

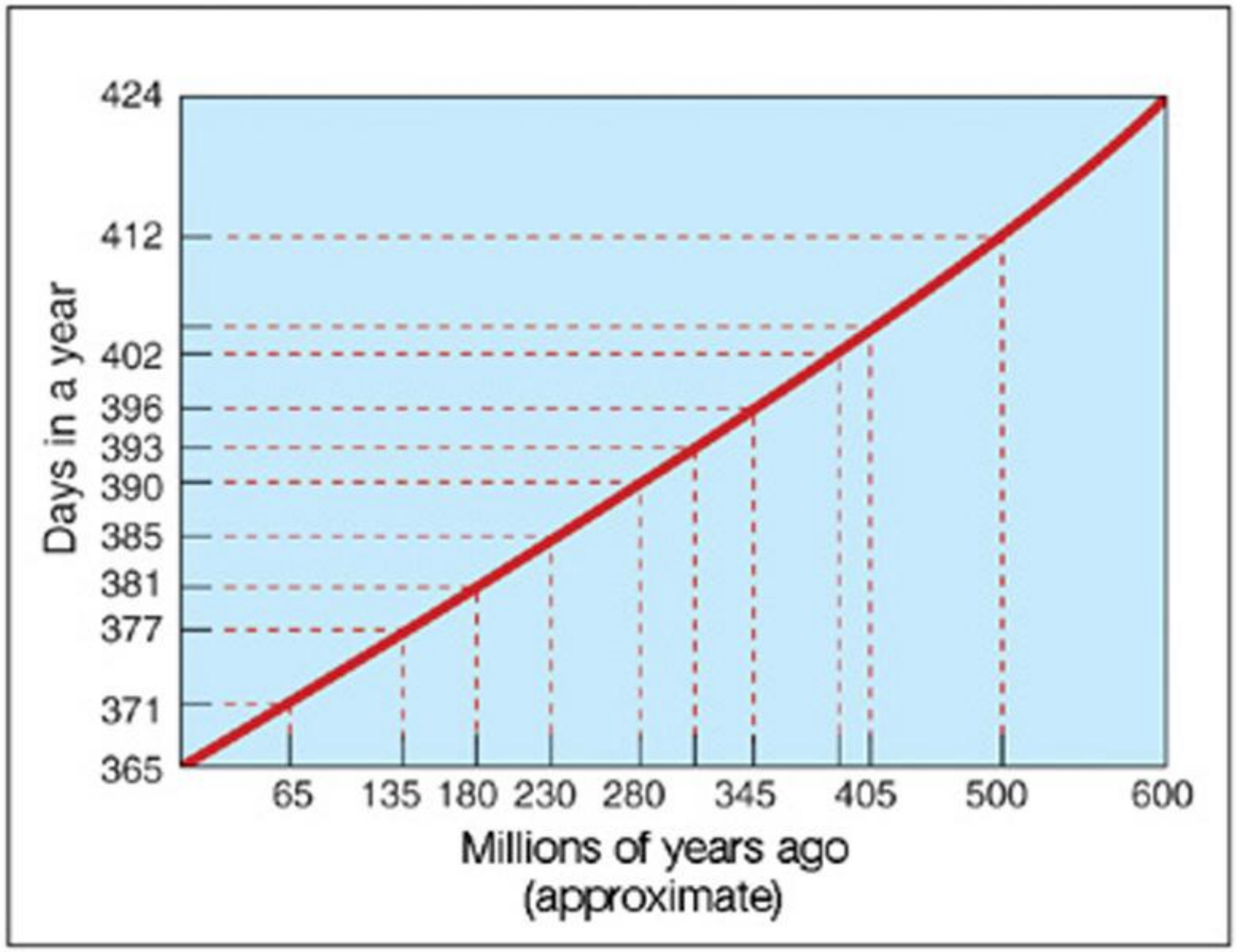
From coral shell increments

During the Devonian the year had 398 days

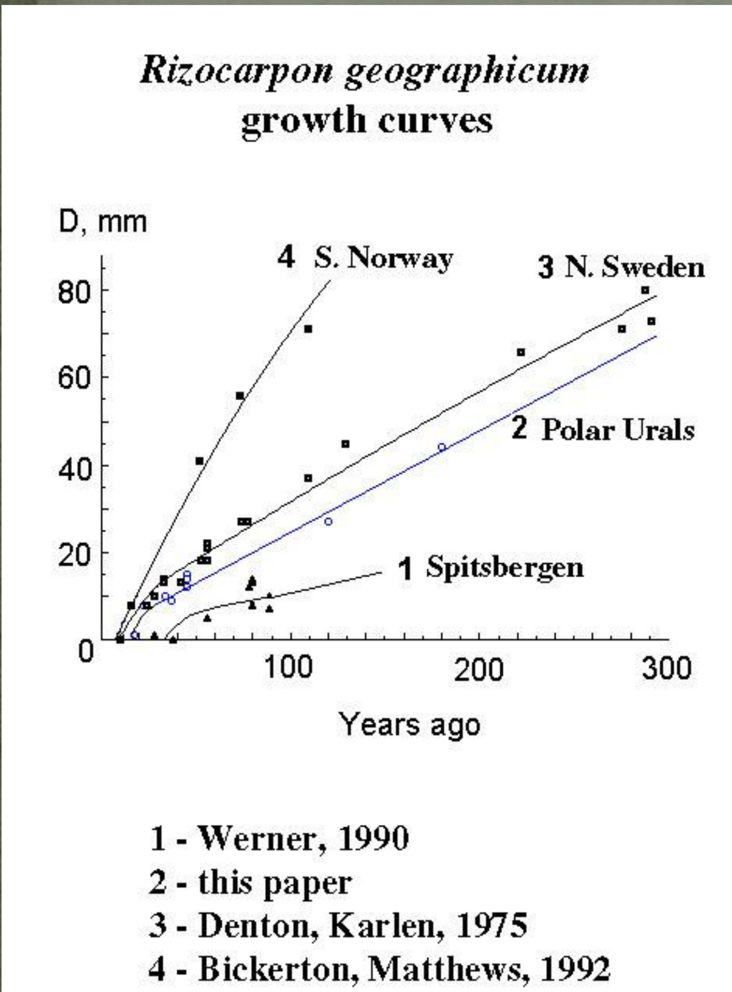
In the Neoproterozoic the day had 18.2 hours

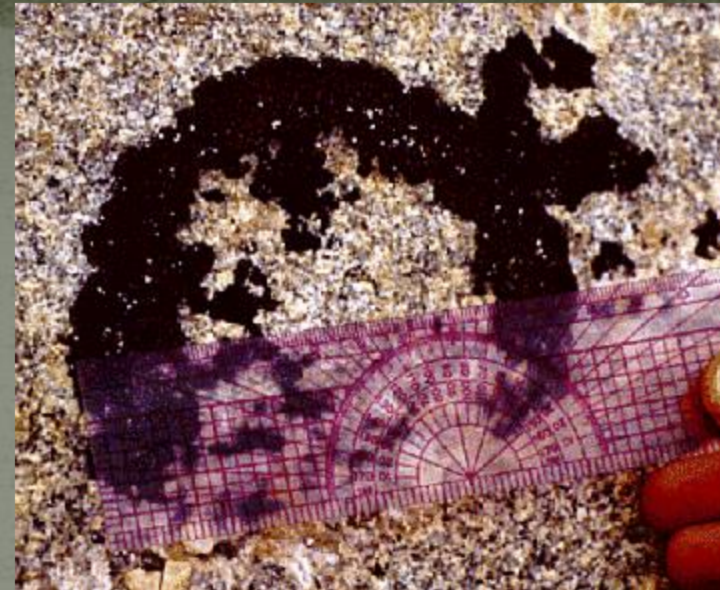
Earth was rotating faster in the past and gradually as time passes it slows down

How long did a day lasted during the Proterozoic?



Lichenometry





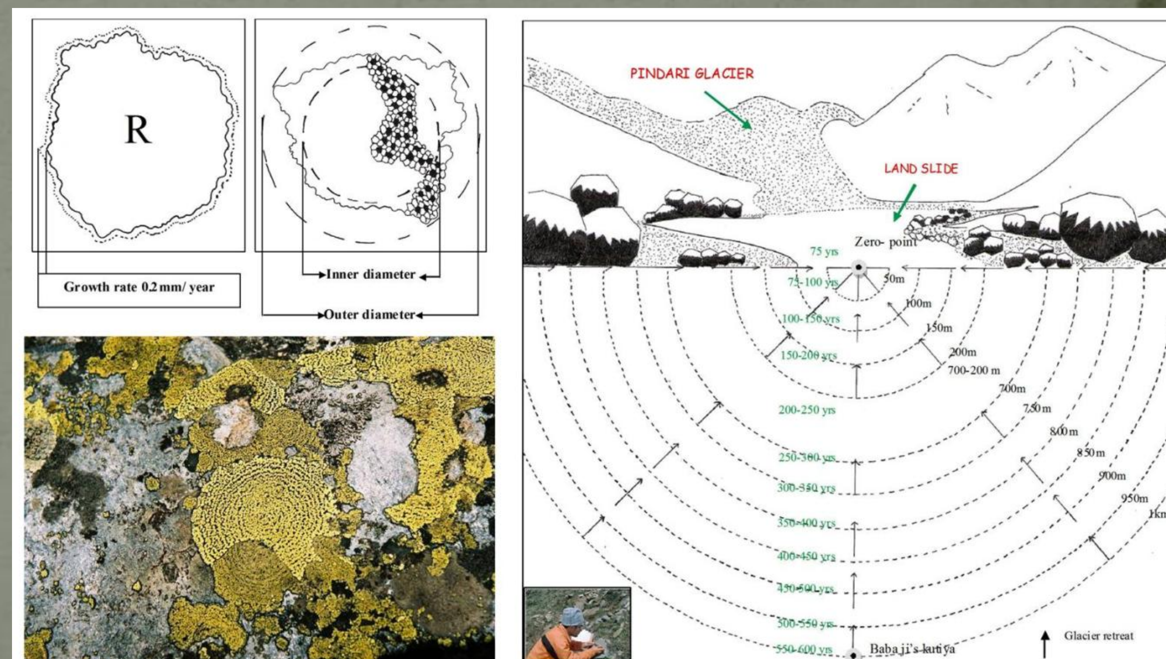


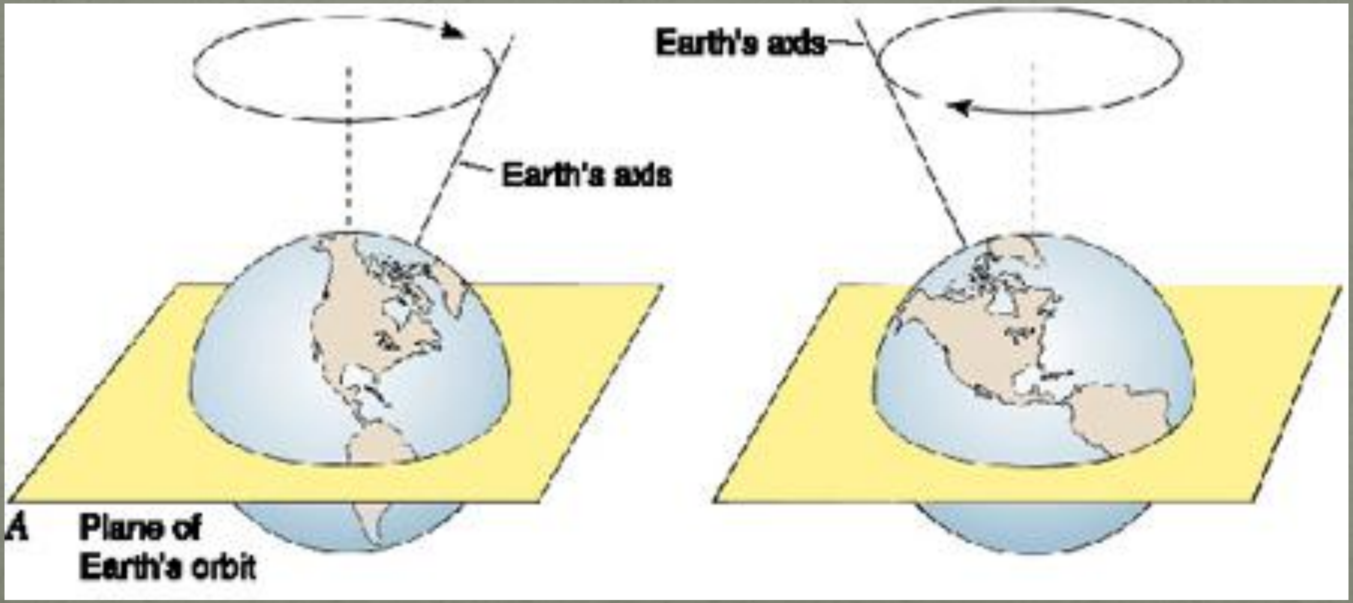
Figure 5. *Rhizocarpon geographicum* (L.) DC., a widely used lichen species in lichenometry; Diagrammatic representation of lichenometric study performed in the vicinity of Pindari Glacier by two of the authors (From Joshi and Upreti 2010).

Astronomical methods : Milankovitch Cycles

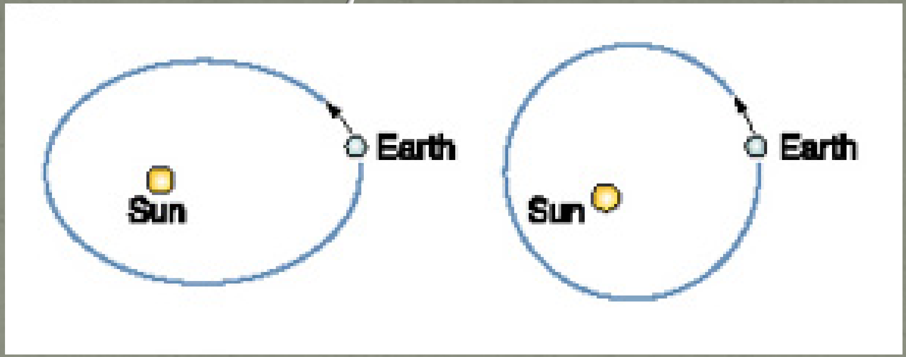
- Periodic changes in earth's annual temperature due to earth's orbit oscillations
- These cyclical temperature changes due to periodic changes of the distance of the earth from the sun and its rotation angle

Milankovitch Cycles

1. Precession– The axis of earth rotates every 26,000 χρόνια, affecting the amount of solar radiation that the poles receive



Milankovitch Cycles

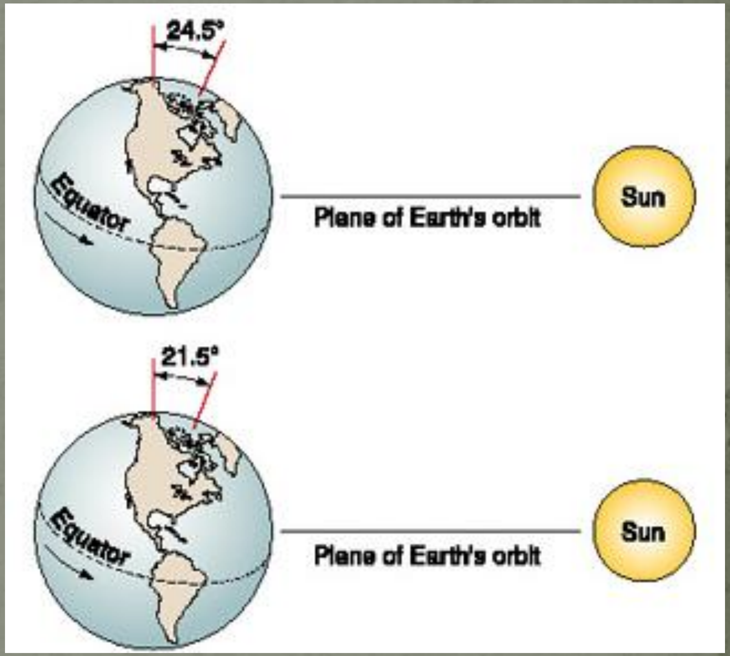


2. Eccentricity– The orbit of the earth around the sun changes from circular to more elliptical by 2% every 100,000 years, thus the earth receives more or less solar radiation.

Milankovitch Cycles

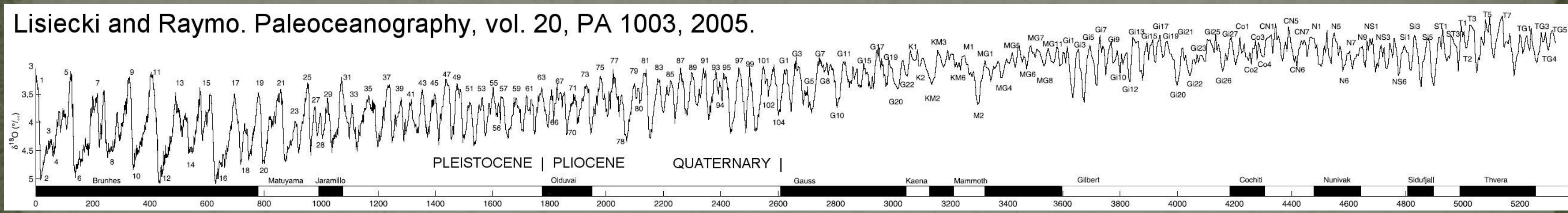
3. Obliquity– today 23.5⁰, this what causes earth's seasons.

   The angle ranges between 21.5⁰ - 24.5⁰ every 41,000 έτη, changing the duration of daytime and the amount of solar radiation that the poles receive.

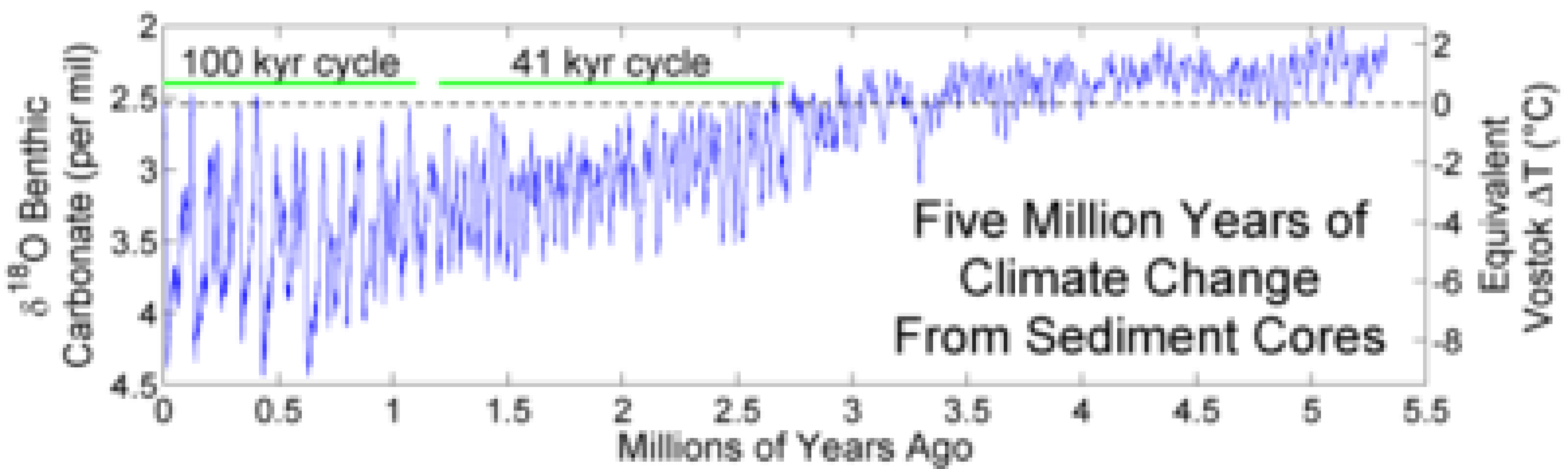


Milankovitch Cycles

- The combined cycles affect periodically the amount of solar radiation that the earth receives and cause rise or drop of annual temperatures and regulate the glacial and interglacial cycles
- They correlate very well with the glacial periods that took place every 100,000 years during the last 600,000 years, according to O isotopes.



Lisiecki and Raymo. Paleoceanography, vol. 20, PA 1003, 2005.
PLEISTOCENE | PLIOCENE
QUATERNARY |
Brunhes
Matuyama
Jaramillo
Olduvai
Gauss
Kaena
Mammoth
Gilbert
Cochiti
Nunivak
Sidufjall
Thvera



100 kyr cycle
41 kyr cycle
Five Million Years of Climate Change From Sediment Cores
δ 18O Benthic Carbonate (per mil)
Equivalent Vostok ΔT (°C)
Millions of Years Ago

Chronometric methods– Absolute dating

- Age in years before today
- Radioactive elements – radiometric dating
- Based on the stable decay rate of Radioactive isotopes
- The original parent element disintegrates gradually and with a stable rate into its respective daughter
- Unit: Half life time
- Different methods depending on the rock and the age

Measuring Decay Rates

The decay rates of the various radioactive isotopes are measured directly using a mass spectrometer.

Basically, the mass of a quantity of a radioactive element is measured. Then after a particular period of time, it is analyzed again. The change in the number of atoms over time gives the decay rate.

Decay Rates are Uniform

- Radioactive decay occurs at a constant exponential or geometric rate.
- The rate of decay is not affected by changes in pressure, temperature, or other chemicals.
- The rate of decay is proportional to the number of parent atoms present.

Prerequisites for calculating rock age

1. The sample originally should not contain any daughter isotope
2. Parent and daughter isotopes have not leached
3. The daughter isotope came only from the decay of the parent
4. Knowing the exact half life time
5. Exact measurements Parent and daughter isotopes
6. Fresh unweathered and uneroded samples
7. For lead methods we avoid metamorphic rocks

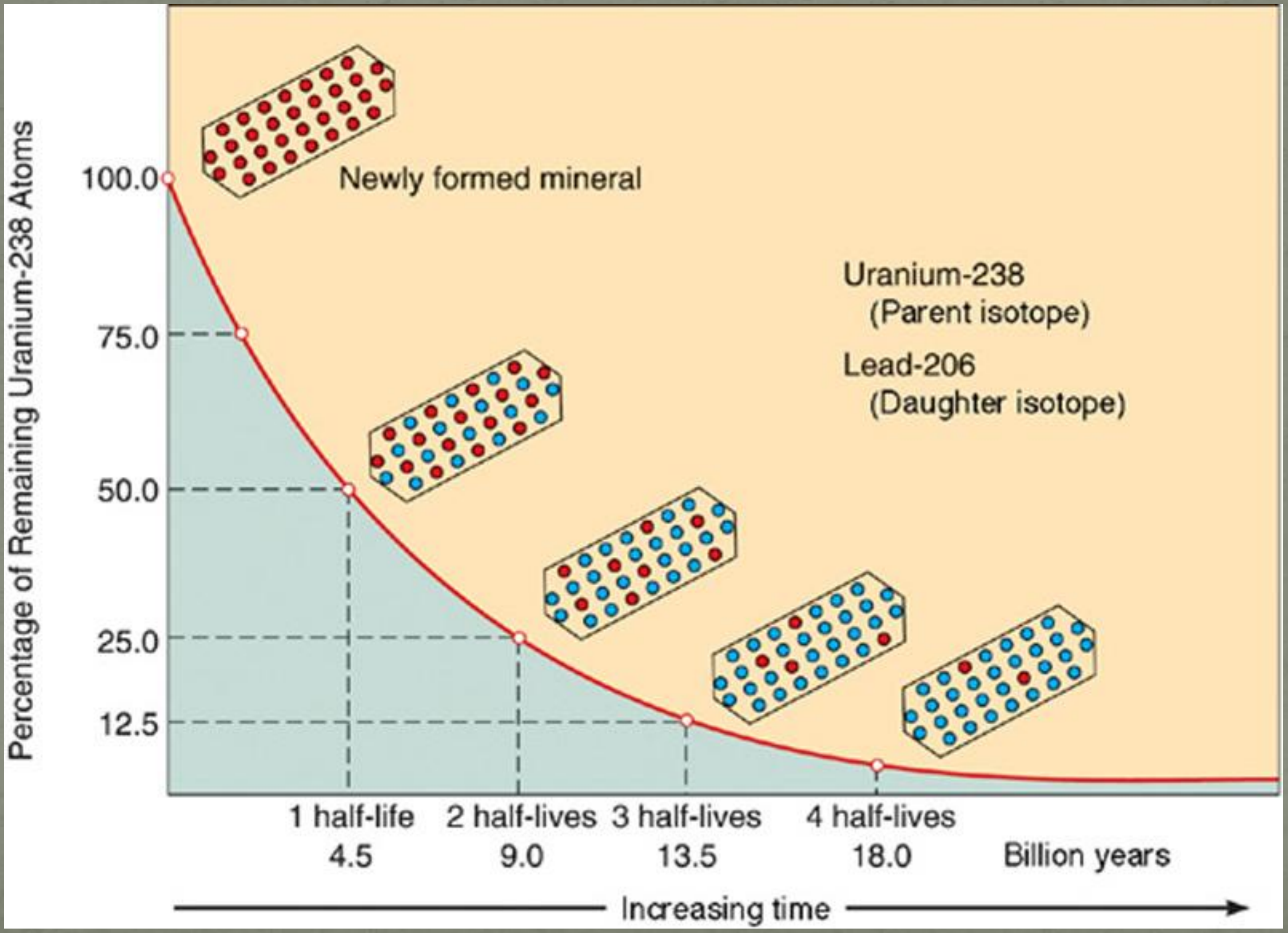
Radioactive Parent Isotopes and Their Stable Daughter Products

Radioactive Parent Isotope	Stable Daughter Isotope
Potassium-40	Argon-40
Rubidium-87	Strontium-87
Thorium-232	Lead-208
Uranium-235	Lead-207
Uranium-238	Lead-206
Carbon-14	Nitrogen-14

Half Lives for Radioactive Elements

Radioactive Parent	Stable Daughter	Half life
Potassium-40	Argon-40	1.25 billion yrs
Rubidium-87	Strontium-87	48.8 billion yrs
Thorium-232	Lead-208	14 billion years
Uranium-235	Lead-207	704 million years
Uranium-238	Lead-206	4.47 billion years
Carbon-14	Nitrogen-14	5730 years

Decay Curve for Uranium-238



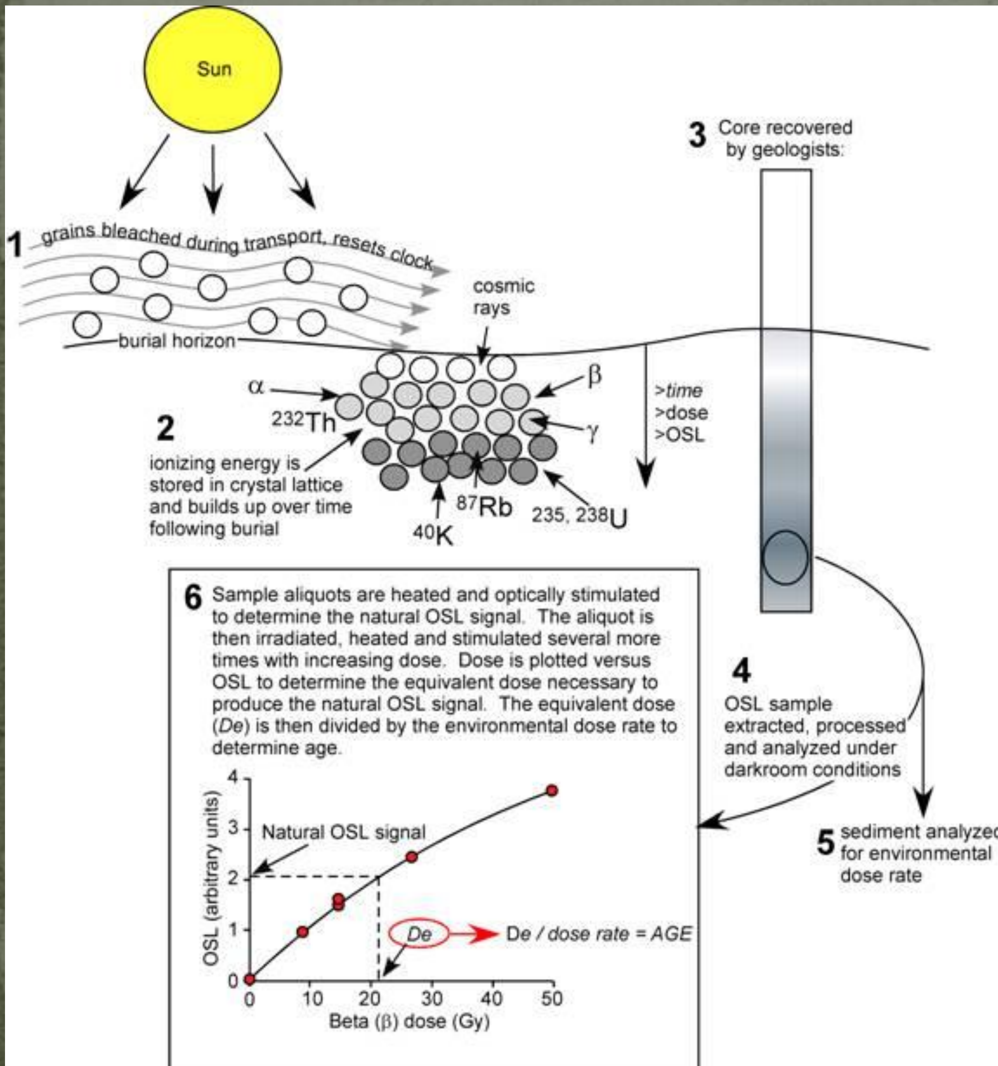
Other dating methods

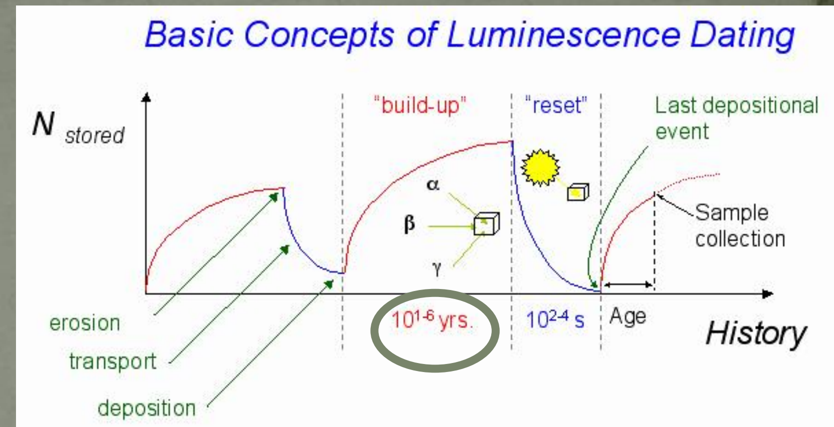
- Fission Track Dating
- Optically Stimulated Luminescence (OSL)
- Electron Spin Resonance(ESR)
- Palaeomagnetism, Magnetostratigraphy
- Chemostratigraphy

Fission Track Dating

- Recent method
- Some uranium atoms due to the spontaneous fission breakdown into two same size nuclei
- Every year 1 atom per 69×10^{6} atoms breaks down
- An anomaly caused in minerals (muscovite, zircon, epidote, titanite, alanite, monazite) which after acid preparation and neutron emission we calculate the age
- 400 – 1250 my

Optically Stimulated Luminescence(OSL)





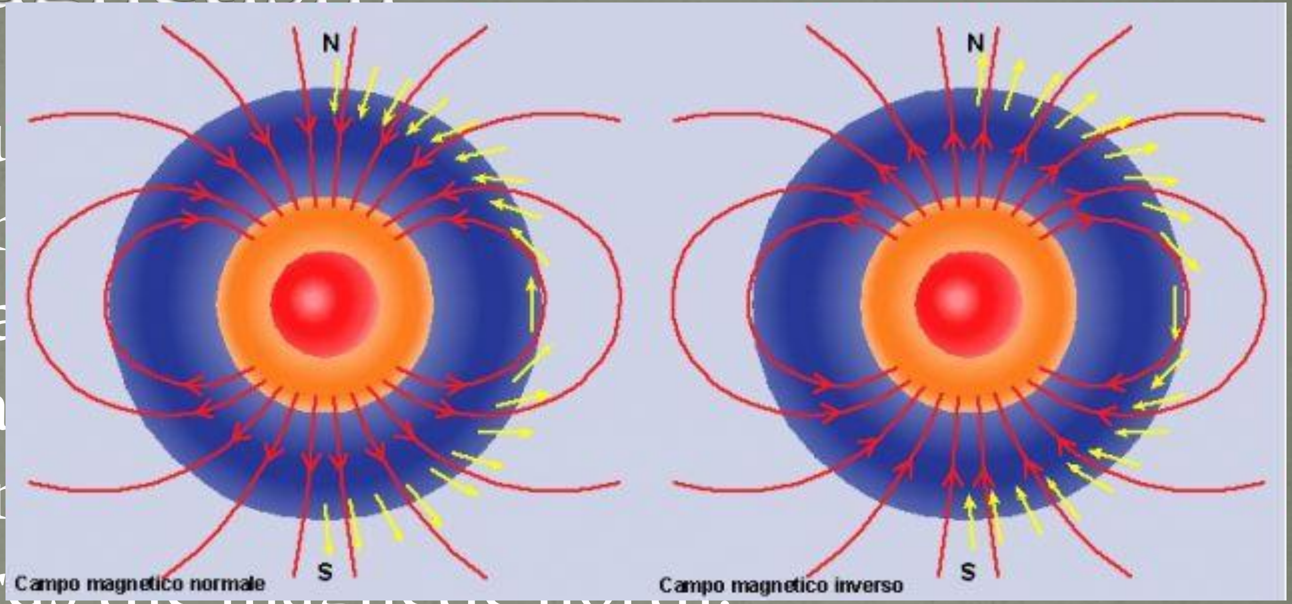
Measures the energy of the released photons. Ionizing radiation is absorbed and stored in the crystal lattice while after being stimulated it is released as luminescence. Age is calculated from the last exposure to sunlight. The sunlight turns off the luminescence signal and zeroes the age clock. The main minerals used quartz and K-feldspars.
300.000-400.000 έτη

Electron spin resonance (ESR)

- It is based on the absorption of microwave radiation from a single electron, exposed to a strong magnetic field

Palaeomagnetism

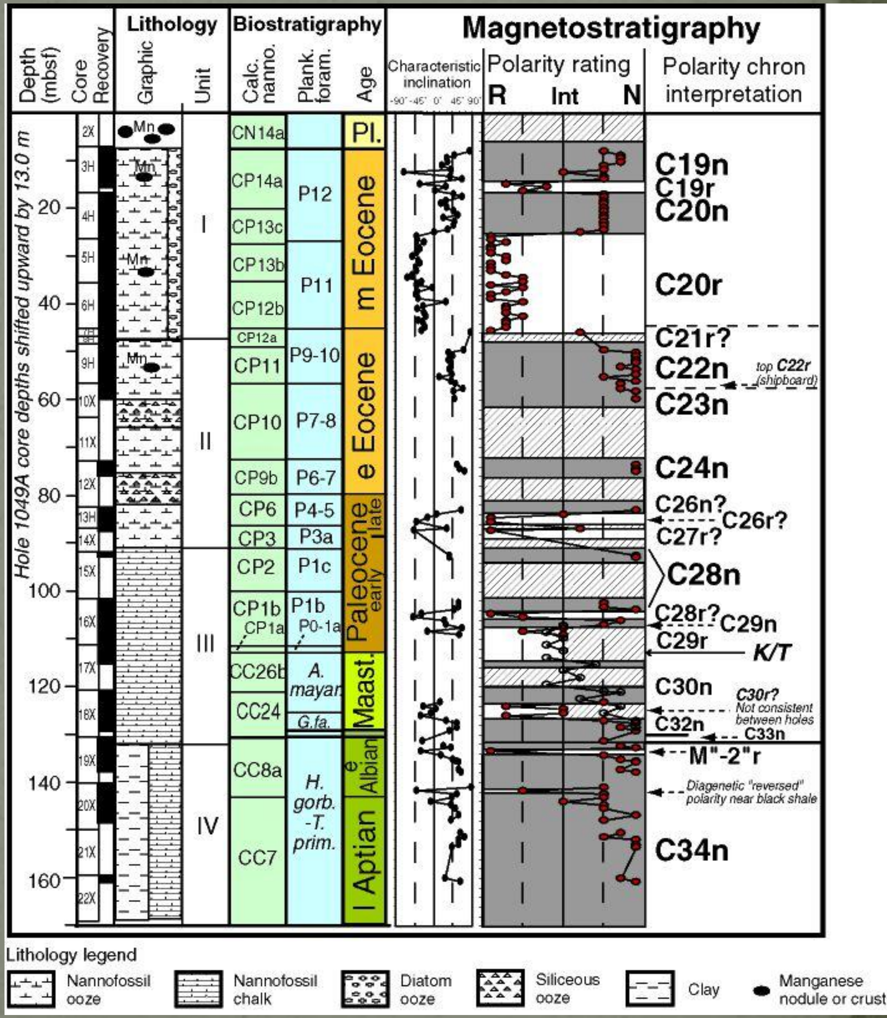
- Earth is surrou
and acts as a gr
Various minera
or deposition a
Magnetite, ferr
oriented towards the magnetic north.
The magnetic field changes and thus the magnetic poles change constantly during geological time.
Magnetic minerals behave as fossils indicating the direction of magnetic field in the past.



Earth's magnetic field

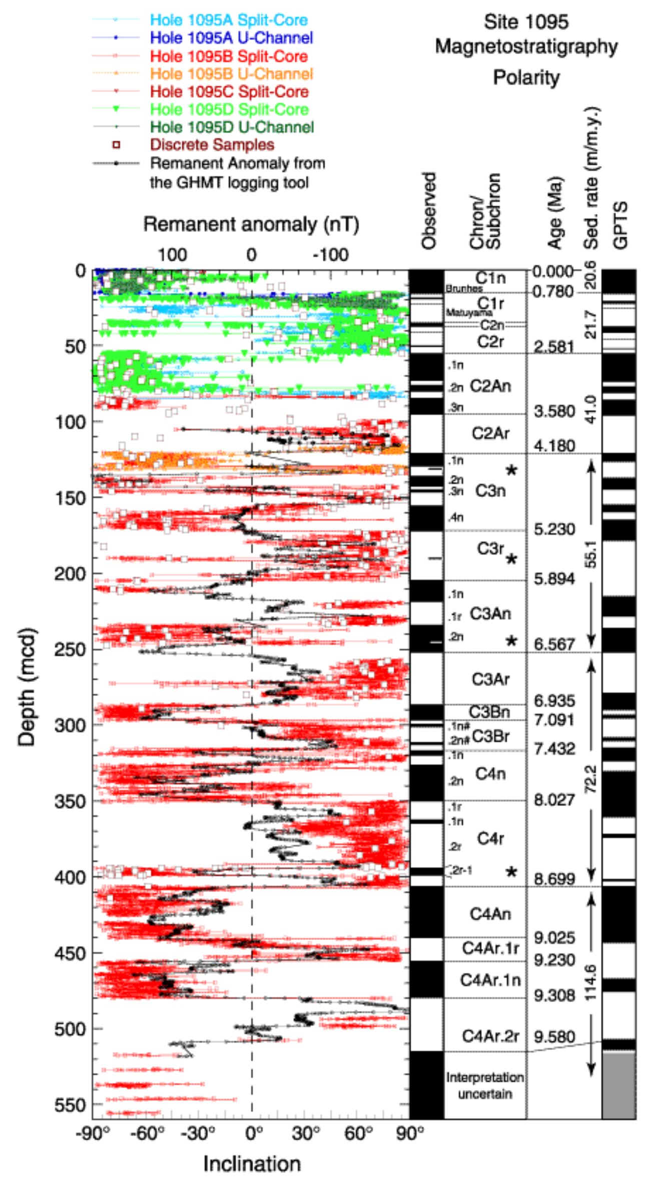
Magnetostratigraphy

- Magnetostromatography is a geophysical correlation technique used to date sedimentary and volcanic sequences. The method works by collecting specimens at oriented intervals.



Sequential series of Oriented Samples in which magnetic susceptibility and relative magnetic magnetization are measured

Magnetostratigraphy



Magnetostromatographic modules

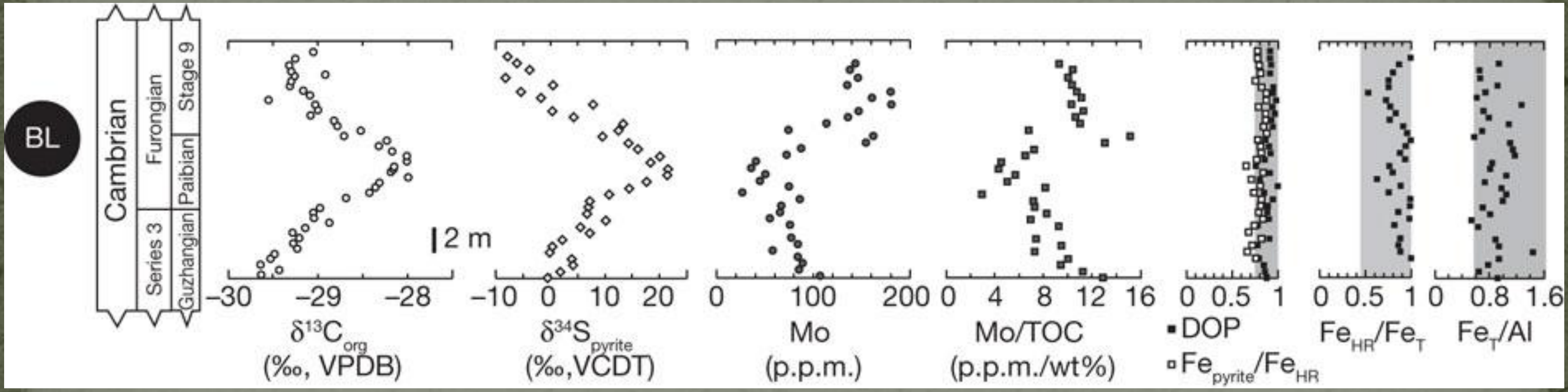
Chronozone

C2An (normal)
C2Ar (reverse)

Subchronozone
-1n
-1r

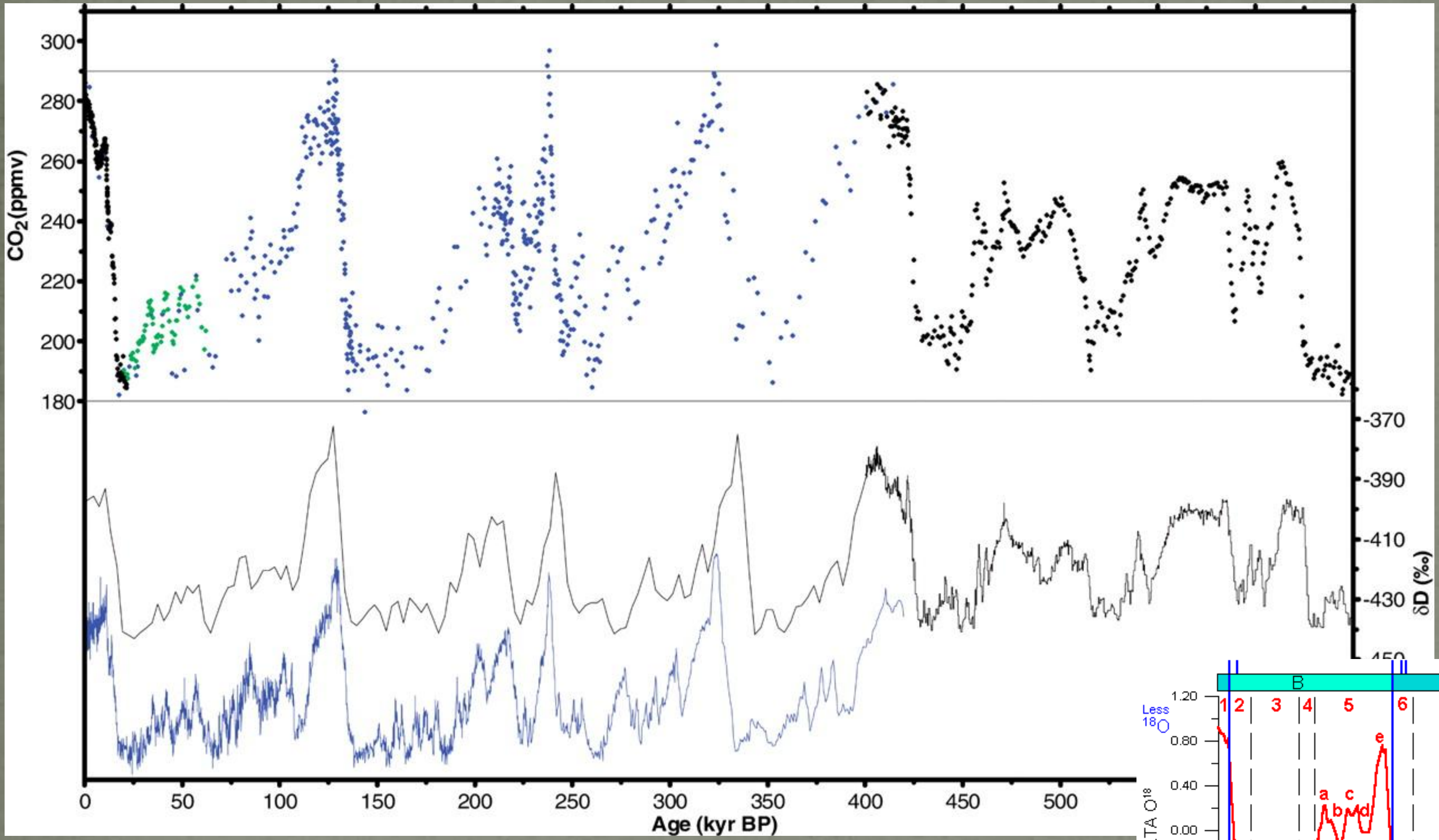
Chemostratigraphy

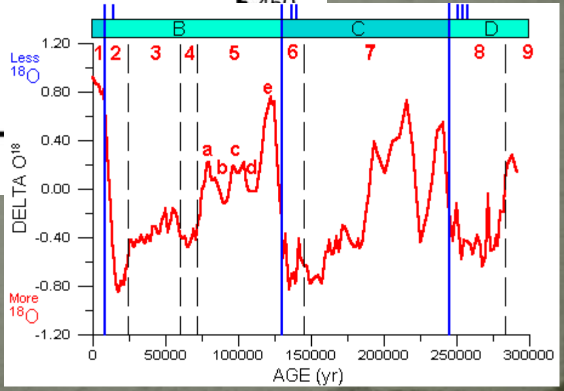
- Chemostratigraphy is the study of the geochemical changes in sedimentary sequences.



Chemostratigraphic charts in shrimps of Cambrian, Sweden.

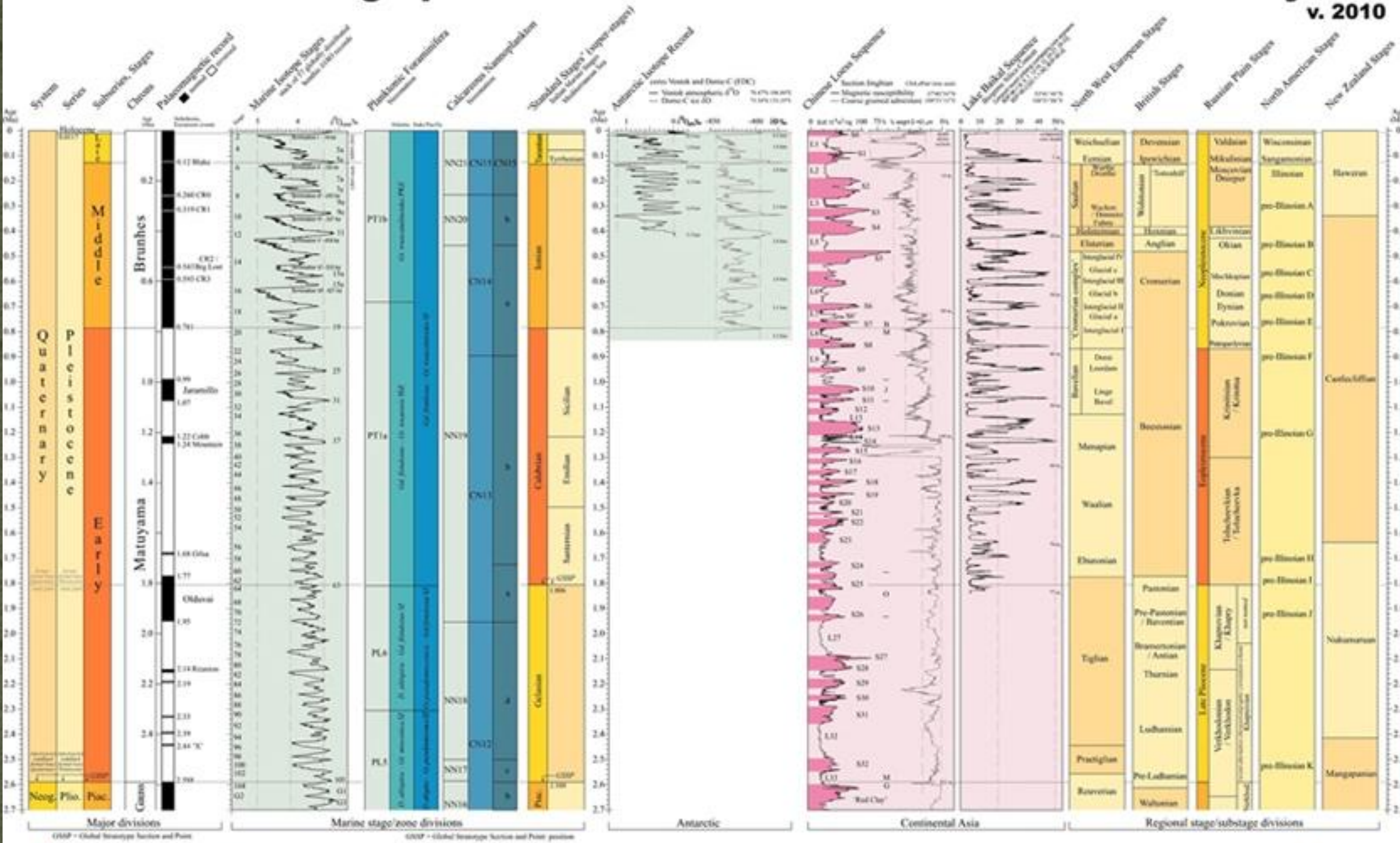
Chemostromatography





Global chronostratigraphical correlation table for the last 2.7 million years

v. 2010



UNIVERSITY OF CAMBRIDGE

http://www.cam.ac.uk/

http://www-qpg.geog.cam.ac.uk/

Universiteit Utrecht

http://www.geo.uu.nl/

http://www.inqua.tcd.ie/

http://www.stratigraphy.org/

Correlation

- Reciprocal relationships between two or more sections
- The synthesis of all data from all sections of an area into a composite section acceptable for the whole region
- It also indicates equivalences between lithological units and their fossil contents
- A key element of stratigraphic research
- Globally it contributes to the creation of the general time-scale scale

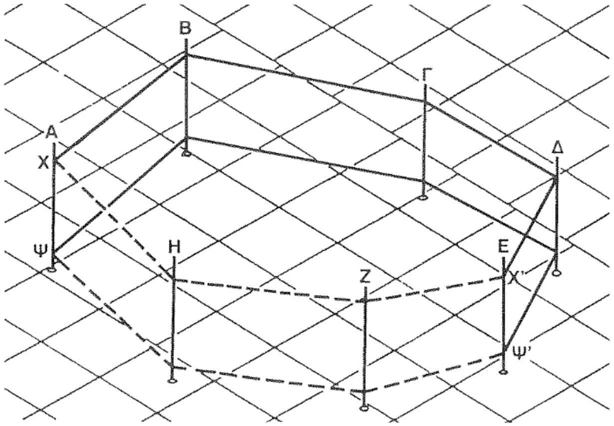
Criteria for correlation

- Natural or lithological
  1. Physical continuity
  2. Lithographic similarity
  3. Elements and measurements from boreholes
  4. Stratigraphic position and sequence
  5. Absolute ages from radiometric datings
- Palaeontological or biological
  1. Fossils
  2. Stage of evolution
  3. Faunal similarity
  4. Proportion of extant species

Lithostratigraphic correlation

- Locate and compare the stratigraphic position of sections or layers of correlated sections
- Accurate and fully applicable for short distances
- As distance increases, the reliability decreases
- Lateral variations due to phase change, section or layers breakage
  It is usually necessary to compare multiple sections with closed correlation intersections or correlation networks

Lithostratigraphic correlation



Σχήμα Γ-15. *Κλειστή διασταύρωση συσχετισμού.*

(KRUMBEIN - SLOSS, 1963)

Lithostratigraphic correlation

- Correlation based on lateral continuity
  It is based on the detection of contacts between units or characteristic index layers (+ aerial photographs, drilling, physical properties)

- Correlation based on lithological characteristics
  Any visible or measurable lithological feature, color, grain size and shape, thickness, mineral composition, fossil content, electrical properties, etc.

- Correlation based on the position of the unit within a known sequence
  Each unit has a specific position in a known sequence, up and down there will always be the same layers. Conversely, recognizing an overlying or underlying layer also recognize the layer of interest. On a small scale, discontinuities or tectonic structures may be used

Biostratigraphic correlation

- It is based on palaeontological data
- Chronological correlation resulting from time equivalence of evolutionary sequences of fossils or faunal sets
- More successful in uninterrupted sequences
- It makes possible correlation on a global scale
- The methods are based on biozone species
- Problems and difficulties:
  Changes in facies, the presence of faunal provinces, different faunal areas
  Time differences in the appearance of different taxa per region

Facies analyses

- Facies is the lithological and palaeontological view of a rock as well as the determination of its formation conditions and its depositional environment
- It comes from the study of the rock and its fossils
- It contains all the lithological and biological characteristics of the rock with simultaneous definition and interpretation of the conditions of the depositional environment

Facies analyses

- The branch dealing with Facies is called Facies analyses
- Lithology and fossils are objective elements
- Environmental identification is based on a subjective assessment
- In order to improve it and to have accuracy we examine several samples
- The large number of samples is also necessary to detect the changes in Facies

Types of Facies

- Isotope Facies : lithological and paleontological elements come from the same enviroment
- Heterotope Facies : lithological and paleontological elements come from different sites (eg Coastal conglomerates with terrestrial and marine fossils)
- Allotope Facies: the lithological and paleontological data come partly from a neighboring area (eg land fossils in marine deposits)

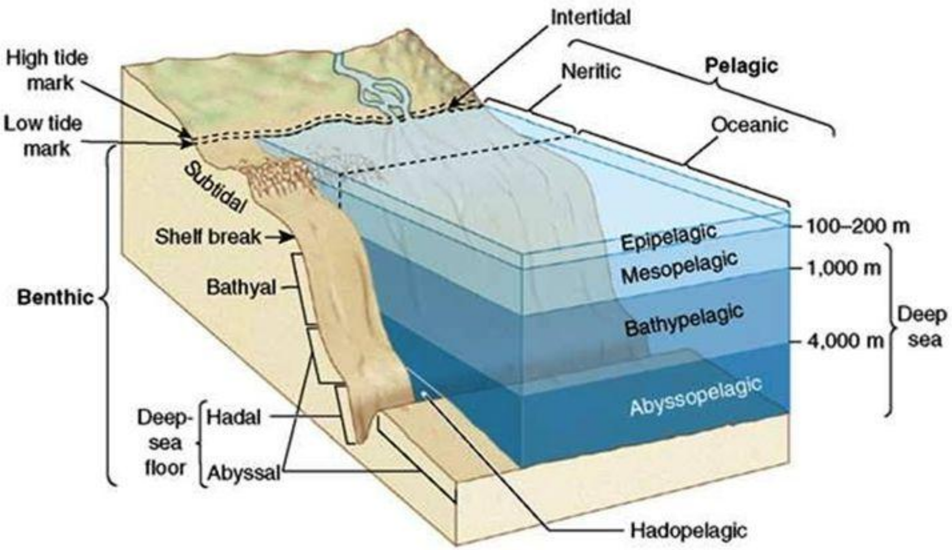
Facies categories

- Continental
  Continental, lacustrine, cave, riverine, aeolian, alluvial, marsh, glacial, brackish
- Marine
  Lagoonal, coastal, super-tidal, slope, bathyal, abyssal

- They are also distinguished in neritic (0-200 meters) and pelagic

- What rocks and fossils characterize each phase?

Marine Environments



Lithofacies

- Lithophacies is the lithological appearance of a sedimentary rock (chemistry, mineral species, sedimentary structures) or else its sedimentary character
- Its determination is based on the percentage of rock components or on the presence of dominant or index minerals
- The latter determine with absolute accuracy the depositional environment

Lithofacies

- Glauconite - indicator of marine environment
- Red earths- dry or tropical-liquid terrestrial environment indicators
- Bituminous clays - indicators of anaerobic hydrated environment
- Carbonates - hot climate indices
- Evaporites - warm and dry climate indices with intense evaporation
- Coal - lignite - indicators of hot and humid climate
- Silicates - indicators of deep sea environment

Biofacies

- Biofacies is the palaeontological view of a sedimentary rock
- Its definition is based on “facies" fossils that give information about the living environment of the original organisms
- For these we need to know precisely: medium of living regime, ecological and environmental factors

Types of biofacies

- biofacies without life with complete beds
  Closed anaerobic basins with thanatocoenoses
- biofacies with life and complete beds
  Poorly oxygenated basins with a few benthic organisms and thanatocoenoses
- biofacies with life and without bedding
  Coastal areas with oxygenated waters and moving water and thus biocoenoses
- biofacies without life and without bedding
  Coastal areas with high energy waters and hence the deposition of sediments to be colonised by organisms impossible
- biofacies with life and no beds
  Coastal areas with oxygenated and high-energy waters and biocoenoses whose remains build rocks