Archaeo 202

The Chronostratigraphic Record and Methods of Relative and Absolute Dating in Archaeology

Alfred Pawlik – ASP 2016

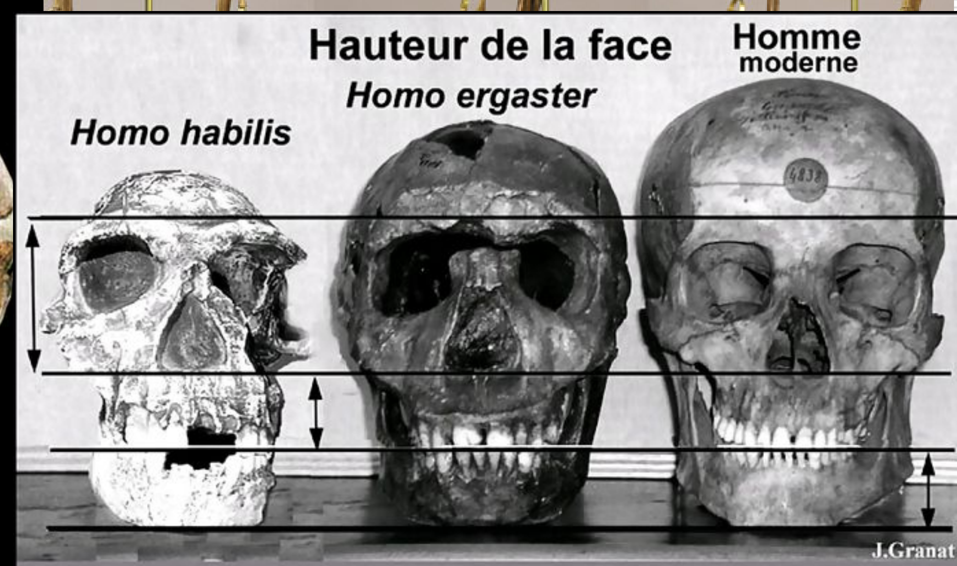
Dating our history

- James Ussher, 'Archbishop of Ireland and Primate of All Ireland'
- Chronological study based on the Julian Calendar to establish the time and date of:
- "The entrance of the night preceding the 23rd day of October… the year before Christ 4004"; that is, around 6 pm on 22 October 4004 BC

James Ussher,
(1581-1656)

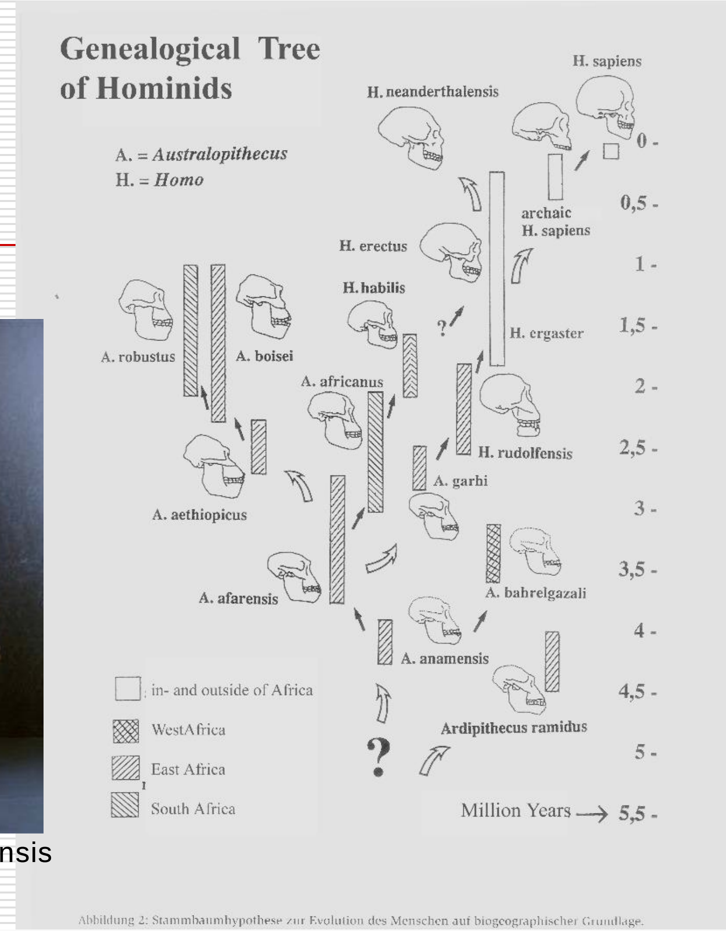
Evolution

- Links
  - Missing and Found

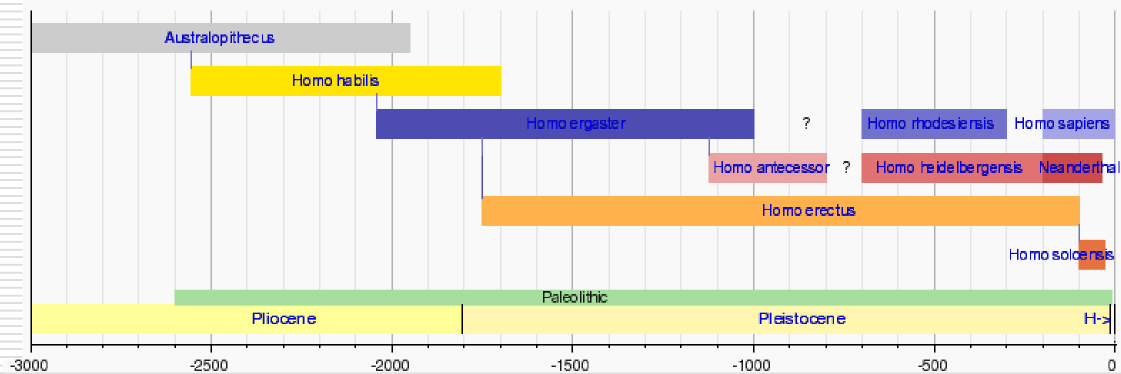


Time line of the genus *homo*

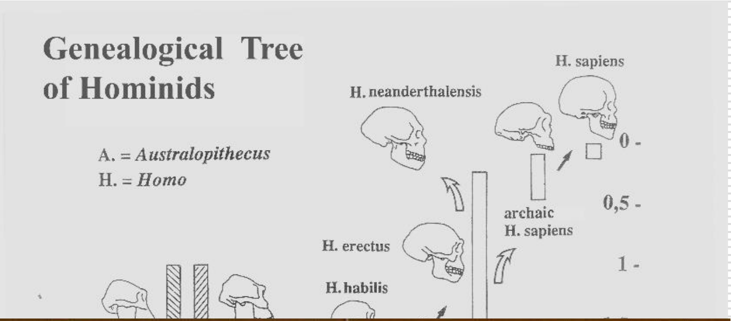
Homo floresiensis

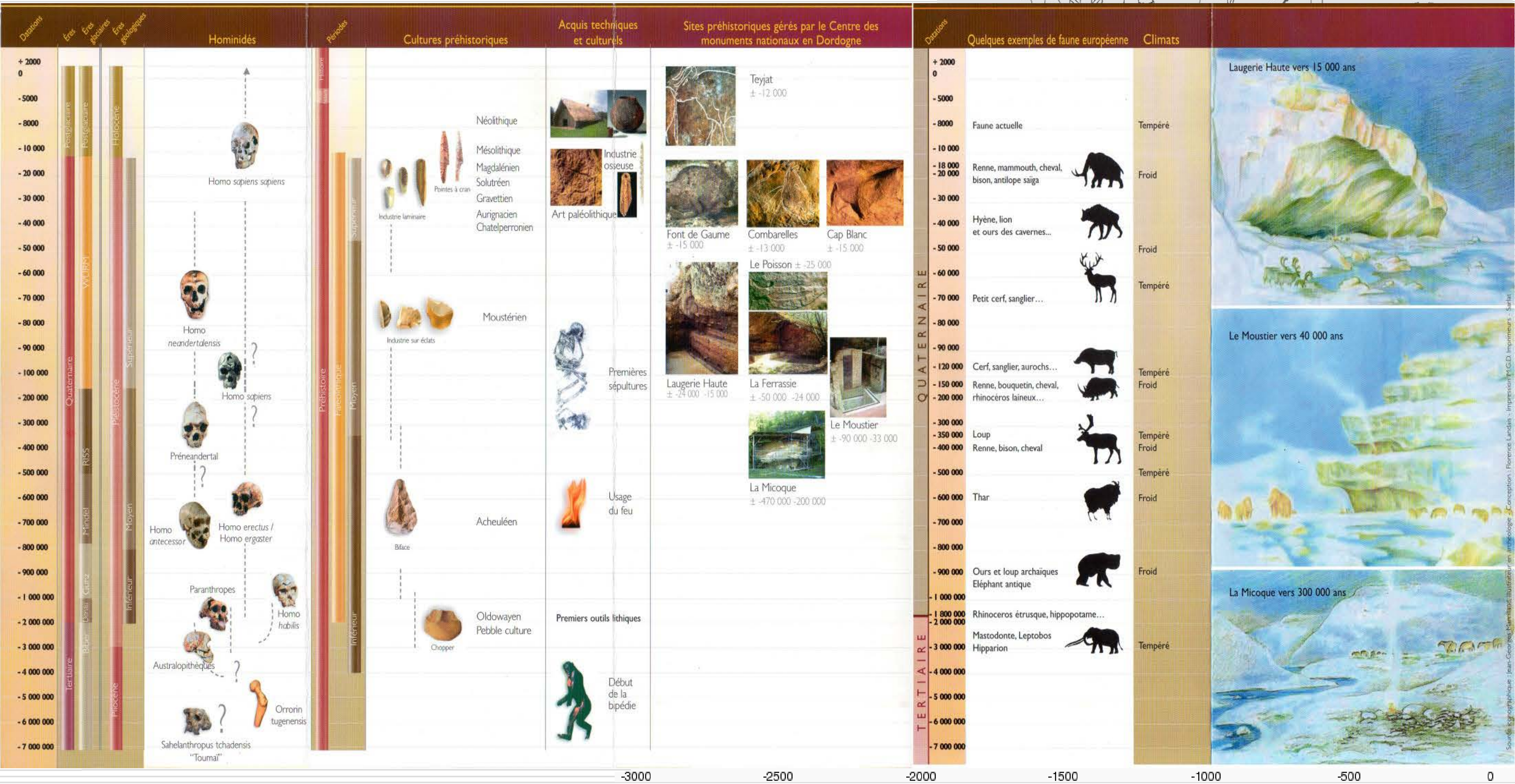


"Hominid family". Left to right: Top row: Kenyanthropus platyops, Homo neanderthalensis;
middle row: Australopithecus afarensis, Paranthropus boisei, Homo habilis;
bottom row: Australopithecus africanus, Homo erectus, Australopithecus anamensis, Homo rudolfensis.



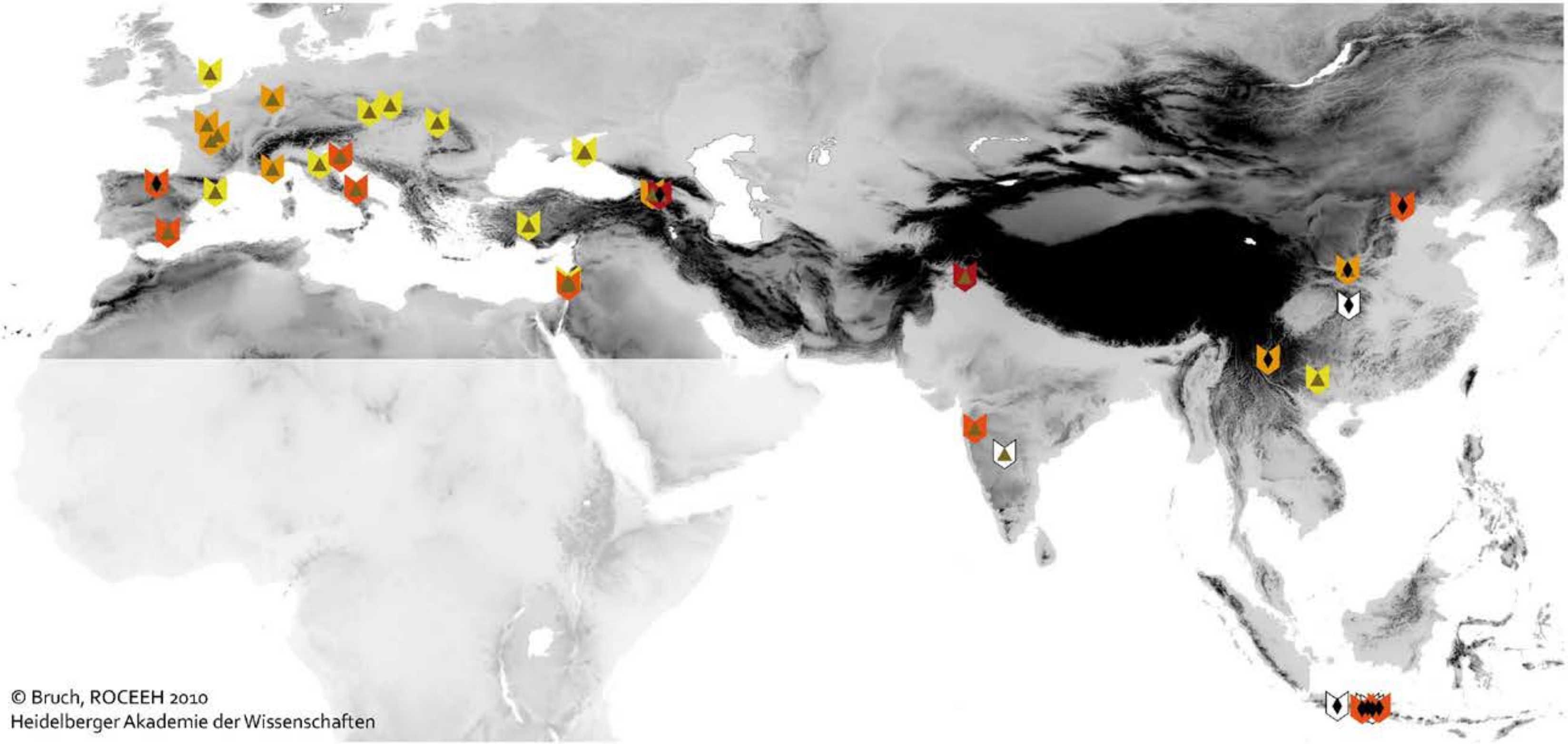
Time line of the genus *homo*





THE ROLE
OF CULTURE
IN EARLY
EXPANSIONS
OF HUMANS

Early Pleistocene presence of *Homo* in Eurasia



Legend

Hominin presence based on: ♦ human remains ▲ stone tools

Stratigraphic range: Olduvai pre-Jaramillo ± Jaramillo post-Jaramillo Early Pleistocene, not specified

Stratigraphy - Nicholas Steno (1638-1686)

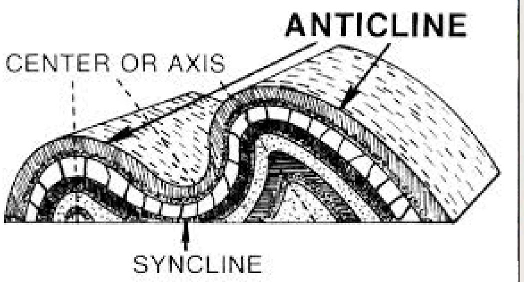
Pioneered in Anatomy and **Geology**

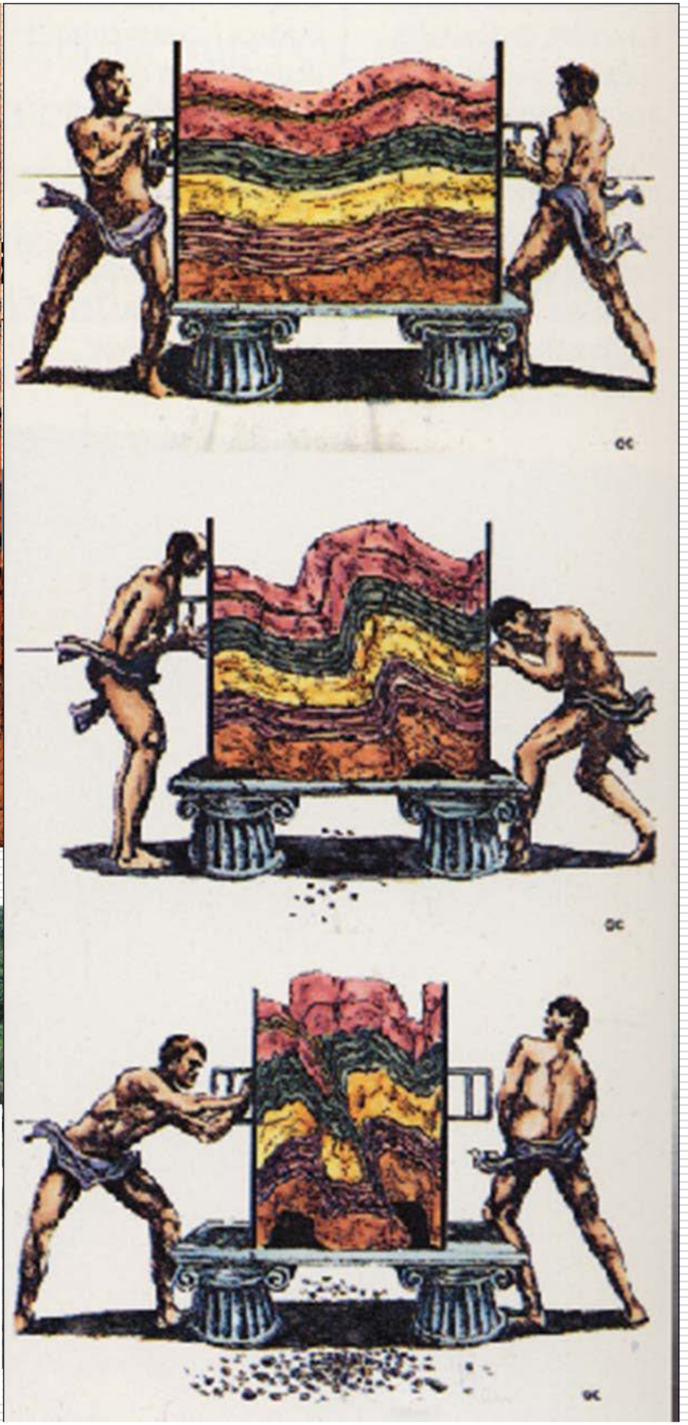
Principles of Stratigraphy (1669)

1. Superposition
2. Original horizontality
3. Lateral continuity and cross-cutting discontinuities

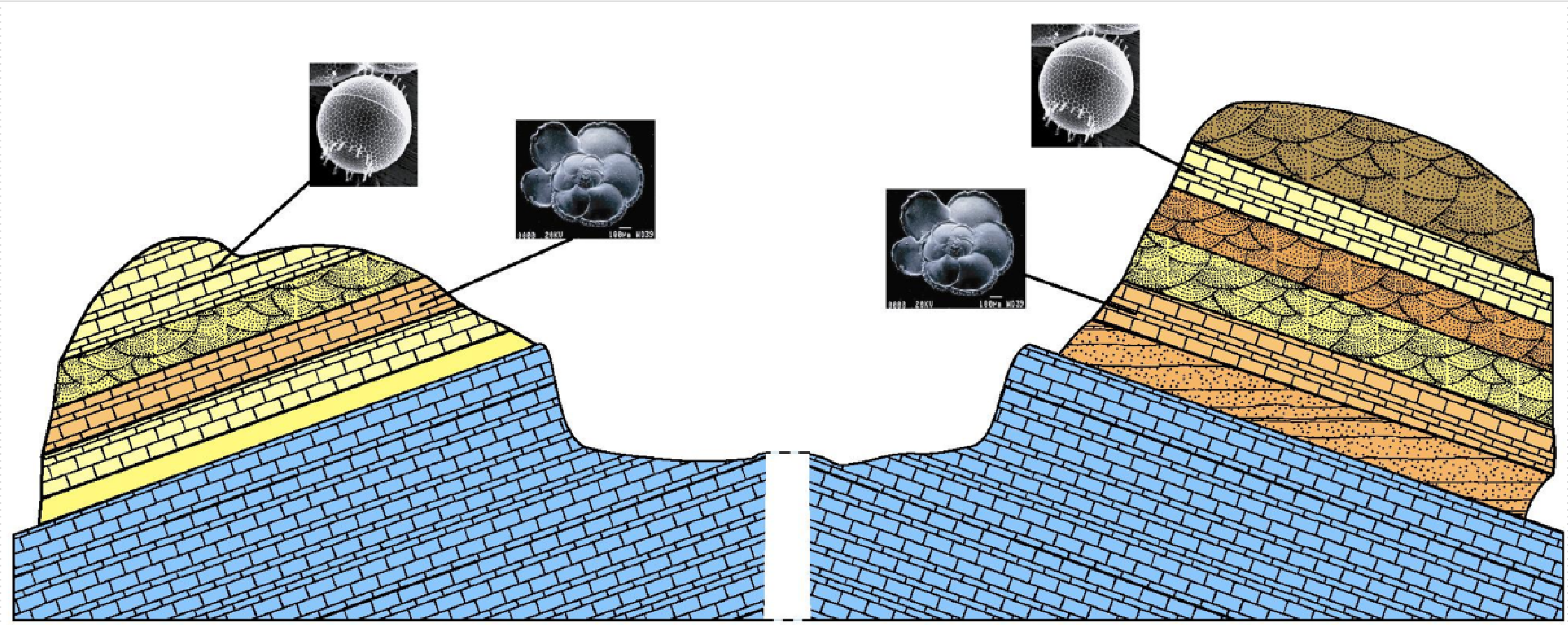
Illustration from Steno's 1667 paper comparing the teeth of a shark head with a fossil tooth

3. Lateral continuity and cross-cutting discontinuities





One more stratigraphic principle



Principle of palaeontological identity: Two layers with the same fossil contents have the same age.

Chronology of Antiquarianism

THE THREE AGE SYSTEM

Christian Thomsen (1836)

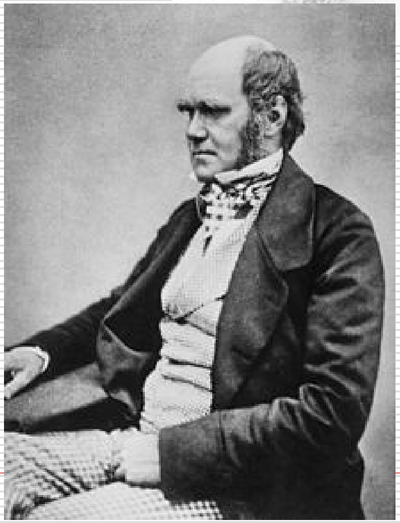
Years BP		
		Historic Age
2.500		**Iron Age**
3.500		Late Bronze Age
4.000		Middle Bronze Age
5.500	**Holocene**	Early Bronze Age
		Bronze Age
7.000		Copper Age (Chalcolithic)
8-10.000		Neolithic
12.000		Mesolithic
50.000		Upper Palaeolithic
350.000		Middle Palaeolithic
	Pleistocene	Lower Palaeolithic
2.000.000		**Palaeolithic**
		Stone Age: 1865 divided into Palaeolithic and Neolithic by John Lubbock

Chronology of Geology and Naturalism

Charles Lyell (1797-1875)

Principles of Geology (1830):

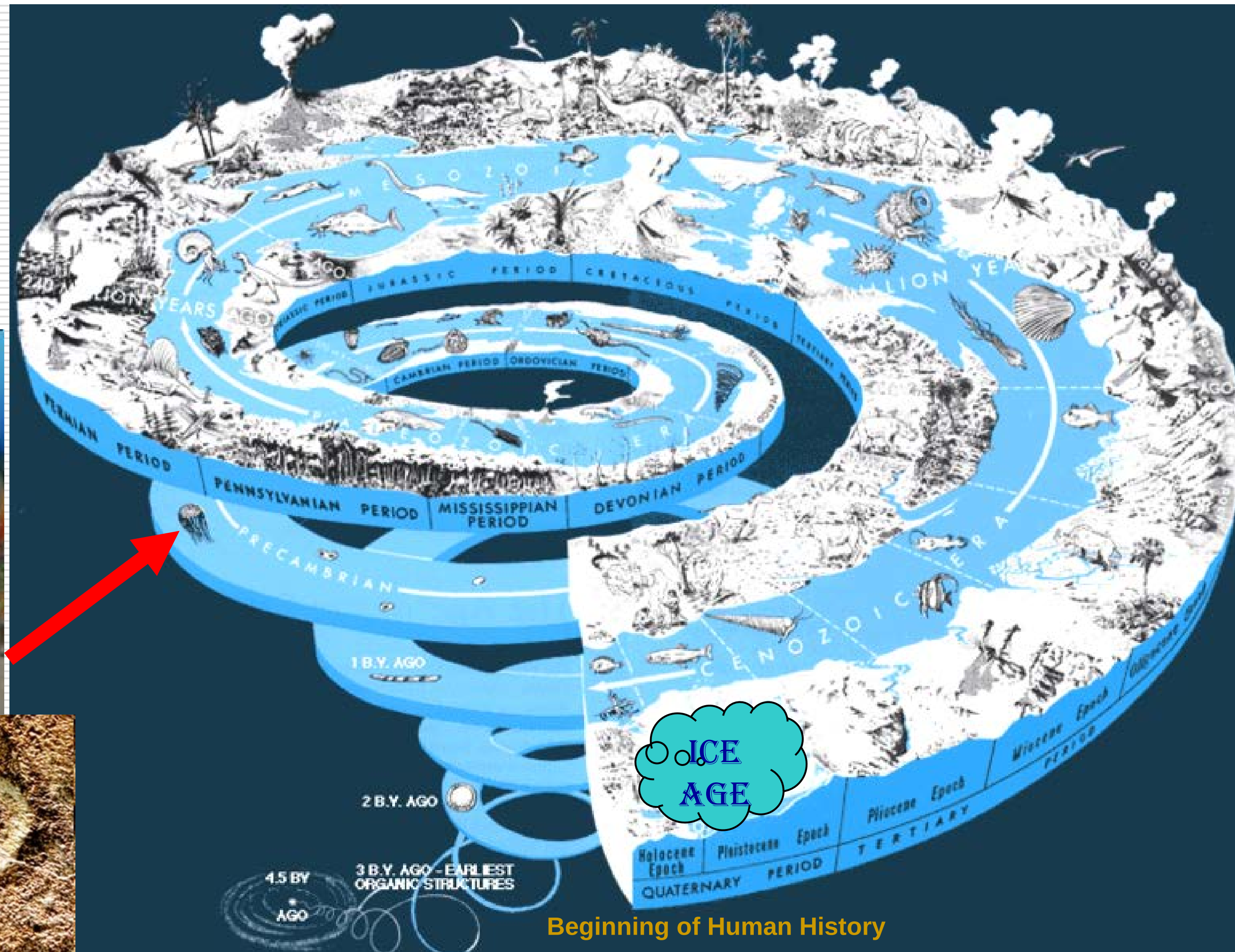
Continuity and uniformitarianism - the Earth was shaped by the same processes that are still in operation today



Charles Darwin (1809-1882)

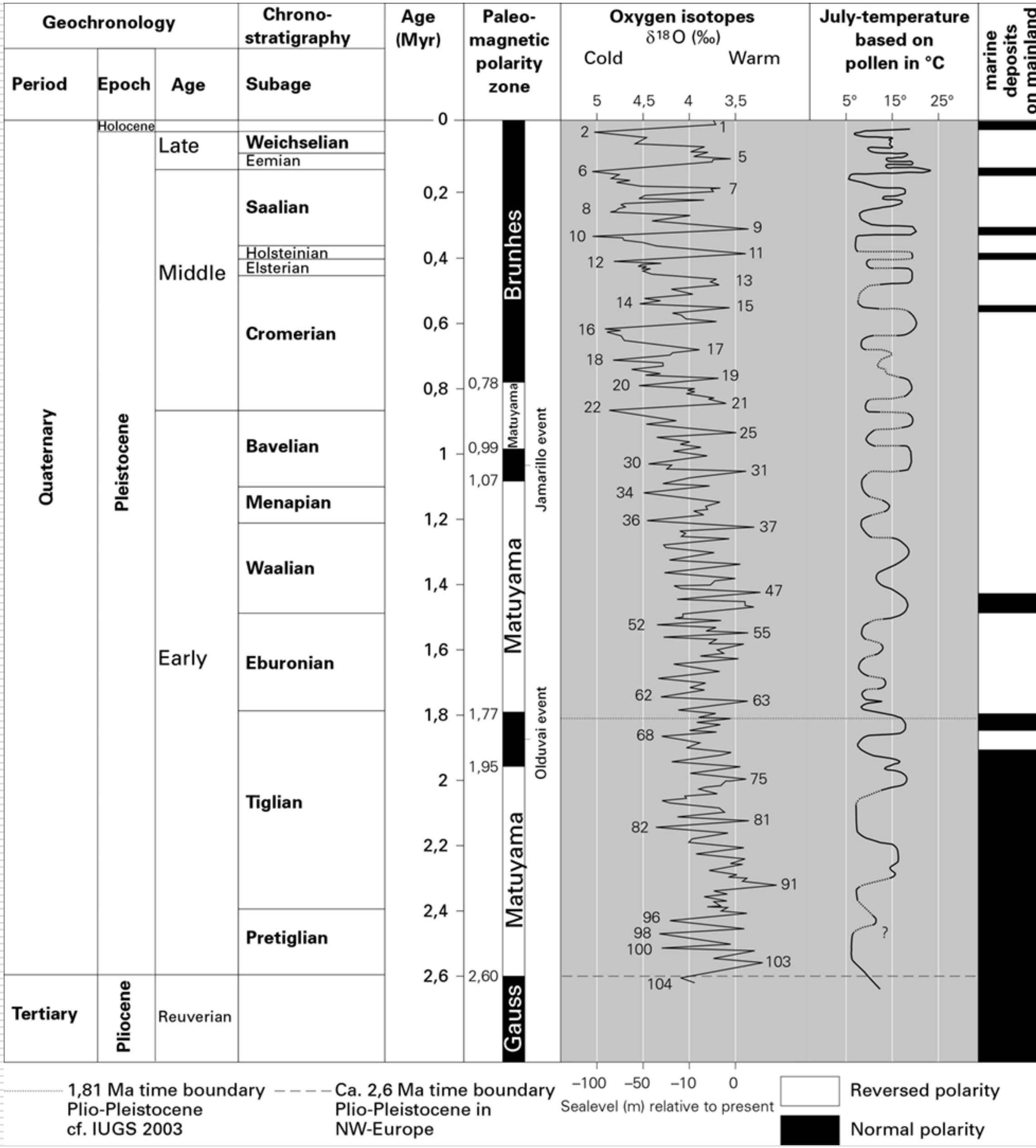
Origin of Species (1859):
Evolution
Faunal assemblages change over time

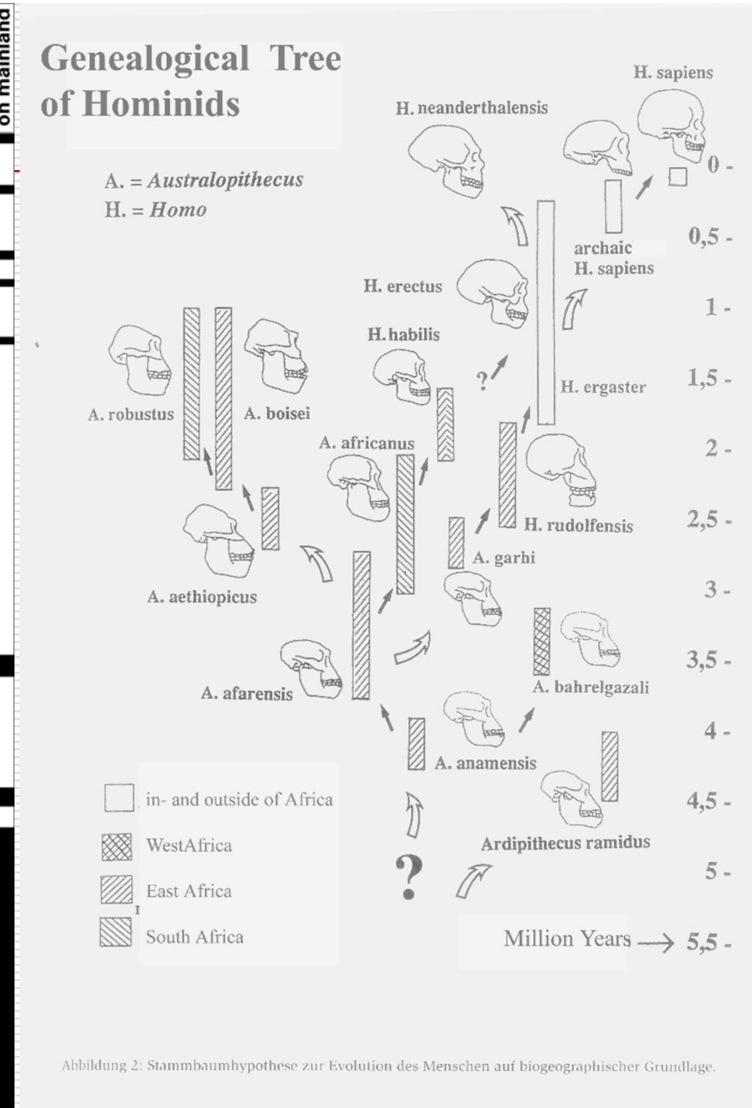
Geological Time Spiral



Ediacara fauna: The „Dawn of Animal Life“ (600 ma-542 ma)

The Quaternary: The Age of Humans





Terms

- BC / BCE
- AD /CE
- BP
- BP: Present refers to 1950 AD
- cal BC / BP– calibrated radiometric date
- ky / ka – kilo years, x1000
- my / ma – million years,   x 1,000,000

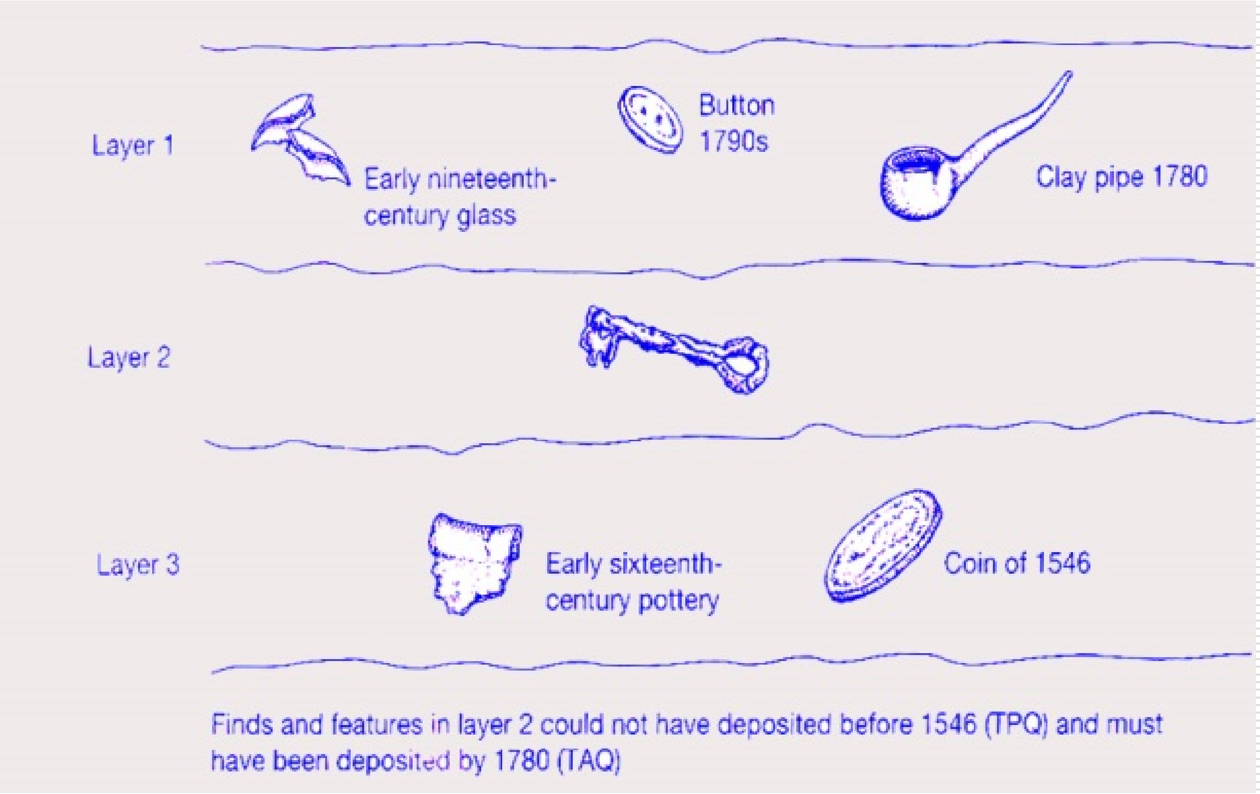
Historical Dating

The recovery of material of a known age from a site, i.e. coins, bottles, ceramics, beads can be used to date the site itself.

Roman coin dating to the reign of Nero 54-68 AD,

Celadon bowl, Yuan/Ming Dynasty China, 14th century AD

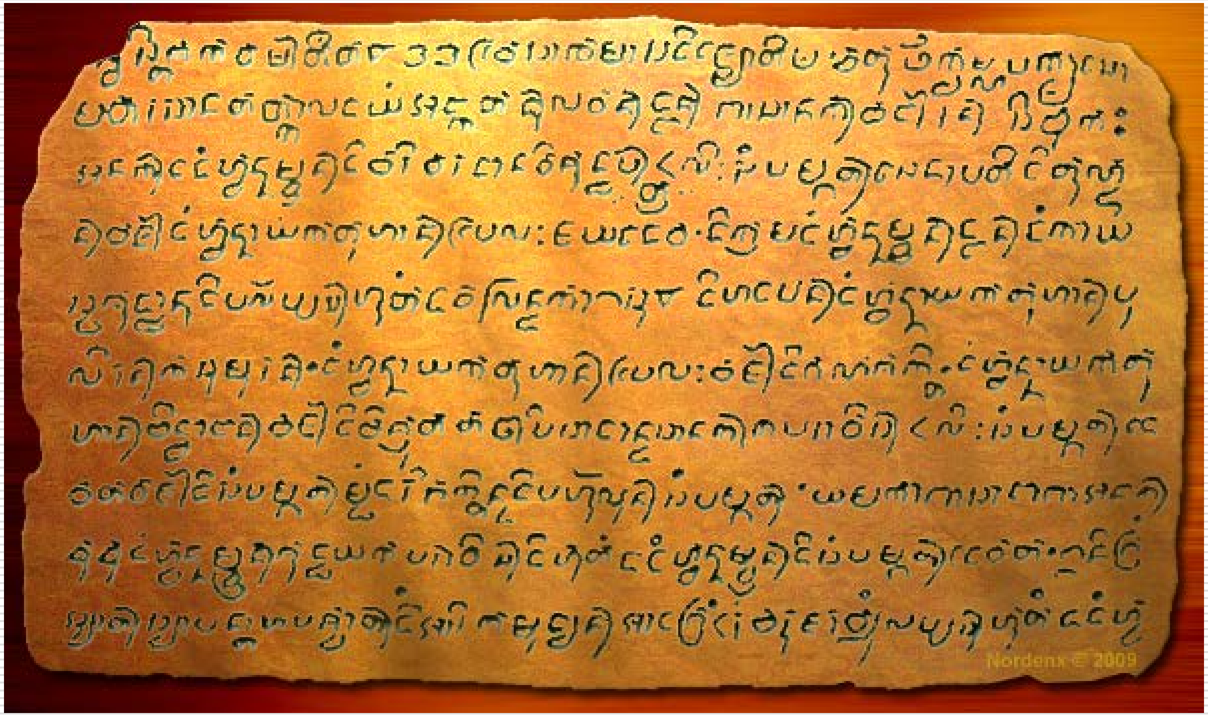
Historical Dating



TPQ- *Terminus post quem* or the earliest possible date for an archaeological deposit

TAQ- *Terminus ante quem* or the latest possible date for the deposit

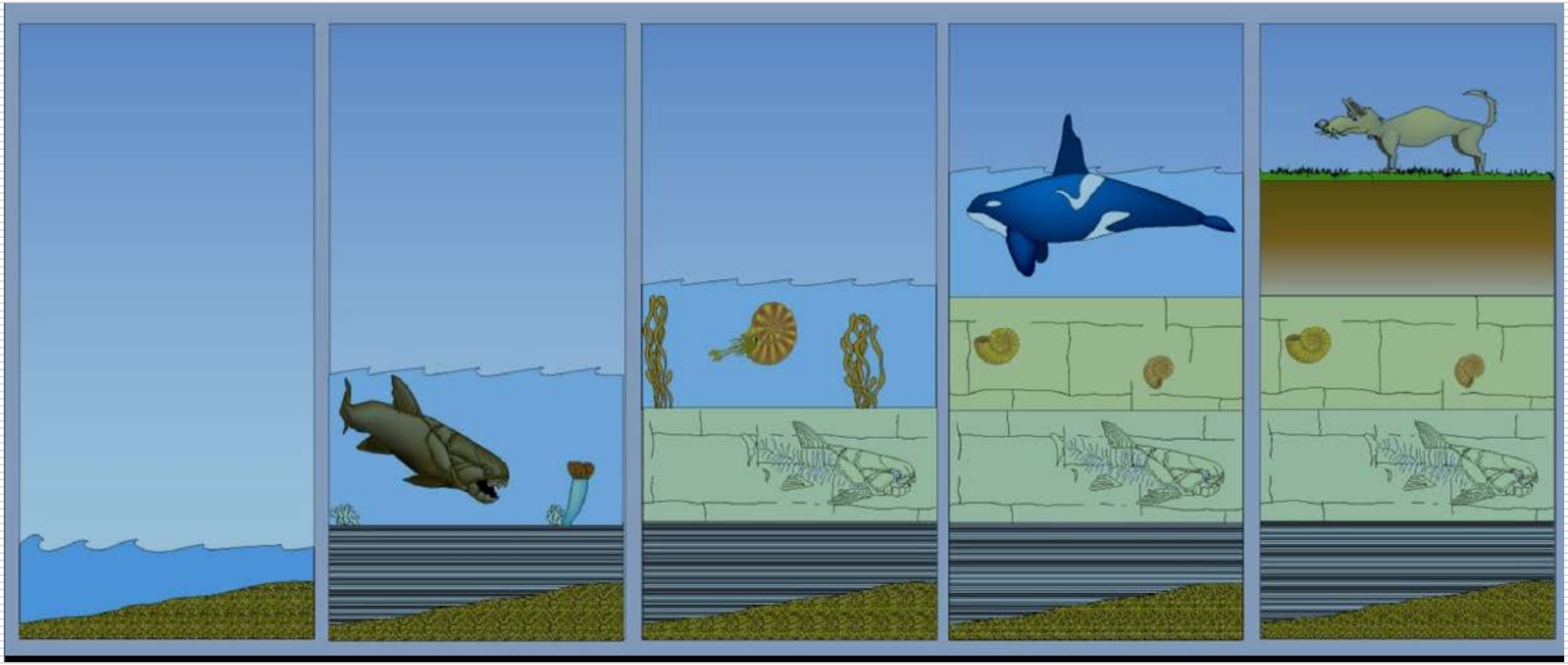
Laguna Copper Plate



Legal document written in Old Javanese/Old Tagalog script

The document bears a date of Saka 844 or **922 AD**

Prehistoric Chronology



The stratigraphic method

Relative Chronology

Oskar Montelius (1901)

“Relative Chronology tells us if an object is younger or older than another object."

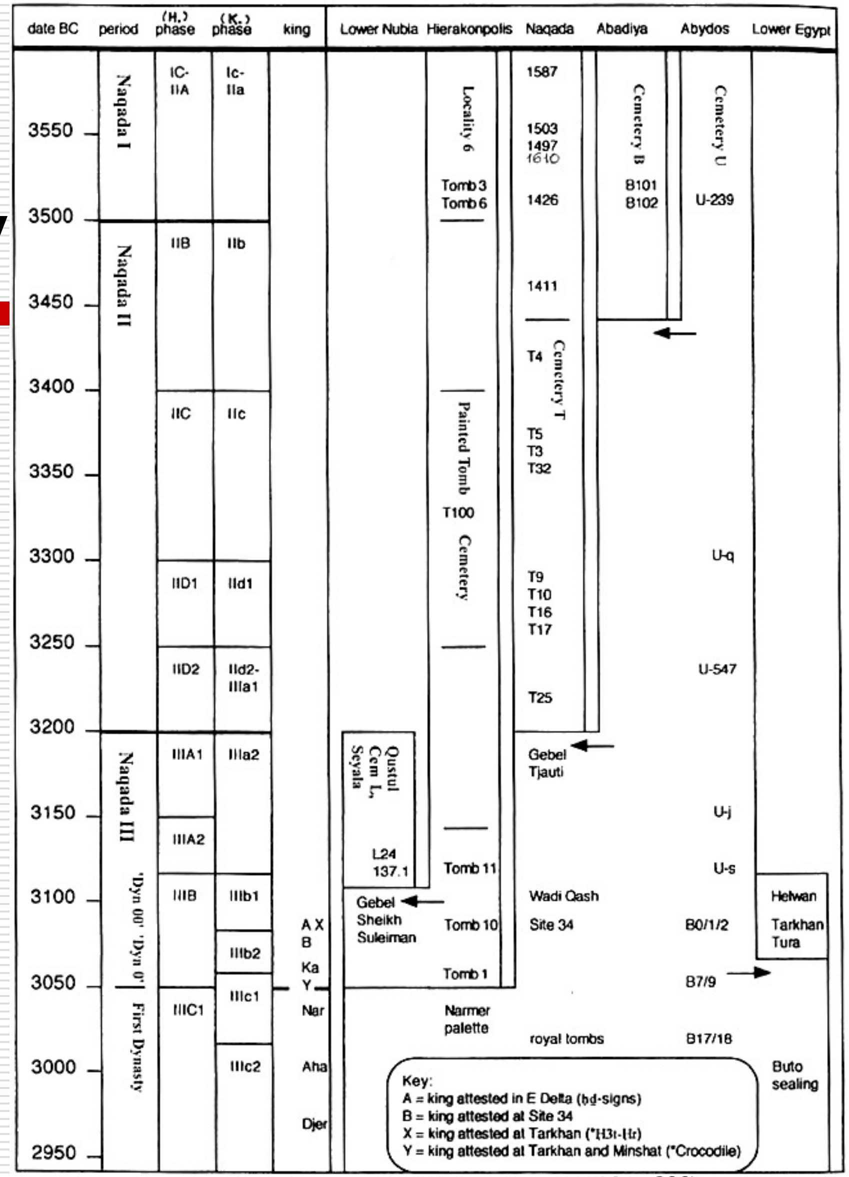
TPQ- *Terminus post quem* or the earliest possible date for an archaeological deposit

TAQ- *Terminus ante quem* or the latest possible date for the deposit

Relative Chronology

Historic Accounts in combination with Archaeology:

Predynastic and early Dynastic Egyptian Kings and Tombs



T.A.H. Wilkinson (M.D.A.I.K. 56, 2000 p. 392)

Fig. 5: Summary chart of political unification

Dates BC are approximate. The two columns headed 'phase' give the divisions of the Predynastic cultural sequence devised by HENDRICKX (1996) and KAISER (1957, 1990), respectively

Relative Chronology

Different Kings or Different Names?

Historic Accounts in combination with Archaeology:

Predynastic and early Dynastic Egyptian Kings and Tombs

However, it is not always a straightforward process, and often hampered by the ambiguity of records and different interpretations and translations

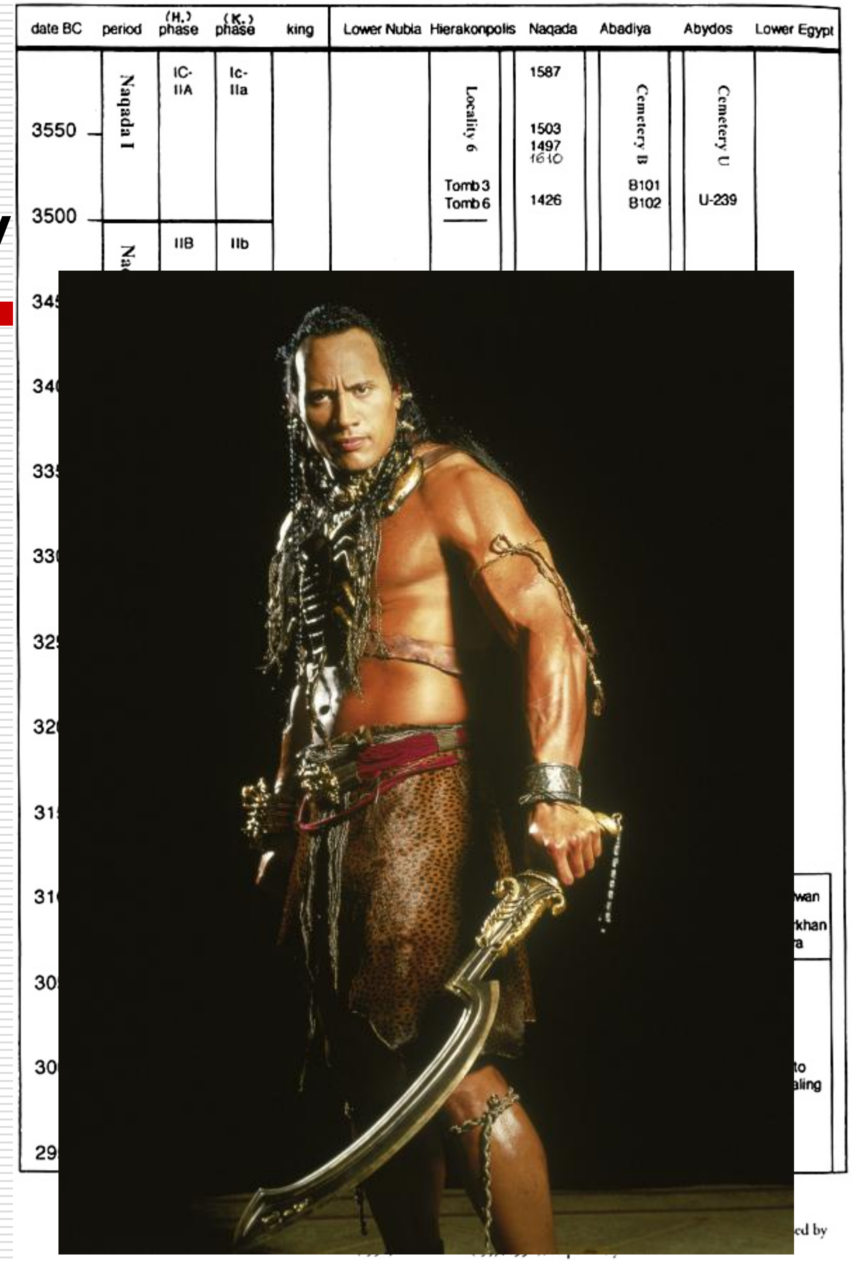
Example: Ka and Narmer

They can be the same person.

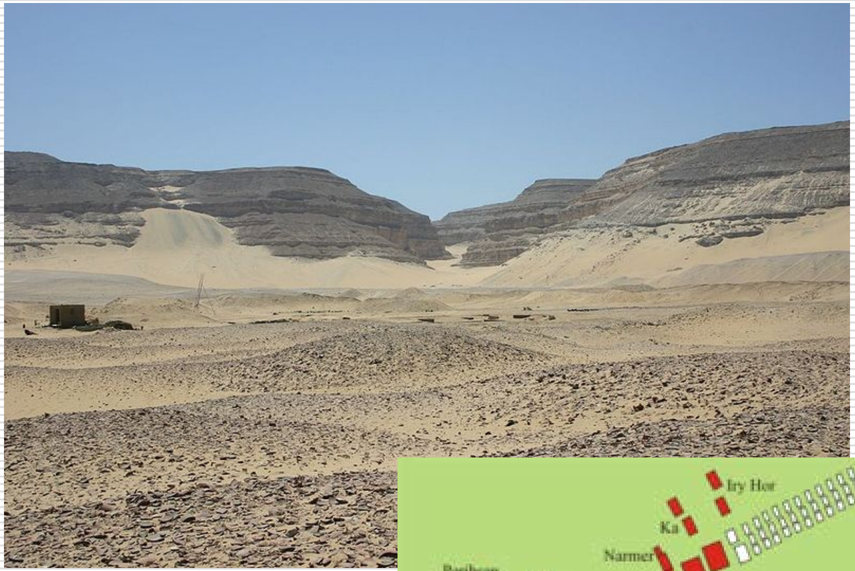
Narmer could be identical with Pharaoh Menes, the legendary founder of the First Dynasty

Both of them could be the legendary “Scorpion King”! Or not!

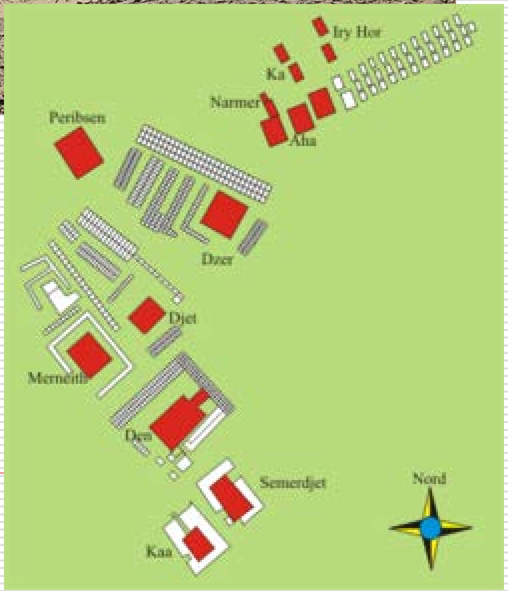
The Scorpion King could have been an unknown King who ruled in Egypt between the reigns of Ka and Narmer



Relative Chronology



The Tomb of King Narmer in Umm-al-Qaab, Abydos



Map of pharaonic tombs at Abydos

Relative Chronology

The Scorpion King Macehead

Palette of King Narmer

Relative Chronology

Known rulers in the history of Egypt for the First Dynasty are as follows:

Name	Comments	Dates
Narmer	- probably Menes on earlier lists	c. 3100–3050 B.C.
Hor-Aha		c. 3050–3049 B.C.
Djer	-	c. 3049–3008 B.C. 41 years (Palermo Stone)
Djet	-	3008–2975?
Merneith	the mother of Den	3008?
Den	-	2975–2935 30 to 50 years (40 years?)
Anedjib	-	2935?–2925? 10 years (Palermo Stone)
Semerkhet	-	2925?–2916? 9 years (Palermo Stone)
Qa'a	-	2916?–2890 B.C.

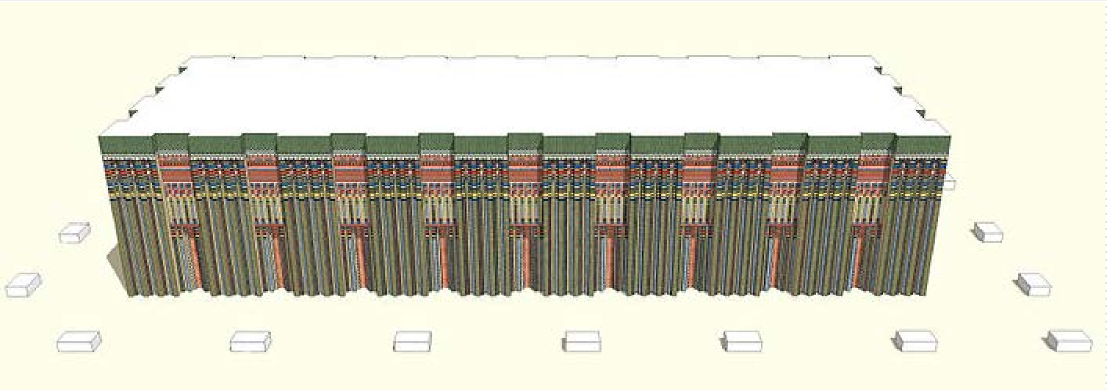
Relative Chronology

Chronology of Technological Developments

E.g. Pyramids

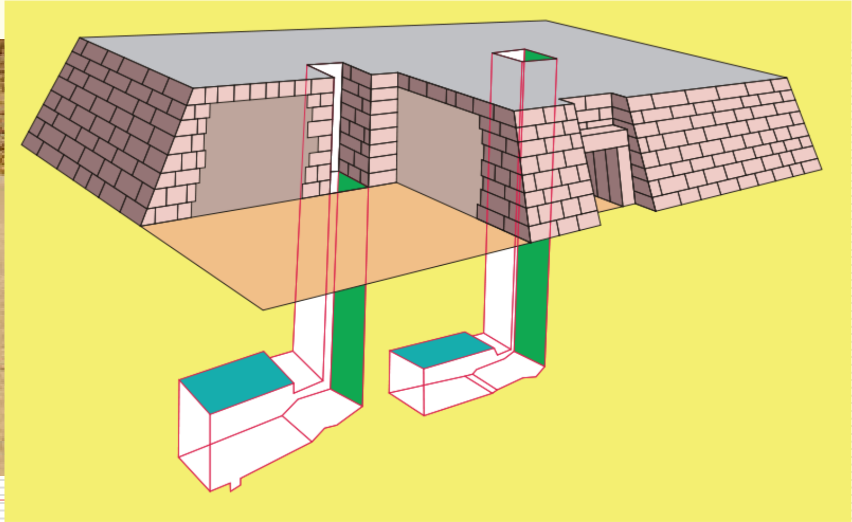
Relative Chronology

Mastaba of Ptahchepses



Reconstruction of a 1st Dynasty Mastaba

Mastaba at el-Faraoun

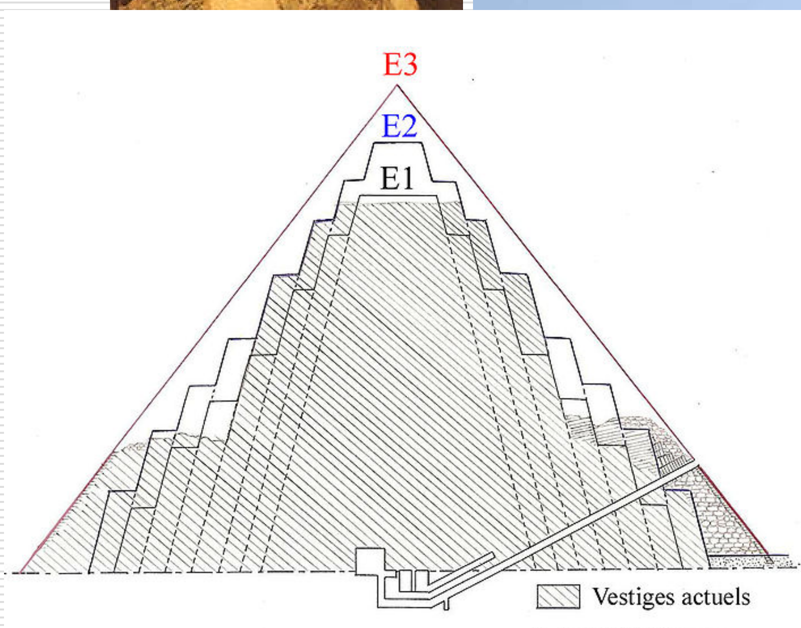


Typical architectural design of a Mastaba

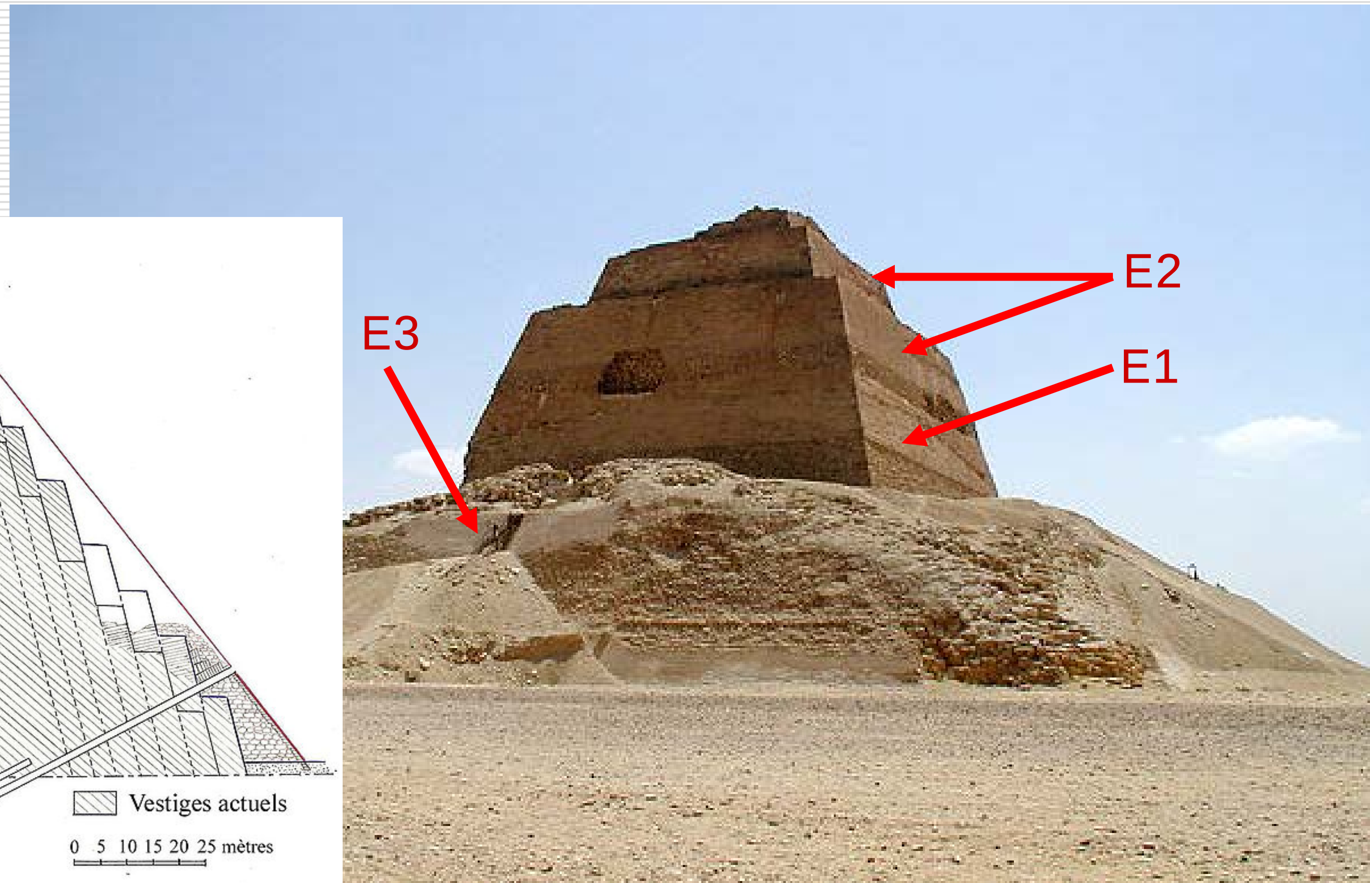
Relative Chronology

Step Pyramid of King Djoser in Sakkara

Relative Chronology

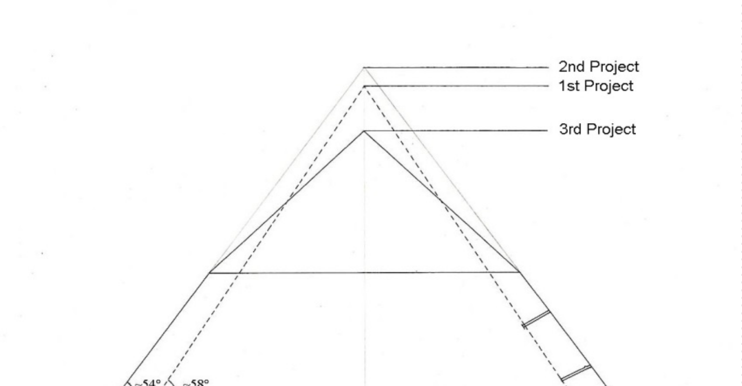


Collapsed limestone filling



The “Pyramid King”: 5-Step Pyramid of Pharaoh Sneferu in Meidum

Relative Chronology



The "Pyramid King": The "Bent Pyramid"

"Built on sand"

Relative Chronology

The "Pyramid King": The "Red Pyramid" of Pharaoh Sneferu in Dashur

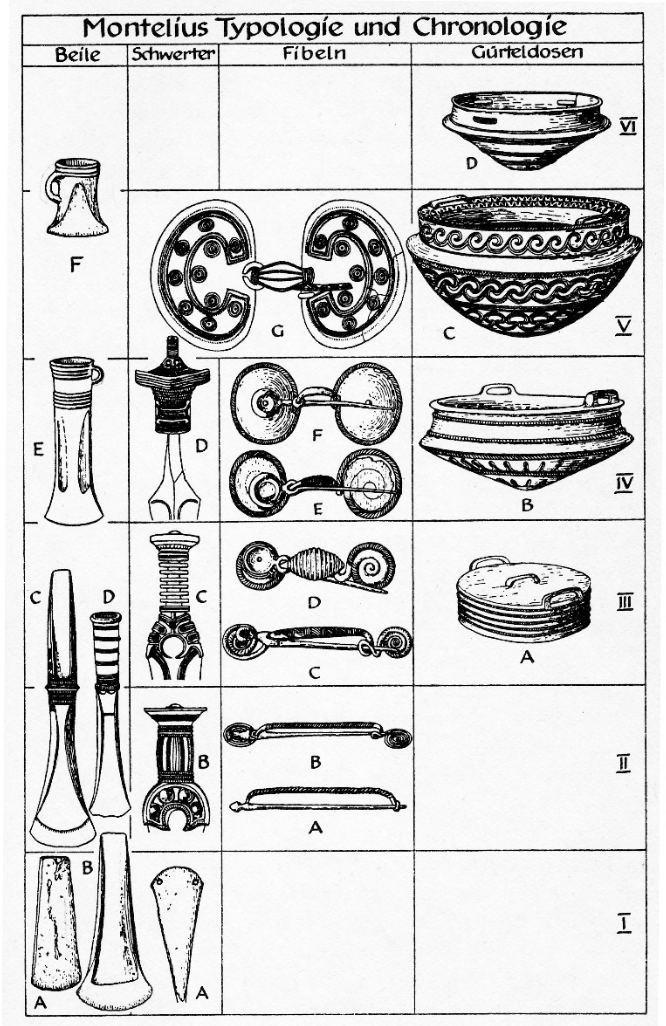
Relative Chronology

Finally: The Great Pyramid of Khufu in Giza

Relative Dating Methods

- Typology
- Seriation

Typological Method:
Tells us whether an object is older or younger than another object

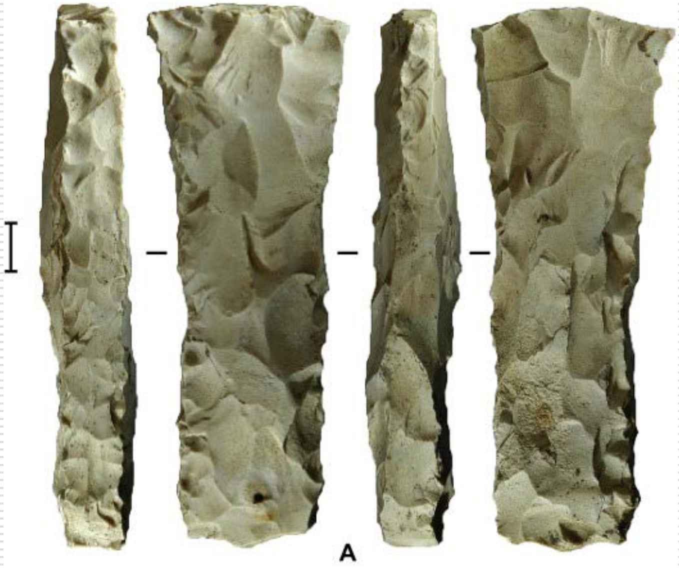


Typology

Typological Method:

Development of Adze Blades
Bronze Age Adzes in N-Europe

Shell Adze from Bubog, Ilin Island



Flaked Stone Adze from Liang Bua, Flores

Polished “Shoe-last“ Adzes from Lower Rhineland, Germany

Typology

Chronology of the Palaeolithic

Gabriel de Mortillet (1821-1898)

Chronology based on characteristic type forms within lithic assemblages. Each period (‘culture’) is named after its type locality (1872):

Period of Saint-Acheul or **Acheuleén**

Period of Moustier or **Mousterién**

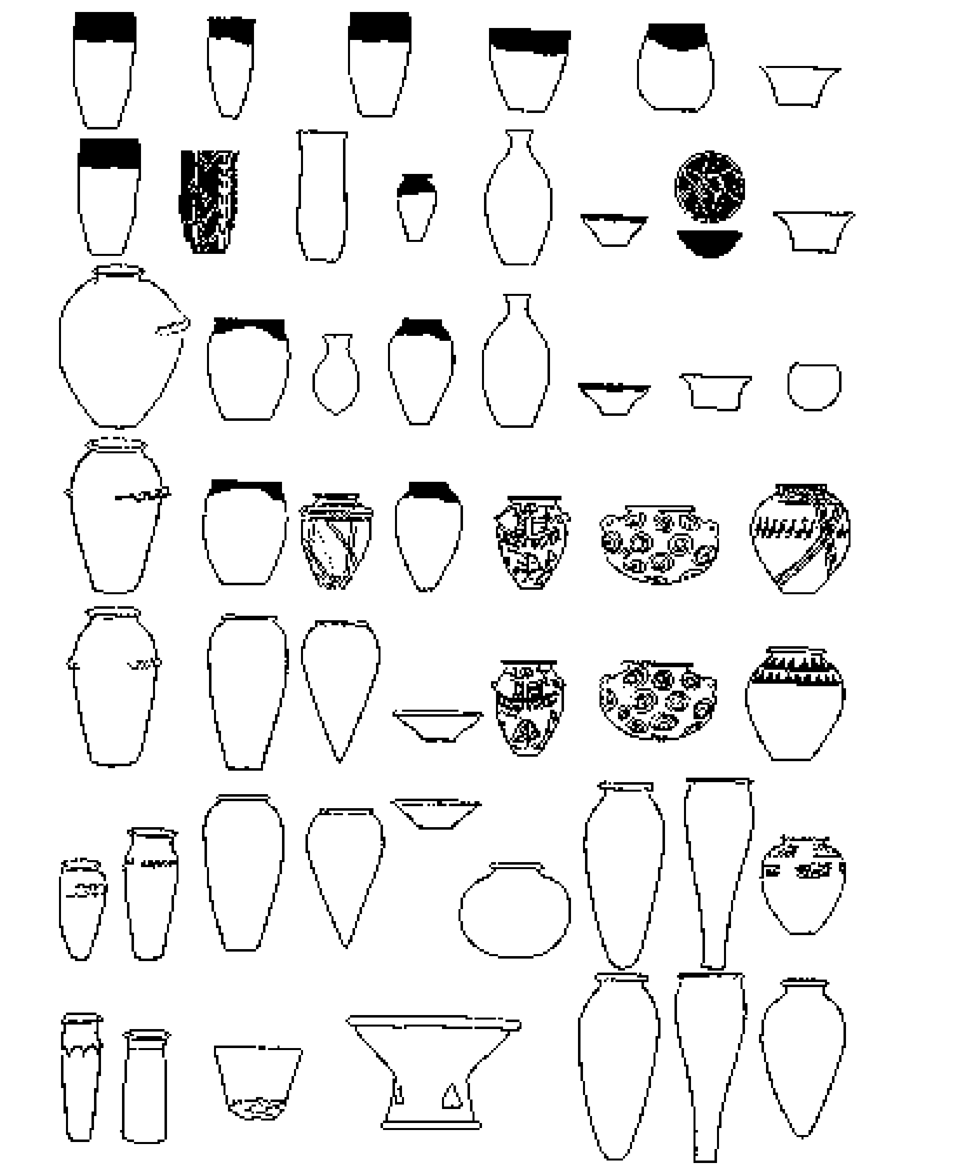
Period of Solutré or **Solutreén**

Typology

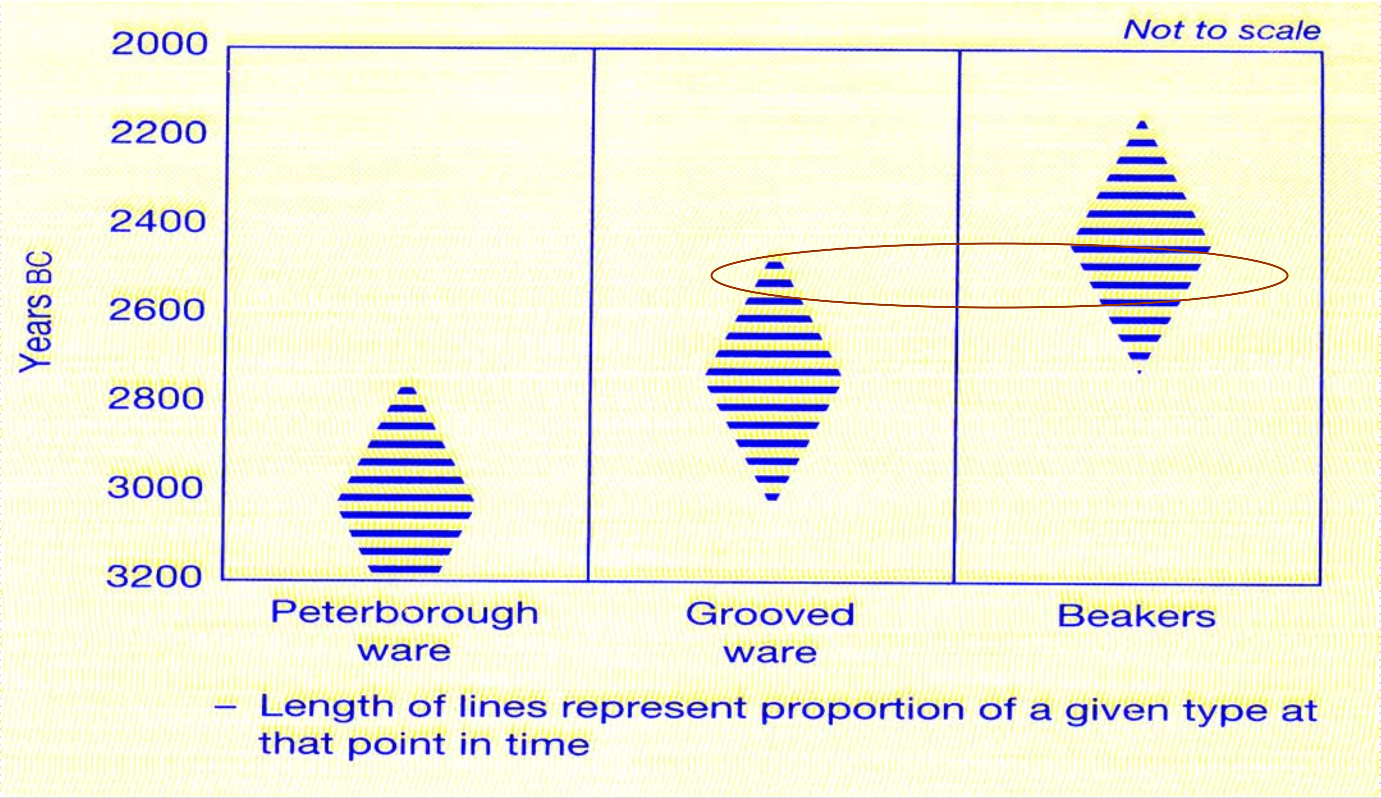
Egyptian pottery:

Changes and evolution of pottery styles and decors

After Flinders Petrie

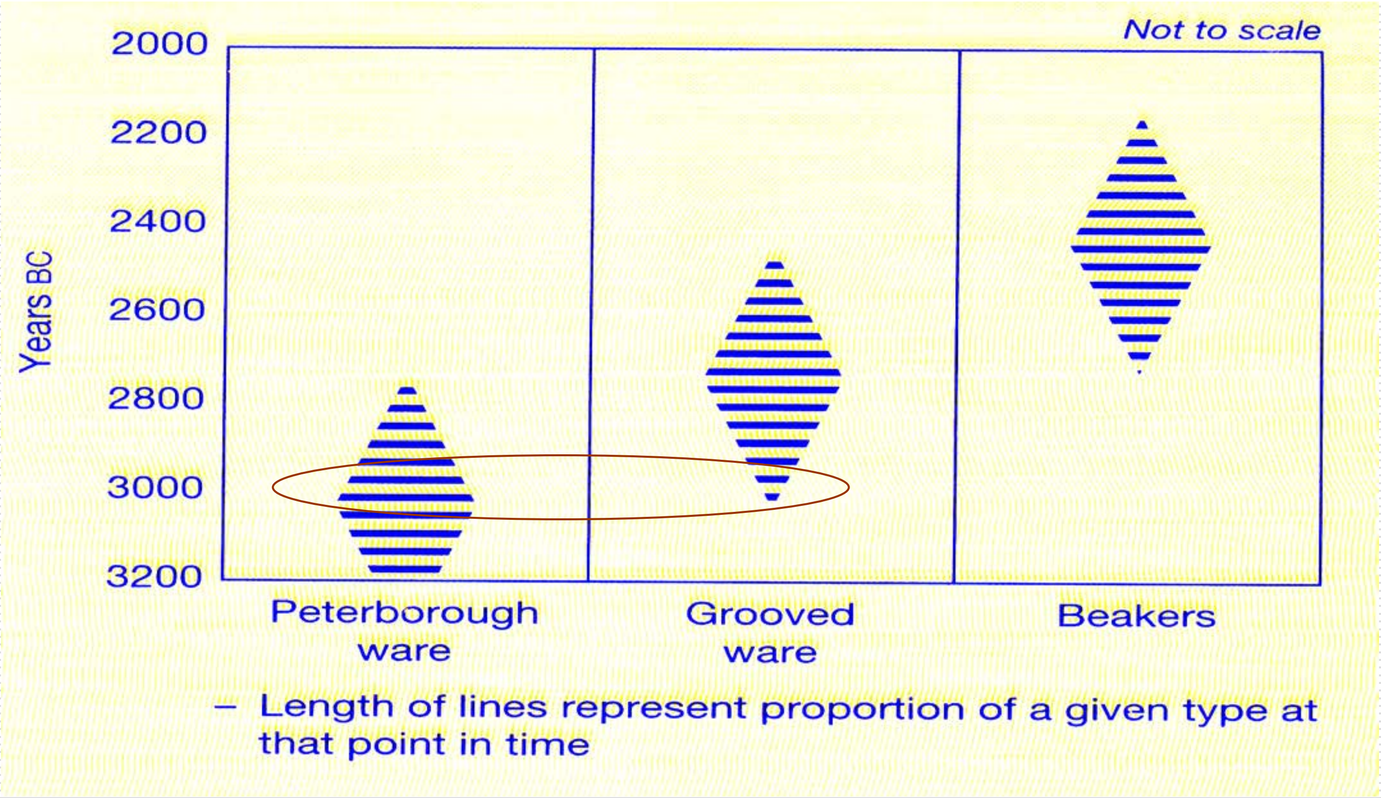


Seriation - Chart for Pottery Types



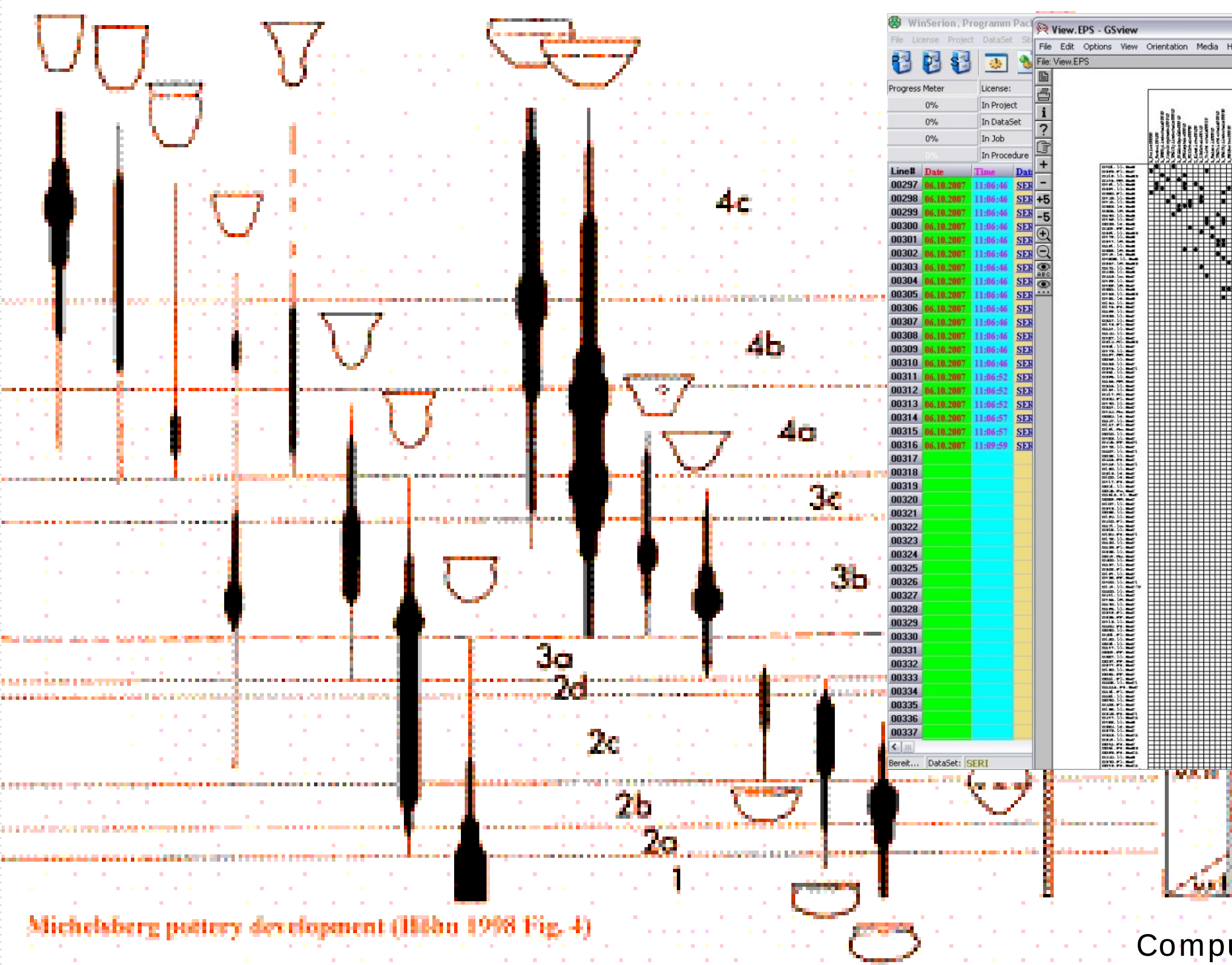
If one finds a lot of Beakers and few Grooved ware , the site can be relatively dated to c. 2500 BC

Seriation - Chart for Pottery Types

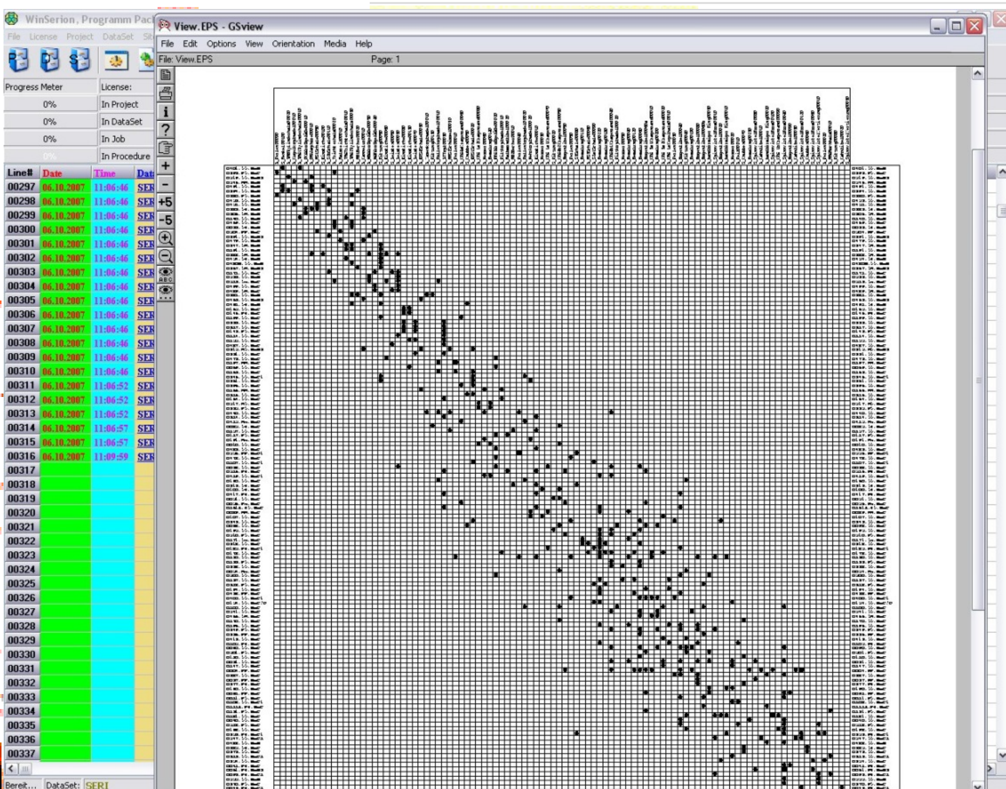


If one finds a lot of Peterborough ware and few Grooved ware, the site can be relatively dated to c. 3000 BC

Seriation - Chart for Pottery Types



Michelsberg pottery development (Höhn 1998 Fig. 4)



: of Grooved ware

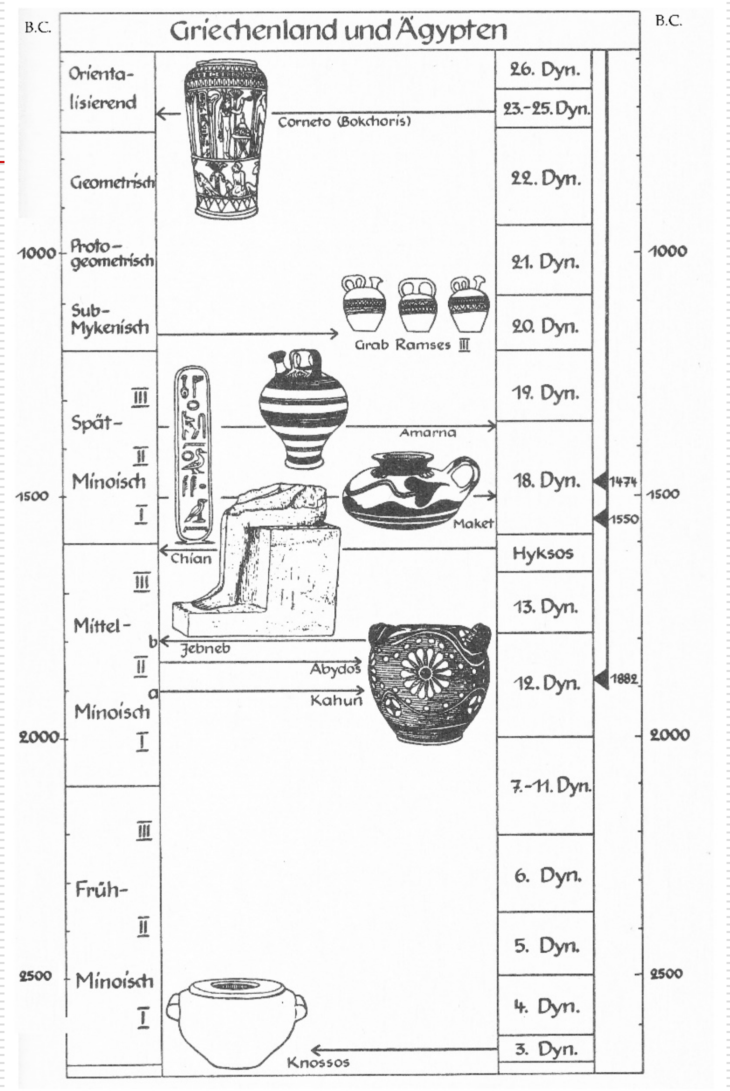
ted to c. 2700 BC

Computer software WinSerion for Seriation

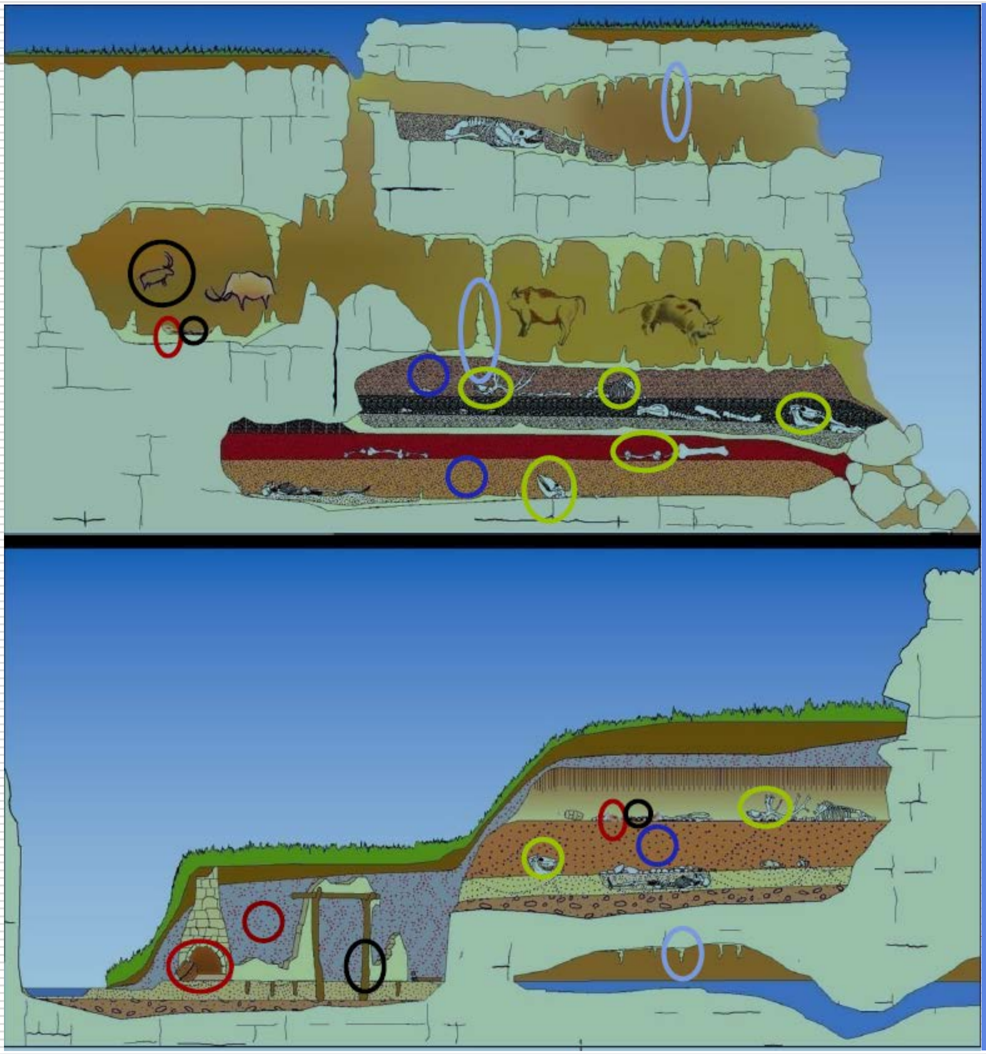
Absolute Chronology

Oskar Montelius (1901)

“Absolute Chronology tells us from what century before or after Christ’s birth an object dates."



Absolute Dating



What can be dated?

Carbonates

Bones and teeth of larger mammals

Sediments

Volcanic minerals

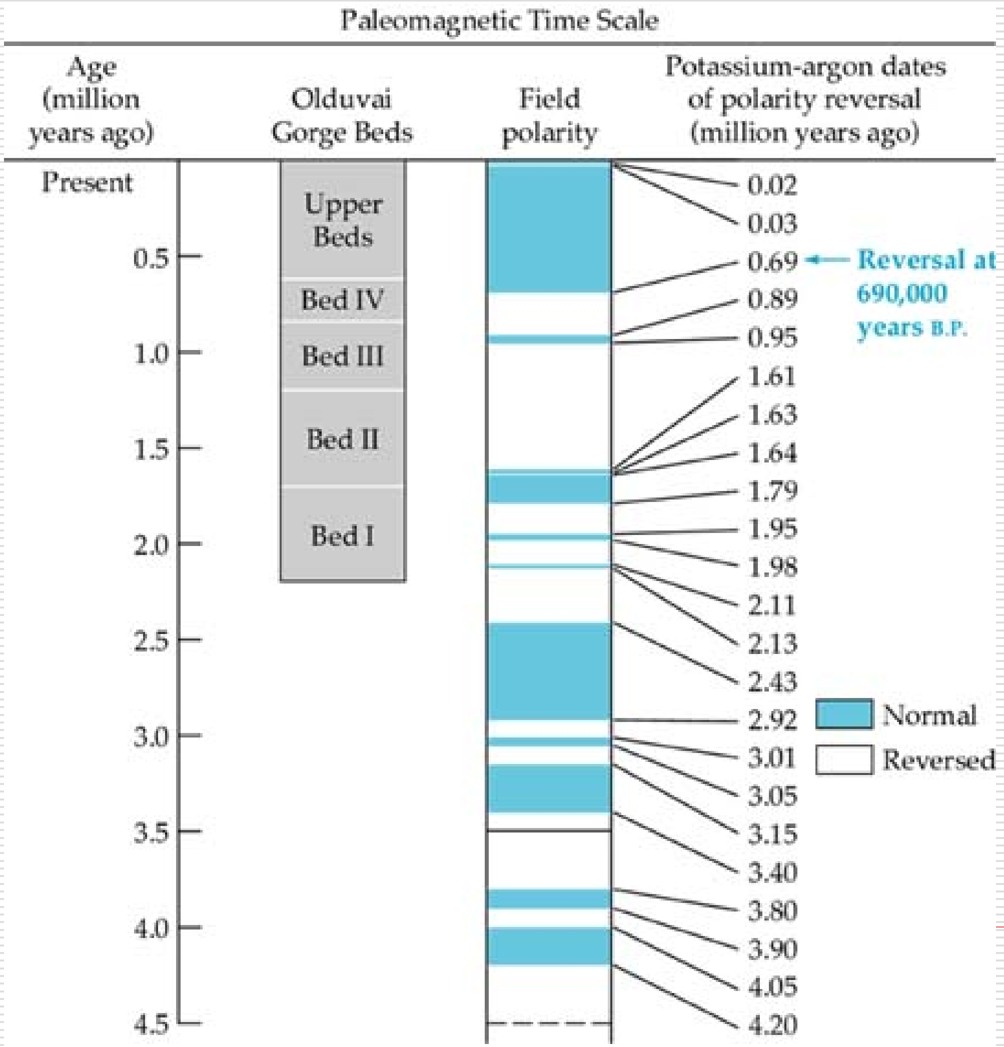
Wood/charcoal

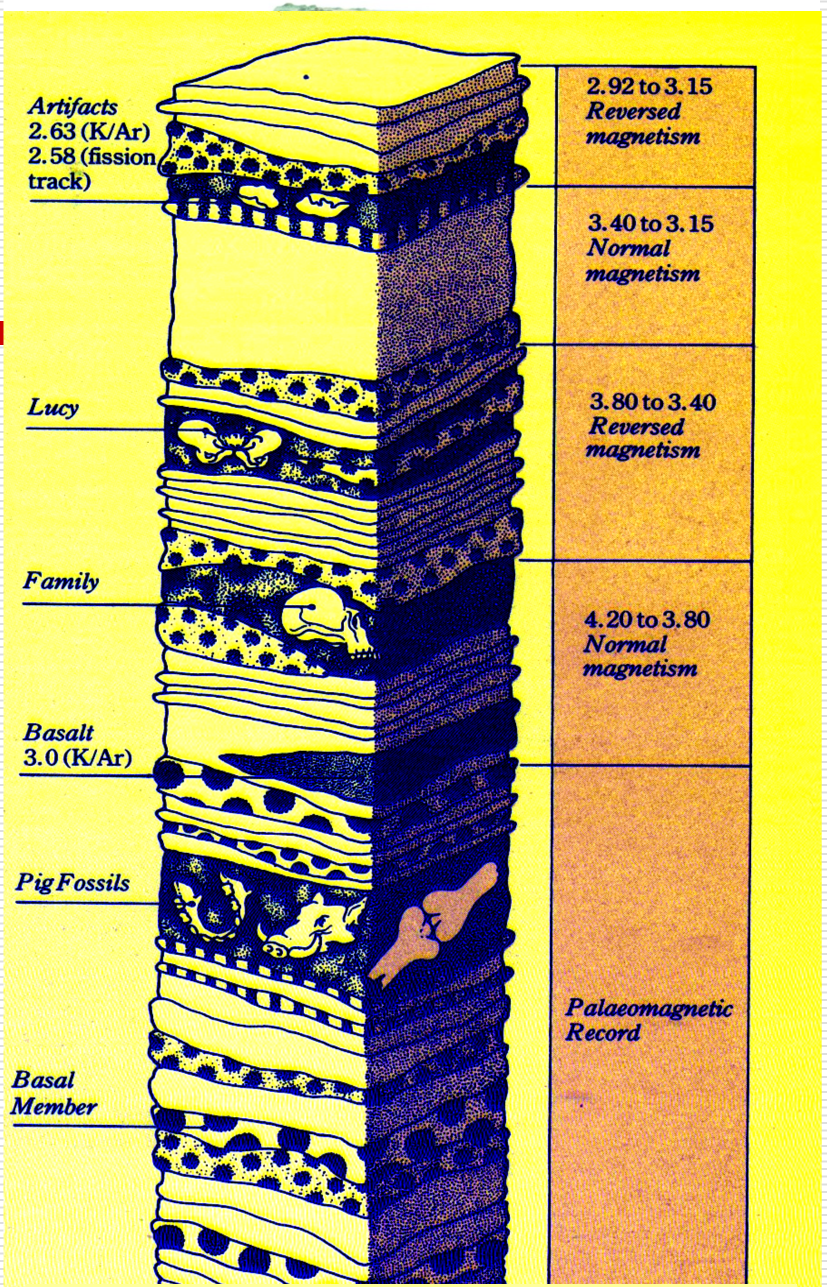
Burnt materials

Absolute Dating

- Palaeomagnetism
- Dendrochronology
- Radiocarbon Dating
- Electron-Spin-Resonance
- Argon Dating
- Thermoluminescense / Optoluminescence
- Uranium Dating

Palaeomagnetism



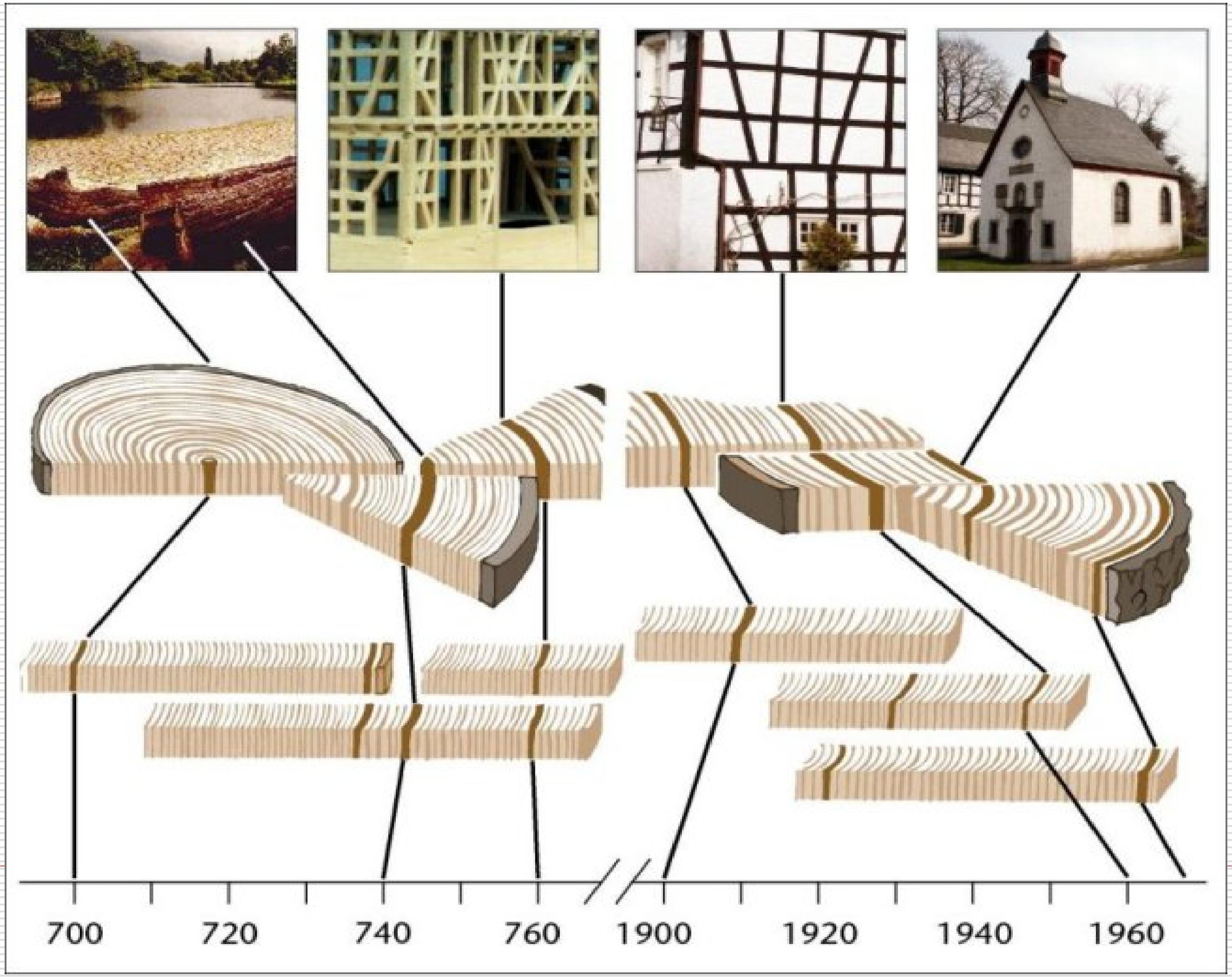


Several short events refine the palaeomagnetic chronology

Dendrochronology

A cross-section of a downed tree, showing annual growth rings.

Dendrochronology



Dendrochronology

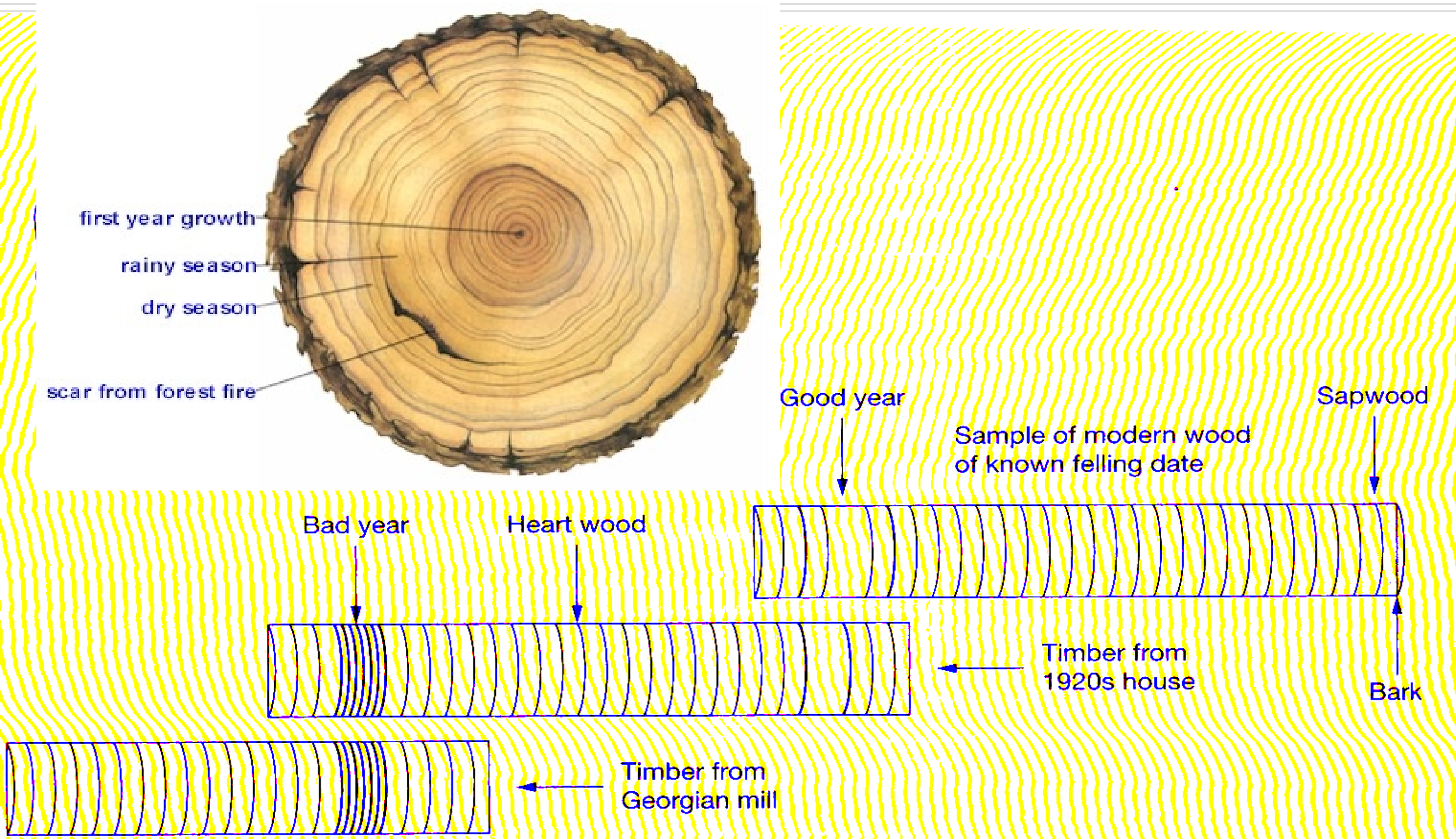


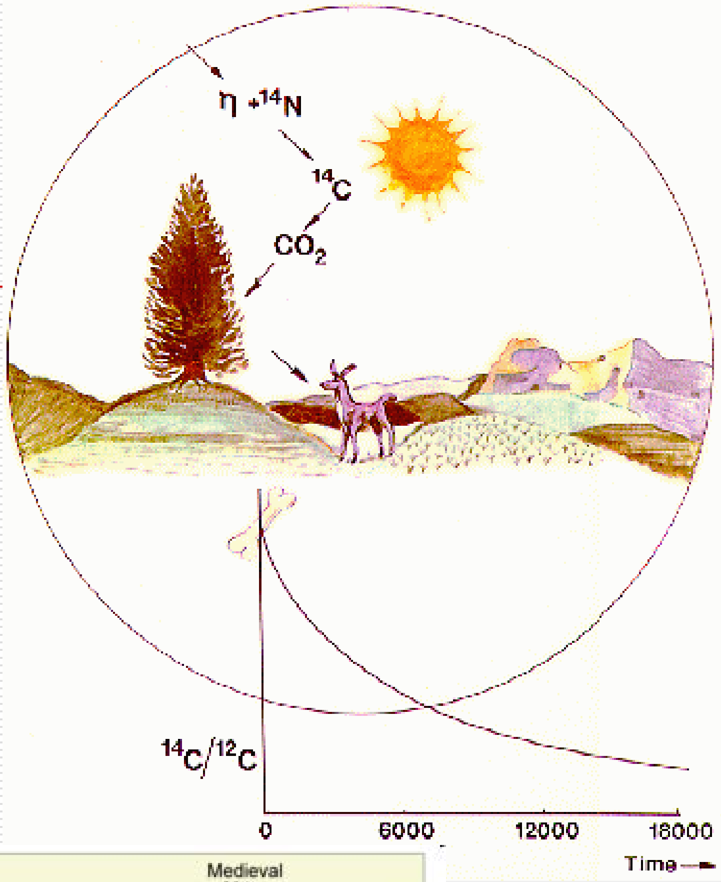
Figure 4.9 *The key principles of dendrochronology*

Principle of tree ring dating: overlaps are matched to take the sequence back from a known date to date old timbers. Samples are taken at 90 degrees to the grain and numbers of rings and their thickness measured by eye or computer.

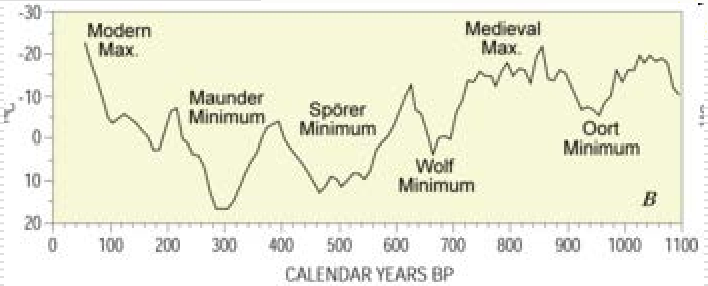
Radiocarbon Dating

All living organisms absorb Carbon and its isotopes from the atmosphere - until they die.

Radioactive Carbon 14 (^{14}C) decays at a known rate or half-life (5730 years). Calculation of the amount of the remaining ^{14}C provides a date for dead matter



The level of cosmic radiation has fluctuated over time, hence the need to calibrate.

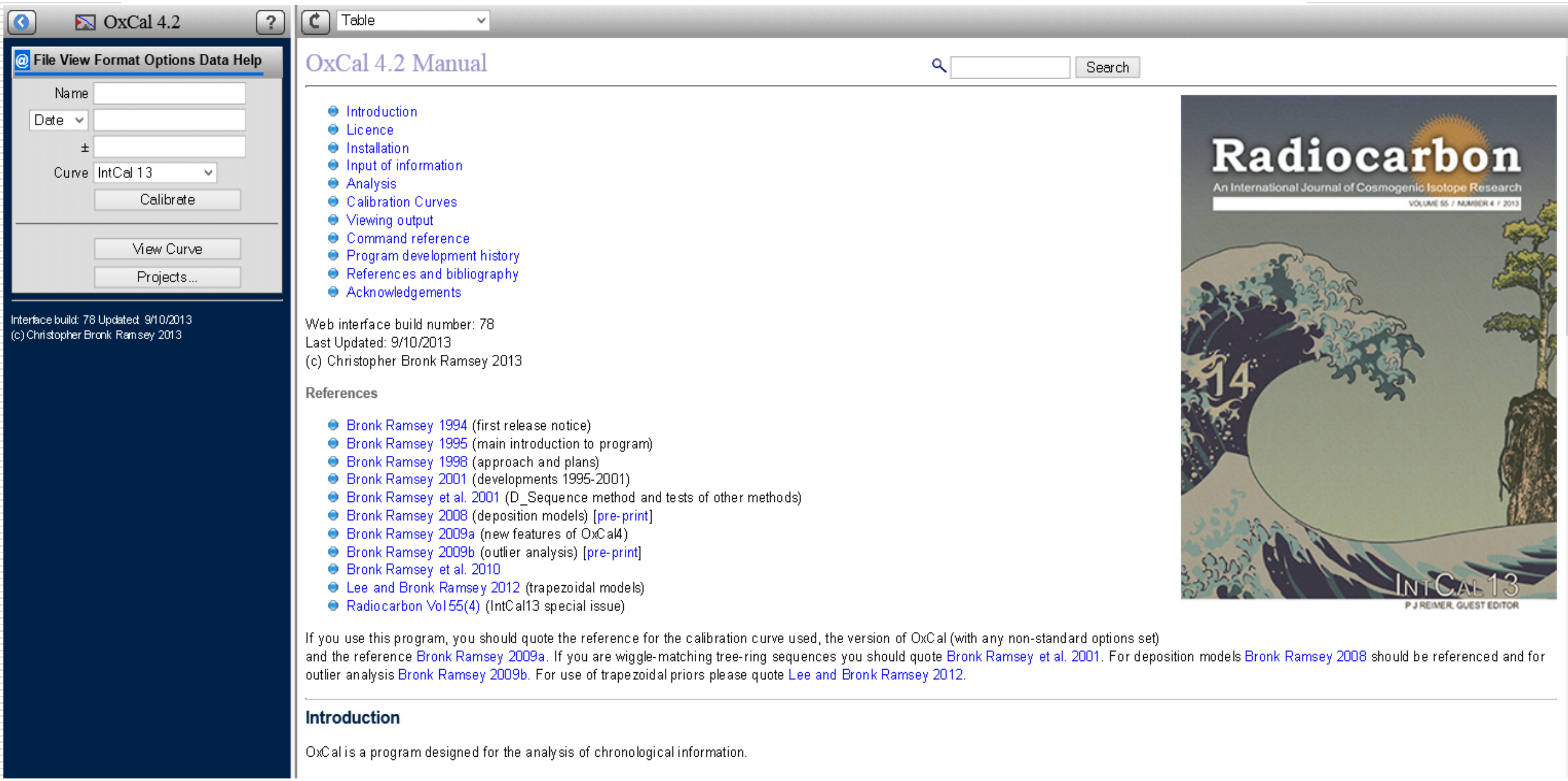


Calibration routines used to convert radiocarbon years to calendar years

A statistical estimation of error is expressed as standard deviation

Sample size for conventional 14C dating is 10-20g, for Accelerator Mass Spectrometry (AMS) is 0.1g

Radiocarbon Dating



https://c14.arch.ox.ac.uk/oxcal/OxCal.html

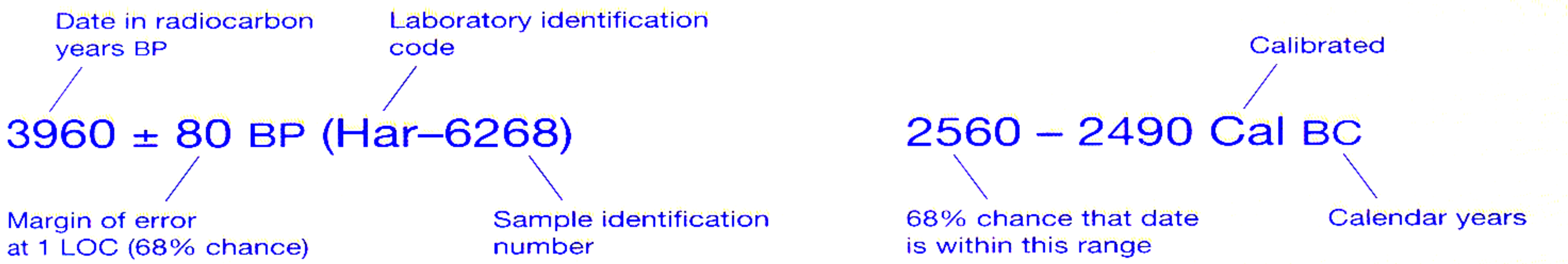
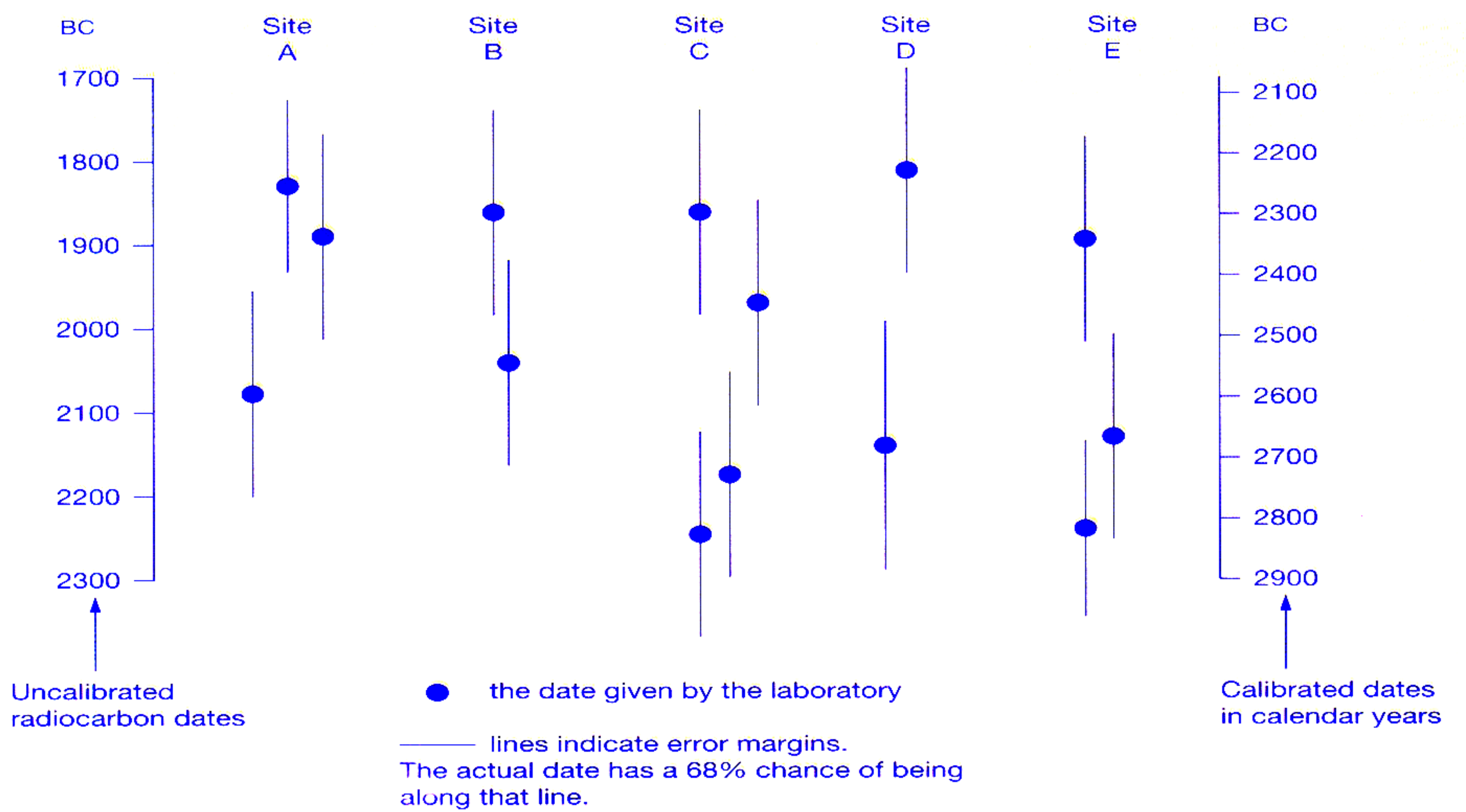


Figure 4.12 *Understanding a radiocarbon date*



Radiocarbon Dating

Radiocarbon Laboratory
Australian National University

The University of Waikato
Radiocarbon Dating Laboratory

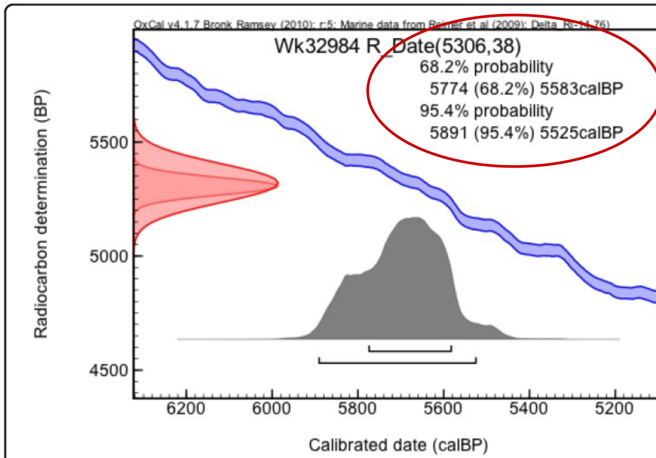
Private Bag 3105
Hamilton,
New Zealand.
Fax +64 7 838 4192
Ph +64 7 838 4278
email c14@waikato.ac.nz
Head: Dr Alan Hogg

Report on Radiocarbon Age Determination for Wk- 32984

Submitter	P Piper
Submitter's Code	IV-2011-G3-573
Site & Location	Bubog Island, Philippines
Sample Material	Conus sp.
Physical Pretreatment	Surfaces cleaned. Washed in an ultrasonic bath. Tested for recrystallization: aragonite.
Chemical Pretreatment	Sample acid washed using 2 M dil. HCl for 120 seconds, rinsed and dried.

$\delta^{13}C$	0.2 ±	0.2 ‰
$D^{14}C$	-483.4 ±	2.5 ‰
$F^{14}C\%$	51.7 ±	0.2 %
Result	**5306 ± 38 BP**	

Comments



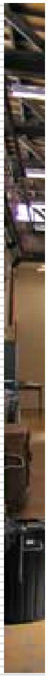
Result after calibration

Ali Hogg
21/02/12

- Result is *Conventional Age or Percent Modern Carbon (pMC)* following Stuiver and Polach, 1977, Radiocarbon 19, 355-363. This is based on the Libby half-life of 5568 yr with correction for isotopic fractionation applied. This age is normally quoted in publications and must include the appropriate error term and Wk number.
- Quoted errors are 1 standard deviation due to counting statistics multiplied by an experimentally determined Laboratory Error Multiplier.
- The isotopic fractionation, $\delta^{13}C$, is expressed as ‰ wrt PDB.
- $F^{14}C\%$ is also known as *Percent Modern Carbon (pMC)*

Radiocarbon Dating

Radiocarbon Laboratory
Waikato University



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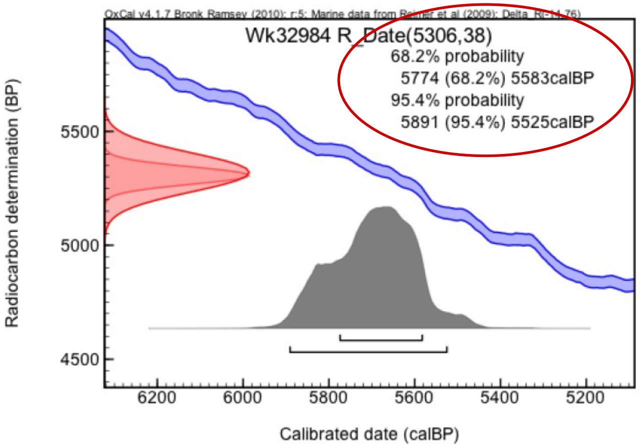
Result	**5306 ± 38 BP**	

Comments

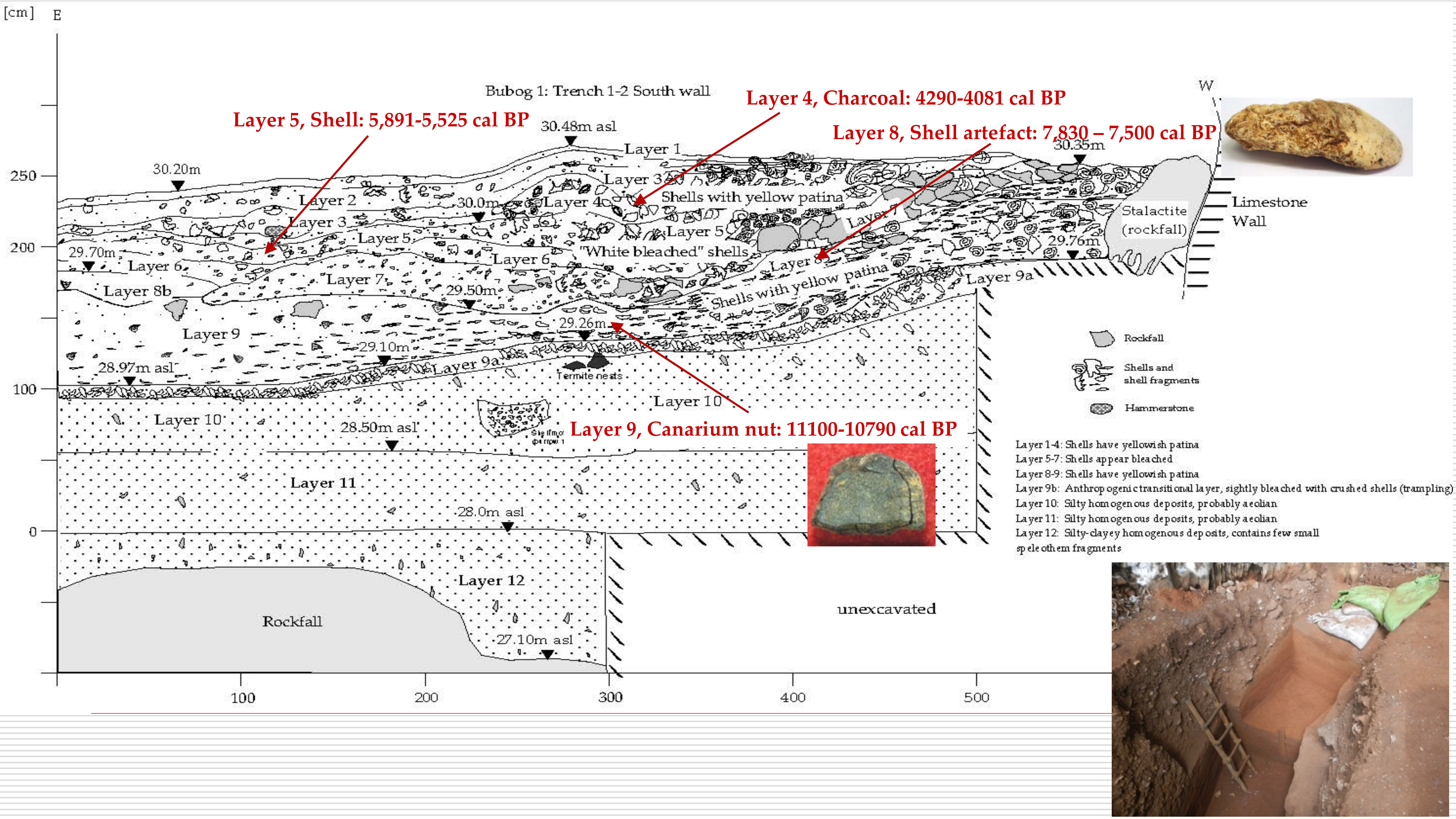


Result after calibration

AlHogg
21/02/12

- Result is *Conventional Age or Percent Modern Carbon (pMC)* following Stuiver and Polach, 1977, Radiocarbon 19, 355-363. This is based on the Libby half-life of 5568 yr with correction for isotopic fractionation applied. This age is normally quoted in publications and must include the appropriate error term and Wk number.
- Quoted errors are 1 standard deviation due to counting statistics multiplied by an experimentally determined Laboratory Error Multiplier.
- The isotopic fractionation, $\delta^{13}C$, is expressed as ‰ wrt PDB.
- $F^{14}C\%$ is also known as *Percent Modern Carbon (pMC)*

Radiocarbon Dating – Bubog 1, Mindoro Occ.

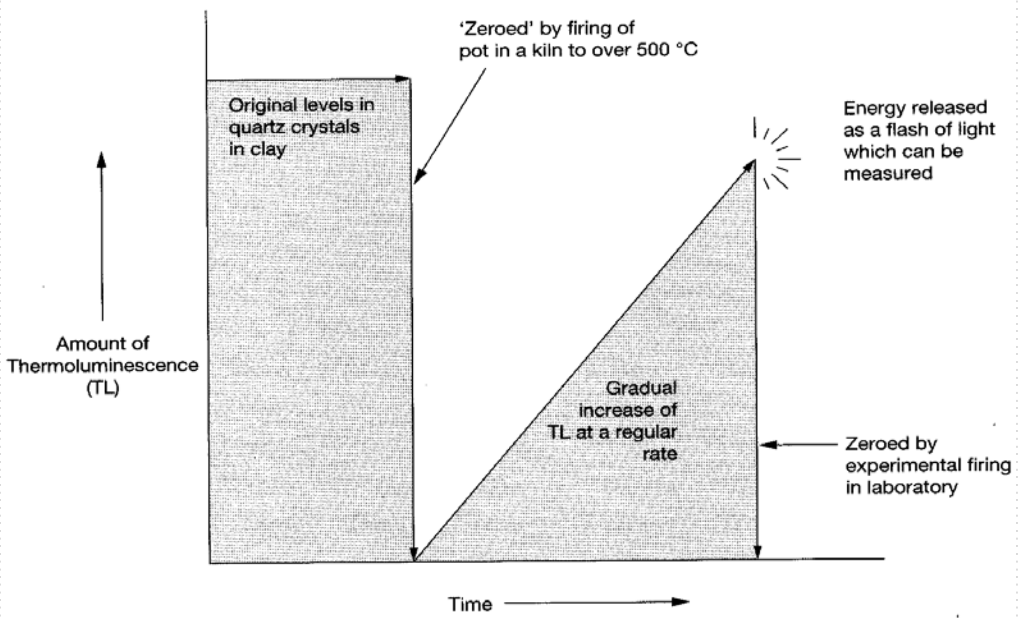


Electron Spin Resonance (ESR)

- ESR dating measures the amount of unpaired electrons in crystalline structures that were previously exposed to natural radiation. Electric charges build up at known rate in some crystal structures.
- Age of substance can be determined by measuring the accumulated dose of radiation since the time of its formation (AD) versus the concentrations of radioactive materials in the sample and its surrounding environment (DR). Age=AD/DR.
- AD can be calculated by measuring the charge produced when subjected to an external magnetic field and irradiated with microwaves.
- Range: 50 ky to 1my
- Materials: Tooth enamel, shells and calcite

Thermoluminescence (TL)
Optical Stimulated Luminescence (OSL)

- Radioactive decay in quartz crystals leads to a build up of electric charges at a known rate. This electrical charge is released as light when the crystals are heated for TL or light induced for OSL.
- Like for ESR, the natural radiation of the surrounding environment has to be calculated.
- Material: Rocks, minerals and pottery



The amount of energy released is relative to the amount of time since last heated to over 500 °C the 'clock setting event'.

Gamma ray mass spectrometry of the sediment measures background radiation

Potassium-Argon ($^{40}K/^{40}Ar$) Argon-Argon ($^{40}Ar/^{39}Ar$)

Potassium decays to its daughter element Argon with a half life of 1.25 ma.

Argon-Argon requires neutron activation in a research reactor. It has a precision advantage compared to $^{40}K/^{40}Ar$ for younger periods (100ky - 10ky)

Applicable for dating volcanic rocks such as ignimbrites containing hornblende and sanidine.

Uranium Series Dating

Using uranium isotopes marks the beginning of radiometric dating. Arthur Holmes developed the uranium–lead dating method already in 1911 at the age of 21, one year after graduation.

The U-Pb method relies on two separate decay chains, the uranium series from 238U to 206Pb, with a half-life of 4.47 billion years and the actinium series from 235U to 207Pb, with a half-life of 704 million years.

It can be used to date rocks of an age between 1ma to over 4500ma. Applied for the determination of the age of the earth. Mostly not applicable in Archaeology.

Uranium-Thorium Dating

Uranium-234 is water-soluble and occurs in all natural waters.

It decays to Thorium-230 which is not water-soluble with a half-life of 245ky.

Thorium-230 is itself radioactive with a half-life of 75ky and so instead of accumulating indefinitely it approaches a secular equilibrium with its parent isotope.

At equilibrium, the number of Thorium-230 decays per year within a sample is equal to the number of Uranium-234 decays per year in the same sample.

Can be used to date calcium carbonate material, i.e. cave speleothem, corals, fossilized bones and teeth

Upper age limit is 500ky

Uranium-Thorium Dating

U/Th Dating of human fossils from Tabon Cave: Low collagen contents prevented ^{14}C dating. U/Th method permitted a direct dating of the human bones. Redated „Tabon Man“ from c. 22ky to 16.5ky

Sample	U (ppm)	234U/238U	230Th/232Th	230Th/234U	Age (Kyrs BP)
Frontal bone **P-XIII-T-288**	2.88	1.115 ± 0.069	> 100	0.142 ± 0.016	16.5 ± 2.0
Right mandibular fragment PXIIIT436-Sg19	0.56	1.169 ± 0.210	48	0.249 ± 0.049	31 +8/ -7
Tibia fragment (IV-2000-T-197)	1.11	1.174 ± 0.150	53	0.354 ± 0.061	47 +11/ -10

courtesy C. Falguères (IPH, Paris)

Geochronological Dating

Geochronological Dating

Loess

- Time witnesses in the dust

Aeolian deposits:

Smallest particles of silt and sand are picked up from exposed surfaces.

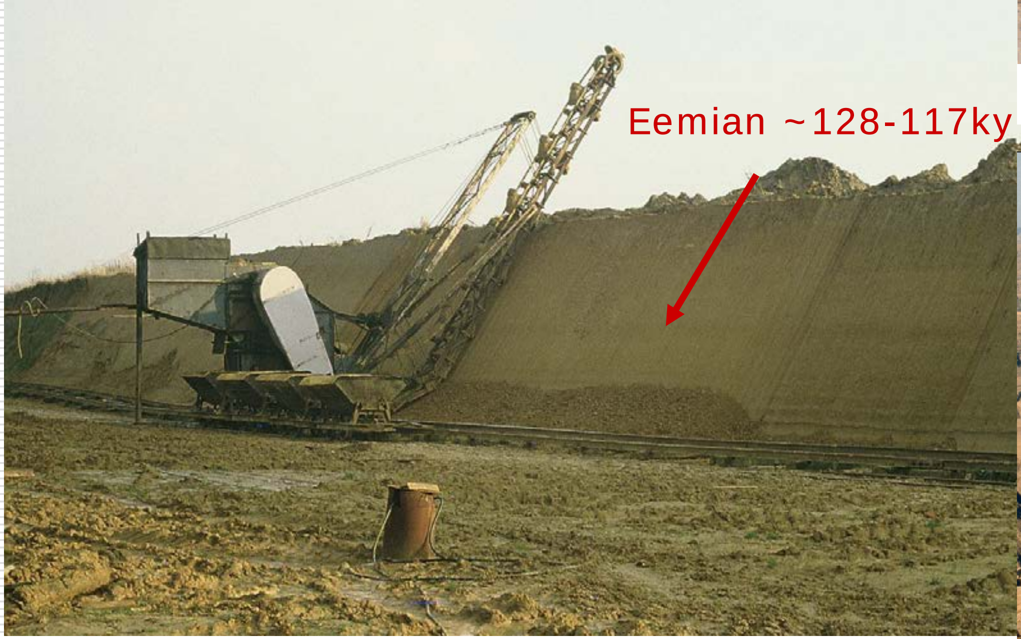
Vegetation-free polar deserts of high latitudes and alpine mountain ranges are especially suited to wind abrasion.

- Grain size between 10-50µm
- Non stratified, homogenous deposit with porous structure
- Composition dominated by quartz grains
- Originates in periglacial context (cold arid to semi-arid, for instance cold steppe environment)
- Loessification: process of synsedimentation diagenesis

Sand storm in the Gobi desert (Mongolia), June 2008

Geochronological Dating

- Loess
  - Time witnesses in the dust: Palaeosols captured by aeolian deposits



Bucket excavator in Lower Rhine Basin, Germany

Loess bluff at Edwardsville, Illinois, USA

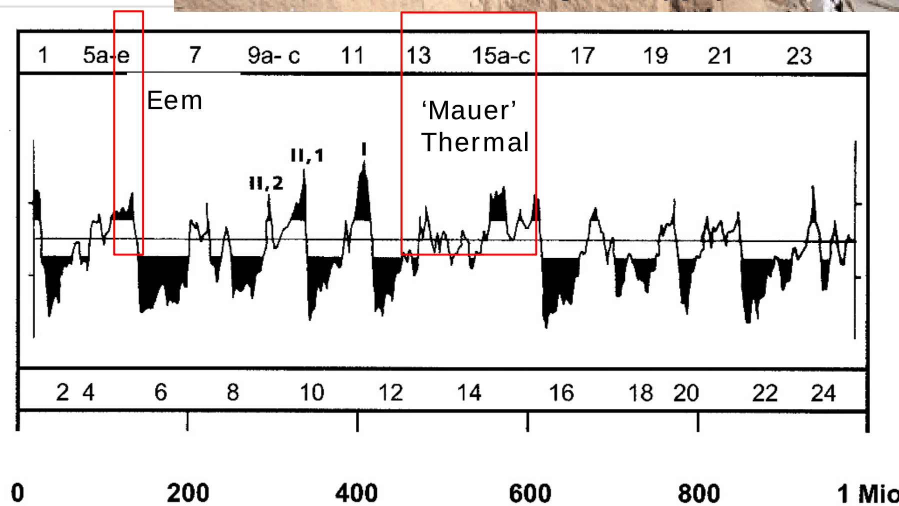
Loess landscape in Shanxi, China

Geochronological Dating

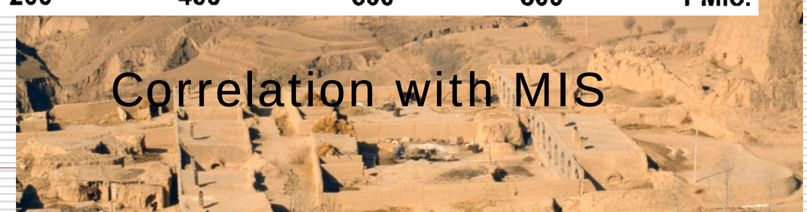
Loess

- Time witnesses in the dust: Lower Rhine Basin

- Loess deposition is related to periglacial environments during glacial maxima (pleniglacial stages)
- Geological features and structures related to cold climate and permafrost
- (topsoil is frozen during the entire year and thus watertight)
- Records also climatic variations. During climatic ameliorations, vegetation growth leads to soil formation. These soils are characteristic for certain climatic and biological environments (e.g. Eemian)



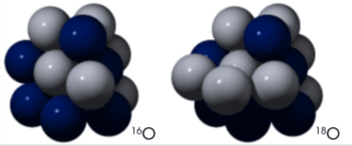
Correlation with MIS

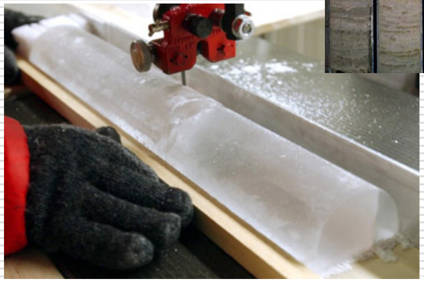


Loess landscape in Shanxi, China

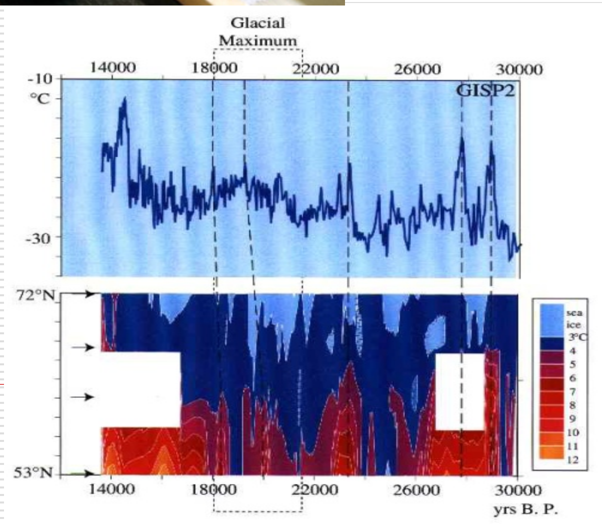
Geochronological Dating

- MIS/OIS
  - Time witnesses in marine sediments and ice





- All oxygen atoms have 8 protons, but the nucleus might contain 8, 9, or 10 neutrons. “Light” oxygen-16, with 8 protons and 8 neutrons, is the most common isotope found in nature, followed by much lesser amounts of “heavy” oxygen-18, with 8 protons and 10 neutrons.
- Oxygen Isotope Stages are cyclical variations in the ratio of the abundance of O-18 to the abundance of O-16. The ratio is linked to water temperature of ancient oceans, which in turn reflects ancient climates.



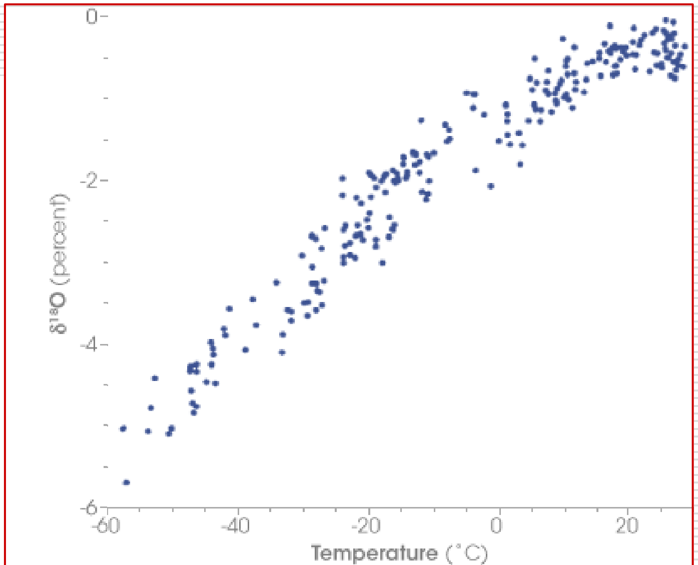
Geochronological Dating

MIS/OIS

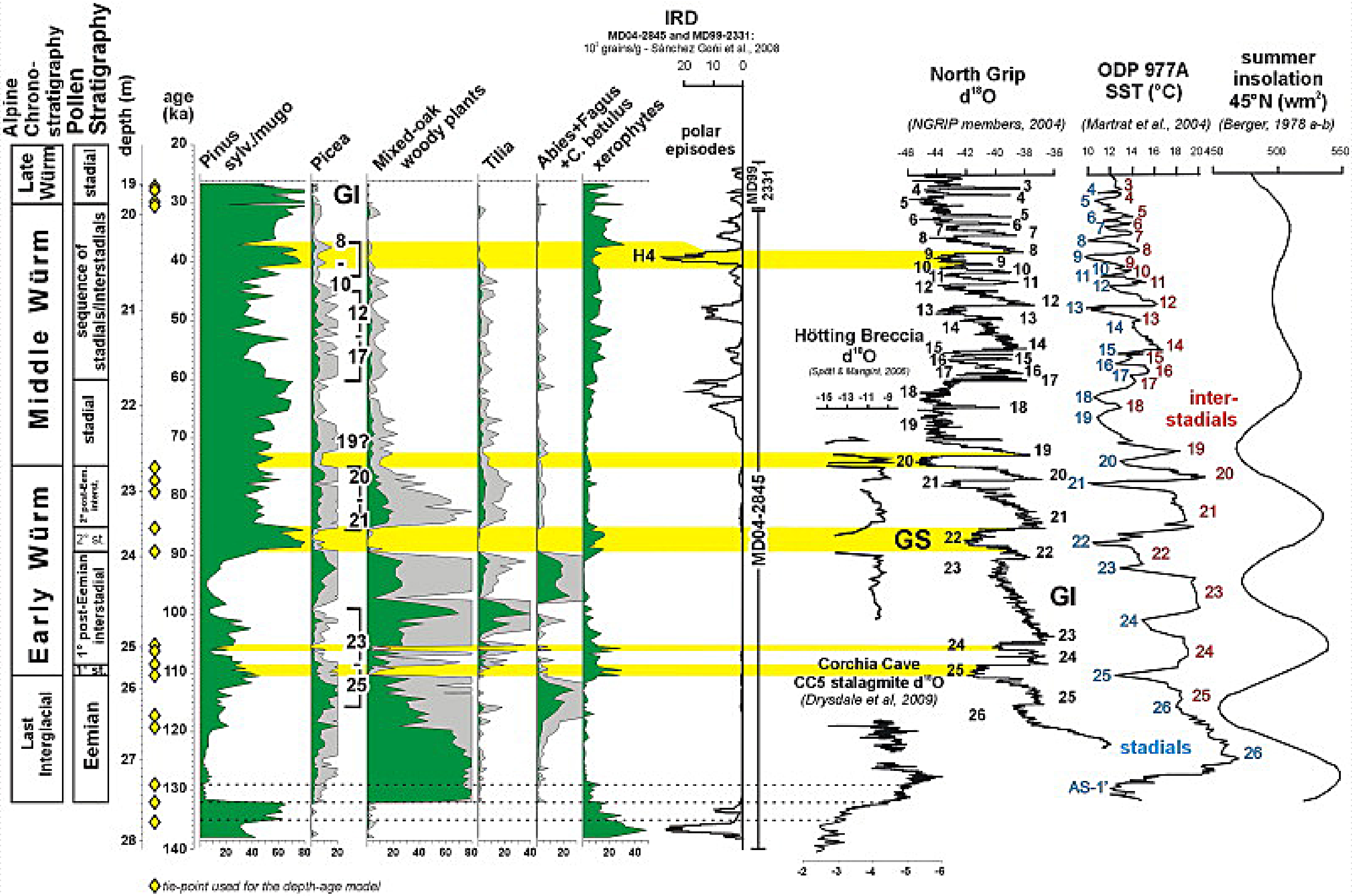
During ice ages, cooler temperatures extend toward the equator, so water vapor containing heavy oxygen rains out of the atmosphere at even lower latitudes than it does under milder conditions. The water vapor containing light oxygen moves toward the poles, eventually condenses, and falls onto the ice sheets where it stays -> Ocean waters become rich in heavy oxygen

The water remaining in the ocean develops increasingly higher concentration of heavy oxygen compared to the universal standard, and the ice develops a higher concentration of light oxygen. Thus, high concentrations of heavy oxygen in the ocean tells us that light oxygen was trapped in the ice sheets. The exact oxygen ratios can even show how much ice covered the Earth.

Conversely, as temperatures rise, ice sheets melt, and freshwater runs into the ocean. Melting returns light oxygen to the water, and reduces the salinity of the oceans worldwide -> Ocean waters become rich in light oxygen



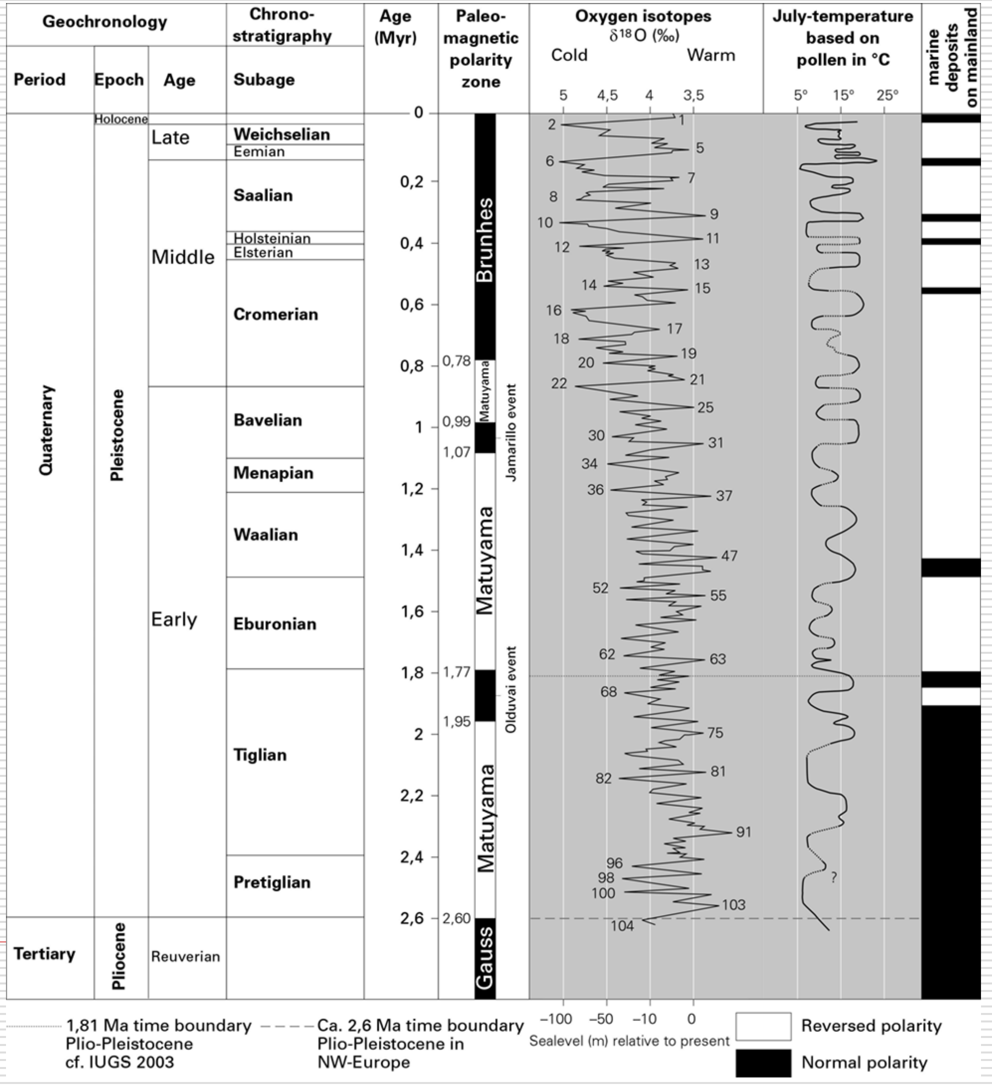
The concentration of ^{18}O in precipitation decreases with temperature. This graph shows the difference in ^{18}O concentration in annual precipitation compared to the average annual temperature at each site. The coldest sites, in locations such as Antartica and Greenland, have about 5 percent less ^{18}O than ocean water. (Jouzel *et al.*, 1994)



Correlation of geological, pedological and biological stratigraphic sequences for the Upper Pleistocene

Combining Relative and Absolute Dating

- Interdisciplinary Approach
  - Archaeology
  - Stratigraphies
  - Climate Proxies:
    Pollen analysis
    Faunal record
    OIS/MIS



Chronology

Archaeological Chronological Record for Europe: A 1my sequence

Chronology of Europe						
Time	OIS	Geological Period	Climate / Vegetation phase	Archaeological Period	Culture / Techno complex	Hominin
	1	Holocene	Subatlantic	Iron Age	Medeaval	Homo sapiens
2.5 ky					Hallstatt /La Tène	
5.7 ky			Subboreal	Late Neolithic / EBA	Cortaillod / Bell beaker	
6.5 ky			Atlantic	Neolithic	Bandkeramik	
7.5 ky				Late Mesolithic	Tardenoisien	
8.5 ky			Boreal	Early Mesolithic	Sauveterrien	
10 ky			Preboreal		Beuronien A	
12 ky			Bølling / Dryas	Terminal Palaeolithic	Azilien / Federmesser	
18 ky	2	Terminal Pleistocene	Würmian Maximum (LGM)	Upper Palaeolithic	Magdalénien	
22 ky					Solutréen	
30 ky	3	Upper Pleistocene	Hengelo / Denekamp Interstadial		Périgordien / Gravettien	
40 ky					Aurignacien	
75 ky	4			Middle Palaeolithic	Mousterien / Micoquien	H. neanderthalensis
	5		Early Würmian			
130ky	5e	Middle Pleistocene	Eemian			
	6		Saalian Complex		Late Acheulean	
200ky	7			Lower Palaeolithic	Upper Acheulean / Clactonian	
	8					
	9				Classic Acheulean	H. steinheimensis
	10		Saalian Maximum		Lower Acheulean	H.heidelbergensis / H. erectus
400ky	11		Holstein			
	12		Elsterian			
450-900ky	13-21		Cromer Complex			H. antecessor

Home work

- Review the methods of Relative and Absolute Dating