

Dating Techniques

Dating techniques in the Quaternary time range fall into three broad categories:

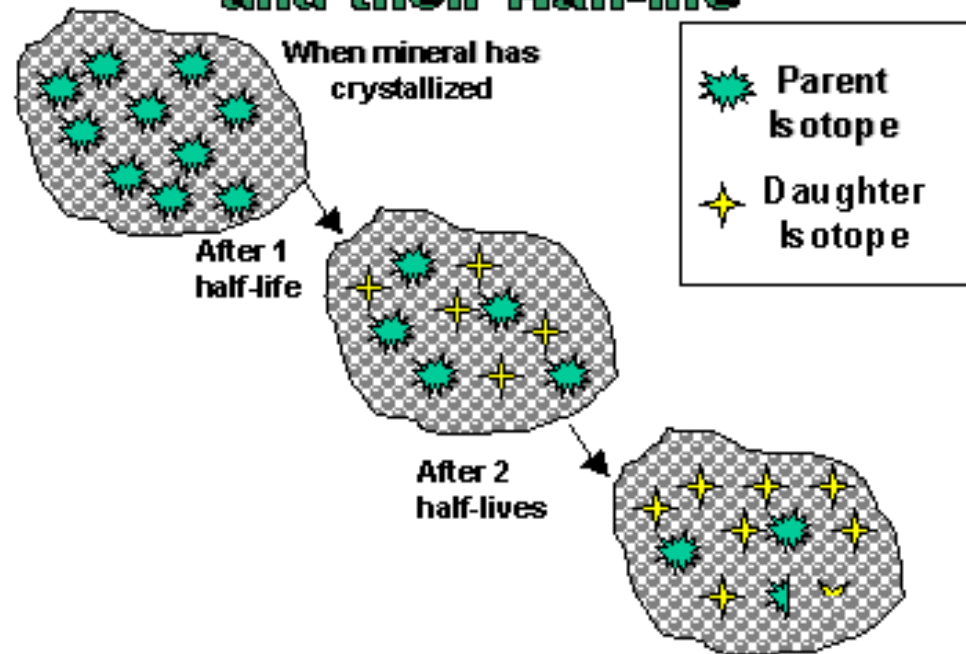
- **Methods that provide age estimates.**
- **Methods that establish age-equivalence.**
- **Relative age methods.**

Dating Techniques

Age Estimates: Radiometric dating techniques

Are methods based in the radioactive properties of certain unstable chemical elements, from which atomic particles are emitted in order to achieve a more stable atomic form.

Radiogenic isotopes in minerals and their Half-life



Dating Techniques

Age Estimates: Radiometric dating techniques

Application of the principle of radioactivity to geological dating requires that certain fundamental conditions be met.

If an event is associated with the incorporation of a radioactive nuclide, then providing:

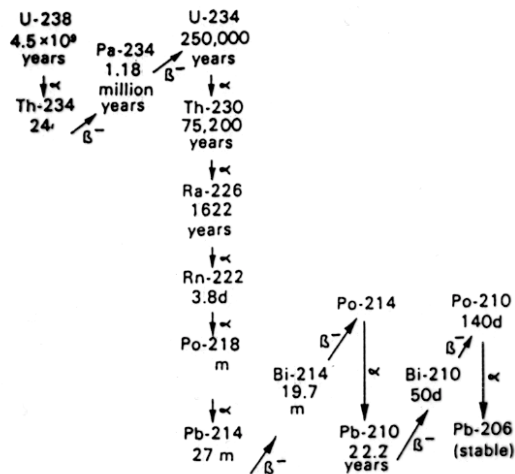
- (a) that none of the daughter nuclides are present in the initial stages and,
- (b) that none of the daughter nuclides are added to or lost from the materials to be dated,

then the estimates of the age of that event can be obtained *if* the ratio between parent and daughter nuclides can be established, and *if* the decay rate is known.

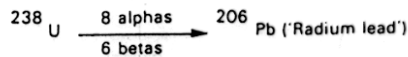
Dating Techniques

Age Estimates: Radiometric dating techniques - Uranium-series dating
 ^{238}U , ^{235}U and ^{232}Th all decay to stable lead isotopes through complex decay series of intermediate nuclides with widely differing half-lives.

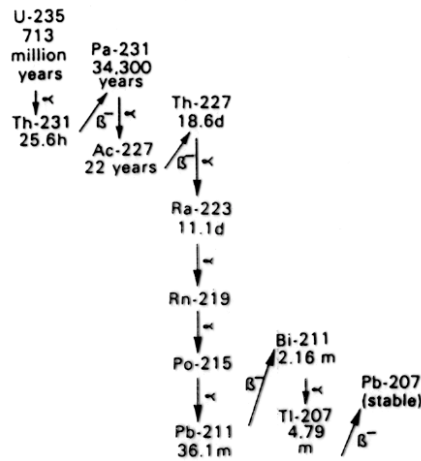
U-238 Series



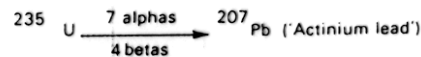
summary



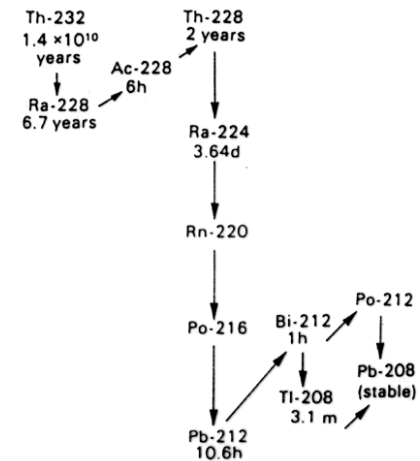
U-235 Series



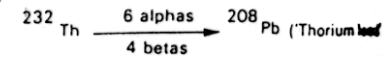
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Th-232 Series



summary:



Dating Techniques

Age Estimates: Radiometric dating techniques - **Uranium-series dating**

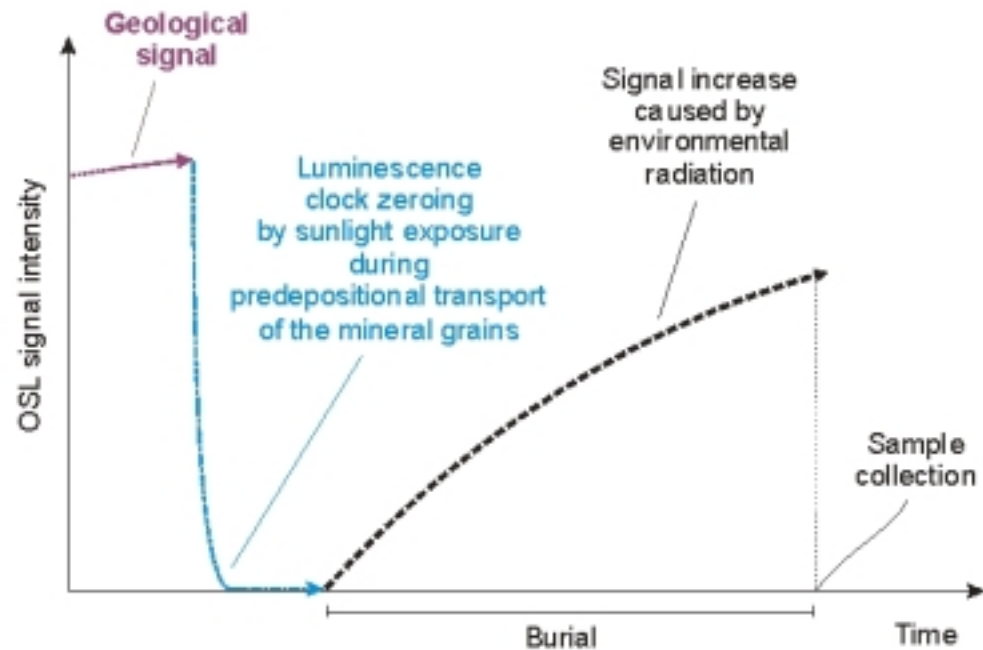
- Bone
- Speleothems
- Lacustrine deposits
- Peat
- Coral

Dating Techniques

Age Estimates: Radiometric dating techniques - **Thermoluminescence (TL)**

Electrons can be freed by heating and emit a characteristic emission of light which is proportional to the number of electrons trapped within the crystal lattice.

Termed *thermoluminescence*.



Basic principles of the luminescence dating of Quaternary deposits

Dating Techniques

Age Estimates: Radiometric dating techniques - Thermoluminescence (TL)

Applications:

- archeological sample, especially pottery.
- deep sea sediments and,
- loess deposits

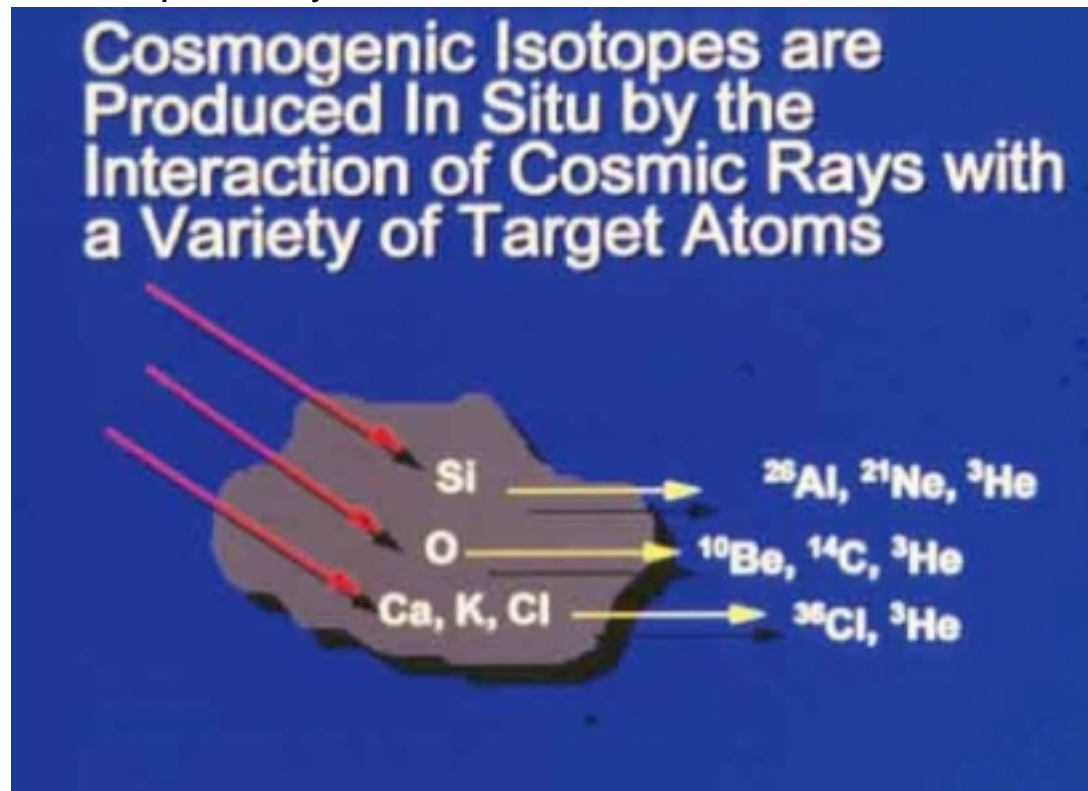


www.pastperfect.info/archaeology/lo/tl.jpg

Dating Techniques

Cosmogenic Dating

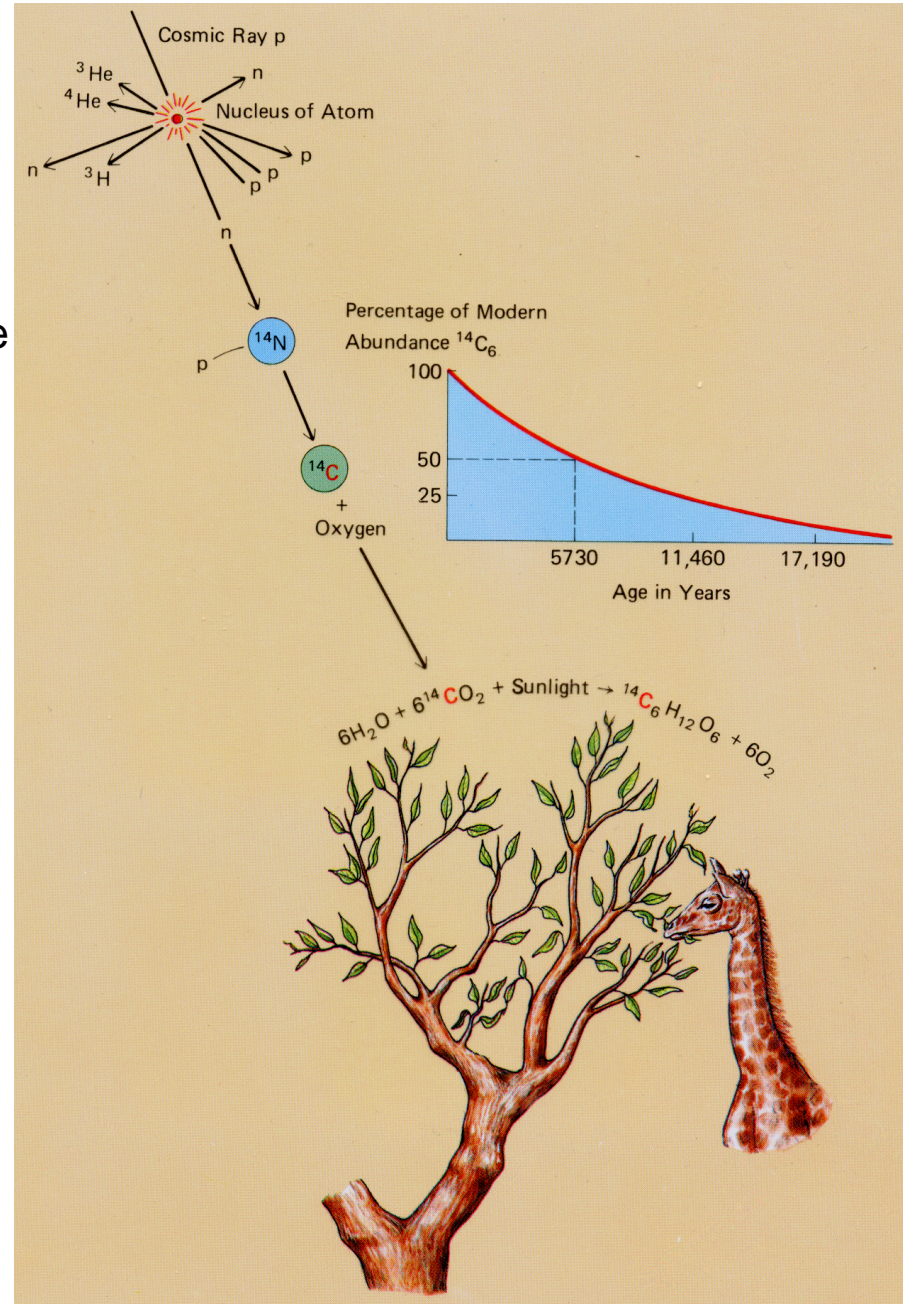
Cosmogenic isotopes are created when elements in the atmosphere or earth are bombarded by high energy particles (cosmic rays) that penetrate into the atmosphere from outer space. It was discovered about a decade ago that cosmic ray interaction with silica and oxygen in quartz produced measurable amounts of the isotopes Beryllium-10 and Aluminium-26.



Dating Techniques

Radiocarbon Dating

Free neutrons resulting from nuclear reactions in the upper atmosphere collide with other atoms and molecules, and one effect is the displacement of protons from nitrogen atoms to produce carbon atoms.

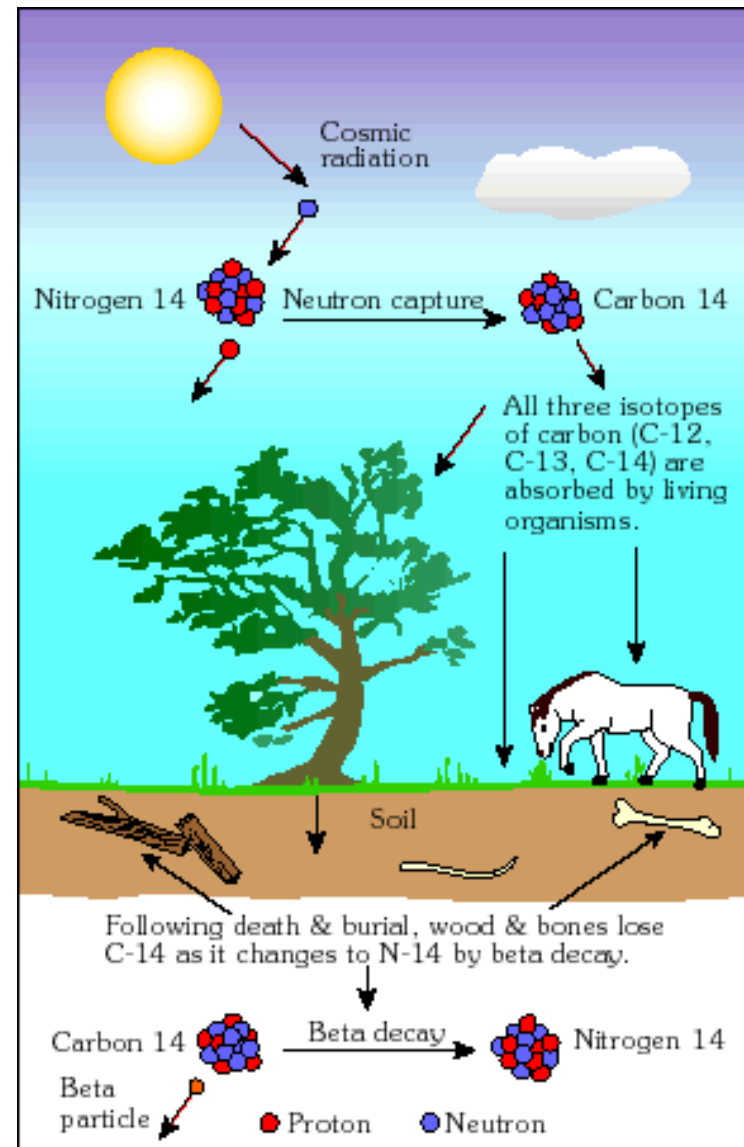


Dating Techniques

Radiocarbon Dating

All living matter that absorbs carbon dioxide during tissue-building, therefore, contains carbon isotopes in a ratio which is in equilibrium with atmospheric carbon dioxide.

Upon death, ^{14}C within the inorganic tissues will continue to decay, but no replacement takes place. Hence if the rate of decay of ^{14}C is known, date of death can be computed from the measured ^{14}C activity.



earthsci.org/fossils/geotime/radate/cycle.gif

Dating Techniques

Radiocarbon Dating

Radiocarbon dating rest on four fundamental assumptions:

- that the production of ^{14}C is constant over time
- that the ^{14}C : ^{12}C ratio in the biosphere and hydrosphere is in equilibrium with the atmospheric ratio,
- that the decay rate of ^{14}C is known; and
- that an equilibrium constant has been achieved between production and decay, which does not vary substantially over time.

Dating Techniques

Sources of error in ^{14}C dating

- Variations of ^{14}C over time.
- Circulation of marine carbon.
- Hard water.
- Contamination.

If it weren't for Carbon-14,
I wouldn't date at all.



Dating Techniques

Incremental Methods

Incremental methods are those based on regular additions of material to organic tissue or sedimentary sequences. Those which have been most widely used are

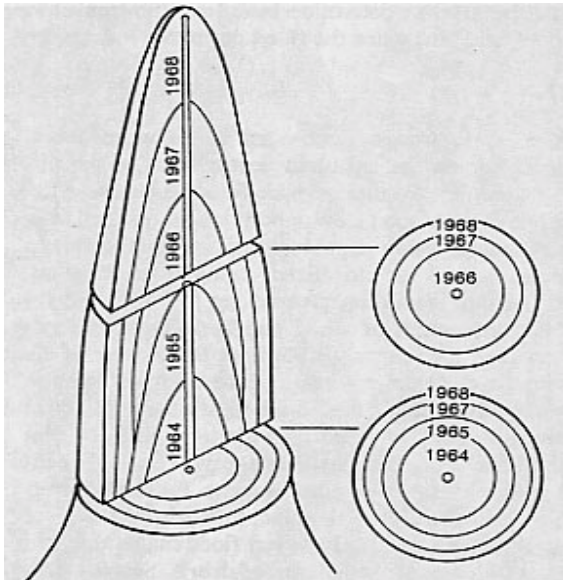
1. dendrochronology (tree-ring dating),
2. varve chronology, and
3. lichenometry.

These techniques are restricted in application largely to the Holocene although varve chronology has been used as a means of dating earlier Quaternary successions.

Dating Techniques

Dendrochronology

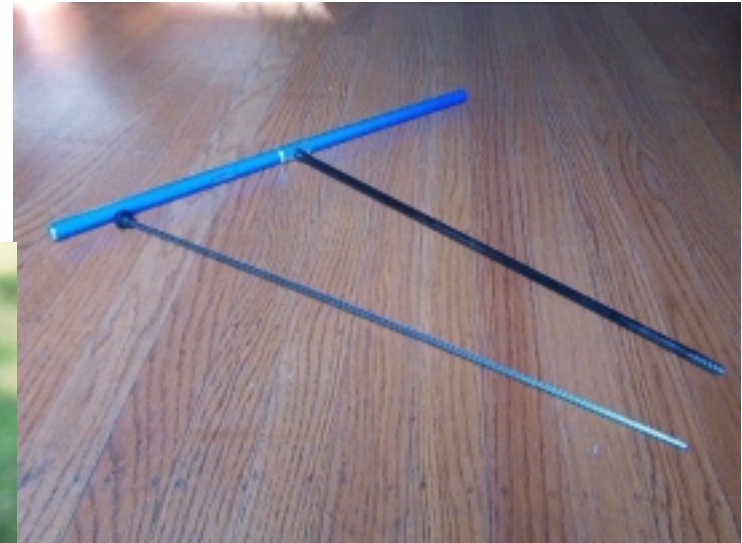
In most temperate trees, new water and food-conducting vessels are added to the outer perimeter of the trunk each growth season, following an interactive period in winter. This produces a distinct line between successive annual increments of wood growth and counting of these lines (tree-rings) allows the age of the tree to be established.



Dating Techniques

Dendrochronology

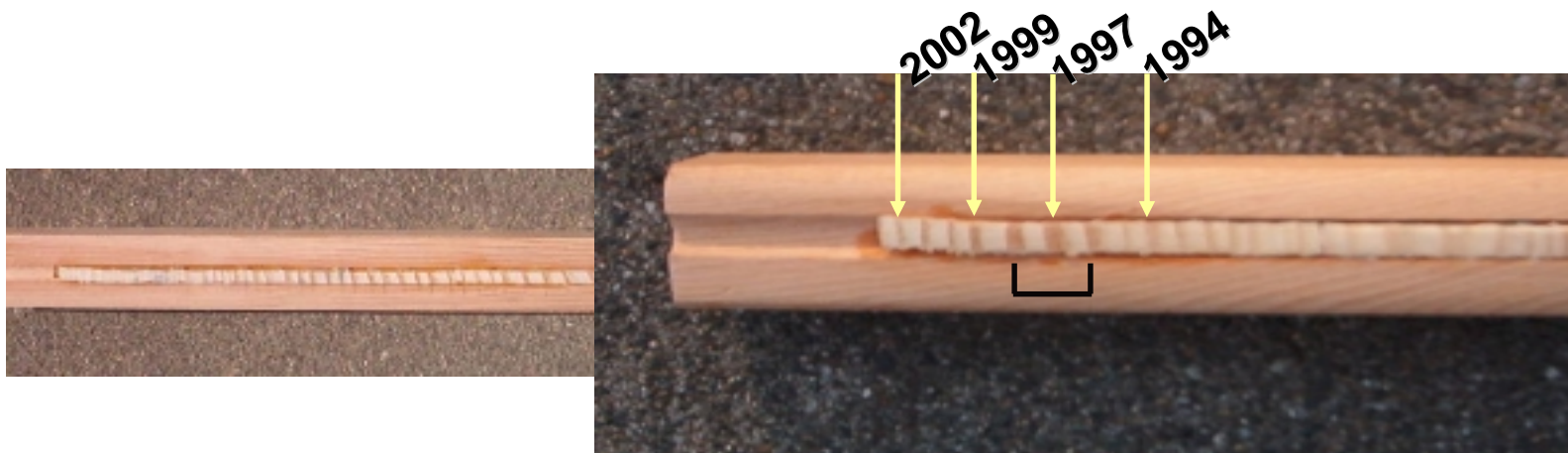
Obtain a core or cut dead tree for cross-section.



Dating Techniques

Dendrochronology

- Ring patterns within trees from a limited geographical area can be matched through the technique of cross-dating.
- Climatic variations within a particular area will be reflected in characteristic ring-width patterns in the trees of that area.
- Distinctive rings, or grouped of rings, form markers and these can be used as a basis for cross-matching between trees of overlapping age range.

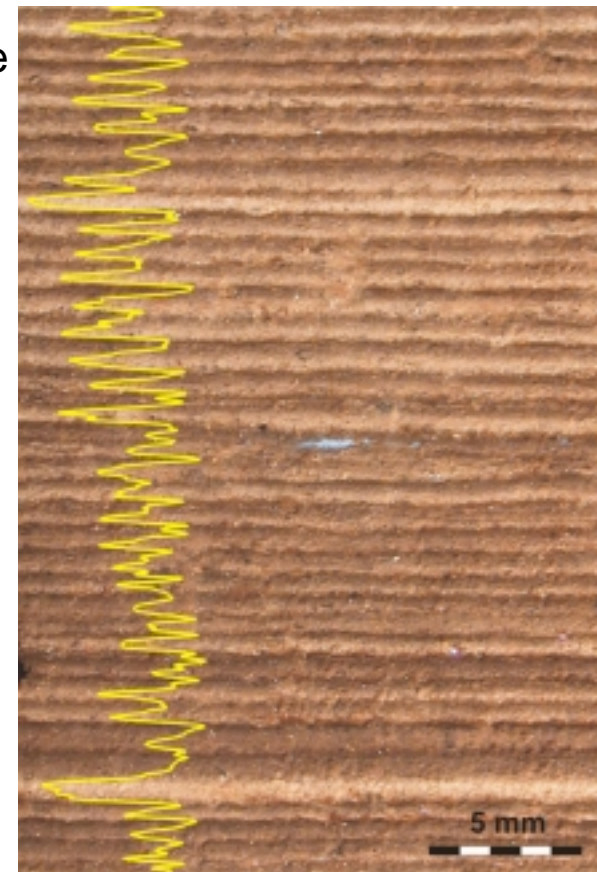


Dating Techniques

Varve Chronology

Rhythmic accumulations of sediments (**varves**), forming laminae of fine sands, silts or clay, are common in the geological record.

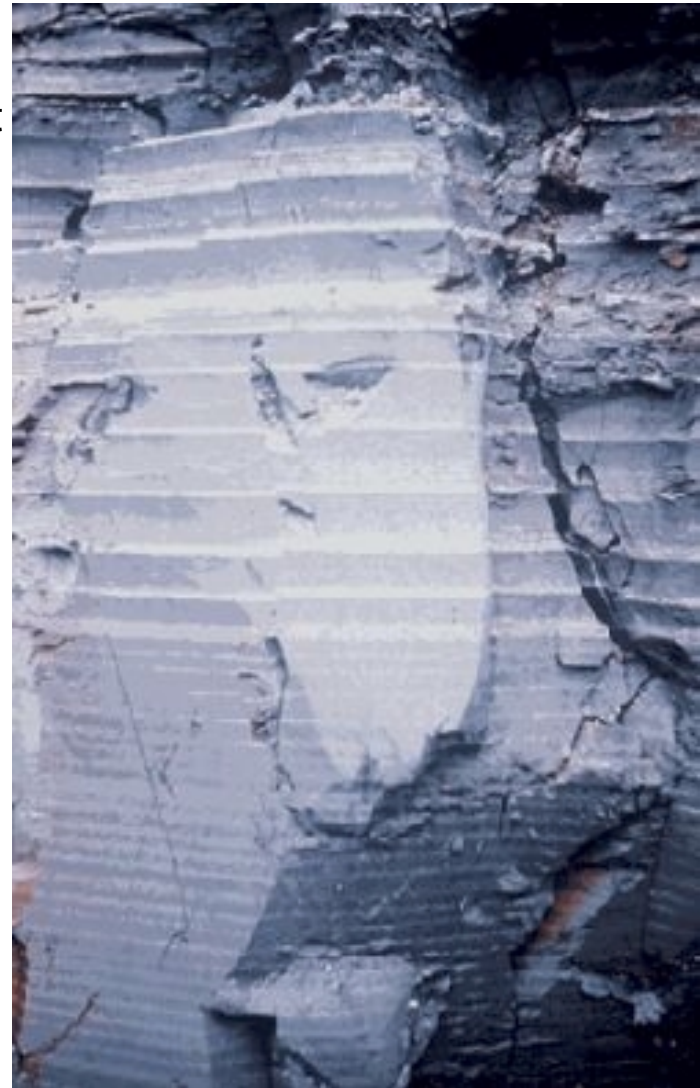
Because they are deposited annually, varves can be used as a means of dating, for time intervals can be calculated and a floating chronology established. It may be possible to assign calendar dates to the varve record.



Dating Techniques

Glaciolacustrine and glaciomarine varves

Large supplies of sediment are deposited in proglacial lakes and shallow seas as a result of rapid spring and summer ice melt.



Dating Techniques

Other varved sediments

- In deep lakes with oxygen deficient basal water, the numbers of bottom-dwelling fauna are restricted, vertical water circulation does not extend to the bottom of the water column and fine laminations may be preserved.
- Diatom-rich summer layers in lamination have been observed in interglacial and modern sediments.
- Seasonal variation in iron oxide precipitation may also lead to the formation of laminations. In some lakes, variations in the accumulation of organic matter or of chemical precipitates are superimposed on particle-size variations, thereby emphasizing contrasts between winter and summer layers.

Dating Techniques

Lichenometry

Lichenometry as a dating technique rests on the principle that there is a direct relationship between lichen size and age.

Lichenometry has been most widely employed in the dating of glacier recession.



academic.emporia.edu/.../ice/lec10/lichen04.jpg

Dating Techniques

Lichenometry

Not all lichens are suitable for lichenometrical purposes, however; only those that show a gradual and progressive rate of growth can be employed.



academic.emporia.edu/.../ice/lec10/lichen04.jpg

Dating Techniques

Age-equivalent stratigraphic markers

In many Quaternary deposits, distinctive marker horizons are found that are broadly synchronous and form time planes across different sedimentary sequences.

- **Paleomagnetism**
- **Tephrochronology**
- **aminostratigraphy**

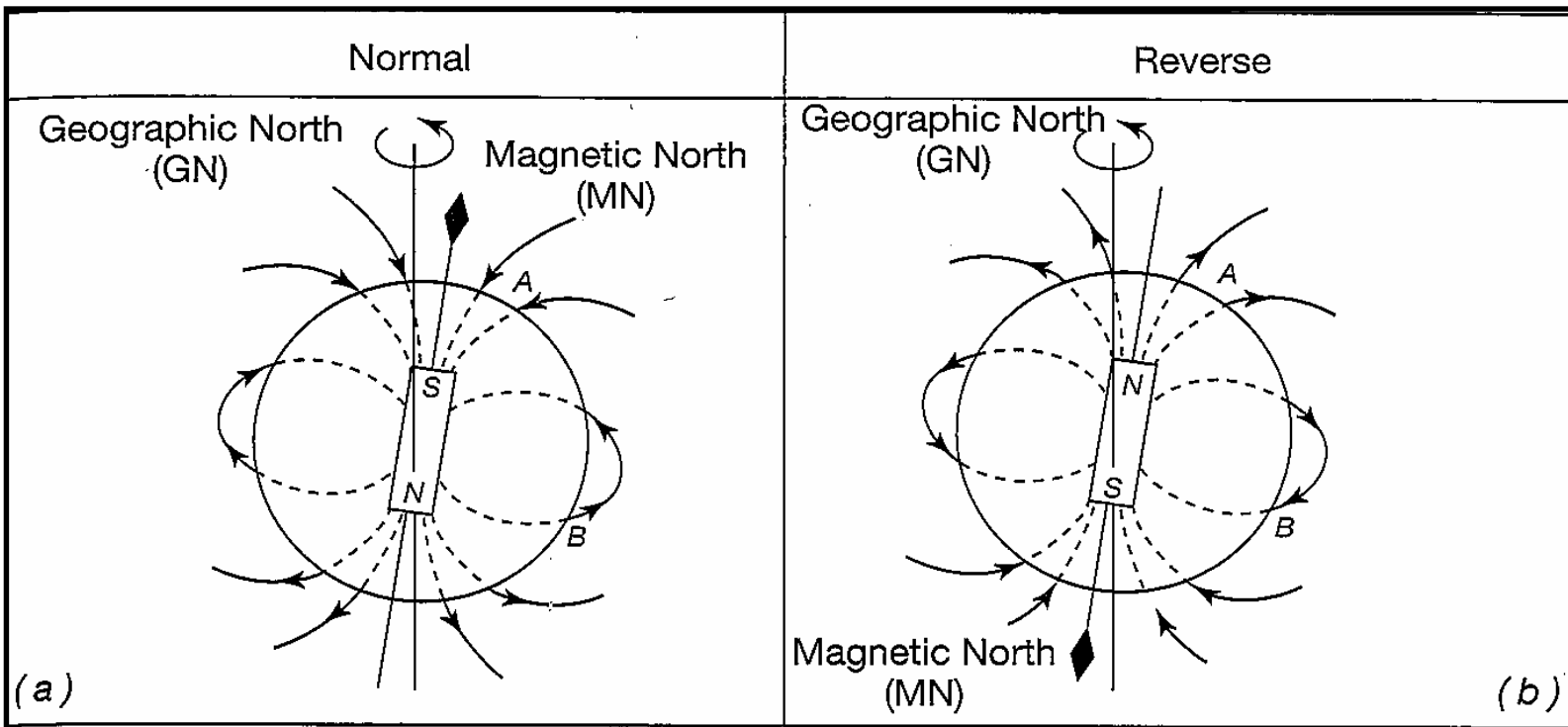
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Dating Techniques

Paleomagnetism

The earth's magnetic field varies constantly both in field strength and in polarity direction. Rocks and unconsolidated sediments containing magnetic minerals are magnetized during formation, and individual crystals or particles therefore become aligned in the ambient magnetic field.



Dating Techniques

Paleomagnetism

Volcanic rocks contain minerals with various ferromagnetic properties. The presence of a magnetic field then influences and aligns the orientation of ferromagnetic minerals.

Sedimentary rocks and unconsolidated sediments accumulating on the sea floor or in lakes also contain evidence of former geomagnetic fields, for a record is preserved in the alignment of ferromagnetic sedimentary particles as they settle in water or in water-saturated sediments.



www.ub.es/ggac/research/piris/sampling.jpg

Dating Techniques

Magnetostratigraphy

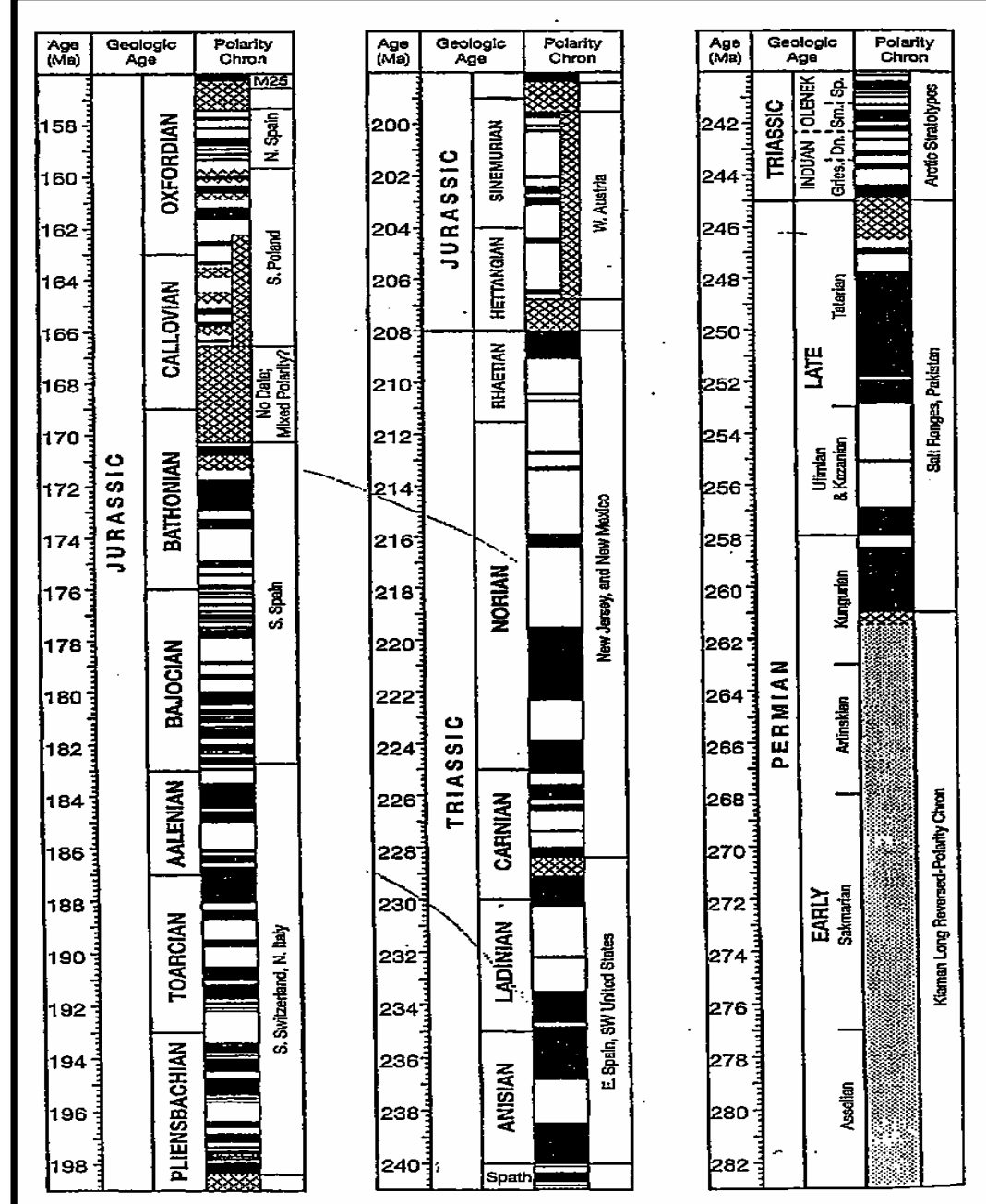
The study of variations in magnetic properties through a sequence of rocks or sediments is termed magnetostratigraphy. provides a means of relative dating and correlation.

Field reversals and the paleomagnetic time-scale

From time to time the geomagnetic field reverses so that the geomagnetic poles change relative positions through 180° and these then remain stable for a while. These polarity reversals can be detected in the geological record and are of fundamental importance in paleomagnetic studies.

Dating Techniques

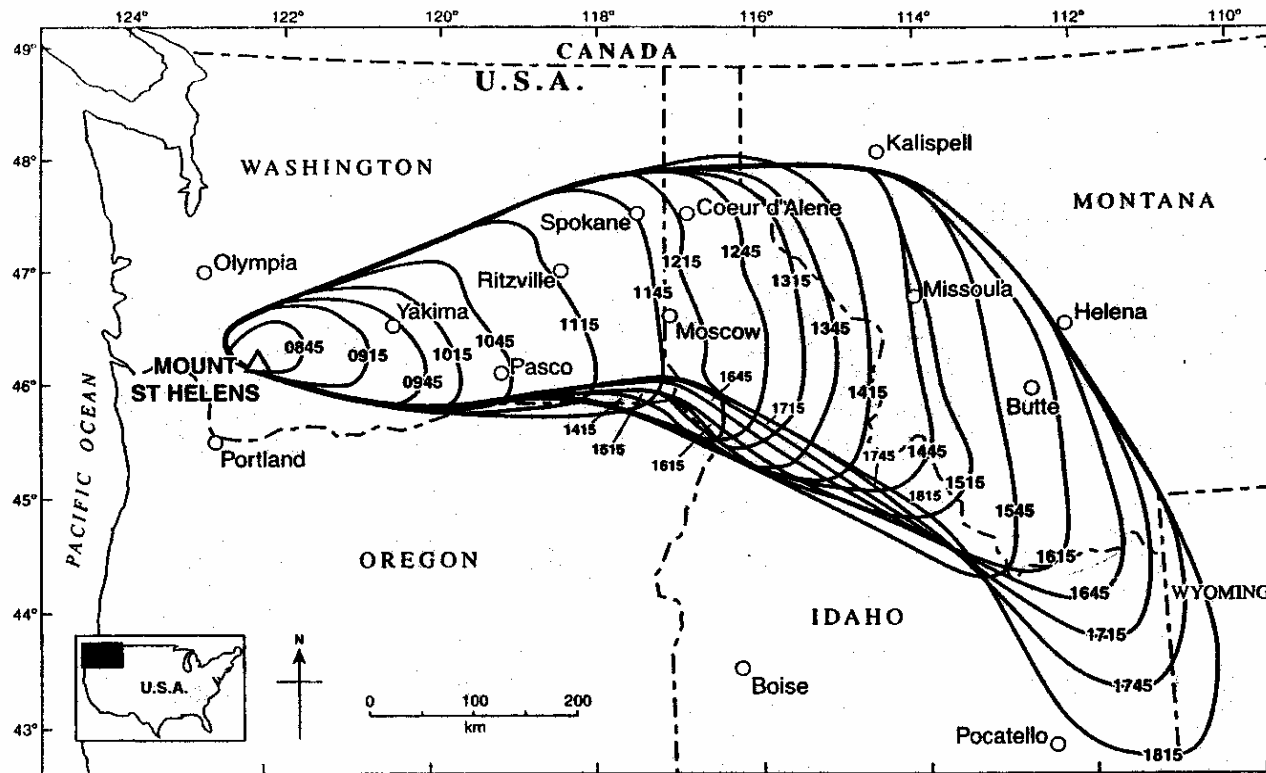
Magnetostratigraphy



Dating Techniques

Tephrochronology

Following a volcanic eruption ash or tephra is often spread rapidly over a relatively wide area and forms a thin cover over contemporaneous peat surfaces, lake floor sediments, estuarine sediments, river terraces, etc.



Dating Techniques

Relative chronology based on processes of chemical alteration

Fossils, sediments and rocks are affected by a number of chemical reactions that are partly time-dependent. The degree of alteration brought about by different chemical reactions increases with time, and this therefore offers a basis for relative dating.



epod.usra.edu/archive/images/soilprofile22.jpg

Dating Techniques

Relative chronology based on processes of chemical alteration

Biogeochemistry of amino acids (aminostratigraphy)

All living organisms contain proteins made up of amino acids. The proteins produced by organisms consist almost entirely of amino acids in the L-isomer (left-handed) configuration. Upon death, the L amino acids begin inverting to their respective D-isomer (dextral or right-handed) configurations. This process is called **racemization**.

The use of amino acids ratios to rank fossils and their associated sediments according to relative age is termed **aminostratigraphy**.