Geochronology

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Why geochronology?

- **Calibration**
  - Geological time scale
  - Events- mass extinctions
    great oxygenation events
    snowball earth
    age of the earth and the solar system
  - Astronomical clock

- **rates**
  - Tectonic- plate to outcrop scales
  - Metamorphism and fluids
  - Evolution of life

What is geochronology?

"Geochronology means dating of geological events"
or
"Geochronology is the science of determining the age of rocks, fossils, and sediments using signatures inherent in the rocks themselves"

- ✓ **Absolute geochronology can be accomplished through radioactive isotopes, whereas relative geochronology is provided by tools such as palaeomagnetism and stable isotope ratios.**

- ✓ **The science of geochronology is the prime tool used in the discipline of chronostratigraphy, which attempts to derive absolute age dates for all fossil assemblages and determine the geologic history of the Earth and extraterrestrial bodies.**

Geochronology methods

- Radiometric dating
- Fission-track dating
- Cosmogenic nuclide geochronology
- Luminescence dating
- Incremental dating
- Paleomagnetic dating
- Magnetostratigraphy
- Chemostratigraphy
- Correlation of marker horizons
- Geological hierarchy of chronological periodization

➢ Radiometric dating

- ✓ By measuring the amount of radioactive decay of a radioactive isotope with a known half-life, geologists can establish the absolute age of the parent material.
- ✓ A number of radioactive isotopes are used for this purpose and depending on the rate of decay are used for dating different geological periods.
- ✓ Most radiometric methods are suitable for geological time only, but some such as the radiocarbon method and the $^{40}Ar/^{39}Ar$ dating method can be extended into the time of early human life and into recorded history.

Some of the commonly used techniques are:

- Radiocarbon dating:- Measures the decay of carbon-14 in organic material and can be best applied to samples younger than about 60,000 year.
- Uranium–lead (U-Pb) dating:- Measures the ratio of two lead isotopes (Pb-206 and Pb-207) to the amount of uranium in a mineral or rock.
- Uranium–thorium (U-Th) dating:- This technique is used to date speleothems, corals, carbonates, and fossil bones. Its range is from a few years to about 700,000 years.
- Potassium–argon (K-Ar) dating and argon–argon (Ar-Ar) dating:- These techniques date metamorphic, igneous and volcanic rocks.

➢ Fission-track dating

- ✓ Fission track dating is a radiometric dating technique based on analyses of the damage trails, or tracks, left by fission fragments in certain uranium-bearing minerals and glasses.
- ✓ It is a relatively simple method of radiometric dating that has made a significant impact on understanding the thermal history of continental crust, the timing of volcanic events, and the source and age of different archeological artifacts.
- ✓ Fission tracks are sensitive to heat, and therefore the technique is useful at unraveling the thermal evolution of rocks and minerals.
- ✓ Fission track analysis of these minerals provides information about the thermal evolution of the source rocks and therefore can be used to understand provenance and the evolution of mountain belts that shed the sediment.

Using the fission-track dating

—understanding the evolution of mountain belts
—determining the source or provenance of sediments
—studying the thermal evolution of basins
—determining the age of poorly dated strata
—dating and provenance determination of archeological artifacts

➢ Cosmogenic nuclide geochronology

- ✓ Surface exposure dating or Cosmogenic radionuclide dating is a collection of geochronological techniques for estimating the length of time that a rock has been exposed at or near Earth's surface.
- ✓ Surface exposure dating is used to date glacial advances and retreats, erosion history, lava flows, meteorite impacts, rock slides, fault scarps, cave development, and other geological events.
- ✓ It is most useful for rocks which have been exposed for between 10 years and 30,000,000 years.

Cosmogenic radionuclide dating

The most common of these dating techniques is *Cosmogenic radionuclide dating*[citation needed]. Earth is constantly bombarded with primary cosmic rays, high energy charged particles — mostly protons and alpha particles. These particles interact with atoms in atmospheric gases, producing a cascade of secondary particles that may in turn interact and reduce their energies in many reactions as they pass through the atmosphere. This cascade includes a small fraction of hadrons, including neutrons. When one of these particles strikes an atom it can dislodge one or more protons and/or neutrons from that atom, producing a different element or a different isotope of the original element. In rock and other materials of similar density, most of the cosmic ray flux is absorbed within the first meter of exposed material in reactions that produce new isotopes called cosmogenic nuclides. At Earth's surface most of these nuclides are produced by neutron spallation. Using certain cosmogenic radionuclides, scientists can date how long a particular surface has been exposed, how long a certain piece of material has been buried, or how quickly a location or drainage basin is eroding.[1] The basic principle is that these radionuclides are produced at a known rate, and also decay at a known rate.[2] Accordingly, by measuring the concentration of these cosmogenic nuclides in a rock sample, and accounting for the flux of the cosmic rays and the half-life of the nuclide, it is possible to estimate how long the sample has been exposed to the cosmic rays. The cumulative flux of cosmic rays at a particular location can be affected by several factors, including elevation, geomagnetic latitude, the varying intensity of the Earth's magnetic field, solar winds, and atmospheric shielding due to air pressure variations. Rates of nuclide production must be estimated in order to date a rock sample. These rates are usually estimated empirically by comparing the concentration of nuclides produced in samples whose ages have been dated by other means, such as radiocarbon dating, thermoluminescence, or optically stimulated luminescence.

➢ Luminescence dating

- ✓ Luminescence dating techniques observe 'light' emitted from materials such as quartz, diamond, feldspar, and calcite.
- ✓ Many types of luminescence techniques are utilized in geology, including optically stimulated luminescence (OSL), cathodoluminescence (CL), and thermoluminescence (TL).
- ✓ Thermoluminescence and optically stimulated luminescence are used in archaeology to date 'fired' objects such as pottery or cooking stones and can be used to observe sand migration.

➢ Incremental dating

- ✓ Incremental dating techniques allow the construction of year-by-year annual chronologies, which can be temporally fixed (i.e., linked to the present day and thus calendar or sidereal time) or floating.
- ✓ Archaeologists use tree-ring dating (dendrochronology) to determine the age of old pieces of wood. Trees usually add growth rings on a yearly basis, with the spacing of rings being wider in high growth years and narrower in low growth years. Patterns in tree-ring growth can be used to establish the age of old wood samples, and also give some hints to local climatic conditions. This technique is useful to about 9,000 years ago for samples from the western United States using overlapping tree-ring series from living and dead wood.

Techniques of incremental dating

- Dendrochronology
- Sampling Ice cores
- Lichenometry
- Paleomagnetic dating
- Varves
- Speleothems
- Acanthochronology
- Sclerochronology

➢ Paleomagnetic dating

- ✓ A sequence of paleomagnetic poles (usually called virtual geomagnetic poles), which are already well defined in age, constitutes an apparent polar wander path (APWP). Such a path is constructed for a large continental block.
- ✓ APWPs for different continents can be used as a reference for newly obtained poles for the rocks with unknown age. For paleomagnetic dating, it is suggested to use the APWP in order to date a pole obtained from rocks or sediments of unknown age by linking the paleopole to the nearest point on the APWP.
- ✓ Two methods of paleomagnetic dating have been suggested: (1) the angular method and (2) the rotation method.
- ✓ The first method is used for paleomagnetic dating of rocks inside of the same continental block. The second method is used for the folded areas where tectonic rotations are possible.

➢ Magnetostratigraphy

- ✓ Magnetostratigraphy is a geophysical correlation technique used to date sedimentary and volcanic sequences.
- ✓ The samples are analyzed to determine their characteristic remanent magnetizatio, that is, the polarity of Earth's magnetic field at the time a stratum was deposited.
- ✓ This is possible because volcanic flows acquire a thermoremanent magnetization and sediments acquire a depositional remanent magnetization, both of which reflect the direction of the Earth's field at the time of formation.
- ✓ This technique is typically used to date sequences that generally lack fossils or interbedded igneous rock.

Techniques

- Polarity Chron
- Sampling procedures
- Analytical procedures
- Correlation and ages

➢ Chemostratigraphy

- ✓ Global trends in isotope compositions, particularly carbon-13 and strontium isotopes, can be used to correlate strata.

➢ Correlation of marker horizons

- ✓ Marker horizons are stratigraphic units of the same age and of such distinctive composition and appearance, that despite their presence in different geographic sites, there is certainty about their age-equivalence.
- ✓ Fossil faunal and floral assemblages, both marine and terrestrial, make for distinctive marker horizons.

➢ Geological hierarchy of chronological periodization

Geochronology: From largest to smallest:

- Supereon
- Eon
- Era
- Period
- Epoch
- Age
- Chron

Thank You!