HIS6E01-PRINCIPLES AND METHODS OF ARCHAEOLOGY

MODULE-4 ABSOLUTE AND RELATIVE DATING

Prepared by
Priyanka.E.K
Dept of History
Little Flower College
Guruvayoor

- Archaeological scientists have two primary ways of telling the age of artefacts and the sites from which they came: relative dating and absolute dating.
- **Types of Dating**
- There are mainly two types of dating; **i) relative and ii) absolute or chronometric dating.**
- **Relative dating** fixes a time frame in relation to other strata or material and not in absolute dates in numbers.
- It can only define the antiquity in terms of older or younger than something else and makes it possible to arrange a series of things in proper chronological order.
- But it is difficult to know the total time span involved in the intervals between the things.
- On the other hand the **absolute dating** technique exhibit chronology in terms of years.
- It offers precise and accurate dating. There may be marginal errors which are almost negligible.

- Some of the common and widely applied **absolute dating** methods are Carbon-14, Potassium-Argon or K-A40, Thermoluminesence or TL. Dendrochronology etc.
- In the early stage of prehistoric studies there was only relative chronology. But in the last fifty years, with the emergence of C14 method there has been total change in dating scenario.
- Relative dating, however, is still applied in those areas where the deposits containing organic materials cannot be dated by any absolute dating techniques.
- Several disciplines like geology, physics, chemistry, botany, palaeontology contributed towards their development.

- These methods can be discussed under two categories, absolute and relative dating methods. A list of some of the absolute and relative methods are given below -
- **1. Relative Dating:**
- Stratigraphy
- Typology
- Cross dating
- Sequence dating
- Fluorine, uranium and nitrogen analysis
- Palaeontology- study of fossil remains of animals
- Palynology-pollen analysis

- **2. Absolute Dating**
- Carbon Dating
- Potassium- argon Dating
- Thermoluminescence
- Dendrochronology
- Electron Spin Resonance
- Fission Track Dating
- Palaemagnetic dating
- Obsidian hydration
- Varve analysis
- Amino Acid Racemaization.

- **Distinction between Relative and Absolute Dating:**
- In the early stage of prehistoric studies, dating of any event or site was obtained tentatively. A particular event or specimen is dated in relation to other event or some reference point.
- By relative methods one can know whether a particular culture is younger or older than another one, and thereby arrange a series of things in a sequential time frame.
- These methods were basically depending upon stratigraphic position of the site or kind of remains associated with the site. However, these methods have never been able to provide a date in terms of years, nor it can calculate the total time span involved in each cultural period.
- The relative chronology, in the words of Wheeler (1956), is "...the arrangement of the products of non-historic societies into a time relationship which may not have any dates but which has a sequence..."

- Unlike relative dating, absolute or chronometric dating is primarily sought to facilitate time sequence in terms of years. It provides the actual time spanned by a site
- These methods can provide chronological sequence of even geographically isolated events or culture. Thus, the rate of change differential development in separate areas, and the identification of the geographic sources of widespread cultural influences can be established with the help of different absolute dating.
- Absolute dating or chronometric dating usually demands high technology, laboratory and hence costly. It also demands the help of sciences like geophysics, geochemistry, astronomy, nuclear physics etc.

FISSION-TRACK DATING

- New technique of geoarchaeology
- Fission-track dating, method of age determination that makes use of the damage done by the spontaneous fission of uranium-238, the most abundant isotope of uranium
- The fission process results in the release of several hundred million electron volts of energy and produces a large amount of radiation damage before its energy is fully absorbed.
- The damage, or fission tracks, can be made visible by the preferential leaching (removal of material by solution) of the host substance with a suitable chemical reagent; the leaching process allows the etched fission-track pits to be viewed and counted under an ordinary optical microscope.
- The amount of uranium present can be determined by irradiation to produce thermal fission of uranium-235, which produces another population of tracks, these related to the uranium concentration of the mineral
- Thus, the ratio of naturally produced, spontaneous fission tracks to neutron-induced fission tracks is a measure of the age of the sample.

- A wide variety of minerals have been fission-track dated, as have natural and artificial glasses. Fission-track dating has been used for very old samples (*e.g.*, meteorites i.e. piece of rock or metals)) and also for the dating of very young specimens (*e.g.*, artifacts from archaeological sites).
- Some volcanic minerals and glasses, such as obsidian(vollcanic rock), contain uranium-238 (^{238}U).
- Over time, these substances become "scratched." The marks, called tracks, are the damage caused by the fission (splitting) of the uranium atoms.
- When an atom of ^{238}U splits, two "daughter" atoms rocket away from each other, leaving in their wake tracks in the material in which they are embedded.
- The rate at which this process occurs is proportional to the decay rate of ^{238}U. The decay rate is measured in terms of the half-life (time required for a quantity to reduce to half its initial value) of the element, or the time it takes for half of the element to split into its daughter atoms.

Electron Spin Resonance (ESR)

- In the last 20 years, the Electron Spin Resonance (ESR) dating method has allowed the establishment of a chronological time frame over most of the history of human evolution.
- Despite many difficulties found for ESR dating of bones and carbonates, tooth enamel dated by Electron Spin Resonance (ESR) has been proven as a reliable method in its application to fossil teeth and quartz.
- Both of the latter materials have allowed dating of Early and Middle Pleistocene sites which are not datable using other methods.
- In particular, recent discoveries of human remains in Western Europe have been proposed to be sites of the earliest arrival of humans there, and have been dated to the Early Pleistocene by Electron Spin Resonance (ESR) using quartz and tooth enamel.
- Electron Spin Resonance (ESR) method can be applied to different types of samples in various environments; its contribution to the elaboration of a chronostratigraphic(stratigraphichy that studies the age of rock strata) frame is of a great importance for the understanding of the Homo erectus dispersals out of Africa and especially for the first settlements in Europe.
- Electron Spin Resonance (ESR) dates ranging between 1.7 and 2.3 Ma have been proposed for the South African sites Sterkfontein and Swartzkrans, indicating that the whole Quaternary period can be dated.

VARVE ANALYSIS

- Varve analysis, one of the oldest dating methods which demonstrate seasonal variation and also reflect the climatic conditions of ancient time
- Evolved by Gerard De Geer
- Depends on the waters thaat flow down from the glaciated areas
- The word varve in Swedish means annual layers of sediments deposited at the bottom of the lakes by the runoff from melting glacial ice.
- The method is based on the relative thickness of the varves and their comparison to the new sections as in tree ring analysis.
- Formation of varves depends on climatic variation.
- In summer when ice melts coarse sediments deposits at the bottom and in winter when the lake is frozen, the finer sediments deposit at the top.
- It is possible to measure the relative thickness of the varves and obtain a series to which one can compare and correlate new sections as they are discovered.

- The application of varve dating is restricted by several factors.
- First, it is because varve accumulation occurs only to glacial areas of the world.
- Second, many of the Pleistocene glacial areas has receded nowadays and affecting the supply of sediments. Therefore outside Scandinavia it is difficult to find continuous sequence of varves reaching the present. The longest sequence known goes back only 17,000 years.
- Third, the varves may form frequently rather than annually depending on the pattern of the melting.
- However, instead of the limitations, varve analysis can be used indirectly for archaeological dating.
- It has been used in Baltic area, North America, South America and Africa.
- In North America, Ernst Antevs has made several attempts to relate Pleistocene geological formations in the American Southwest to events that produced varves in the northern parts of North America.

Amino Acid Racemisation Technique

- Amino Acid Racemisation, a method of absolute dating applied to human fossils is developed very recently.
- This is based on the fact that all living organisms have L-amino acid in their protein and after death, and over a long period of time all the L-amino acids except glycine undergo change called racemisation and became non protein D-amino acid.
- The proportion of these D-amino acids increases with time.
- Thus the age of the skeletal materials that are found in archaeological sites can be estimated by determining the amount of change, racemisation that has occurred.
- Amino Acid Racemisation (AAR) is a useful comparative dating method with great potential, but it introduces problems of calibration and the requirement of an intimate knowledge of the palaeo-environmental conditions of the bone deposition site.

- Amino acid racimization is based on the principle that amino acids (except glycine, a very simple amino acid) exist in two mirror image forms called stereoisomers.
- Living organisms (with the exception of some microbes) synthesize and incorporate only the L-form into proteins.
- This means that the ratio of the D-form to the L-form is zero (D/L=0).
- When these organisms die, the L-amino acids are slowly converted into D-amino acids in a process called racimization.
- This occurs because protons (H^+) are removed from the amino acids by acids or bases present in the burial environment.
- The protons are quickly replaced, but will return to either side of the amino acid, not necessarily to the side from which they came. This may form a D-amino acid instead of an L–amino acid. The reversible reaction eventually creates equal amounts of L–and D-forms (D/L=1.0).

- The rate at which the reaction occurs is different for each amino acid; in addition, it depends upon the moisture, **temperature** , and **pH** of the postmortem conditions.
- The higher the temperature, the faster the reaction occurs, so the cooler the burial environment, the greater the dating range.
- The burial conditions are not always known, however, and can be difficult to estimate.
- For this reason, and because some of the amino acid racimization dates have disagreed with dates achieved by other methods, the technique is no longer widely used.

OBSIDIAN HYDRATION

- **Obsidian hydration dating** (OHD) is a geochemical method of determining age of an artifact made of obsidian.
- Obsidian, or volcanic glass, is formed by the rapid cooling of silica-rich lava.
- Obsidian is a volcanic glass that was used by prehistoric people as a raw material in the manufacture of stone tools such as points, knives, or other cutting tools through knapping, or breaking off pieces in a controlled manner.
- In 1948, two geologists, Irving Friedman and Robert Smith, began looking into obsidian's potential as a time marker.

- They introduced the obsidian hydration dating method to the archaeological community in 1960.
- It may be used in two ways: as a relative dating method to determine if one artifact is older or younger than another, or as an absolute dating method where a calendar date (AD/BC) is produced.
- The decision to use it as a relative or absolute dating method depends upon whether the environmental conditions (eg. soil temperature and soil relative humidity) of the archaeological site are known.
- Obsidian hydration dating is based on the fact that a fresh surface is created on a piece of obsidian in the tool manufacturing, or flint knapping, process.
- Obsidian contains about 0.2 percent water.

- When a piece of obsidian is fractured, atmospheric water is attracted to the surface and begins to diffuse into the glass.
- This results in the formation of a water rich hydration rind that increases in depth with time.
- The hydration process continues until the fresh obsidian surface contains about 3.5 percent water. This is the saturation point.
- The thickness of the hydration rind can be identified in petrographic thin sections cut normal to the surface and observed under a microscope.
- A distinct diffusion front can be recognized by an abrupt change in refractive index at the inner edge of the hydration rind.

- These fronts or rinds of hydration are denser than the un-hydrated inside, and the un-hydrated zone has different optical properties.
- Friedman and Smith reasoned that the degree of hydration observed on an obsidian artifact could tell archaeologists how long it had been since that surface was created by a flint knapper.
- Three steps are required to determine a calendar date from an obsidian artifact. These are the determination of: 1) the hydration rate, 2) the thickness of the hydration rim, and 3) the soil temperature and soil relative humidity at the archaeological site.

- **The Limitations of Obsidian Hydration Dating**
- The rate of hydration is not uniform throughout the world. Variations exist in temperature over time from site to site. Temperature effects are particularly difficult to evaluate. Variations also exist in sample chemical composition. Samples from different obsidian sources hydrate at different rates. Moisture is another source of variability. The amount of moisture present at a site can affect the hydration rate of an obsidian sample.
- Artifact reuse may lead to an erroneous date. For example, one person fashions a tool out of an obsidian nodule and uses it to skin a deer. Once that person finishes using the tool, it is discarded. Several hundred years later, a second person finds the tool, re sharpens it, uses it to shave the bark off of a tree branch, and then later discards it as well.

- Several thousand years later, an archaeologist discovers the tool and takes it to a laboratory to be dated. The archaeologist found the tool at a site that was an arrowshaft workshop. However, instead of dating the surface on the tool that was used to shave bark, the surface that was used to skin the deer several hundred years earlier is dated. The archaeologist, would be lead to believe by this erroneous date that arrow production started several hundred years earlier than what was expected.

RELATIVE DATING

- Dating methods, such as radiocarbon dating, dendro-chronology or tree-ring dating, and potassium-argon dating, that may furnish an absolute date for an archaeological site, are a contribution of the physical and the natural sciences.
- But absolute dating methods are not always useful; the particular circumstances to which they apply do not exist at every site.
- In such cases, archaeologists may employ relative dating techniques. Relative dating places assemblages of artifacts in time, in relation to [artifact] types similar in form and function.

- **I. Stratigraphy or the Law of Superposition**
- Stratigraphy can be described as a "layer cake" type arrangement of deposits called strata, with the older layer beneath the latest.
- Stratigraphy is the study of layers of rocks or the objects embedded within those layers.
- It is based on the assumption that deeper layers were deposited earlier, and thus are older than more shallow layers.
- The sequential layers of **rock** represent sequential intervals of time.
- Although these units may be sequential, they are not necessarily continuous due to erosional removal of some intervening units.
- The smallest of these rock units that can be matched to a specific time interval is called a bed.
- Beds that are related are grouped together into members, and members are grouped into formations.

- This technique helps the archaeologist arrange the site in a vertical temporal sequence, which may then be compared to sites of similar age or type.
- For example a pile of newspapers that have been stacked every day for a week. The oldest newspaper will be on the bottom, the remainder stacked in relative chronological order from the oldest to the latest edition. This is the concept of stratigraphy--or the Law of Superposition.
- Stratigraphic sequences in the field, however, are sometimes unreliable.
- Suppose the inhabitants of a previous site dug a large hole. The top of the heap of excavated dirt would date the oldest.
- Or perhaps a burrowing animal tunneled down through a site, causing artifacts buried above to fall to lower levels.

- Natural processes like frost heaving, erosion, and the down-slope movement of soils in colder climates (solifluction) can alter the original context in which the artifacts were deposited.
- Stratigraphic levels can be horizontal as well as vertical.
- On beaches, where the configuration of the shoreline has changed through time, the earliest site may be inland, the later site closest to shore.
- The stratigraphic levels would then be spatially horizontal, conforming to the changing coastline.
- Horizontal stratigraphy may also occur when a later culture settles next to an earlier abandoned site, thereby appearing to be contemporary to the older site.
- Despite problems of interpretation, stratigraphy is a powerful archaeological tool in unlocking the mysteries of past lifeways.

- **II. Seriation**
- When a stratigraphic sequence is lacking, another relative dating technique known as seriation may be applied.
- This technique dates a site based on the relative frequency of types of artifacts whose dates of use or manufacture are known.
- The basic assumption underlying seriation is that the popularity of culturally produced items varies through time, with a frequency pattern that has been called the "battleship curve."
- An item is introduced, it grows in popularity, then its use begins to wane as it is replaced by another form.
- Certain types of artifacts have been identified as particularly useful temporal markers, for example, gravestones, projectile points, lamps, pottery sherds.
- Before being able to interpret materials found at a site, an archaeologist faces the task of sorting the artifacts into manageable units for analysis.
- This is frequently a difficult task. Sorting is usually based on form and function. What does it look like? What is it made of? Is it decorated in any way? Have you ever seen it before?

- Seriation is the ordering of objects according to their age. It is a relative dating method.
- In a landmark study, archaeologist James Ford used seriation to determine the chronological order of American Indian pottery styles in the Mississippi Valley.
- Artifact styles such as pottery types are seriated by analyzing their abundances through time.
- This is done by counting the number of pieces of each style of the artifact in each stratigraphic layer and then graphing the data.
- A layer with many pieces of a particular style will be represented by a wide band on the graph, and a layer with only a few pieces will be represented by a narrow band.
- The bands are arranged into battleship-shaped curves, with each style getting its own curve. The curves are then compared with one another, and from this the relative ages of the styles are determined.
- A limitation to this method is that it assumes all differences in artifact styles are the result of different periods of time, and are not due to the immigration of new cultures into the **area** of study.

URANIUM SERIES DATING

- Uranium-series dating is based on measurement of the radioactivity of short-lived daughter isotopes of uranium formed in samples which initially contained only the parent uranium.
- Materials suitable for U-series dating are found in many prehistoric archaeological sites, and include stalagmitic layers (flowstones), and spring-deposited travertines(limestone deposited by mineral springs). Some marls(lime rich mud) and calcretes(lime stone formed by cementation of soil) are also datable using isochron methods, whereas dates on molluscan shells, bones and teeth are less reliable.

- Uranium series dating techniques rely on the fact that radioactive uranium and thorium isotopes decay into a series of unstable, radioactive "daughter" isotopes; this process continues until a stable (non-radioactive) **lead** isotope is formed.
- The daughters have relatively short half-lives ranging from a few hundred thousand years down to only a few years.
- The "parent" isotopes have half-lives of several billion years.
- This provides a dating range for the different uranium series of a few thousand years to 500,000 years.
- Uranium series have been used to date uranium-rich rocks, deep-sea sediments, shells, bones, and teeth, and to calculate the ages of ancient lakebeds.
- The two types of uranium series dating techniques are daughter deficiency methods and daughter excess methods.

- In daughter deficiency situations, the parent radioisotope is initially deposited by itself, without its daughter (the isotope into which it decays) present.
- Through time, the parent decays to the daughter until the two are in equilibrium (equal amounts of each).
- The age of the deposit may be determined by measuring how much of the daughter has formed, providing that neither isotope has entered or exited the deposit after its initial formation.
- Carbonates may be dated this way using, for example, the daughter/parent isotope pair protactinium-231/uranium-235 ($^{231}Pa/^{235}U$).
- Living mollusks and corals will only take up dissolved compounds such as isotopes of uranium, so they will contain no protactinium, which is insoluble.
- Protactinium-231 begins to accumulate via the decay of ^{235}U after the organism dies.
- Scientists can determine the age of the sample by measuring how much ^{231}Pa is present and calculating how long it would have taken that amount to form

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