METHODS OF DATING IN ARCHAEOLOGY

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Abstract
This study presented an in-depth discussion on methods of dating in Archaeology. Dating methods are approaches used by archaeologists to analysethe age of artefacts, features and sites, so as to place them in appropriate historical/temporal context in relation to other finds in the archaeological record. In this way, dating is invaluable in explaining howhuman beings and the universe have evolved through time. Critical analysis of literature was employed as a data collection technique. This has to do with a critical evaluation of studies on a subject matter. The study highlights the importance of chronology to archaeological studiesand identified two categories of dating: relative and absolute dating. Relative dating (historical chronology) is used to ascertain how old an object or site is in relation to others, but cannot be used to state the exact age. Conversely, absolute dating pinpoints the specific number of yearsan objecthas lasted. Techniques involved in relative dating include seriation, typology, stratigraphical succession and synchronism while examples of absolute dating techniquesare potassium-argon,dendrochronology, archaeomagnetism, radio-carbon dating, and thermoluminescence.

Keywords: *Archaeology, chronology, dating methods, relative and absolute dating*

Introduction

Archaeology is an eclectic discipline, which engages in the systematic study of past human societies through the remains of their material culture uncovered majorly by excavation. Investigations in Archaeology cannot be tenable if the chronological sequence of events andartefacts are not established. Green (2002 p.140) remarked that "dating the past has been a central issue in archaeology throughout its development, and remains fundamentally important".Consequently, the dating of archaeological finds (assigning chronological values to past events, sites and artefacts) has become an indispensable feature in the practice of Archaeology. Dating is vital to the discipline of Archaeology because it helps in constructing models of the past and in the placement of archaeological materialsproperly in relation to one another.This is to say that dating assists archaeologists to establish areliable sequence of artefacts, cultures and sites.

This paper presents a comprehensive discussion of dating in Archaeology, using literature analysis as a data-gathering technique. Among other things, the paper discussed the centrality of datingto the practice of Archaeology. The study discussed at length, twomain types of dating (relative and absolute), together with their various dating techniques, such as radiocarbon and potassium-argon dating techniques for absolute dating; seriation and typology for relative dating.The demerits of relative and absolute dating cannot be overlooked; thus, they were equally considered in the discourse.

Establishing Chronological Structure in Archaeology

Chronology is a major aspect of the archaeological process and a key issue to further inferences about actual and potential influence, between people and the understanding of the evolution of cultures (Doerr, Plexousakis, Kopaka and Bekiari, 2005).Facts or shreds of evidenceused to establish a sequence (chronology) of events and artefacts could be derived internally or externally. According to Harding in Graeme (Ed.) (1999 p.188), internal evidence is derived directly from the archaeological material, for example, its form, appearance, historical content (such as inscription), or its physical and chemical properties. External evidence, on the other hand, is derived from its context, its find-spot and position, its relationship to other material, or its relationship to known outside events.

Under the heading of internal evidence, it is possible to distinguish between typological evidence, which considers the form and appearance of an artefact, in whole or in part; direct historical evidence, where, for instance, an aspect of an artefact can be related directly to known historical events (for instance the head of an emperor on a coin, or an inscription on a building or tombstone); or physical evidence, such as the carbon-14 content of an object, or its luminescence properties (Harding in Graeme (Ed.) (1999 p.190)).

External evidence includes first and foremost positional evidence, referring to the context in which an object occurred-whether in a given stratigraphic layer, on a particular site, in a region or even a country (Harding in Graeme Ed. 1999 p.190). Positional evidence is heavily dependent on taphonomy, while depositional and post-depositional transformations critically affect its validity (Harding in Graeme Ed. 1999 p.190).

In all, archaeologists establish chronological sequence through the process known as dating. Dating refers to the determination of the age of archaeological materials, e.g.,artefact/biofact, sites and culturallandscapes. The two fundamental types of dating methods - relative and absolute are discussed below.

Relative Dating

Following the lead by O ‘Brien and Lyman (1999 p.v), contemporary students of Archeology may wonder how archaeologists who researched before the advent of chronometric or absolute dating methods (e.g., radiocarbon dating) were able to determine the ages of archaeological materials and place them in proper sequence. Well, relative dating is the answer. Also known as “Historical Chronology”, relative dating methods are mainly non-scientific dating methods, which were relied on prior to the introduction of scientific methods of dating, otherwise known as absolute dating. In the view of Gagne (2013), relative dating includes methods that rely on the analysis of comparative data or the context (e.g., geological, regional, cultural) in which the object one wishes to date is found. In the view of Harding in Graeme (1999 p.190),

> *Relative chronologies place archaeological phenomena, and by implication events, in a particular relationship to each other: that is, before, contemporary with, or after. In some cases, such as stratigraphic succession, indications of priority or posteriority are all that can be determined, but with some classes of evidence, terminus dates are obtained (terminus meaning the end-point, the position beyond which an event cannot go). There are two sorts of terminus date: the terminus ante quem and the terminus post quem. A terminus ante quem is a point before which something must be placed, or something occurred. If, for instance, a site is known to have been abandoned at a particular date and not reoccupied (such as Pompeii in AD 79), then all the material on that site must date prior to the abandonment, even if only by a few days. A terminus post quem, by contrast, represents a point after which an event must have occurred. Coins,*

> *and coin hoards in particular, are good examples of this: coins can remain in circulation for considerable lengths of time, and the finding of a coin in a given layer only tells us that the layer was laid down after the minting of the coin, but not by how much.*

In all, relative dating assists archaeologists to situate events and artefacts in chronological order; however, it lacks the capacity to give thedefinite age of archaeological resources in terms of years. This is to say that the main demerit of relative dating is that it cannot provide an accurate year or a specific date of use; thus, it lacks precision.

Methods of Relative Dating

- **Stratigraphic Analysis**

Stratigraphy is an aspect of geology which deals with the study of strata or rock layers and layering also known as stratification. It is concerned with examining the formation, composition,sequence and correlation of stratified rocks(Miller, et al.2018). In the context of Archaeology, stratigraphy refers to a section cut vertically through the earth showing its different layers and allowing artefacts to be dated according to the layers in which they are found (Microsoft Encarta Dictionary, 2009).

The fundamental principle of stratigraphic analysis in archaeology is that of superimposition, i.e.action of placing or laying one thing over another. This suggests that, in a series of undisturbed soil, upper horizons are newer than lower horizons (see for example,Peppe and Deino, 2013). Thus, in the context of archaeology, this would mean that older artefacts are usually found below younger artefacts. Archaeologists are basically interested in stratigraphy in order to establish cultural sequences and chronological frameworks which form the bases for the reconstruction of human behaviour in relation to his environment through time (Andah&Okpoko 1994 p.110).

A key example of stratigraphy is varve analysis. A varve refers to sediment (e.g., banded layers of sand and silt) deposited in still water, especially close to ice sheets onan annual basis. By dividing the rate of sedimentation in terms of units per year by the number of units deposited following a geologic event, an archaeologist or geologist can roughly establish the age of an event in years (Lamoureux, 2009). The counting and correlation of varveshavebeen used to measure the age of Pleistocene glacial deposits by way of the strata annually deposited in lakes by retreating glaciers (Lamoureux, 2009). Another example of stratigraphy, as noted by (Lamoureux, 2009), is biostratigraphy. Lamoureux remarks that chronological information may be conveyed by the presence, absence and form of the bones from one or more animal groups, which were known to have fixed periods of existence, found in a stratum at an archaeological site. This technique is central to paleoanthropology and the development of voles was crucial to the dating of the English Lower Paleolithic site of Boxgrove, he concluded.

However, a major weakness of dating by stratigraphic analysis is that one cannot be certain that the soil of an excavated site has not been disturbed. Thus, merely concluding that cultural material is olderbecause it was retrieved from a lower stratum may not always be the case. Natural and anthropogenic forces have always shaped and reshaped landscapes, thus, an archaeological site can be reshaped by these forces resulting in the placement of what is younger beneath an older oneas in reversed stratification (see, for example, Grahame, 2020).

Since stratigraphy is not an approach to absolute dating, the best it can do for archaeologists is to help them determine *terminus post quem* (TPQ) dates, which establishes the earliest probable date of a sediment, and *terminus ante quem* (TAQ) dates, which assists in providing the most recentprobable date for sediment.

- **Typology**

Typology is the study or systematic classification of types (Microsoft Encarta Dictionary, 2009). According to Gagne (2013), typology is a method that compares reference objects in order to classify them according to their similarity or dissimilarity and link them to a specific context or period. Generally, as stated by Gagne, this technique allows archaeologists to identify the period to which a cultural site or object belongs, without specifying the date of occupation. This relative dating method is mainly applied to projectile points and ceramic vessels because the items possess features for comparison, such as morphology and raw materials as in stone tools, and decorative techniques and motifs as in earthenware (Gagne 2013).

Typology,as a dating technique, can be applied to various categories of artefacts, so long as it bearssufficient variation for differences among artefacts under study.In the use of typology as a dating technique, attention is not placed only on the shape of artefacts, but also on properties of the raw materials e.g., chemical characteristics, hardness, the technology with which the artefact was produced, as well as the context in which the material culture was found. Typology acquires an added importance when it can be combined with the techniques collectively called seriation, since by this means; groups of individual typologies can be used together (Cowgill 1972; Marquardt 1978).

- **Seriation**

Seriation entails the use of style and frequency as the basis for sorting and classifying artefacts within the same culture to establish relative chronology. A main assumption in seriation is that in most conditions, alteration in culture and style follow gradual processes, consequently, similar assemblages ought to be closer in sequence and in age than assemblages that are less similar to one another (Rowe, 1961).

The use of seriation in the discipline of Archaeology is credited to English Egyptologist, Sir William Flinders Petrie (1853 – 1942), who carried out excavations in various Predynastic Egyptian cemeteries. Flinders Petrie conceived the concept of seriation in his attempts to deal with large quantities of pottery and other cultural materials found in Egyptian tombs of the prehistoric periods at sites such as Nagada and Abydos (Petrie 1901, curled from Harding in Graeme (Ed.) 1999)). Petrie wrote the contents of every grave on a narrow piece of cardboard and swapped the papers until he arrived at a satisfactory sequence. From this, he concluded that the most precise sequence was the one where concentrations of certain design styles had the shortest duration across the sequence of papers (Renfrew and Bahn 1996; Shennan 1997).

There are two variants of seriation, namely contextual and frequency seriation (Renfrew and Bahn 1996, Pp. 116–117). Contextual seriation is determined by the presence or absence of a design style, while frequency seriation is determined by measuring the frequency/proportional abundance of a design style. As reported by Harding in Graeme (Ed.) (1999), a typical example demonstrating the strength of the seriation method is the work of Hodson on the Hallstatt cemetery in Austria (Hodson, 1990) and the Münsingen-Rain cemetery in Switzerland (Hodson, 1968); in both cases, a good overall sequence for the material was arrived at by judicious use of seriation, including the definition of 'horizons', and by an analysis of the horizontal stratigraphy of the cemeteries.

Other relative dating methods may include faunal and pollen dating. Faunal dating refers to the use of animal bones to establish the relative age of sedimentary layers or cultural materials embedded within those layers. Pollen dating has to do with the analysis of pollen grains released by seed-bearing plants on a yearly basis.

Absolute Dating

Absolute dating is the assignment of numeric age to objects, sites or events. It is the process of ascertaining the number of years (calendar years) an item, for instance, has existed or survived. Green (2002 p.141) traces the emergence of absolute dating to two disciplines of human knowledge. First are the environmental sciences, which, in the twentieth century, initiatedthe counting of yearly layers of lake sediments or tree rings from the present into the past. Second is the discipline of nuclear physics which started providing radiometric dates for the age of the earth andthe succession of geological ages.

There are absolute dating techniques grouped under radiometric dating (see Cohen 2003, p.403), because they all depend on radioactivity. Radioactivity, also known as radioactive decay or nuclear disintegration, is the process by which an unstable atomic nucleus loses energy by emitting radiation (Helmenstine, 2019).It is, in essence, an attribute of individual atomic nuclei (Rasmussen and Steinberg, 2020). The most common forms of radioactivity are the alpha (α) particle, the beta (β) particle, and the gamma (γ) rays (see Ridha, 2016). The more popular techniques for radioactive dating are radiocarbon dating, potassium-argon dating and uranium-lead dating.

- **Radiocarbon Dating**

Radiocarbon dating is a method of age determination that depends on the radioactive decay of carbon-14 (Tavolacci, 2005 p.1310). This method of dating could be traced to the pioneering work of an American chemist, Willard Libby (1908–1980), who recognized that carbon-14 decay could be useful in dating. In carbon, there are two stablenaturally-occurring isotopes: carbon-12 (^{12}C) and carbon-13 (^{13}C), and one isotope, carbon-14 (^{14}C), which is unstable, thus, radioactive. The amount of ^{14}C in living organisms is roughlyunvaryingbut decreases predictably to its half-life after death.Half-life is “the time [about 5,730 years] required for half of a quantity of radioactive material to decay away” (Macdougall 2008 p.253).It is this half-life phenomenon that makes it possible to date the age of substances that contain carbon, such as organic materials.

Radiocarbon dating proceeds by measuring the radioactivity of a sample from a dead animal or plant, and calculating the time that has elapsed since its death from the amount of ^{14}C that remains (Green 2002 p.161, also see Andah& Okpoko 1994 Pp.188-189). Harding in Graeme (1999 p.207) opines that depending on the quality of context and suitability of samples, it is possible to obtain results that are fully satisfactory in terms of precision and accuracy for many periods of the past. Today, Radio-carbon dating appears to be the most widespread of all scientific dating techniques in use in that it occupies a prestigious position among scientific dating methods.Falola (2002) remarks that radiocarbon dating (carbon-14) has made it possible to provide an approximate age for a variety of organic materials, such as charcoal and bones that are as much as 50,000 years old.

However, this is not to say that the radiocarbon method of dating does not have shortcomings. One glaring demerit is that the radiocarbon dating technique is that it cannot be used to date specimen earlier than 62,000 years ago, suggesting that the method may not be suitable for dating fossils, such as those of the extinct dinosaurs. Another demerit is the large amount of material required for analysis. Once it has been reduced to its carbon-containing compounds, the material must contain enough carbon for the ^{14}C activity to be measurable with a Geiger counter at least over a few days (Tavolacci 2005 p.1311). Despite theseshortcomings, radiocarbon dating has transformed the discipline of archaeology by triggering more innovativeand scientific approaches to practisingarchaeology.

Examples of radiocarbon dating laboratories in the world includethe Centre for Isotope Research (CIO), which conducts radiocarbon-based research located atGroningen University, Netherlands; The Rafter Radiocarbon Laboratory in Gracefield, Newzealand; The InstitutFrançaisd'Archéologie Orientale (IFAO) in Cairo, Egypt; The Beta Analytic radiocarbon dating laboratory in Miami, USA; The radiocarbon dating laboratory in Lund University (southern Sweden). This laboratory performs dating on geological and archaeological samples of materials such as wood, charcoal, peat, macrofossils, bone (including cremated bones) and marine shells. The Waikato Radiocarbon Dating Laboratory in Hamilton, Newzealand, undertakes both Accelerator Mass Spectrometry Dating (AMS) and standard radiometric radiocarbon dating.

Figure 1: A Section of The Beta Analytic radio carbon dating laboratory in Miami, USA. Source:https://www.radiocarbon.com/beta-analytic.htm

- **Potassium-Argon Dating**

Potassium (K) is an element that occurs in an abundant quantity in the earth's crust. In its natural form, potassium contains an isotope, ^{40}K, which is radioactive**.** Potassium argon (K/Ar) dating is based on the known rate of decay of an unstable isotope of the element - potassium into the gas - argon (Deino, Renne& Swisher 1998). When lava comes out of a volcano, any argon that had previously accumulated in the rock is released into the atmosphere, essentially setting the natural clock in the lava to time zero. When the lava solidifies, argon begins accumulating as the unstable potassium atoms decay, getting trapped in the now-solid rock (Feder, 2004 Pp.140-141). The age of the rock itself can be determined by measuring the amount of argon that has built up and calculating the length of time it would have taken for that amount to accumulate based on the half-life of radioactive potassium, which has been measured at 1.25 billion years (Feder 2004 p.141).

According to Murray (2007 p.436), Potassium-argon dating was a crucial development in improving our understanding of the archaeology of Africa; it was applied in the early 1960s to date the rocks in which the fossilized bones of *Australopithecines* were found. The massive expansion in the chronology of human ancestors (the early dates added at least another million years to human history) profoundly changed the terms under which the human story could now be told.

- **Uranium-Lead Dating**

Uranium (U) is a radioactive chemical element of the actinoid series of the periodic table, with atomic number 92 (Lester, 2020). Lead is also a chemical element which belongs to the carbon group with the symbol 'Pb', derived from the Latin word - *plumbum.* Being radioactive, uranium decays very slowly to lead, meaning that ancient zircon crystals (zircon is a mineral, a source of the metal zirconium) contain lead (Pb) that has come from the decay of uranium (Ian, 2018 p.136).

The rate at which uranium decays to lead can be measured accurately using pure uranium compounds and an instrument like a Geiger counter, which can detect the tiny pulse of energy released as each U atom decays (Ian, 2018 p.136). Also, the minuscule amount of uranium and the even smaller amount of lead in a zircon crystal can be measured precisely with the help of an instrument called a mass spectrometer (Ian, 2018 p.136). So, by knowing the amount of uranium still present in a zircon crystal, the amount of lead that has built up there, and also knowing the rate at which uranium changes to lead, it is possible to calculate the time that has elapsed since there was no lead in the zircon crystal; this is the crystal's age (Ian, 2018 p.136).

One problem that may be encountered when applying uranium dating methods is that, as rocks are heated during deep burial, lead may be partially or even completely get lost from the minerals holding it. A means of evaluating the problem of lead loss is to compare the apparent ages from ^{238}U and ^{235}U (Mathez&Webster, 2004 p.34).

- **Thermoluminescence**

In the view of Andah and Okpoko (1994 p.191), "Thermoluminescence (TL) is a dating method that is associated with the effects of high energy radiation, that is, alpha, beta and gamma rays emitted as a result of the decay of radioactive impurities in pottery". TL was first observed in 1663 by the English chemist, Sir Robert Boyle, who reported on the remarkable glowing properties of a large diamond to the Royal Society (Murrah, 2007 p.473). Common artefacts that can be dated using thermoluminescence include flint stone tools, pottery, burned stones, and earth ovens.

The following explains how the thermoluminescence dating technique works as summarized byFeder (2004). The background radiation in the soil surrounding, for example, a buried ceramic or stone object produces energy that becomes stored in the atomic structure of the object. When the archaeological object is recovered, the energy that has accumulated as a result of the background radiation can be released, through the application of heat (thermoluminescence) or laser light (optically stimulated luminescence), and then measured (Feder, 2004 p.142). knowing the rate of energy accumulation in an archaeological object once it ended up in the soil, and then knowing how much energy has actually accumulated, allows for a calculation of how long the object has been accumulating the energy; in other words, how old it is (Feder, 2004 p.142). For details about the procedures from a laboratory that conducts TL analysis (http://www.users.globalnet.co.uk/~qtls).

- **Dendrochronology**

Dendrochronology or tree-ring science is the technique of dating events and archaeological materials using the characteristic patterns of annual growth rings in tree trunks.Feder (2004) defines dendrochronology as the actual study of tree rings to determine the nature of past climates and as a dating method. In dendrochronology, the age of the wood can be determined bycounting the number of annual rings in its cross-section.

Dendrochronology was initiated by Douglass, A.E.in the first two decades of the twentieth century. According to Murray (2007), Douglass's interest in the effect of sunspots on the earth's weather led him to investigate the annual growth layers of Arizona pine trees to ascertain if there were any variations in tree-ring width. He discovered a relationship between rainfall and tree growth and between cyclical variations in tree growth and sunspot cycles. Looking for extensive tree-ring records to help to substantiate his theories, Douglass asked archaeologists in Tucson for pieces of wood from the ruins of a Southwestern pueblo. Within a decade, Douglass was able to date some of these wooden remains back to AD 100 and others to AD 700. He went on to develop the study of tree rings into the science of dendrochronology or tree-ring dating (see Murray, 2007 p.394).

Dating using the technique of dendrochronology stems from the fact that there is no repeating pattern of rainfall variation and, therefore, no chronological sequence of ring width sizes that repeat across time (Feder, 2004 p.148). In other words, any sufficiently long period of years has a unique sequence of rainfall amounts that is never repeated.Consequently, any sufficiently long sequence of tree-ring widths also is unique and never repeated (Feder, 2004:148). This unique sequence, according to Feder (2004), is what makes dendrochronology a viable and highly accurate dating method. For further readings on this, see McGraw (2001), and Nash (1999).

As noted by Green (2002 p.157), one problem with the tree-ring dating technique is that not all species of trees are sufficiently susceptible to display distinctive variations in their ring characteristics. Secondly, wood survives only under exceptionally wet or dry conditions, and large timbers must be recovered to provide sufficient rings for valid comparisons; this is a herculean task. Despite these problems, tree ring dating appears to be the sole medium of providing absolute dates on annual basis. However, it is necessary to bear in mind that dendrochronology cannot have a universal application owing to regional and environmental disparities in the growth of trees.

- **Archaeomagnetic Dating**

Archaeomagnetic dating is a method for dating fired materials and sediments from archaeological sites, based on their preserved magnetic remanence (Batt, 2013). Based on the principle of archaeomagnetism, materials heated to high temperatures, acquire a remanent magnetisation with a direction parallel to, and intensity proportional to the ambient Earth magnetic field at the time of cooling (Hus, Geeraerts &Spassov 2003). Measurement of this remanence allows the determination of this direction and intensity of the Earth's magnetic field at the moment of cooling.Conversely, knowledge of the past variations of the Earth's magnetic field allows the dating of the last heating of the baked and burned materials, called archaeomagnetic dating (Hus, Geeraerts &Spassov 2003). Other dating methods not discussed in this paper include fluorine dating for fossil bones and teeth (Pyddoke, 1963 p.112), fission track, paleomagnetic dating, etc.

Conclusion

In this discourse, we have seen that chronology is very germane to the discipline of archaeology, which focuses on the study of how human cultures have evolved over time. Since archaeological materials require dating so as to place them in appropriate sequence in relation to one another, it became imperative to devise means of dating, hence, relative and absolute dating methods were formulated. Relative dating techniques include seriation, typology, stratigraphical succession, and synchronism; while absolute dating techniques include, potassium-argon, dendrochronology, archaeomagnetism, radio-carbon datingand thermoluminescence.

Though relative dating cannot provide an accurate year, or a specific date of use, it is still very relevant in contemporary archaeology, especially in regions where absolute dating is still not tenable. Archaeological dating has been bolstered by advances in scientific techniques, such as those mentioned under the sub-section titled 'absolute dating techniques. As noted by Green(2002), scientific dating techniques add accuracy and allow interpretation to move beyond simple hypotheses about the chronological relationships between sites, regional cultures or forms of artefacts.

As archaeology continues to make attempts at reconstructing the history of man, dating techniques will continue to be very relevant to the discipline. Concerted efforts are, therefore, needed to improve the effectiveness of the dating techniques for a deeper understanding of the evolution of human cultures.

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