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Research Article

APPLICATION OF DATING TECHNIQUES IN ARCHAEOLOGICAL SCIENCES: AN OVERVIEW

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ABSTRACT

Archaeological dating has under gone rapid development through the advance scientific methodology in the field of Archaeological science research. Fifty one studies of advance dating methods have been reported. The present study intend to report about the dating techniques with the application in Archaeological studies such as dating of pottery, ceramics, quartz, glass, zircon, human bones and metal. This paper also emphasis the recent requirements of archaeological scientist for the dating of archaeological samples and will benefit to the new researcher of Archaeological Sciences.

INTRODUCTION

Archaeologists are the world's greatest jigsaw puzzlers piecing together tiny fragments to create a coherent picture of the past (Simon, 2007). Dating is the process of attributing to an object or event a date in the past, allowing such object or event to be located in a previously established chronology. This usually requires what is commonly known as a "dating method". (https://en.wikipedia.org/wiki/Chronological_dating). Many Buildings of historical interest were developed in various construction stages over the centuries. In carrying out restoration on them as well as in studying the evaluation of the site, it is often necessary to determine the chronology of the different periods of construction and thus, some restoration teams include historians as well as architects. (Vendrell Saz, 1996). In recent years many research papers have discussed and demonstrated, the importance of combining appropriate scientific methodologies to provide experimental data which can supports Archaeologist hypothesis regarding both the age and province of artifacts and the technologies with trade routes used in their manufacture and distribution (Bordet, 1929; Troja,1996). Perhaps the best-known analytical method in archaeology is radiocarbon dating. It has been used for the past 50 years to date the samples based on the decay of the naturally occurring radioactive isotope of carbon (^{14}C).The isotope is constantly formed in the atmosphere by cosmic radiation, and is incorporated into plants and ultimately every living tissue. When an organism dies and stops taking up ^{14}C, the extent of its radioactive decay with a half-life of 5730 years can be used to determine the time at which it died (Simon, 2007).This paper reports the basics of some dating techniques with its advance applications in the field of Archaeological Sciences.

Dating techniques

Dating techniques are classified into two categories these are relative dating and absolute dating. Relative dating methods can determine the impossibility of a particular event happening before or after another event of which the absolute date is well known. Relative dating refers to non-chronometric methodologies that produce seriation based on stylistic comparison and stratigraphic assumptions. On the other hand, absolute dating methods are based on scientific techniques that yield a chronometric age for a phenomenon in direct or indirect physical relation to the archaeological objects or materials (same age, older, or younger). Dating of some binders in pictographs or the alterations of surfaces by petroglyphs are examples of direct ages related to rock art production. However, it is controversial to consider these dates as "absolute" as they merely reflect experimental propositions, which often lack independent verification (Bednarik 2007; Pettitt, 2007; https://en.wikipedia.org/wiki/Chronological_ dating). We are going to further discussion on the relative and absolute dating.

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Relative Dating

This type of dating technique is the science of determining the relative order of ancient times actions. Archaeologists and geologists used relative dating to determine ages of materials. Though relative dating can only determine the sequential order in which a series of events occurred, not when they occurred, it remains a useful technique. Relative dating by biostratigraphy is the preferred method in paleontology and is, in some respects, more accurate (Stanley, 1999). Relative dating places assemblages of artifacts in time, in relation to artifact types similar in form and function by the Archaeological scientist (Griggs, 1988). Relative dating is also used to determine the order of events on solar system objects other than Earth; for decades, planetary scientists have used it to decipher the development of bodies in the solar System, particularly in the vast majority of cases for which we have no surface samples (Hartmann, 1999). The law of superposition and seriation are the basic terms of relative dating.

Stratigraphy (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. This technique helps the archaeologist to arrange the site in a vertical temporal sequence, which may then be compared to sites of similar age or type. 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. 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.

Seriation

Seriation dating 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 (such as clay pipes or obelisk gravestone markers) 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 (Griggs, 1988).

Absolute dating

Any method of measuring the age of an event or object in years on the basis of the concept of isotopes and half life is known as Absolute dating. In archaeology, absolute dating is usually based on the physical, chemical, and life properties of the materials of artifacts, buildings, or other items that have been modified by humans and by historical associations with materials with known dates (coins and written history). Techniques include tree rings in timbers, radiocarbon dating of wood or bones, and trapped charge dating methods such as thermo luminescence dating of glazed ceramics. Coins found in excavations may have their production date written on them, or there may be written records describing the coin and when it was used, allowing the site to be associated with a particular calendar year (*Kelly, 2012).* In the absolute dating, scientists use the relative amounts of stable (daughter) and unstable (parent) isotopes in an object to determine the age of the object which are described in the table 1. Absolute dating technique is further classified into several methods such as radiometric techniques, luminescence dating, dendochronology, amino acid dating but Now a days scientific disciplines have provided the variety of the dating methods which are relevant to the archaeological sciences. These are:

Physical Dating Techniques

Radio Carbon Dating

The term “radiocarbon” is commonly used to denote ^{14}C, an isotope of carbon which is radioactive with a half-life of about 5730 years. The radiocarbon method is based on the rate of decay of the radioactive or unstable carbon isotope 14 (^{14}C), which is formed in the upper atmosphere through the effect of cosmic ray neutrons upon nitrogen-14. The reaction is: $^{14}N + n \Rightarrow ^{14}C + p$ (Where n is a neutron and p is a proton) (Beta analytic, 2017). It can be applied for dating materials of biogenic origin, such as wood, charcoal, bones, grains, paper, parchment, textile, etc. Due to very low natural ^{14}C concentration the radiocarbon dating method requires special techniques for chemical preparation of samples and measurement of ^{14}C. Particular care has to be taken for sample collection and/or storage as well as during sample pretreatment and chemical preparation (Bronić, 2015).^{14}C atoms, thus produced, combine with oxygen to from carbon-di-oxide ($^{14}CO_2$). This $^{14}CO_2$ and ordinary carbon-di-oxide ($^{12}CO_2$) are distributed in nature through the carbon cycle. The plant fix carbon-dioxide by photosynthesizing their food. As plants are consumed by animals and humans alike, they are labeled by ^{14}C. Through molecular exchange across the air sea interface, ^{14}C reachs oceans and then on to the marine biosphere. Through this carbon-carbon cycle, ^{14}C is dispersed in nature and all the living matter is labeled with it (Agarwall 1974). Any remains of organic origin such as hair, bone, antler, tooth, charcoal, wood and seeds can be dated using carbon dating. A sample should be yield 5 gram of the pure carbon. Some threshold limit of the weight of the samples to be required for the analysis; Charcaoal: 15gms; Bone: 350 grams; Wood: 20 grams; Shell: 20 grams; Antler: 200 grams. There are two basic methods for measuring the ^{14}C: 1. Radiometric: this method counts the decay rate of individual atoms in a sample using a gas proportional counter (a form of Geiger counter) or a liquid scintillation counter; radiometric dating takes about a month to achieve satisfactory statistics, requires about a 100 grams. It is a good method for averaging material composed of material of various ages (lake sediments etc.)., 2. Accelerator mass spectrometer (AMS): this method can evaluate the complete isotopic analysis of the materials. AMS dating takes about a week, requires only about a gram. It is a good method for dating of specific samples, a pine needle for example, when the sample may contain younger extraneous material (http://www.geospectra.net/lewis_cl/geology/geo15.jpg).

Table 1 Radioactive element commonly used for absolute age determinations with parent and daughter isotopes. (Gupta, 2011)

SN	Parent isotope	Production mechanism	Daughter isotopes	Half-Life (Million years)
1	7-Berylium (^{7}Be)	Cosmogenic	7-Lithium (^{7}Li)	53 days
2	210-Lead (^{210}Pb)	Uranium decay	210-Bismuth (^{210}Bi)	22.3 years
3	226-Radium (^{226}Ra)	Uranium decay	222-Radon (^{222}Rn), 4He	1,622 years
4	14-Carbon (^{14}C)	Cosmogenic, Bomb	14-Nitrogen (^{14} N)	5,730 years
5	231-Protactinium (^{231} Pa)	Uranium Decay	227-Thorium (^{227}Th), 4He	0.033
6	234-Uranium (^{234}U)	Uranium Decay	230-Thorium (^{230}Th), 4He	0.25
7	36-Chlorine (^{36}Cl)	Cosmogenic, Bomb	36-Argon (^{36}Ar)	0.31
8	26-Aluminum (^{26}Al)	Cosmogenic, Stellar	26-Magnesium (^{26} Mg)	0.73
9	230-Thorium (^{230}Th)	Uranium Decay	226-Radium (^{226}Ra), 4He	0.75
10	60-Iron (^{60}Fe)	Stellar	60-Nickel (^{60}Ni)	1.5
11	10-Berylium (^{10}Be)	Cosmogenic, Stellar	10-Boron (^{10}B)	1.6
12	53-Manganese (^{53}Mn)	Cosmogenic, Stellar	53-Chromium (^{53}Cr)	3.7
13	107-Paladium (^{107}Pd)	Stellar	107-Silver (^{107}Ag)	6.5
14	182-Hafnium (^{182}Hf)	Stellar	182-Tungsten (^{182} W)	9
15	129-Iodine (^{129}I)	Stellar, Cosmogenic	129-Xenon (^{129}Xe)	15.7
16	244-Plutonium (^{244}Pu)	Stellar	Various fission products	80
17	146-Samarium (^{146}Sm)	Stellar	142- Neodymium (^{142}Nd)	103
18	235-Uranium (^{235}U)	Stellar	207-Lead (^{207}Pb), 4He	704
19	40-Potassium (^{40} K)	Stellar	40-Argon (^{40}Ar) ; 40-Calcium (^{40}Ca)	1,270
20	238-Uranium (^{238}U)	Stellar	206-Lead (^{206}Pb), 4He	4,469
21	232-Thorium (^{232}Th)	Stellar	208-Lead (^{208}Pb), 4He	14,010
22	176-Lutetium (^{176}Lu)	Stellar	176-Hafnium (^{176}Hf)	35,700
23	187-Rhenium (^{187}Re)	Stellar	187-Osmium (^{187}Os)	41,600
24	87-Rubidium (^{87}Rb)	Stellar	87-Strontium (^{87}Sr)	48,800
25	147-Samarium (^{147}Sm)	Stellar	143-Neodymium(^{143}Nd), 4He	106,000
26	190-Platinum (^{190}Pt)	Stellar	186-Osmium (^{186}Os)	450,000

Luminescence Dating

The method uses an optically and thermally sensitive light or luminescence signal in minerals such as quartz and feldspar. During exposure to light or heat the luminescence signal within the grains is erased (optically bleached or thermally annealed) until it is completely removed (zeroed). Once the grains are sealed from daylight and remain at normal environmental temperatures, the luminescence signal accumulates again, being induced by naturally occurring radioactivity. For dating, the amount of absorbed energy per mass of mineral [1 J kg-1 = 1 Gy (Gray)] due to natural radiation exposure since zeroing known as the palaeodose, is determined by comparing the natural luminescence signal of a sample with that induced by artificial irradiation. Several laboratory techniques have been developed to accomplish the necessary stimulation and recording of the weak but measurable luminescence emitted from minerals. The time elapsed since the last daylight exposure or heating is calculated by dividing the palaeodose by the dose rate, the latter representing the amount of energy deposited per mass of mineral due to radiation exposure acting on the sample over a certain time (Gy a^{-1}). This relation is represented by the following simple equation: Luminescence age (a) = Palaeodose (Gy) /Dose rate (Gy a^{-1}) (1). Luminescence dating has been applied to a wide range of topics within quaternary research such as landscape evolution, palaeoclimate, geohazards and (geo)-archaeology, and has undergone several important methodological refinements since its early days. Luminescence dating comprises a range of different but related phenomena. The fact that a strict nomenclature is not always adhered to and that some techniques are not often used may cause some confusion to the non-specialist. Recent reviews of luminescence dating in archaeology can be found in Roberts, 1997 and Wagner, 1998.

One of the first publications suggesting the use of thermoluminescence (TL) as a research tool was by Daniels *et al*, 1953 and a few years later TL was used to date ceramics (Grögler *et al*, 1958; Aitken *et al*, 1964, 1968). An important benchmark was the application of TL to the dating sediments (Wintle *et al*, 1979, 1980; Wintle, 1980). Another breakthrough came with the introduction of optical stimulation by both visible (Huntley *et al*, 1985) and infrared light (Hütt *et al*, 1988). More recent advances concern the development of measurement procedures. Of these, notable developments are the use of a single aliquot (Duller, 1991; Murray *et al*, 2000), as well as single grain dating techniques (Murray *et al*, 1997; Duller *et al*, 2000), new analytical tools such as linearly modulated luminescence (Bulur, 1996), radiofluorescence (Krbetschek *et al*, 2000; Erfurt *et al*, 2003) and spatially-resolved luminescence (Greilich *et al*, 2002; Greilich *et al*, 2006). The most-widely used terminology and the techniques used in luminescence dating are described in Table 2.

Thermoluminescence (TL)

The term thermo luminescence (TL) describes the light emitted by a mineral, other than incandescence or black body radiation, when heated. The light originates from captured electrons being freed due to heat stimulation and subsequent recombination. Thus, it is also (and more correctly) referred to as thermally-stimulated luminescence (TSL) although this term is not often used. The basic processes leading to a latent luminescence signal: A valence electron is excited by ionizing radiation, and has sufficient energy to reach the conduction band, leaving a hole in the valence band. Most of the excited electrons dissipate their energy by recombining immediately with a hole in the valence band; the transition is sometimes accompanied by photon emission.

Table 2 List of various types of luminescence dating with basic applications

SN	Luminescence Dating Methods	Application	References
1	Thermo-luminescence (TL)	Dating heated materials	Aitken *et al*, 1964
2	Isothermal Thermo-luminescence (ITL)	Experimental (quartz)	Jain *et al*, 2005
3	Optically Stimulated luminescence (OSL)	Dating sediments (quartz)	Huntley *et al*, 1985
4	Infrared stimulated luminescence (IRSL)	Dating sediments (feldspar)	Hütt *et al*, 1988
5	Infrared radiofluorescence (IR-RF)	Dating sediments (feldspar)	Trautmann *et al*, 1999a
6	Linearly modulated OSL (LM-OSL)	Analytical tool (quartz)	Bulur, 1996
7	Spatially-resolved luminescence (HR-OSL)	Dating rock surfaces	Greilich *et al*, 2002
8	Thermally transferred OSL	Experimental (quartz)	Wang *et al*, 2006a

Prompt transition of a few excited electrons into localised energy states below the band edge resulting in electron trapping; light is potentially emitted during these processes. A hole in the valence band may be filled by electrons from localised levels above the valence band edge; hence the hole transfers from the valence band to the localised level. The application ranges from lower Paleolithic to Neolithic archaeological sites, with a major focus on the middle Paleolithic, which is often beyond the range of the ^{14}C-dating method. The application of TL dating on heated flint is mainly limited by the detection limits of the equipment for very young samples, the saturation of the signal measured for very old samples, and, of course, the presence of sufficiently burnt flint. It is thus, in principle, possible to date fire use over the entire human evolution. The first measurement of TL empties the electron traps after which a second heated measurement is undertaken to record the unwanted light signal due to black body radiation or incandescence. This starts to grow around 400°C when using blue-violet detection filters, and the sum of this is subtracted from the first signal. The different TL peaks of the glow curve represent different trap populations, with electrons from "shallow" traps recombining at lower stimulation temperatures than those from "deep" traps at higher temperatures, and a comparison of naturally and artificially induced TL reveals information about the stability of different signal components. This characteristic is utilised to identify the appropriate thermal pre-treatment for reliable measurement, and to investigate the extent to which a sample was zeroed by the natural heating/bleaching process. TL was the only method used in retrospective dosimetry and luminescence dating until the mid-1980s, and was originally developed for the dating of ceramics (Aitken, 1964), although it was also used later to date volcanic rocks (Hwang, 1970; May, 1979; Raynal *et al*, 1982), heated artefacts and sediments (Huxtable *et al*, 1978) as well as aeolian deposits (Wintle, 1979, 1980, 1981; Singhvi *et al*, 1982, Godfrey-Smith *et al*, 1988). A modification of the classical TL approach is the isothermal TL (ITL) method, in which TL is recorded while the sample is held at a constant or isothermal temperature (Jain *et al*, 2005; Huot *et al*, 2006). The advantage of this method is that a specific trap population is emptied while deeper traps are not stimulated. In contrast to TL it is thus possible to focus on a trap population with certain physical properties. A first test study indicated that the potential of the method lies in the prospect of increasing the age range towards older samples (Jain *et al*, 2005; Choi *et al*, 2006a), although, while some tests on quartz showed quite promising results, other test studies identified several problems and age overestimates in comparison to optical dating (Buylaert *et al*, 2006). Nevertheless, ITL appears to be an interesting approach with some potential, especially for older sedimentary samples and heated objects.

Optical Stimulation (OS)

The most important breakthrough in recent years in luminescence dating has been the use of optical stimulation (optical dating). This area of luminescence dating mainly comprises stimulation by visible light as introduced by Huntley *et al*, 1985, and by infrared (IR) as first described by Hütt *et al*, 1988, may be collectively referred to as photoluminescence or photon-stimulated luminescence (PSL). The advantage of any optical method is that only the light-sensitive part of the luminescence signal is stimulated, which for sedimentary deposits considerably minimizes the problem of incomplete bleaching of the luminescence signal prior to deposition. Furthermore, more reliable and precise methods for determining the palaeodose have been developed since the mid-1990s and have revolutionized luminescence dating. These methods will be described below. Regardless of what kind of photon-stimulation is used, optical filters are placed between the sample and the light-sensitive surface of the photomultiplier tube to minimize crosstalk between light from the stimulation source and light emitted from the sample. When optical excitation begins the latent luminescence in the mineral will start to decay, resulting in a so-called decay curve recorded by the photomultiplier. Further classification of the OS dating described in the table No 2.

Table 3 List of various principles of Dendochronology with basics

SN	Principles of Dendochronology	Basics	References
1	The Uniformitarian Principle	the physical and biological processes that link contemporary environmental processes to current variations in radial tree growth existed in the past	Fritts, 1976
2	The Principle of Aggregate Tree Growth	the individual tree-ring growth series of a tree can be broken down into an aggregate of environmental factors, both human and natural, that affect the patterns of tree-ring growth over time	Cook,1987
3	The Principle of Ecological Amplitude	that tree growth is particularly sensitive to environmental factors at the latitudinal, longitudinal, and elevation limits of the distributional range of the species	Fritts, 1976; Luckman, 2005
4	The Principle of Site Selection	the most useful locations for environmental reconstruction can often be identified based upon site characteristics	Fritts, 1976; Cook, 1987
5	The Principle of Cross dating	cross dating ensures that individual tree rings are assigned their exact year of formation. This is accomplished by identifying recognizable patterns of wide and narrow rings within a living tree-ring chronology	Fritts, 1976; Cook, 1987

Archaeomagnetic Method

This method depends upon the properties of clay to acquire thermoremanent magnetism. The clays containing magnetic oxides of iron, when heated beyond the curie point, lose their magnetism. Between the Curie point and the blocking temperature these baked clays (terracotta, pottery) acquire the direction and the proportionate intensity of the ambient magnetic field. Thus they become permanent records of the earths magnetic field. This record can then be read later. If we have a plot of the change in earth's magnetic field with respect to time we can compare the thermoremannet magnetism of un dated old potsherds with the curve based on the past changes and thus date them. Thelleir has done work in this field in France and others elsewhere. Athawale carried out this type of work at the tata Institute of Fundamental research, Bombay. Samples from about 30 Indian Archaeological sites dating from c. 300 to 4000 BP were measured. The results show that over the past 4000 years the average field was not much different from the the present- in fact it was lower only by about15%. But the results of Thellier indicate an increase in the field intensity in the past with peak of 1.6 times the present value for 2000 BP samples. Bucha on the other hand reports maximum intensity (1.6 times) around 100 BC and minimum at c. 4000 BC (0.6 times). The Japanese results show sharp increase for 2000 year old basalt samples, and an equally sharp decline to present value for the 3000 year old sample. Thus, at the moment, due to this divergence in results they cannot use this method for dating on a word wide scale (Agrawal,1974).

Botanical Methods

Dedochronology

Dendochronology het deals with the dating and study of the annual growth layer or tree rings in woody trees and shrubs. In temperate climate, these layers of wood (tree rings) attains seasonal cell structures (early wood and late wood) that signify one annual growth ring. As early as the fifteenth century, Leonardo da Vinci noted that the annual nature of tree rings, widths and recognizing a relationship between tree ring widths and precipitation (Stallings, 1937).(Studhalter, 1955, 1956). Douglass had developed a 500-year cross dated pine chronology and established a positive correlation between ring width and precipitation of the preceding winter (Douglass, 1914). Archeological tree-ring sequence provided precise dates of construction for numerous previously undated pueblo sites, bringing the science of Dendrochronology to age as a dating tool (Dean, 1997). The various principles are applicable for the Dendochronology have been described in table no.3.

Application of Dendochronology

Tree-ring dating typically begins with the measurement of tree-ring widths or a density parameter, followed by the development of a master tree-ring chronology. The primary objective in developing tree-ring chronologies is to develop stationary time series that are directly comparable and appropriate for statistical analysis (Fritts, 1976). Chronology development follows a three-step procedure: (1) Cross dating: is used to check for measurement errors and false or missing rings. Although skeleton plots of tree-ring series are useful for visually identifying dating or measurement problems (Stokes, 1968), the application of quality checking software programs provides a statistical measure of quality control (Holmes, 1983). (2) Standardization: Although ring-width increments are assumed to change in response to climate variability, they also vary in size with tree age, stem height above the ground surface, in response to site specific characteristics, and productivity (Fritts, 1976). For the purpose of climate reconstruction, it is essential to determine if the changes in ring width are associated with aging or disturbance factors, and to then remove these influences from the chronology. This correction is known as standardization, and the transformed values are referred to as ring-width indices (Fritts, 1976). Each set of tree-ring measurements requires a different standardization, depending on the statistical and morphological properties of the ring-width series (Cook *et al*, 1990). (3) Master chronology development: The transformed time-series are combined into a single dimensionless ring-width index, or site chronology, that reflects the extrinsic (environmental) constraints on growth (Cook, 1986). Cross dating provides the means to assign an absolute date to each ring in a tree-ring series of unknown age by matching the undated ring-width patterns to those of a known dated series. If the entire ring sequence is present in the outermost perimeter of the undated sample (early wood and latewood tissue), it is assumed that the sample was killed sometime between the end of one year's growth period and the beginning of another. Precise dating is possible when a sample has bark, as this infers that the last year of growth is present (Baillie, 1982).

Palynology

Palynology is the "study of dust" or "particles that are strewn". A classic palynologist analyses particulate samples collected from the air, from water, or from deposits including sediments of any age. The condition and identification of those particles, organic and inorganic, give the palynologist clues to the life, environment, and energetic conditions that produced them(https://en.wikipedia.org/wiki/Palynology). They are characteristic of each species and are very resistant to decay, even hydrofluoric acid does not attack them. Pollen analysis can help the Archaeologist in three ways: 1. For dating purposes, 2. For reconstruction of ecology, and 3. To see the role of man in it.

In some part of the world the pattern of change has been established in the pollen grains over a long periods of the past, so that even isolated analysis may be fitted in the sequence. Though in India for the pro historic periods their dating value is limited, yet the ecological importance is great. (Agrawal, 1974).

Recent Trends of Dating Techniques in Archaeological Sciences

Several dating methods were used by Archaeological scientist with respect to historical materials which are described in table no 4. In recent pattern the thermo luminescence (TL) dating techniques can be used for pottery, terracotta, basalt lava, quartz, ceramic, calcite as well as marble. Mullar *et al*, 1993 were used TL dating for evaluate the dates of glass materials. Zircon grains of fired materials were dated by templer *et al*, 1993, using auto regenerative TL dating. Organic materials such as bone, bone collagen, teeths, beewax, etc. were dated using stable isotopes of carbon, nitrogen, oxygen and strontitum as well as radio carbon dating.

Table 3 Description of various dating studies of Archaeological samples with Archaeological sites

SN	Type of Samples	Archaeological Site	Type of Dating / instruments used	References
1	Prehistoric Pottery Sherds	Milena (cattanissetta, Sicilly)	Thermo luminescence	Troja, 1996
2.	Arcaheological sediments (Loessic colluvial sediments)	Neolothic Bruchsal Aue (south west Germany)	Infrared stimulated luminesecene (IRSL)	Lang, 1996
3.	Lime mortars	Sant Quizre de pedret north catalonia (Romanesque Monastry) and Santa Maria de repoll (Catalonia Romanesque)	Chemical data with dendogram using XRD pattern and ICPMS	Vederell sez, 1996
4.	Galena	England wales, Scotland and Ireland	Modern lead Isotopes measurement using mas spectrometry	Rohl,1996
5.	Terracotta Jemaa Head	Nile Valley, Nok Culture , Nigeria	Thermo luminescence	Fagg, 1970
6.	Pottery	Nine Chineses "Six Dinasties	Thermo luminescence	Fleming, 1970
7.	Besalt Lava	McMurdo (Antartica), Montsenatt, St Vincent	Thermally Stimulated Current (TSC) technique	Hwang, 1970
8.	Tree	North Wales, North west England	Dendochronology	Hughes, 1981
9.	Human Skull and Skeleton	Galley Hill, Kent	Radiometric assay (^{238} U)and absolute (^{14} C) dating	Demetsopullos, 1983
10.	Bone collagen	Not mentioned	Carbon Isotopes Measurements	Chisholm, 1983
11.	Fresh water bivalve (Unio willcocksi Bullen Newton and Etheria elliptica Lamark)	Predynastic Gerzean (Nagada II), Hierakonpolis, Egypt	Radio Carbon	Bureigh, 1983
12.	Travertines Under- and Overlying the Hominid-beraing marl	Vertesszollos, Hungary	Uraniaum Series	Schwarcz, 1984
13.	Oak Boards and Planks, Panels , Sapwood	England	Dendochronology	Baillie, 1984
14.	Meta carpals of Sheep (Ovis aries), Goat (Capra hircus) and Nubian ibex(Capra ibex nubiana)	Various Locality of Israel	Radiograph with X-rays source.	Smith,1984
15.	Bone Collagen	Freshly Killed Animals, California , USA	Carbon and Nitrogen Isotopes Ratio	DeNiro, 1985
16.	Bone	Samples From Oxford	Radio Carbon	Gillespie, 1984
17.	Schist Honestones	Kaupang(Norway), Aggersborg (Denmark), Hedeby (West Germany) and Wolin (Poland)	Potassium-argon	Mitchell, 1984
18	Mink and Rabbit Bone Collagen	Tehuacan Valley of Maxico	Stable carbon and Nitrogen Isotopes ratio	DeNiro, 1983
19.	Palaeolithic Artifacts	Cave of La chaise-de- Vouthon (Charente), France	U-Series Dating	Blackwell, 1983
20.	Pontic Amphora	Copenhagen	Thermoluminiscent	Fleming, 1970
21.	Pottery (Quartz)	Not Mentioned	Thermoluminicent	Fleming, 1970
22.	Ores	West Mediterranean	Lead Isotope	Stos-Gale, 1995
23.	Pottery	Lezoux in central France	Rehydration and rehydroxylation (RHX) processes	Le Goff, 2014
24.	Medieval Ceramic fragments	Syrian	rehydroxylation (RHX) dating	Le Goff, 2015
25.	fired-clay artifacts	Not Mentioned	rehydroxylation dating	Le Goff, 2015
26.	Volcanic eruptions	Mount Etna, italy	^{226}Ra-^{230}Th radiochronology	Tanguy, 2007
27.	Ceramic	Dankrike,Vaer, Ellum, Uldal, Denmark	Thermoluminicent	Mejdahl, 1969
28.	Pottery	Twenty Seven Archaeological Sites	Thermoluminicent Dosimetry	Aitken, 1969
29.	Prehistoric Glass	New England area, French	Fission track	Brill, 1964
30.	Pottery	Not mentioned	Thermoluminicent	Fremlin, 1964
31.	Masonry	Pompey, Otia, Rome	Statiscal analysis (Teichography)	Schwarz,1964
32.	Ancient Ceramics	Knosso Crete Stratum III, Stratum II, Strata v-VII, Syria, Cyprus, France	Thermolumenence	Tite, 1966
33.	Crystalline extracts from pottery	Syria, France, Mexico, Roman	Thermolumenecence	Fleming, 1966
34.	Ancient Pottery(fine grains)	Cyprus, Lezoux	Thermoluminescence	Zimmerman, 1967
35.	Artifacts, copper, Iron and its Ores	Anatolia, Turkey, USA	Lead Isotopes	Saryre, 1992
36.	Layer 10 of calcite	Mausoleum cave Greece	Uranium Series	Latham, 1992
37.	Stalagmitic Calcite	Caunedel Arago, Tautavel, Southern France and Pontnewydd cave, Northern wales	Thermoluminescence and Uranium series	Debenham, 1994
38.	Basalt Impliments	Mount carmel Late Epipalaeolithic sites	K/Ar Dating	Weinstein-Evron, 1995
39.	Beeswax figure	Prihistoric rock art of Northern Austrelia	Radiocarbon	Nelson, 1995
40.	Estuarine mollusk shells	Pasific coast of southwestern mexico	Oxygen and carbon Isotopes	Kennett, 1995
41.	Zircon grains of fired materials	Method development	Auto- regeneratve thermoluminescence	Templer, 1993
42.	Fossil bones	Alpine Caves	Uranium series	Wild, 1993
43.	Prehistoric metal Artifacts	Data interpretation of old analysis	Lead Isotope	Budd, 1993
44.	Crucible fragments	Taurus mountains at Goltepe in South central Turkey	Thermo-luminescence	Vandiver, 1993
45.	Glass (Lithium disilicate samples)	Limitation of method (standardization of methods)	Thermo-luminescence	Muller, 1993
46.	Stone axe	Stonehenge Environs	Laser microprobe Argon 39-Argon	Kelley, 1994
47.	White Marble	Classical quarrying areas in Greece, Italy and Turkey	Cathadoluminescence	Barbin, 1992
48.	Bone collagen	medieval hospital of St. Giles, Brough, Yorkshire	δ^{13}C and δ^{15}N isotope	Bownesa, 2018
49.	Dog bones	39 archaeological sites between Denmark and Switzerland	stable carbon (δ^{13}C) and nitrogen (δ^{15}N) isotope analyses	Ewersena, 2018
50.	Teeth	Roman and Byzantine Hierapolis	strontium isotope	Wonga, 2018
51.	Human and animal teeth	Cemeteries of Basel-Gasfabrik (Switzerland)	strontium (^{87}Sr/^{86}Sr) isotope	Brönnimanna, 2018

Rehydroxylation dating method were used by Le-Goff *et al*, 2014; 2015, for dating of ceramics and fired clay artifacts. Metals and Gallena samples were dated using Lead Isotopes techniques which were described by Saryre, 1992; Budd, 1993; and Rohl, 1996. The study concluded that there are no any standardized dating method for archaeological metal and its objects. Archaeological scientist are required more standardized techniques for evaluating the dates of metal and its artifacts and also requires such method which will apply directly on the site or museum objects for calculation of manufacturing dates.

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