Biblical Archaeology
Module Sixteen

In this paper we will examine radiocarbon, dendrochronology, and thermo luminescence as dating methods used in archaeology. We will consider the method, limits, weaknesses, and expected results for each dating method. We will then consider how these dating methods could be used in the general field of biblical archaeology.

Radiocarbon Dating

Radiocarbon dating is more commonly known as carbon 14 dating. It is based upon that principle that all organic matter contains a content of radiocarbon. This was first suggested by Libby, a professor of chemistry at the University of Chicago. Of Libby Sheridan Bowman writes, "In 1946 he published a paper suggesting that radiocarbon might exist in living matter. One year later, a single-page paper appeared in the journal *Science* in which Ernest Anderson and Libby, together with collaborators in Pennsylvania, summarized the first detection of radiocarbon in material of a biological origin."[1] Since that initial find, radiocarbon dating has become the first quoted line of defense for the dating of archaeological finds. Often this dating method is misunderstood, misquoted, and sometimes misused; yet, at other times it has been used properly, scientifically, and accurately to establish a high level of probability for the historic age of archaeological finds. In 1960 Libby was awarded the Nobel Prize for chemistry for his important discovery and research.

[1] Sheridan Bowman, Radiocarbon Dating: Interpreting The Past, (London: British Museum Publications, 1990), 9.

There are varying opinions about the origin of carbon 14 and how it becomes a part of organic matter. One opinion teaches that carbon 14 is formed in the atmosphere when cosmic rays strike nitrogen atoms in the air. According to this theory it stays in the atmosphere for twenty-five years before being absorbed through photosynthesis or rainwater. Another view holds that carbon 14 is a naturally occurring isotope of carbon 12. It turns into nitrogen 14, does not decay, and is very stable. This view holds that this change occurs at a constant rate that is not affected by the environment. A problem with both of these environmentally based views was discovered when dirt from the moon was found to contain carbon 14. However, the moon has no atmosphere, and therefore, its carbon 14 could not come from cosmic rays striking nitrogen. Since carbon 14 has a half-life of less than 6,000 years, then the carbon 14 on the moon must be fairly young. Since other dating methods prove the moon to be very old, it is then claimed that carbon 14 comes directly from the sun. Some have even collected carbon 14 from space suggesting that this is evidence that carbon 14 comes from the sun.

It is theorized that the sun creates carbon 14 in its nucleus and sends the carbon 14 out in solar flares. Some contend that it is carried by the solar winds rather than in solar flares. Many believe that the sun sends out carbon 14; however, we need to understand that the sun is a fairly unstable star that goes through cycles that dramatically affect the climate of the earth. This most likely affects the amount of carbon 14 distributed by the sun.

Regardless of how carbon 14 is generated, scientist are fairly certain that carbon is absorbed into plants through photosynthesis and is stored in the wood and plant matter. Animals eat the plants and deposit carbon into their wastes. The amount of carbon 14 in their wastes can be used to date the animals. Wood is known to store carbon 14 as it can be found and measured in the various rings of trees. Other organic materials store carbon 14 such as bone; however, it should be noted that since bone is porous, Therefore, it easily absorbs carbon 14 from the environment around it.

Carbon 14 has a half-life of 5,730 years and was thought to stay in the atmosphere for twenty-five years before being absorbed through photosynthesis or rainwater. Certain man made interferences to carbon 14 levels in our environment have revealed that the absorptions rate for carbon 14 at the surface level of our environment could be as rapid as 4-6 years. For the deep ocean these rates are thought to be significantly higher. The amount of carbon 14 in the atmosphere that is available for absorption by living organisms is fundamental to radiocarbon dating. The revelation of these rapid absorption rates has the tendency of making radiocarbon dating more complicated and less accurate.

Since carbon 14 is unstable, the amount of carbon 14 in organic matter begins to decrease at a given rate once the organic matter dies. This dissipation rate is thought to be vary accurate and measurable, hence the amount of carbon 14 in a given sample at the time of its measurement is thought to reveal it relative age. Knowing the amount of carbon 14 available for absorption by a living organism is essential for the accurate determination of the age of the sample being tested.

A sample of organic matter is tested by burning it into carbon. The carbon is then converted into graphite, and the levels of carbon 14 in the graphite are then measured. Very sensitive and carefully calibrated instruments are used to measure the levels of carbon 14 in the graphite. It must be noted that “only about one part in a million million of modern carbon is ^{14}C."[2] Therefore, the smallest portion of contamination in any given sample can alter the results of the test.

It is important to note that there are scientific limits for any radiocarbon dating. Henry Morris notes that a half-life for carbon 14 is approximately 5,730 years, and he adds, "Therefore, by about six half-lives, or about 35,000 years, there would be practically no carbon 14 left to measure (some claim to be able to measure an extremely small amount out to as much as 80,000 years, or 14 half-lives, but that is very doubtful)." [3] M. J. Aitken sets the half-life of carbon 14 at 5,730 years and indicates that radiocarbon dating is limited to about 50,000 years at a maximum on account of contamination. He hopes that if contamination can be eliminated in the future, dating can be extended to a 70,000-year maximum range.[4]

The critical element in radiocarbon dating is the level of carbon 14 contained in the sample at the moment of its demise; this would be its zero carbon 14 age. Taylor writes, "One of the most fundamental assumptions of the ^{14}C method is the requirement that natural ^{14}C concentrations in materials of 'zero ^{14}C age' in a particular reservoir are equivalent to that which has been characteristic of living organisms in that same reservoir over the entire ^{14}C time scale."[5] Therefore, the veracity of radiocarbon dating is dependent upon the levels of carbon 14 that are and have been contained in the atmosphere. If the earth is very old then carbon 14 levels would be at a constant level having reached saturation. However, if the earth is young then carbon 14 levels may not be at saturation yet and would still be building

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[2] Bowman, 10.
[3] Dr. Henry M. Morris and Dr. John D. Morris, The Modern Creation Trilogy: Volume II, Science and Creation (Master Books, Green Forest, 1996) 320.
[4] M.J. Aitken, Science-based dating in archaeology, (London: Longman House, 1990) 84.
[5] R.E. Taylor, Radiocarbon Dating: An Archaeological Perspective, (Orlando: Academic Press, 1987), 16.

to a constant level. If this is the case, then the starting point for dating a sample may not be as straightforward as some have assumed.

In addressing the issues of carbon 14 levels in our atmosphere, there are varying opinions in the scientific field. Sheridan Bowman suggested, "in principle there is a constant ^{14}C level in all living organisms."[6] His assumption is based on the presupposition that there is a constant level of carbon 14 in our atmosphere and environment at all times. If there is a constant level of carbon 14 in our environment and has been for millions, even billions of years then dating with carbon 14 becomes rather easy. In the early years of radiocarbon dating this assumption permeated the radiocarbon scientific field.

Through dendrochronology, which is the study of tree rings, some have suggested that it is possible to build a tree-ring ladder that dates back as far as about 9000 B.C. They suggest that it is then possible to determine the amount of carbon 14 that was in the atmosphere each year by measuring the carbon 14 in each ring. They note that the amount of carbon 14 in the atmosphere has fluctuated over the years. Henry Morris suggests that the evidence obtained from these tree-ring carbon 14 studies indicates that the levels of carbon 14 in the atmosphere have been and continue to be on a climb to saturation. He suggests that this indicates that the earth may be younger than 50,000 years old since it would take approximately 50,000 years for the carbon 14 levels on the earth to reach a saturation level. He also notes that this fact affects the actual dating process since the assumption has been that carbon 14 is already at a stable level; yet, the evidence indicates that the level has been consistently climbing throughout history.[7]

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[6] Bowman, 10.
[7] Morris, 320.

The saturation theory suggested by Morris appears to be substantiated by a chart placed in Aitken's text. The chart demonstrates the findings of data derived from dendrochronologically dated wood and indicates that carbon 14 levels have been constantly changing throughout history.[8] Taylor writes specifically of this saturation effect and includes charts that demonstrate that it would take at least 35,000 years for carbon 14 levels to reach saturation. However, he makes the assumption that our current levels of carbon 14 must have reached saturation a couple of hundred thousand years ago. He also notes that the "zero" age for any sample is fully dependant upon the stability of carbon 14 in the atmosphere and the various global reservoirs.[9]

Therefore, the lack of a stable saturation of carbon 14 in our environment presents a formidable problem for radiocarbon dating. Whether one holds the young earth presupposition and believes that our carbon 14 is not constant because the earth has not existed long enough to reach saturation. Or, if one is of the ancient earth point of view and believes that the earth must have reached saturation long ago. The fact that tree ring carbon 14 studies reveal an unstable and changing level of carbon 14 in our environment makes radiocarbon dating a random guess at its very best.

Taylor defines numerous major anomalies that affect the amount of carbon 14 in our atmosphere at any given time. He notes the reservoir effect and claims that there are various reservoirs in our environment that absorb and release carbon 14 as carbon 14 levels vary. The oceans are one such large carbon 14 reservoir. The assumption in the early years of radiocarbon dating was that these reservoirs stabilized the amount of carbon 14 in our world. However, Taylor notes, "one of the earliest illustrations of the breakdown of this assumption

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[8] Aitken, 67.

[9] Taylor, 16-18.

was the determination that living samples from a fresh water lake with a limestone bed exhibited apparent ^{14}C 'ages' of as much as 1600 years."[10]

Taylor also noted the de Vries effect which identifies that in at least the last 1600 years there have been significant changes in the levels of carbon 14 contained in our atmosphere. This effect "created a situation in which it is not possible to assign an actual calendar age to any sample derived from this time period to better than about a 300-year time span unless 'wiggle-matching' procedures are employed."[11] In other words, adjustments have to be made to the results of the tests in order to arrive at an accurate date. For samples of a known age this wiggle-matching is possible. However, how does one know whether one's wiggle-matching has returned a successful age on a sample of unknown antiquity.

A third anomaly has been identified as the Suess effect. The Suess effect is caused by the significant use of fossil fuels in the twentieth century. Fossil fuels release large volumes of CO^2 into our atmosphere that contains no carbon 14. Hence, these fossil fuels have lowered the amount of carbon 14 in our atmosphere. This effect was first noted in 1950 by Hans Suess of the United States Geological Survey. While this effect is noted by Taylor, an appropriate compensation is not prescribed.

The last anomaly noted by Taylor is that of the Atomic Bomb Effect. The test of atomic bombs in our atmosphere has produced significant amounts of artificial carbon 14. Taylor notes, "between 1955 and 1963, the ^{14}C activity in terrestrial organics almost doubled. Unfortunately, it was during this period that early work on the ^{14}C method, using solid or particulate carbon, occurred."[12] The effect of atomic weapons made it complicated to do accurate low-level carbon 14 testing. Since the1963 international agreement halted the

[10] Taylor, 34.
[11] Ibid., 35.
[12] Ibid, 38.

testing of atomic weapons in the atmosphere, it would be assumed that the carbon 14 levels would have returned to normal. However, the continuing growth in the use of fossil fuels has probably over compensated for the Atomic Bomb Effect.

When radiocarbon dates are suggested it should be understood that these dates are not the same as actual calendar dates because a radiocarbon date represents a range of dates falling along a bell-shaped curve. Each fragment taken from a sample will very in date by a couple of hundred years and will follow along the bell of a curve. Therefore, the center point of the curve is presumed to be close to the accurate date of the wood or organic matter. One should keep in mind that carbon 14 tests are expensive to do and often only a few samples are taken at a given site. Therefore, carbon 14 dates are, at best, only a ballpark figure.

Removing contaminating materials from a sample can be a daunting task for radiocarbon dating. When dating things like charcoal, it is important to remove things like roots; however, root hairs are microscopic. Hairs from roots that had already died may be impossible to find and can add more recent carbon to the sample. Once the contamination is removed, the sample is burned to carbon; the carbon is converted to graphite; and, the graphite is dated. This conversion process may also introduce contamination to the sample. It has been noted by many researchers that the simple selection of a laboratory can affect the date returned for a given sample.

Since the amount of carbon 14 in the atmosphere changes, the testing has to be carefully calibrated to remain accurate. This calibration can often be daunting. It is thought that items from 8000 B.C. actually carbon 14 date at about 9000 B.C.. This date-gap widens with older items. This is compounded by the calibration curve used, as different curves are available. Taylor discusses the complicated process of calibration by providing a series of more than fifteen charts and over twenty pages of explanation that reveal that the calibration curve used on a particular sample could easily vary the resulting date by as much as 1,000 years, if not more.[13]

Other difficulties can affect the results of radiocarbon dating. When a pool of water sits on limestone for a long time, old carbon dissolves into the water. This is illustrated by living plant life taken from Montezuma's well which carbon 14 dates at about 25,000 B.C. If a site was underwater for a long time before it was uncovered, it may carbon 14 date to be much older than it really is. Also, bone is a very porous material and will absorb carbon 14 from materials around the bone including the soil in which it is buried. These are just two examples of the many circumstances that surround radiocarbon dating.

Items that are thought to be reasonably datable include wood, bone, shell, sediments and soil, peat, mortar, seeds, grain, ivory, paper, and textiles. However, there is considerable debate about the veracity of radiocarbon dating for many of these items. Radiocarbon dating was successful in dating one of the Dead Sea scrolls to what would be considered a relatively accurate date range, but the target range was known and expected and may have contributed to the calibration procedures selected for the test.

While some strongly support radiocarbon dating, it must be noted that since our environment is not at the carbon 14 saturation level, as some have assumed, it is very difficult, if not impossible, to know the level of carbon 14 a sample held when it died. Therefore, it is virtually impossible to date organic matter with this dating method. The levels of contamination that may find their way into a sample are numerous and unpredictable. It is of particular interest that the limit of radiocarbon dating is between 30 and 40 thousand years; it may be possible to achieve 70 thousand years, but it is highly

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[13] Taylor, 105-146.

unlikely. Anyone that presents an older radiocarbon date is outside of the scope of Carbon 14 dating and is either ignorant or deceptive with his assumptions.

Therefore, radiocarbon dating is the science of measuring the levels of carbon 14 in ancient organic matter with the intention of dating its approximate age. The method is complicated to perform and requires that numerous calculations be performed on the results in order to achieve a presumed level of accuracy. The changing levels of carbon 14 in our atmosphere challenge the method, as the amount of carbon 14 absorbed by the organic matter at its death is its 'zero carbon 14 age.' Radiocarbon dating is limited to approximately 40,000 years at the outside as any sample of older antiquity would have too little carbon 14 to measure.

Dendrochronology

After the inception of radiocarbon dating and as its dating method was being employed with an assumed and blind accuracy, dendrochronology appeared in the scientific dating community and challenged the assumed accuracy of carbon 14 dating. Dendrochronology compares the tree rings of trees. As successively older trees are added to the chronology, a tree-ring dating scale has developed. Dendrochronology has challenged radiocarbon dating in that it has revealed that the amount of carbon 14 in our environment is not at saturation and is still changing. The tree rings also reveal that the dates assumed to be represented by various carbon 14 results have not always been accurate.

While tree ring dating appears to be relatively simple and straightforward, there are problems that arise in tree ring studies. Stephen Nash writes, "Tree-ring dating is a straightforward procedure, at least in principle. In practice, it can be astonishingly difficult."[14] Some tree species may show vary little variation in their tree ring growth while others may be aggressive in their response to their environmental conditions. Some species may not grow at all in a given year, yielding a missing ring, while others may provide false rings during some years. Against the problems of missing and false rings, there are two good defenses. First, examining the whole circumference of the ring may yield a partial ring at some point in the ring. This becomes increasingly difficult in situations that require that an increment corer be used, such as when dating the wood out of an ancient cathedral or other structure. In such circumstances only a portion of the circumference of a tree may be available for examination. Secondly, comparison between contemporary old and young trees may provide a valuable defense, as the younger trees are less susceptible to missing or false rings.

There are four conditions that must be fulfilled before dendrochronology can be considered for a given region. First, the tree species being examined can only add one tree ring per year. The dendrochronologist must be able to identify missing and double rings that are sometimes present in stressful years. Second, the growth of the tree species must only be limited by one environmental factor at a time. In some regions tree growth is limited by a lack of moisture. In Alaska tree growth is limited by the cold climate. A combination of these factors would make tree-ring dating virtually impossible. Third, the tree species must show a variation in its growth pattern from year to year. Nash notes, "Trees that enjoy beneficial growth factors tend to produce annual rings that are relatively uniform in their width and, in a sense, have no pattern."[15] Trees that grow under an environmental factor that stresses their growth develop variations in their ring growth that lend themselves to dating.

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[14] Stephen Edward Nash, Time, Trees, and Prehistory: Tree-Ring Dating and the Development of North American Archaeology 1914-1950, (Salt Lake City: The University of Utah Press, 1999) 10.
[15] Ibid., 14.

Lastly, the geographical region within which the trees are being studied has to be extensive enough that the tree-ring data can be crossdated with trees somewhat removed from each other by distance.

There appears to be some influence upon a tree's ring growth based upon its actual growing conditions. Aitken notes, "Although it is evident that trees carry a climatic signal the relative importance of different factors is not easy to assess and interpretation in terms of past climate is far from straightforward. Also, such interpretation – as well as dating – is subject to interference by local environment, e.g. whether the tree was in a dense forest or isolated."[16] Hence trees growing in an open field will demonstrate different growth patterns than trees growing in a forest. When trying to date ancient timber found in a tell or other archaeological site identifying these trees can be troublesome.

The best that dendrochronology can provide is the date that the tree was felled. In order for this date to be provided the sapwood as well as the heartwood must be intact. The sapwood is rarely left attached during woodworking. However, if it was left intact the likelihood of it preservation is small, especially in wet burial conditions. Aitken notes that if the sapwood is not present "then an estimate of the number of rings of missing sapwood has to be made."[17]

In order to check the correctness of a dendrochronological ladder, Baillie notes three levels of replication. Primary replication provides matches between individual tree-ring patterns that go to make up a site chronology. Secondary replication provides a more robust and internal replication as it allows for comparisons between independent site chronologies.

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[16] Aitken, 38.
[17] Ibid., 39.

Tertiary replication “provides the ultimate test, involves correlations between the chronologies of independent workers.”[18]

The tree ring ladder currently extends back to 6700 B.C. for the Bristlecone Pine chronology of the White Mountains of California.[19] A European chronology known as the Irish bog-oak ladder extends back 7300 years.[20] Both of these chronologies have floating chronologies that are thought to be able to add to both ladders significantly if a linking tree can be found. Concerning the suggested ladder of tree-ring data for these chronologies, Baillie suggests that there are gaps in the chronology where the ladder is connected by one or two trees, which makes the chronologies open to significant error. There are also places where chronologies from different regions have been linked together, which causes significant criticism. As a result, the extension of the chronology is open to speculation.[21]

Therefore, dendrochronology is the science of tree-ring dating that works to build a dating ladder based on the study of tree-rings. This science has been used to date ancient architecture and archaeological sites. It has also been used to correct the calibration scales for radiocarbon dating as tree-rings store carbon 14 for calibration purposes. Dendrochronology currently extends back to approximately 6700 B.C.

Thermo Luminescence Dating

Thermo Luminescence dating (which will be referred to as TL in this paper) is used to determine how long ago a piece of pottery or other crystallized element was placed in a

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[18] M.G.L. Baillie, A Slice Through Time: Dendrochronology and Precision Dating, (London: B.T. Batsford, 1995) 28.
[19] Aiken, 44.
[20] Ibid., 45.
[21] M.G.L. Baillie, Tree-Ring Dating and Archaeology, (Chicago: The University Of Chicago Press, 1982), 213-216.

kiln. TL measures the electrons trapped in the crystals in the pottery. This measurement can point to how long ago the pottery was baked in a kiln. This dating method could be used in conjunction with most archaeological sites since pottery and pottery shards are normally present at these sites.

Luminescence dating is based on the principle that when pottery is baked in a kiln, it released its accumulated radiation. Fleming notes, “Each of the minerals used to make a piece of pottery had geological radiation histories even before they were brought together in ceramic manufacture, but kiln-firing at 600°C or more will have completely erased the associated TL signal.”[22] A scientific explanation is given when Nash writes, “The natural radioactivity present in these materials and their surroundings cause ionization of atoms, which leads to subsequent trapping of charged particles at defects in the crystal lattice. Exposure to sufficient heat or light releases the charge from these traps and results in a luminance signal whose intensity is proportional to the time elapsed since the previous detrapping event.”[23] Aitken notes, “The act of firing ‘drained’ all previous TL, thereby setting the clock to zero.”[24] Once the collected luminance is released from the crystals contained in the pottery, it begins to build its luminescence at a constant rate that is measurable when the pottery is exposed to sufficient heat again.

Thermo luminescence dating is significantly harder to perform than radiocarbon dating. In radiocarbon dating the carbon14 decays at a regular rate in spite of the element that contains it. With Thermo Luminescence dating, each material holds a different sensitivity and “each sample must be measured individually because it will be influenced by

[22] Stuart Fleming, Thermoluminescence Techniques in Archaeology, (Oxford: Oxford University Press, 1979) 2.
[23] It’s About Time: A History of Archeaological Dating in North America, ed. Stephen E. Nash, (Salt Lake City: The University of Utah Press, 2000) 152
[24] Aiken, 142.

the actual impurity content and thermo history."[25] Nash notes, "Luminescence requires the measurement of a multitude of variables, each with its own error term, which when propagated lower precision."[26] In essence there are more tests that need to be performed and more calculations that need to be completed. On the other hand radiocarbon dating does not produce a calendar date with its result; Thermo Luminescence dating does.

It should be noted, as well, that while radiocarbon dating only extends back 30 to 40 thousand years, and Dendrochronology reaches back approximately 8,000 years, Thermo Luminescence dating can reach back nearly 500,000 years. Giving it the longest reach of those dating methods studied in this paper. For those holding an old earth philosophy this would be a strong selling point.

When a piece of pottery is tested for Thermo Luminescence, it is first ground to a fine powder and is then placed in an oven that is fitted with a photomultiplier. When the sample is heated it will give off three types of light. The first is incandescence, which is the red-hot glow that emanates from the sample. This light will overload the photomultiplier and must be filtered out using a special filter. The second light is spurious thermo luminescence and is the result of the impurities in the sample as well as the process of preparing the sample. This spurious emission is controlled through the use of an inert gas like nitrogen, argon, or helium. This also requires the evacuation of oxygen from the oven before injecting the gas.

Another important requirement of laboratory preparation is that all processing must be completed under red light. Aitken notes, "exposure to light causes most minerals to lose some of their latent TL (i.e. to be 'bleached'); sunlight, daylight and fluorescent white lights

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[25] Aiken, 143.
[26] Nash, It's About Time, 160.

are particularly effective."[27] This genders a question. What if the owner set the pottery out in the sun for days, months, and years after it was baked,? Would this effect the Thermo Luminescence dating? If momentary exposure in the laboratory will impact the sample, one has to wonder about the samples treatment throughout its history, including its discovery at the archaeological site. One safe guard that is imposed in the testing process is that a second sample is tested that is carrying an artificial dose of TL that is applied for the purpose of verifying the testing procedure that is employed.

Aitken notes that the position of the sample in the ground is a large part of the accuracy of Luminescence dating. In his text Aiken provides a figure that shows how a sample buried less than 30 cm under the surface would be contaminated by the gama radiation that could penetrate the soil to that level. He also notes that debris buried near the sample could contaminate the sample as well. In his figure Aitken notes even a rock, if it does not have the same level of radioactivity as the sample, could significantly affect the same.[28]

In considering Thermo Luminescence dating for archaeological purposes one must consider the error margins of the method. Fleming demonstrates in his text that the error margins for this dating method may make it impractical for most archaeological sites that are within the dating range of radiocarbon dating. He notes, "little effort has been (or indeed should be) expended on pottery from Mediterranean cultures active in the first millennium BC or on Roman wares of the first four centuries AD, unearthed in northern Europe. Stylistic dating for those parts would rarely carry more than twenty years uncertainty, but a TL result would be unlikely to carry a standard error, σ, of less than ± 150 years per

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[27] Aitken, 147.
[28] Ibid., 154.

analysis."[29] Therefore, the error margins of samples that can be more accurately dated with other methods are to be preferred over Thermo Luminescence dating.

It is interesting that Aitken writes, "pottery was not made much before 10,000 years ago and it is earlier, in the Palaeolithic, beyond the 40,000—year range of radiocarbon that TL makes it most important contribution to archaeology."[30] Here Aitken turns his discussion toward dating materials like flint, burnt stones, volcanic lava, and other elements. The difficulty with each of these other elements revolves around how well the TL clock was set to zero. Was the element heated enough to release the TL content within the sample? That is a question that may never be answered.

Possibly the most noted problem discussed in the study of Thermo Luminescence dating is the question of contaminating the sample with outside influences. It is difficult to understand how a sample buried less than 30 cm in the ground could be contaminated while the same sample was originally created to be used in daily life. Certainly, the piece of pottery was not created and then immediately buried. It most likely had significant exposure to sunlight, most likely direct sunlight. How would long-term exposure to direct sun light effect the luminescence dating of the object? Having searched for an answer none was found in the texts available to this author.

Therefore, Thermo Luminescence dating attempts to date an artifact based on its thermo luminescence radioactive content. It is based on the principle that pottery and certain other elements release their luminescence content when they are exposed to enough heat, like the heat of a kiln oven. This heat essentially sets the luminescence clock to zero for the sample in question. Over time, the sample will recollect and store luminescence radioactivity

[29] Fleming, 127.
[30] Aitken, 167.

that when reheated can be measured to establish through a difficult process believed to be an accurate calendar date for the artifact.

Conclusion

In this study we have considered the scientific dating methods of radiocarbon dating, dendrochronology, and thermo luminescence dating. We have considered the origin, principles and difficulties surrounding each method. We have also considered the reasonable date ranges that might be provided by each method. In the end we find that these scientific methods are less reliable and usable than the general public might currently understand. In subsequent modules of study it will be discovered that these scientific methods are rarely trusted by archaeologists in the field today.

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