

THE USE OF NATURAL SCIENCE TO AUGMENT CHRONOLOGICAL KNOWLEDGE IN BIBLICAL ARCHAEOLOGY

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ABSTRACT

Biblical archaeology, as with all the modern-day scientific fields, benefits from the advances in technology and development of new techniques. Chronology, the study of the order in which things occur, is paramount in biblical archaeology. The application of scientific principles to determine chronology, together with the utilisation of refined techniques in radiocarbon dating, enables biblical archaeologists to obtain a clearer picture of the Holy Land of ancient times. Scientific principles, with the aid of modern technology, enhance the accuracy of relative chronology. Radiocarbon dating presents the biblical archaeologist with a valuable tool in unravelling the past.

INTRODUCTION

Logical empiricists² insist that there is only one kind of knowledge: scientific knowledge (Microsoft Encarta 2009:s.v. epistemology). This view requires “conditions under which a body of evidence supported a scientific hypothesis” (Kitcher 2012). Scientific knowledge of the world is only partial and the progress of science follows the ability of humans to make phenomena perceivable (Encyclopædia Britannica 2012:s.v. history of science). The field of natural science blossomed in the twentieth century and continues to do so in the twenty-first century. Archaeologists greatly benefit from this rich resource, which enables them to garner data previously not possible – to support a scientific hypothesis in the biblical archaeological field by making it perceivable. The archaeologist has to remember what Moses Maimonides,

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² Empiricism: application of observation and experiment: the application of observation and experiment, and not theory, in determining something (Encarta Dictionaries 2009: *s v* empiricism).

also known as Rabbi Moses ben Maimon (1135–1204), a Spanish-born Jewish rabbi, philosopher, and physician said, “A great disparity subsists between the knowledge an artificer has of the thing he has made and the knowledge someone else has of the artefact in question” (Microsoft Encarta 2009:s.v. knowledge).

The modern era of the scientific study of archaeology in Palestine truly began in 1890 when William M. Flinders Petrie (1853-1942) applied the concept of stratigraphy, based on the principle of sequence dating, in his excavations at the Palestinian site of Tell el-Hesi (Currid 1999:28; Poole 2012). In the infancy of biblical archaeology, vast amounts of macroscopic material were discarded due to the lack of expert care and scrutiny, aggravated by poor recordkeeping. An example of poor recordkeeping is the case of Johan Garstang, who did not publish his results from the 1928 excavations at Hazor in detail (Currid 1999:25; Scheepers and Scheffler 2000:59), while Gottlieb Schumacher’s ignorance and avoidance of ceramic work at Megiddo at the turn to the twentieth century made his finds of little service to later archaeologists. Unfortunately, as Currid states, they are not the only culprits in this regard (Currid 1999:29, 79). Today, minute material, such as a grain of pollen or a piece of charcoal, may provide data surpassing that gained from macroscopic finds (Greeff 2005:23–24).

This article will focus on the development and the use of sequence dating to determine chronology in the field of biblical archaeology from the first archaeologist who applied it in Palestine, Flinders Petrie, to one of the modern-day archaeologists, Finkelstein, with their contributions to chronology.

HISTORY OF CHRONOLOGY

Definition of chronology

Chronology is the “study of order in time: the study of the order in which things occur, or the science of determining this” (Encarta Dictionaries 2009). Scientific chronology seeks to place all happenings in the order in which they occurred and at correctly proportioned intervals on a fixed scale, illuminating the sequence of change. However,

it is difficult to fix ancient historical chronologies in relation to scientific chronology, because the terms of reference of ancient peoples were vague and inconsistent when judged by modern standards. Furthermore, many of their inscriptions and writings have inevitably disappeared. This leaves gaps in the chronologies which are increasingly filled, and their inconsistencies removed, by the results of archaeological excavation (Encyclopædia Britannica 2012:s.v. archaeological timescale, chronology).

Relative chronology

Today chronology is divided into relative and absolute chronology. Relative chronology utilises relationships on a single archaeological site to deduce the sequence in which the materials were assembled, based on stratigraphy. Pottery is a major part of materials used to determine the sequence of events in the ancient Near East (Currid 1999:29). Similar objects at two separate sites may link these sites chronologically, but only relatively (Finkelstein 2013:6; Finkl 2009; Krogh 2012).

Absolute chronology

Radiometric dating methods developed since the 1940s, after the discovery of radioactivity, thereby calibrating the relative chronology to create an absolute chronology. Carbon-14 is the principal atom used today in biblical archaeology to enable accurate dating in a resolution of fifty years and less (Finkelstein 2013:6; Finkl 2009; Krogh 2012). The development and methodology in radiocarbon dating are discussed later in the article.

Chronology in the ancient Near East

Petrie's work at Tell el-Hesi was the first stratigraphic excavation in Palestine. Recognising that a Palestinian mound was the result of new towns being built on the ruins of old ones, he began linking every stratum, or level, with the different types of pottery found in each. By examining the imported Egyptian objects contained in each level, Petrie was able to link Palestinian chronology with that of Egypt, thus establishing the general principle that the development of Middle Eastern sites can be

interpreted in terms of stratigraphic levels, ultimately being dated using Egypt or another country with an established chronology as a comparison (Poole 2012). Consequently the archaeological definition of stratigraphy developed, namely “vertical section through ground: 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” (Encarta Dictionaries 2009). In Palestine this is applicable to the excavation of tells³ – mounds formed by the accumulation of the remains of successive ancient settlements (Merriam-Webster 2012).

Willard F. Libby developed the carbon-14 dating technique in 1947 and received the 1960 Nobel Prize in chemistry for this work. Since then techniques to enhance the accuracy of the dating of archaeological samples have developed, and today these are an invaluable part of biblical archaeology.

RELATIVE CHRONOLOGY - POTTERY

Any man-made object found at an excavation site is significant. Currid classifies these finds as architecture, small finds, and ceramics, with the importance of pottery/ceramics placing it in a class of its own (Currid 1999:103).

Pottery is one of the most important aspects in archaeology due to the immense amount of data it provides to the archaeologist, especially regarding dating. The first archaeologists to publish the chronological significance of painted pottery were A. Furtwängler and G. Loeschcke, *Mykenische Thongefässe* in 1879 (Currid 1999:122). They focussed on painted pottery, while Petrie highlighted the value of unpainted pottery in 1890 at Tell el-Hesi. As discussed *supra*, Petrie underscored the identification of pottery within the strata of a tell to form a chronological sequence of the excavation.

Due to the intrinsic properties of pottery, it renders the intact/unbroken vessel vulnerable, but the potsherds are durable and are found in almost all the strata at an

³ The word “tell” is derived from the Arabic word *tall*, meaning small hill (Encarta Dictionaries 2009).

archaeological site. After more than a hundred years of analysing the common pottery of ancient Palestine, archaeologists are now confident that they can date most forms, even small fragments, within about a century. Dever wrote about archaeologists' obsession with pottery:

As one scholar, Robert Ehrich, has observed: 'Pottery is our most sensitive medium for perceiving shared aesthetic traditions, in the sense that they define ethnic groups, for recognizing culture contact and culture change, and for following migration and trade patterns' (Dever 2003:118).

Pottery characteristics, like modern automobile designs, clothing fashions, and modern-day "pottery" (e.g., cold drink, beer and food cans), changed over time, growing and then diminishing in popularity (Rathbun and Buikstra 1984:87–93). By noting these changes, archaeologists can establish long sequences of artefact styles. This helps to understand the sociology of the ancient culture and its daily lifestyle and develop chronological sequences (Fagan 2009).

Some pottery has inscriptions and such a potsherd is known as an ostrakon (plural ostraca). The epigraphic significance of pottery is such that Yohana Aharoni, director of excavations at Tel Arad (1962–1984), decided that all potsherds should be dipped in water and examined prior to scrubbing with a brush. This is now standard practice in Israeli excavations (Scheepers and Scheffler 2000:276, 302). Epigraphy encompasses inscriptions at large, be they on primary writing surfaces or on such assorted objects as vases, potsherds, gems, seals, stamps, weights, rings, lamps or mirrors. A further related discipline is palaeography, which concerns itself with the study of scribal hands and styles of writing and has significance for the *dating* of epigraphic as well as other written documents (Puhvel 2012). Ostraca with epigraphical dating augments the chronological value of pottery.

A potsherd on a table is just what it is – a potsherd. To unlock its full value, a potsherd must be evaluated *in situ* and its position in the excavation site meticulously documented (Seger 1998:359). This is to be able to place the artefacts in sequential perspective, according to not only the excavator, but also subsequent researchers. The

lack of systematic documentation and ignorance regarding the value of pottery from older excavations (e.g., Schumacher at Megiddo, 1903–1905) resulted in a huge loss of potential data (Currid 1999:29, 79). Modern technologies, with for instance accurate GPS positioning and total station transits⁴ with different software programs, are of immense help (Joukowsky 1998:294–295). The pottery tells the story of the people of every stratum of the site and helps the archaeologist to slot them into a certain time in the history of the site.

Relative chronology is based on individual interpretation of artefacts, such as pottery, and results in lively debates in the biblical archaeological field. An example is Kenyon's 1973 chronological sequence vis-à-vis the Late Bronze Age, because "(I)n spite of her keen eye for stratigraphical detail and her implicit caveat against placing too much emphasis on sites that were poorly excavated during the infancy of the discipline, Kenyon's system has not been widely accepted ... Weinstein arrived at the relative chronology that is used in this article" (Leonard 1989:7). However, chronology in biblical archaeology is at such a stage that a respected scholar such as Finkelstein (2013:6) ventures the following statement:

Our knowledge of the chronology ... of the Iron Age strata and monuments in the Levant has been truly revolutionized. In terms of relative chronology, intensification of the study of pottery assemblages from secure stratigraphic contexts at sites such as Megiddo and Tel Rehov in the north and Lachish in the south opened the way to establish a secure division of the Iron Age into six ceramic typology phases: early and late Iron I ... early and late Iron IIA ... Iron IIB and Iron IIC.

⁴ Transit: "Surveying instrument: a surveying instrument surmounted by a telescope that can be rotated completely around its horizontal axis, used for measuring vertical and horizontal angles" (Encarta Dictionaries 2009:s.v. transit). Total station transits combine electronic measurement of angle with distance and have digital data-loggers and on-board computers for a very efficient means of mapping sites, allowing greater detail and accuracy in measurement. The data can be analysed in various ways depending on the software applications being used (Dupras et al. 2012:165–166).

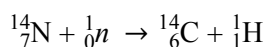
ABSOLUTE CHRONOLOGY

The radioactive carbon-14 atom revolutionised chronology in archaeology, particularly biblical archaeology. The fundamental building block of material in all living organisms is carbon, which forms more compounds than all the other elements combined and is present in all substances known as organic compounds (Encyclopædia Britannica 2012:s.v. carbon; Lutz 2009). The fact that carbon is present in all organic compounds renders it the “perfect” element to use in determining “answers” from organic material.

Carbon-14 dating: theory

The most abundant stable isotope⁵ of carbon is carbon-12, which makes up 98.89% of natural carbon, with carbon-13 isotope only 1.11% (Fig. 1). There are 12 radioactive isotopes, with only the radioactive carbon-14, with the longest half-life of $5\,730 \pm 40$ years, being of value to science vis-à-vis dating of biological matter.

Carbon-14 is not a “naturally” occurring atom, but is formed by the interaction of neutrons, produced by cosmic radiation, with nitrogen (N) in the atmosphere (Fig. 2) in a reaction that may be written as follows (a neutron is symbolized as ${}_0^1n$, the nitrogen atom as ${}_7^{14}N$, and a hydrogen nucleus, or proton, as ${}_1^1H$) (Encyclopædia Britannica 2012:s.v. carbon):



⁵ Isotope: “form of element with same atomic number: each of two or more forms of a chemical element with the same atomic number but different numbers of neutrons” hence constituting the same element, but with different mass numbers (Encarta Dictionaries 2009; Microsoft Encarta 2009:s.v. isotope).

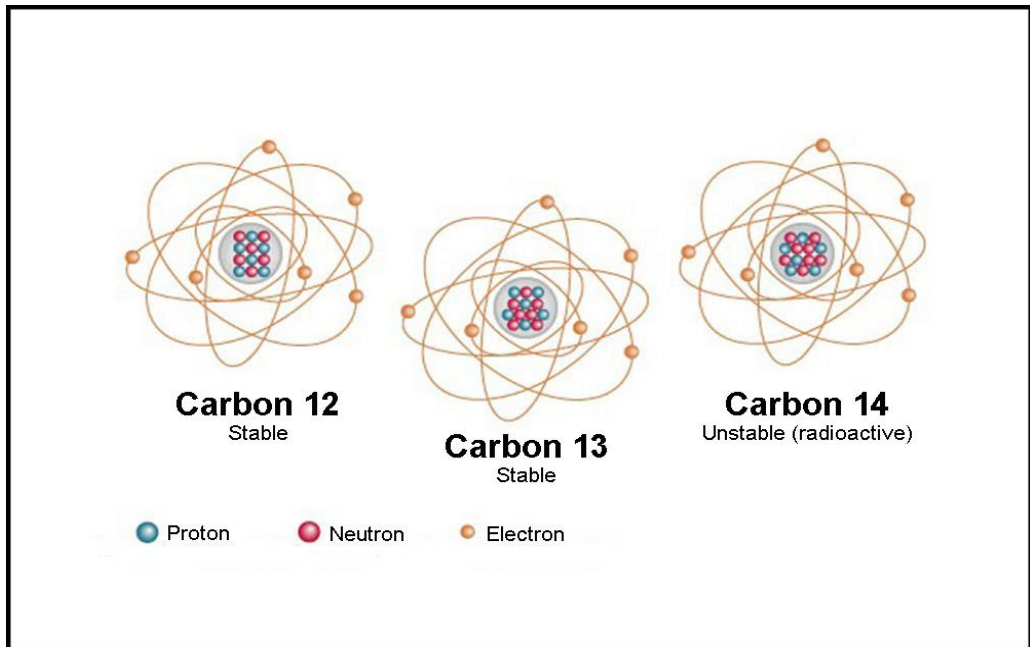


Figure 1: Isotopes of carbon depicting the difference in the nuclei
(Microsoft Encarta 2009: *s v* carbon).

The result is a carbon atom (isotope) with six protons and eight instead of six neutrons. Carbon-14 is radioactive – its combination of protons and neutrons is unstable and a neutron in its nucleus can decay.⁶ The carbon-14 atoms are converted to carbon dioxide by reaction with atmospheric oxygen and mixed and uniformly distributed with the carbon dioxide containing stable carbon-12 (Fraser 2009). Living organisms use atmospheric carbon dioxide, whether with stable or radioactive carbon, through processes of photosynthesis and respiration, and thus their systems contain the constant ratio of carbon-12 to carbon-14 that exists in the atmosphere. Carbon-14 forms one part per trillion of the carbon in the atmosphere, thus the same in any living organism (<http://www.informath.org/Basic14C.pdf>).

⁶ Decay: “NUCLEAR PHYSICS disintegrate: to undergo spontaneous disintegration (refers to radioactive material)” (Encarta Dictionaries 2009).

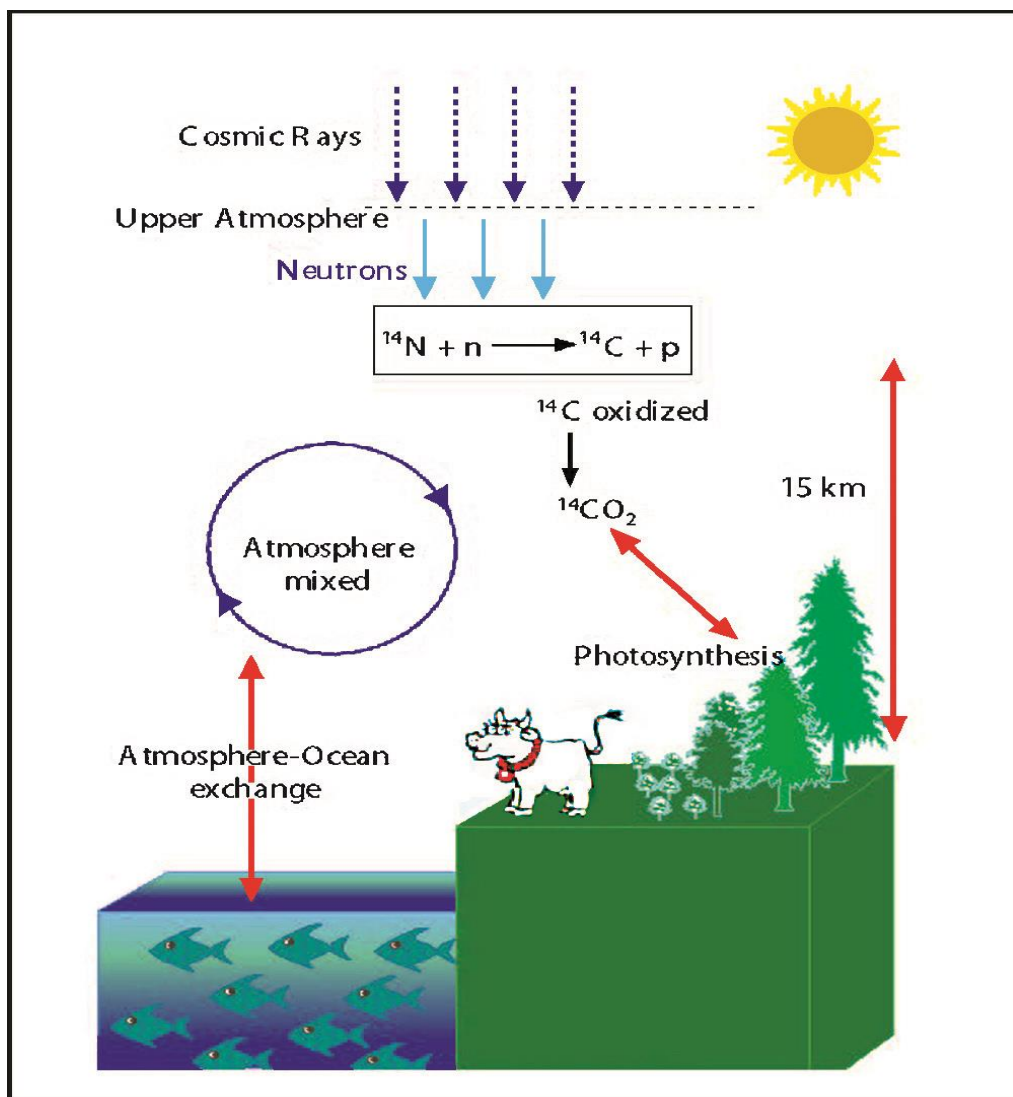


Figure 2: Production and distribution of cosmogenic carbon-14. Produced mainly in the upper atmosphere due to interaction of thermal neutrons with nitrogen, carbon-14 is relatively quickly oxidised and mixed in the atmosphere. Through photosynthesis, it enters the biosphere and through gas exchange, the oceans (Hajdas 2008:3).

The carbon cycle describes the way carbon is incorporated into all living organisms. Photosynthesis utilises carbon dioxide from the atmosphere and forms organic compounds. These compounds are then digested by other organisms and form part of the food chain in the carbon cycle. The result being that all living organisms have

carbon built into their bodies that is in equilibrium with the carbon isotope ratio in the atmosphere (Fig. 2). Every living organism must metabolise substances to stay alive. We assimilate cosmic-ray produced carbon-14 atoms at exactly the same rate that the carbon-14 atoms in our bodies disappear to form nitrogen. Metabolism ensures that the bodily and atmospheric carbon isotopes stay in equilibrium while the organism is alive, but stops the moment the organism dies. The moment the carbon-14 atoms are not replaced from atmospheric carbon-14 in the dead organic matter, the concentration starts to diminish due to carbon-14 decay (Libby 1960:595–596).

These radioactive carbon atoms, by way of a radioactive reaction, convert back to nitrogen at a known rate of conversion. This phenomenon is expressed as the half-life of the carbon-14 atom, the time radioactive carbon-14 takes to lose half its radioactivity through decay. The half-life of carbon-14 is $5\,730 \pm 40$ years (Encyclopædia Britannica 2012:s.v. carbon-14 dating; Finkl 2009; Hajdas 2008:3). Thus, if you know the amount of carbon-14 with which a sample started and know the total of the carbon-14 atoms left in the sample, it is possible to calculate how long it took the sample to “lose” the “converted” carbon-14 atoms (Fig. 3). The techniques used to measure and calculate the carbon-14 concentration since Libby’s first carbon-14 counting changed, as did many fields of science with the development of new advanced techniques.



Figure 3: Radioactive decay of carbon-14
(<http://hyperphysics.phy-astr.gsu.edu/hbase/nuclear/cardat.html>;
accessed 2015/10/25).

Carbon-14 dating: methodology

Libby developed the theory that due to the radioactivity of carbon-14 and its known rate of decay it would be possible to determine the age of a specific sample. He and his partner, Arnold, used the black carbon method, needing about 10 grams of carbon to be able to count the rate at which the sample produced radioactive reactions from carbon-14 decay (Libby 1964?:17). They had to count the individual radioactive incidents as the carbon-14 converts back to nitrogen, using a screen wall Geiger counter (Libby 1964?:7). It took up to three months to carefully measure a sample, such as when Libby attempted to test the limit of sensitivity of radiocarbon dating. He tested a sample of wood that came from a beam from the roof of a house in Nippur, which bore a clear and legible Hammurabian calendar date. This lengthy test helped settle a dispute vis-à-vis the correlation between the Babylonian calendar in the time of King Hammurabi and our current calendar, due to the problem of identification of a particular eclipse from about 4 000 years back (Libby 1960:608-609). Among the samples Libby tested was the linen wrapping (Fig. 4) of one of the Dead Sea Scrolls, the Book of Isaiah (Libby 1960:603).



Figure 4: Box of linen in the Qumran stores, Rockefeller Museum, Jerusalem, with the bitumen impregnated into the fabric (Taylor 2012:xiv).

Newer techniques progressively used less carbon to attain the required results. Libby commented on the “new” CO₂ proportional carbon technique that only requires 4 to 5 grams of elementary carbon per run, thus using less material than the “old black carbon method” (Libby 1964?:17). Today, with the development of several forms of accelerator mass spectrometers and other equipment, very small samples can be analysed (Richter 2009). There are different techniques to analyse the sample, but the basic methodology is to convert molecules into ions⁷ and then to separate the ions according to their mass-to-charge ratio. Accelerator mass spectrometers are used to identify atoms and isotopes and determine the chemical composition of a sample. This allows the scientist to measure the specific ratio of carbon-12, carbon-13 and carbon-14 directly, without counting the radioactive conversions of carbon-14 to nitrogen, as Libby did. Subsequently, the age of a sample can now be calculated, because the amount of carbon-14 at the beginning (equal to atmospheric carbon-14 levels at time of death), as well as the rate of decay is known. A tandem mass spectrometer, consisting of more than one mass spectrometer, is more than a thousand times more sensitive than any single unit, making them useful for analysing extremely small quantities of biological compounds (Brown 2012; Microsoft Encarta 2009:s.v. mass spectrometer).

A single grain of pollen can be used (as little as one milligram of carbon!), following general archaeological methodology vis-à-vis the stratum where it was found, to help determining the chronology of an excavation (Krogh 2012). The average sample size depends on the type of material tested and the carbon content of the sample. For example, a bigger sample of bone (500–1 000 mg) is necessary, where the measurable carbon containing collagen is only part of the composition of the specimen (collagen amounts to 20 weight per cent⁸ of fresh bone, usually much less in archaeological specimens), than specimens with higher carbon content, such as plant remains, charcoal and keratin. These higher carbon content samples usually weigh 20–

⁷ Ion: “electrically charged atom or atom group: an atom or group of atoms that has acquired an electric charge by losing or gaining one or more electrons” (Encarta Dictionaries 2009).

⁸ Collagen weight per cent is the amount of collagen extracted as a percentage of the starting weight of bone.

100 mg, although single entities often weigh 10–20 mg or less (Brock et al. 2010:106; Strafford et al. 1987:24; Yizhaq et al. 2005:197).

Different preparative techniques and safeguards have been refined in treating the different types of samples analysed during radiocarbon dating to ensure that all contaminants, which may give inaccurate results, are removed from the sample prior to testing. Brock et al. (2010:103–112), Higham et al. (2006:179–195) and Yizhaq et al. (2005:193–206) provide detailed descriptions of these techniques. Furthermore, if possible, scientists prefer charcoal to bone as a material for dating, mainly because of the susceptibility of bone to contamination with younger carbon, in addition to the decay of collagen with time (Yizhaq et al. 2005:203). This “radiocarbon-dating-bone-problem” was tackled head on by developing bone-specific procedures utilising new technology and refining techniques, such as newer generation accelerators and the introduction of ultrafiltration in the routine pre-treatment of bone (Higham et al. 2006:182; Strafford et al. 1987:24–44).

Measurement precision determines the T_{\max} (the maximum determinable age) of every individual specimen since the limit for reporting finite carbon-14 ages is reached at twice the total standard error for an individual carbon-14 measurement. With modern-day precision techniques the scatter of results for known-age materials, such as tree rings, are not higher than the reported standard error, consequent to these standards applied during testing (Higham et al. 2006:181). Archaeologists thus have a very powerful tool in their armamentarium.

Carbon-14 dating: problems

Unfortunately, there are some limitations regarding radiocarbon dating. The three main areas causing problems regarding absolute chronology are:

- Current (post 1950) carbon-14 levels cannot be used as the baseline level.
- Fluctuation in the carbon-14 ratio in the atmosphere.
- The relative short half-life of carbon-14.

These problems, as well as their impact on biblical archaeology will be outlined *infra*.

Post-1950 carbon-14 levels

To be able to calculate the age of any sample, the baseline level of carbon-14 must be known, meaning that the levels in a living organism, where the atmospheric and bodily levels of carbon-14 are in equilibrium, must be determined. The problem is that the post-1950 carbon-14 levels are twice as high as the average of the previous 5 000 years (Krogh 2012). This is the result of nuclear explosions, which due to the radioactive reactions with nitrogen, increased the carbon-14 level to double that of the pre-nuclear era. Consequently, living organisms today have a carbon-14 level double than those before nuclear explosions and current baseline carbon-14 levels cannot be used as the baseline for archaeological specimens.

Scientists calibrated their calculations to levels prior to 1950. The significance to biblical archaeologists is that the date assigned to a sample from radiocarbon dating would be “X” amount of years *before present*, with *present* being set at the year 1950 on the Gregorian calendar (Richter 2009: *s v* carbon dating & archaeology). The date assigned to a sample will initially be given as a raw bp or before present. This date can then be calibrated with other dating methods (*vide infra*) to ensure maximum accuracy. The newly calibrated result is then given as a more absolute BP, which can be correlated to the Gregorian B.C.E./C.E. dates (raw dates that are calibrated to the same calendar system are written as lowercase bc/ad or bce/ce). If capital letters are used, Cal BP is used to indicate a calibrated date (Hajdas 2008:16). Archaeologists must remember that dates given in the BP-form are before 1950. With every sample, there is a margin of error due to the half-life of carbon-14 ($5\,730 \pm 40$), thus “X” ± 40 years (Richter 2009).

Unfortunately, not all authors strictly apply this method of uppercase/lowercase lettering when presenting radiocarbon dates in articles or books, though an indication is usually given when referring to a calibrated date.

Fluctuation in carbon dioxide levels

Studies have revealed that the atmospheric radiocarbon level prior to 1 000 B.C.E. deviates measurably from the contemporary (1950) level. In the year 6 200 B.C.E. it

was about 8% above what it is today (1950-level). In the context of carbon-14 dating, this departure from the present-day level means that samples with a true age of 8 200 years would be dated by radiocarbon as 7 500 years old (Krogh 2012).

It is now clear that carbon-14 is not homogeneously distributed among today's plants and animals. Furthermore, levels were not stable throughout the ages. The deviations all involve nonatmospheric contributions of carbon-14-depleted carbon dioxide to organic synthesis. Specifically, volcanic carbon dioxide is known to depress the atmospheric carbon-14 level (Krogh 2012). Although the amount of carbon-14 stays the same, subsequent to more carbon dioxide in the atmosphere, the carbon-12/carbon-14 ratio changes and the percentage in living matter is proportionally smaller after a volcanic eruption. Volcanos spewed huge amounts of carbon-12-rich smoke and ash into the atmosphere (Decker and Decker 2012).

Biblical archaeology is in the fortunate position that it falls mostly in the historical era. This enables archaeologists to date at least certain historical events accurately. For example, ancient calendars, astronomy and documented astronomical events help to determine specific historical dates. An ancient calendar synchronised with the Gregorian calendar enables historians/archaeologists to date a documented event such as the death of a king (Libby 1960:600). If, for example, the tomb of an Egyptian king is excavated, scientists use biological matter from such dated artefacts to calibrate and form chronological levels vis-à-vis “historical” carbon-14 levels. Current laboratories’ submission form lists specific questions related to sample context and archaeological provenance, because this enables the expansion of the carbon-14 level database regarding fluctuations through time (Brock et al. 2010:105). Finkelstein (2013:8) mention Megiddo as an exceptional example:

A statistical model for a single site – Megiddo: circa 100 radiocarbon determinations from about 60 samples for 10 layers at Megiddo, which cover circa 600 years between circa 1400 and 800 B.C.E. ... Megiddo is especially reliable for such a model because the time span in question features four major destruction layers that produced *many organic samples from reliable contexts* [author’s italics]. This, too, is

unprecedented: no other site has ever produced such a number of results for such a dense stratigraphic sequence.

Dendrochronology is another method to calibrate radiocarbon dating. A tree produces a “ring” during every annual growing season. Although a tree may live for hundreds, even thousands of years, each ring of a tree absorbs carbon only during the year in which it grows. The year in which a ring was grown can be determined exactly (by counting), thus radiocarbon dating can be calibrated by measuring the carbon-14 concentrations in tree rings of a known age. The bristlecone pines of California have proven to be particularly suitable for such chronologies, since some individual trees are more than 4 000 years old (Encyclopædia Britannica 2012:s.v. dendrochronology). Again, biblical archaeological chronology fortunately falls in the purview of this calibrating method vis-à-vis radiocarbon dating.

Notwithstanding momentous advances in calibrated radiocarbon dating, especially regarding the biblical archaeological time frame, there are still “wiggles” in the calibration curve. These complications arise from variations in atmospheric carbon-14 content caused by the changes in the production rate and changes in the carbon cycle (Hajdas 2008:16). Carbon-14 decay is constant, thus an age/concentration-graph should be a smooth curve, which the tests do not reflect. One of these “wiggles”, or problem areas in the calibrated chronology graph, is called the Hallstatt plateau (Fig. 5), 2500-2400 BP (700-400 B.C.E.), which prevented Finkelstein giving accurate dates to samples that come from Iron Age IIB and Iron Age IIC contexts (Finkelstein 2013:7). With continuous testing of organic samples from known context, the Hallstatt plateau will probably be calibrated and it will be possible to ascribe accurate dates to samples from unknown context from this period.

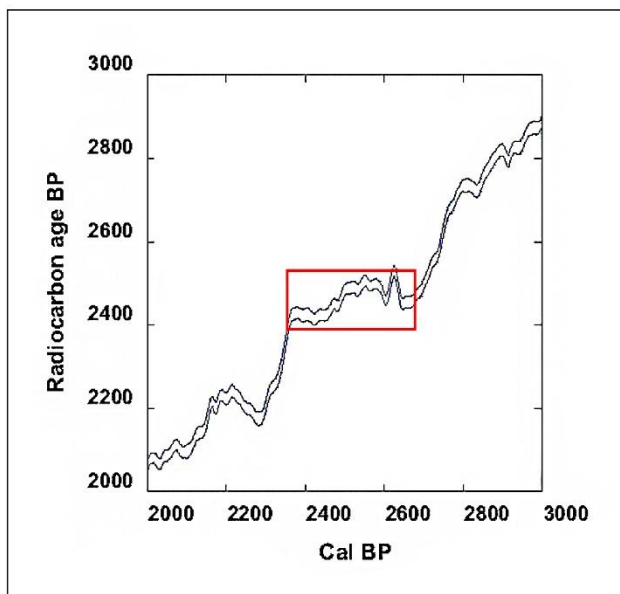


Figure 5: Radiocarbon age plateau (wiggle) at 2400-2500 BP (700 B.C.E. and 400 B.C.E.) known as a “Hallstatt plateau” marked on the radiocarbon calibration curve (Hajdas 2008:16).

Relative short half-life of carbon-14

The half-life of carbon-14 is $5\,730 \pm 40$ years. This is relatively short if compared to, for example, uranium-238, with its practically indefinite half-life (Lewin 2009). It is now known that uranium, radioactive in all its isotopes, consists naturally of a mixture of uranium-238 (99.27%, 4 510 000 000-year half-life), uranium-235 (0.72%, 713 000 000-year half-life), and uranium-234 (0.006%, 247000-year half-life). These long half-lives make determinations of the age of the earth possible by measuring the amounts of lead, uranium’s ultimate decay product, in certain uranium-containing rocks (Encyclopædia Britannica 2012:s.v. uranium). The problem regarding the “short” half-life of carbon-14 compared to uranium emerges when older specimens are dated. The “rapid” disintegration of carbon-14 generally limits the dating period to approximately 50 000 years, although the method is sometimes extended to 70 000 years. Uncertainty in measurement increases with the age of the sample and errors as great as 2 000 to 5 000 years may occur (Finkl 2009).

Biblical archaeology is again the field where the “dark cloud has a silver lining”, because it falls in the time-slot where radiocarbon dating is the most sensitive.

RADIOCARBON DATING IN BIBLICAL ARCHAEOLOGY

As discussed (*vide supra*), biblical archaeology is in the position where the three main problem areas regarding radiocarbon dating do not affect the dating process as much as in some of the other archaeological fields. The fortunate chronology of biblical archaeology places it in the documented historical era. This enables scientists to use these documents, as well as organic archaeological samples from reliable contexts, to calibrate the carbon-14 levels regarding the last 5 000 to 6 000 years. The result is the ability to date samples from the ancient Near East with an accuracy of ± 40 years.

Chronology in biblical archaeology

Finkelstein is one of the modern archaeologists who contributed to calibrate radiocarbon dating, especially in Israel. “The radiocarbon results from Israel are the most intensive for such a short period of time and small piece of land ever presented in the archaeology of the ancient Near East” (Finkelstein 2013:7). Finkelstein based a statistical model (Tab. 1), utilising radiocarbon dating to produce 229 results after 143 samples from 38 strata at 18 sites in Israel were collected.

In Table 1, radiocarbon dating and pottery/ceramic phases are merged to help the biblical archaeologist on yet unexplored (as well as old sites) to propose dates to artefacts/strata, which was previously impossible.

Radiocarbon dating is further applied to facilitate archaeology-based history, which Finkelstein did *vis-à-vis* the northern kingdom of Israel. Yadin reckoned the six-chambered gates in casemate walls at Hazor (Fig. 6), Megiddo and Gezer were built by Solomon’s engineers, who according to 1 Kings 9:15 fortified these three cities. Yadin called them “Solomonic Gates” (Scheepers & Scheffler 2000:65; Yadin 1963:288-289, 374).

Table 1: Dates of ceramic phases in the Levant and the transition between them according to recent radiocarbon results (based on a Bayesian model, 63% agreement between the model and the data) (Finkelstein 2013:7).

Ceramic Phase	Date of Phase [BCE]*	Transition between Phases [BCE]
Late Bronze III	-1098	1125–1071
Early Iron I	1109–1047	1082–1037
Middle Iron I	1055–1028	1045–1021
Late Iron I	1037–913	960–899
Early Iron IIA	920–883	902–866
Late Iron IIA	886–760	785–748
Transitional Iron IIA/B	757–	

* The beginning of the first phase and the end of the last phase cannot be determined by the data at hand.

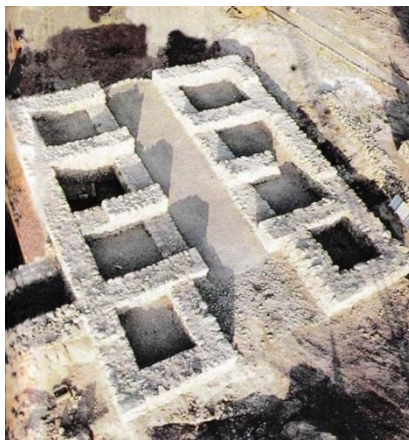


Figure 6: The foundation walls of the six-chambered gate of Hazor (Scheepers and Scheffler 2000:67).

With development in biblical archaeology, together with natural science, it seems as if Yadin was not correct in his reckoning regarding Solomon as the builder of these monumental buildings. Finkelstein's understanding of the chronology of the Omride dynasty, based on scientific data, will be hard to refute:

On the side of archaeology, it has become clear, among other reasons thanks to the *radiocarbon studies* [author's italics] mentioned above, that the monuments that were traditionally perceived as representing the great united monarchy of the tenth century B.C.E. were in fact built during the rule of the Omride dynasty in Israel in the ninth century B.C.E. (Finkelstein 2013:9)

CONCLUSION

The modern archaeologist has the privilege of the availability of modern science. However, it would be imprudent not to use the foundation of sound archaeological doctrine ascertained by the "founding fathers" of biblical archaeology, such as Petrie's stratigraphic approach. The principles applied to establish relative chronology utilising pottery continue to be based on Petrie's guidelines. To be able to combine it with radiocarbon dating enables the biblical archaeologist to form a perceivable world from the ancient sites.

Libby, the "father" of radiocarbon dating, was not wrong when he said in his Nobel Price lecture on 12 December 1960:

The determination of the chronology of ancient civilizations may be said to be the main archeological problem and task of radiocarbon dating... the investigation of the history of man through the use of chemistry. (Libby 1960:607, 609)

BIBLIOGRAPHY

- Basics of radiocarbon dating [sn]. Available: <http://www.informath.org/Basic14C.pdf>. [Accessed 2015/10/2017.]
- Brock, F et al. 2010. Current pretreatment methods for AMS radiocarbon dating at the Oxford Radiocarbon Accelerator Unit (ORAU), *Radiocarbon* 52/1:103-112. Available: [https://www.researchgate.net/profile/Fiona_Brock/publication/236200194_Current_pretreatment_methods_for_AMS_radiocarbon_dating_at_the_Oxford_Radiocarbon_Accelerator_Unit_\(ORAU\)/links/00b7d53903e231b5ff000000.pdf](https://www.researchgate.net/profile/Fiona_Brock/publication/236200194_Current_pretreatment_methods_for_AMS_radiocarbon_dating_at_the_Oxford_Radiocarbon_Accelerator_Unit_(ORAU)/links/00b7d53903e231b5ff000000.pdf). [Accessed 2016/09/16.]
- Brown, L 2012. Mass spectrometer, in Encyclopædia Britannica 2012.
- Currid, J D 1999. *Doing archaeology in the land of the Bible*. Grand Rapids: Baker.
- Decker, W D and Decker, B B 2012. Volcano, in Encyclopædia Britannica 2012.
- Dever, W G 2003. *Who were the early Israelites and where did they come from?* Grand Rapids: Eerdmans.
- Dupras, T L et al. 2012. *Forensic recovery of human remains – archaeological approaches*. 2nd ed. Boca Raton, FL: CRC Press.
- Encyclopædia Britannica 2012. *Encyclopædia Britannica Ultimate Reference Suite*. [Electronic]. Chicago: Encyclopædia Britannica.
- Fagan, B M 2009. Archaeology, in Microsoft Student 2009.
- Finkelstein, I 2013. *The forgotten kingdom: the archaeology and history of northern Israel*. Atlanta: Society of Biblical Literature.
- Finkl, C W 2009. Dating methods, in Microsoft Student 2009.
- Fraser, G 2009. Neutron, in Microsoft Student 2009.
- Greeff, C J 2005. Paleopathology: signs and lesions in skeletal remains of epidemics and diseases of biblical times in Syro-Palestine. Unpublished master's dissertation. Pretoria: UNISA.
- Higham, T F G, Jacobi, R M and Bronk Ramsey, C 2006. AMS radiocarbon dating of ancient bone using ultrafiltration, *Radiocarbon* 48/2:179-195. Available: http://www.rhinosourcecenter.com/pdf_files/133/1330263891.pdf. [Accessed 2016/09/16.]
- Kitcher, P S 2012. Philosophy of science, in Encyclopædia Britannica 2012.
- Krogh, T E 2012. Dating, in Encyclopædia Britannica 2012.
- Leonard, A (Jr) 1998. Archaeological sources for the history of Palestine: the Late Bronze Age, *The Biblical Archaeologist* 52/1:4-39. Available: <http://www.jstor.org/stable/3210180>.
- Lewin, S Z 2009. Half-life, in Microsoft Student 2009.
- Libby, W F 1960. Radiocarbon dating. Nobel Lecture, December 12, 1960. Available: http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1960/libby-lecture.pdf. [Accessed 2015/10/27.]
- _____. 1964? History of radiocarbon dating. Los Angeles: University of California. Available: <http://www.osti.gov/accomplishments/documents/fullText/ACC0336.pdf>. [Accessed on 2015/10/27.]
- Lutz, P 2009. Carbon, in Microsoft Student 2009.
- Magness, J and Gitin, S (eds) 1998. *Hesed ve-emet, Studies in honor of Ernest S. Frerichs*. Atlanta: Scholars.
- Merriam-Webster 2012. Merriam-Webster's dictionary and thesaurus, in Encyclopædia Britannica 2012.
- Microsoft Encarta 2009. *Encarta dictionaries*. [Electronic.] Redmond, WA: Microsoft Corporation.

- _____. 2009. *Microsoft Student 2009*. [Electronic.] Redmond, WA: Microsoft Corporation.
- Poole, G J 2012. Petrie, Sir (William Matthew) Flinders, in *Encyclopædia Britannica* 2012.
- Puhvel, J 2012. Epigraphy, in *Encyclopædia Britannica* 2012.
- Rathbun, T A and Buikstra, J E (eds) 1984. *Human identification: case studies in forensic anthropology*. Springfield, Illinois: Charles C Thomas.
- Richter, A M 2009. Carbon dating & archaeology. Available:
http://www.cyark.org/news/carbon-dating-and-archaeology?gclid=CL-A2f2M4sgCFacewwodTbAPLw_ [Accessed 2015/10/27.]
- Scheepers, C L v W and Scheffler, E H 2000. *From Dan to Beersheba: an archaeological tour book through ancient Israel*. Pretoria: Biblia.
- Seger, J D 1998. Stone scale weights of the Judean standard from Tell Halif, in Magness and Gitin 1998:357-372.
- Smith, R L 2009. Carbon cycle (ecology), in *Microsoft Student 2009*.
- Strafford, T W et al. 1987. Study of bone radiocarbon dating accuracy at the University of Arizona NSF accelerator facility for radioisotope analysis, *Radiocarbon* 29/1:24-44. Available:
<https://journals.uair.arizona.edu/index.php/radiocarbon/article/viewFile/1033/1038>. [Accessed 2016/10/26.]
- Taylor, J E 2012. *The Essenes, the scrolls, and the Dead Sea*. Oxford: Oxford University Press.
- Yadin, Y 1963. *The art of warfare in biblical lands in the light of archaeological discovery*. London: Weidenfeld and Nicolson.
- Yizhaq, M et al. 2005. Quality controlled radiocarbon dating of bones and charcoal from the early Pre-Pottery Neolithic B (PPNB) of Motza (Israel), *Radiocarbon* 47/2:193-206. Available:
<https://journals.uair.arizona.edu/index.php/radiocarbon/article/view/2815/2580>. [Accessed 2016/09/26.]