A Case of "Missing" Decay

An Analysis of C-14 Detected in Very Old Samples

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Abstract

Carbon-14 has historically been extremely useful for archeologists and Quaternary geologists. The recent development of accelerator mass spectrometry has dramatically improved the precision of the method. However, this new capability has raised questions. Many supposedly "ancient" carbon samples contain some level of radiocarbon content. The purpose of this paper is to provide a statistical analysis of published results of radiocarbon measurements made on geologically ancient samples to determine whether there are any significant patterns. The results show that C-14 levels in these ancient samples appear to follow the lognormal model, which entails that their ages follow a normal curve. This implies that all of the samples are of approximately the same age and points to a single burial event for all of them. The results are consistent with a global flood catastrophe and a young age for the earth.

Introduction

Radiocarbon (C-14) dating has grown rapidly as a science and an industry over the past several decades. This growth has been due in part to the development of ultra-sensitive detection equipment known as accelerator mass spectrometry, or AMS. This instrument is capable of detecting minute amounts of radioactive elements present within samples. However, this new technology has brought questions with it, for many geologically ancient samples have been tested and appear to contain trace amounts of radiocarbon. C-14 has a half-life of only 5730 years, which means any carbon sample older than around 100,000 years before the present (YBP) should contain zero radiocarbon. Obviously, if the C-14 found in these ancient samples is intrinsic, such samples cannot be multiple millions of years old. In fact, any such object would be limited to about the past 100,000 years at maximum. Creation scientists argue that the C-14 detected within these ancient samples is in fact intrinsic and provides evidence for a young earth. Critics argue that the observed radiocarbon cannot be intrinsic, since the objects are obviously too old to contain any C-14.

Recently, several important studies have been done by young-earth scientists that focus on this issue. Arguably, the most significant of these was conducted by the Radioisotope and the Age of the Earth (RATE) team as reported in Baumgardner (2005). These studies have attempted to show that many geological carbon samples that should be of "infinite" radiocarbon age in the secular paradigm actually contain small amounts of intrinsic radiocarbon. All such studies, including the RATE project, have been criticized by scientists who accept the standard geological timescale and the results have been

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ignored or dismissed (e.g., Bertsche, 2008; Isaac, 2007). Such criticisms are based on the fact that small amounts of background contamination are thought to occur in radiocarbon measurements. This background is cited to explain the apparent C-14 found in very old samples.

Carbon 14 originates in the upper atmosphere as cosmic rays bombard atmospheric molecules, which produce what are known as "fast" neutrons. These neutrons are able to enter into the nucleus of nitrogen molecules and convert them to radioactive C-14. Carbon in the atmosphere rapidly combines with oxygen to produce carbon dioxide, which can then be taken in by plants, absorbed into ocean water, or retained in the atmosphere. As can be imagined, if any factor in C-14 production is changed, its level in the atmosphere also will change. For example, if the sun has a period of unusually high activity, it can shield the earth from the cosmic rays, thus lowering the amount of C-14 creation. Human activities also can alter the ratio, as in the 1940s when atomic bomb testing created extra C-14 in the atmosphere. All of these factors can create a widely fluctuating C-14/C-12 ratio, which is why calibration is vital for properly understanding radiocarbon "ages." It is important to distinguish between the "radiocarbon age" and the "actual age" of a particular object. The former is the calculated age of a sample based on its radiocarbon content; the latter is its real age, which usually must be found by comparing the radiocarbon results with a calibration curve (see Figure 4).

Analysis of the Data

Statistical

What has been lacking in any of the research on the topic to date is an analysis of the data based on an appropriate statistical modeling technique. Such an analysis could potentially provide evidence for or against the hypothesis that C-14 found in ancient samples is due to contamination. Care must be taken, however, for a misuse of statistics can lead to unreliable conclusions. The results I am presenting grew out of a research project I conducted in the fall of 2009 on radiocarbon dating. Essentially, I have compiled a listing of radiocarbon measurements made on geologically ancient samples taken from results published in the literature. A histogram of the data is analyzed to find any statistically significant patterns. Finally, I draw some conclusions about the data based on the outcomes of the tests.

The purpose of this paper is (1) to determine if existing radiocarbon data fit any recognizable model, (2) to analyze the data in terms of any potential models, and (3) to draw some conclusions about radiocarbon content in ancient samples based on the proposed model. All of the statistical tests and graphs discussed below were prepared using Minitab 15, a statistical software program used by many statisticians and educators.

There were two sources for the radiocarbon data I used in producing this paper: two tables shown in Baumgardner (2005), including his summary of previously published results (pp. 596–597) and the RATE project results on coal (p. 605). The other source was a study by Snelling (2008).

There are several preliminary remarks that should be made about this sample set. First, I made an effort not to include samples that probably do not date to the time of the Flood in the young-earth paradigm. This would include samples such as diamonds and Precambrian (nonbiological) graphites. These objects were not utilized because they probably date to an earlier time than the Flood (possibly the Creation Week). Specifically, I excluded from my study graphite samples reported in Baumgardner (2005) measuring under 0.05 percent modern carbon (pMC), as well as all diamond samples (see Baumgardner, 2005, p. 594). Types of objects that were included in the study were coal, wood, shell, foraminifera, bone, fossils, and others.

The second point to be made is that this sample set is not comprehensive of radiocarbon content in all geologically ancient samples (by "geologically ancient" I mean any sample that dates older than about 100,000 years before the present in the old-earth paradigm). There are several reasons for this. First, there has been to my knowledge no rigorous and systematic study of radiocarbon content in ancient samples done by the scientific community. Second, information about the work that has been done is limited to those who have access to prestigious and expensive journals such as *Radiocarbon* that publish such work. Third, preparation and laboratory methods have changed in the thirty-some years of AMS radiocarbon dating. Thus some of the earlier research may not be reliable, or different methods may produce different results that are not consistent. The purpose of this paper is simply to provide a preliminary look at the general trends we see in the data and to suggest a possible explanation, as well as propose a future research direction.

Radiocarbon Data

I began by attempting to determine if the radiocarbon found in the geological samples fit any recognizable mathematical model, one that could be used to make predictions about future data. A histogram of all the data I have accessed with units in percent modern carbon (pMC), the standard measurement unit for radiocarbon dating, is shown in Figure 1. This histogram shows the number of samples on the vertical axis and the amount of C-14 in them on the horizontal axis. I used a distribution identification test in Minitab to identify all of the possible matches for the data. There were four possible matches in the test results: the lognormal, the loglogistic, the Box-Cox transformation, and the Johnson transformation. Of these four,

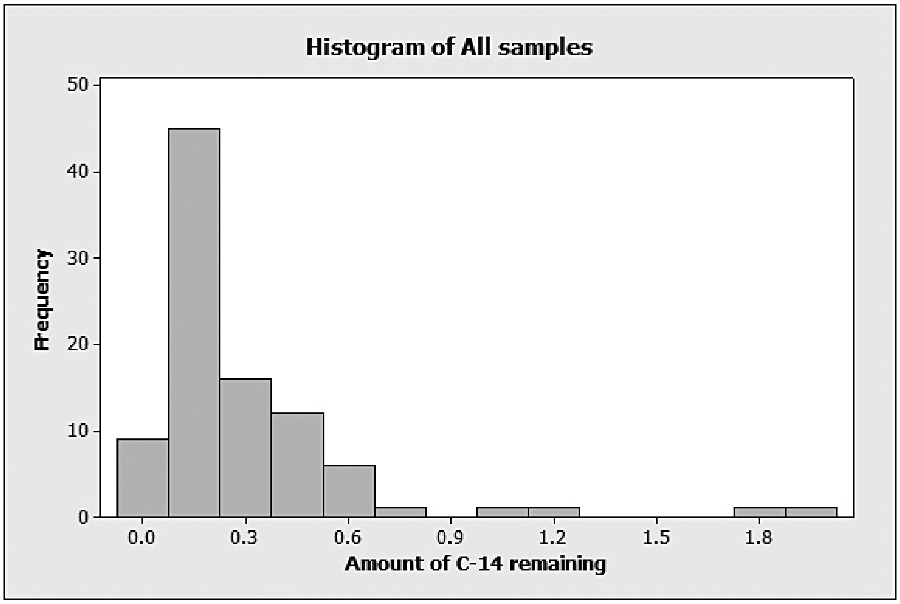

Figure 1. Histogram of radiocarbon levels in ancient samples showing the characteristic shape of the lognormal distribution. Note that none of the samples tested at a zero level; the bar above 0 represents those samples testing between 0.0 and 0.1. The minimum and maximum levels were 0.014 and 1.896 pMC. The median was 0.198 pMC.

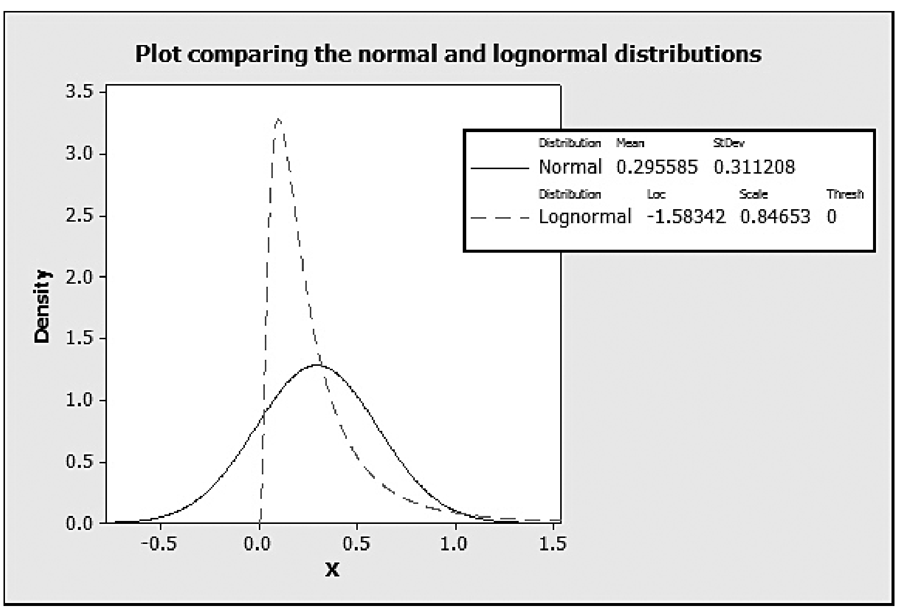

Figure 2. Probability plots generated in Minitab 15 that compare the lognormal and normal distributions. The scale for each of the curves is based on parameters from the actual data. Notice that the lognormal model approximates the pMC amount histogram much better than the normal model.

the Box-Cox and the Johnson are not actual distributions; they are merely data transformations designed to "fix" data so that it can be analyzed as a normal distribution. The shape of the loglogistic distribution is almost identical to the lognormal, but it is used specifically in binary response contexts and thus is probably not applicable to our scenario. I had suspected a lognormal distribution since first viewing the histogram, and it fits the context of exponential decay exactly. Figure 2 compares the normal and lognormal models using measurements taken directly from this data including average, standard deviation, etc. The lognormal model can be seen to approximate the histogram shown in Figure 1 much better than the normal curve.

A further test is possible: we take every value that we originally plotted in Figure 1 and take the natural logarithm, and then make a new histogram of this "transformed" data and run a normality test. I also did this test and obtained a p-value of 0.643. This p-value means that there is no evidence against the normality of the histogram. It is reasonable to conclude that the data follow the lognormal distribution.

We have seen that the lognormal distribution is a very good match for the radiocarbon data. The main characteristic of the lognormal distribution is that if we take the logarithm of each value and create a histogram of the results, we produce a *normal* distribution curve; hence the term "*lognormal*." This particular type of distribution occurs throughout the natural world, including geological contexts (Limpert et. al., 2001). Appendix 1 discusses some of the technical details of the lognormal distribution and the implications of this function in modeling radioisotope concentrations. That radiocarbon levels should follow a lognormal pattern is significant.

Recall from high school physics that the standard formula for radioisotope decay is $A = A_0e^{-\lambda t}$. A is the final, remaining amount of radioactive atoms, A_0 is the initial amount, T is the age of the sample in years, and the symbol λ is the decay constant for the material, equal to the natural logarithm of 2 divided by the half-life of the material, in this case 5730 years. However, in our case we know the final amount: the values that we plotted in the histogram in Figure 1. By rearranging the equation we can produce the formula for conversion of the amount of remaining radiocarbon to age in years before the present. Using 5730 as the value for the half-life, we find $1/\lambda = 8266$, and recognizing that A/A_0 is the same as pMC/100, we get the equation T= −8266 x ln (C-14 content in pMC/100). Notice the natural logarithm present in this equation. By converting each data point to age in YBP, we produce the age graph shown in Figure 3.

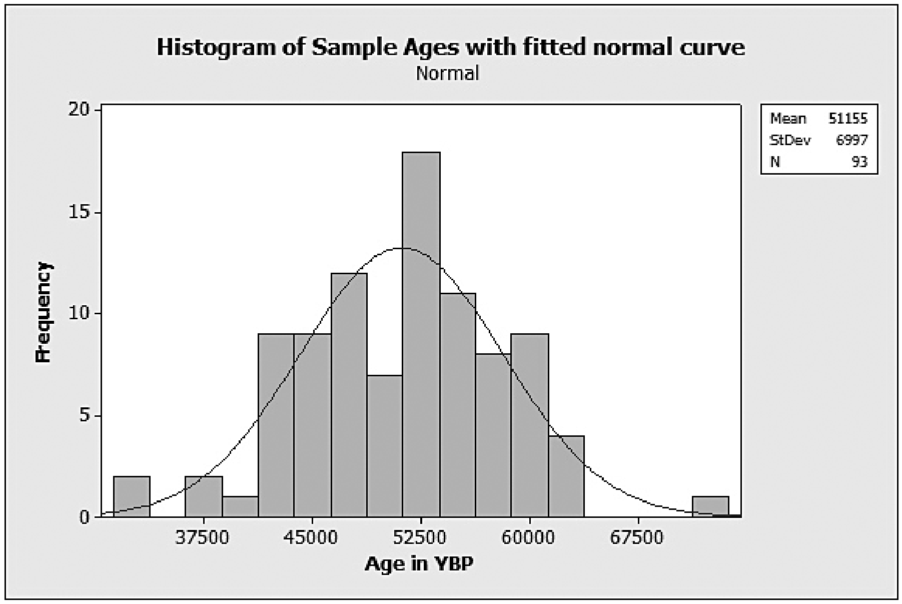

Figure 3. Histogram showing the "apparent" radiocarbon ages of the tested samples with a normal curve fitted to the data. The line shows how the apparent ages of the tested samples appear to conform to the normal distribution. The graph and line fit were done in Minitab.

Significance of the Age Graph-A Normal Distribution

To clarify, this graph is showing the "apparent C-14 ages" of all of the samples that were tested in the studies I mentioned above. These are *not* the actual ages of these samples but their apparent ages. Neither young-earth creationists nor secular scientists would conclude that these samples are in fact the ages shown. However, the pattern that we observe in the data is more significant than the actual ages. The histogram appears to follow a normal distribution pattern. A normality test confirms that it is possible this data comes from a normal population (The Anderson-Darling normality test gives a p-value of 0.643; again this shows that there is no evidence against normality). The histogram is showing the number of samples with a given age; the age is given on the horizontal x-axis and the number of samples with a particular age is shown by the vertical y-axis. A higher bar in the histogram means there are a greater number of samples with that particular age. Again, these are not actual ages but rather the "apparent" ages given by the radiocarbon dating method if radiocarbon levels had remained perfectly constant throughout history, which all scientists agree is not the case. Interested individuals may consult Levine et. al. (2001) or Miller and Miller (2004) for further study of the normal distribution.

The average apparent age of the samples is 51,155 YBP. The standard deviation is 6997 years. The 95% confidence interval for the mean is 51,155 ± 726 YBP. Once again, this is *not* a measure of the real average age but the apparent "radiocarbon" age. There are a number of ways to fit this age within a young-earth paradigm. The simplest is to infer that the C-14/C-12 ratio was much lower in the past relative to today's value. Plants and animals that were buried and preserved in the Flood sediments would therefore, when they died, begin with much lower C-14/C-12 ratios than is the case today. Reasons for lower C-14/C-12 ratio before the Flood could include a larger biomass exchanging with the atmosphere or a lower rate of C-14 production, perhaps due to a stronger magnetic field. Again, the normal curve pattern that we observe is more important than the actual apparent age.

The implications of these results are significant. One of the characteristics of the normal distribution is that "There is a strong tendency for the variable to take a central value" (StatSoft, 2010). The normal curve was first investigated when researchers such as Gauss and Laplace in the late eighteenth and early nineteenth centuries observed that measurement errors consistently fit a pattern that could be approximated by a continuous curve (Miller and Miller, 2004; Grower, 2008). Out of this insight has come the "normal" distribution.

Consider an example: a paper by Jull et. al. (1995) in the journal *Radiocarbon* presents the results of radiocarbon dating several of the Dead Sea Scrolls and linen fragments found in the caves of Qumran and other nearby sites. An example of one of the samples dated and the

Descriptive Statistics for Radiocarbon Data

Geometric mean (μ^*)	Multiplicative s.d. (σ^*)	Mean (μ)	Standard deviation (σ)
0.2053	2.3315	0.2956	0.3112

Table I. Summary of descriptive statistics for the samples that were used in this analysis. "S.d." is standard deviation. Notice that μ^* is multiplied or divided by σ^*, expressed by the notation $\mu^* \cdot / \sigma^*$. This is different from the normal distribution, with notation of $\mu \pm \sigma$. This is a result of the lognormal distribution being multiplicative in nature, while the normal curve is additive.

Radiocarbon Age of Dead Sea Scrolls Parchment Sample

Sample	# of runs	C-14 Age (yr BP)	$\pm 1\sigma$	$\pm 1\sigma$ age range
AA-13415	5	1954	38	AD 5–80

Table II. An example of a sample radiocarbon age as reported by Jull et. al. There were 5 runs taken, which gave five different ages that were averaged and the standard deviation calculated. The notation used is that of the normal distribution. Since the sample must be the same age as itself, several runs are taken in order to get a more accurate representation of the "true" radiocarbon age.

corresponding age with uncertainty is reproduced in Table II. For this particular sample, five runs or trials were made, each giving a particular age. These were averaged and the standard deviation calculated. This is what is represented by the notation $\pm 1\sigma$. The article also contains information on the $\pm 2\sigma$ level of uncertainty for each date.

This article is but an example of the standard method of reporting radiocarbon ages throughout the literature—all use $\pm 1\sigma$, which is calculated from the several runs that are made. If only one run is made, resulting in only a single date, no standard deviation can be calculated because there is no spread to the data, there is only one point. Every sample must be the same age as itself, but due to the nature of experiments and environmental factors some variation can be expected within a sample. In other words, if several small pieces are broken off a larger sample and carbon dated, they will probably not all give the exact same level—they should be close but probably different. This "random error" is modeled by—none other than—the normal distribution.

This use of the normal distribution is further illustrated by the graph in Figure 4. This is an example of a calibration chart, used by scientists to calibrate the "radiocarbon age" from a sample to its real age. This is done because, as we noted earlier, historical fluctuations in the C-14/C-12 ratio in the atmosphere give variation in the actual radiocarbon levels in the past. The "radiocarbon age" of the sample is given on the vertical axis. Notice that on the left-hand side of the graph we see a normal distribution. This is showing that a normal distribution is assumed in giving the age range of the sample. In other words, all of the runs made on a particular sample are expected to show normally distributed ages.

Let me summarize our discussion about the normal curve. Radiocarbon dates, such as those reported in Jull et. al. (1995) and others report the ages of their samples using the standard deviation (or "uncertainty"), which assumes the use of a normal distribution. They do this because while the sample has to be only one age, dating several pieces of a sample often gives slightly different ages because of experimental error; consequently the average gives a better estimate of the sample's true age. The normal distribution is used because all of the pieces or "runs" on the sample must date to the same age.

Now we return to Figure 3 and our sample set. Since the ages of the samples tested can be approximated by the normal distribution, it implies that all of the samples date to the same geological time. This suggests a single event when all of the given samples were isolated from the carbon cycle. Just as a normal distribution is assumed for the ages of the pieces of samples tested in modern radiocarbon labs, the normal distribution we see in Figure 3 implies that all of the samples under consideration—including many different sample types, dating to many different geologic time periods and analyzed in different laboratories—all date to a single event. This is consistent with the young-earth creationist expectation that all of these samples date to the time of the Flood.

A word of caution is in order when considering the results of this study: as

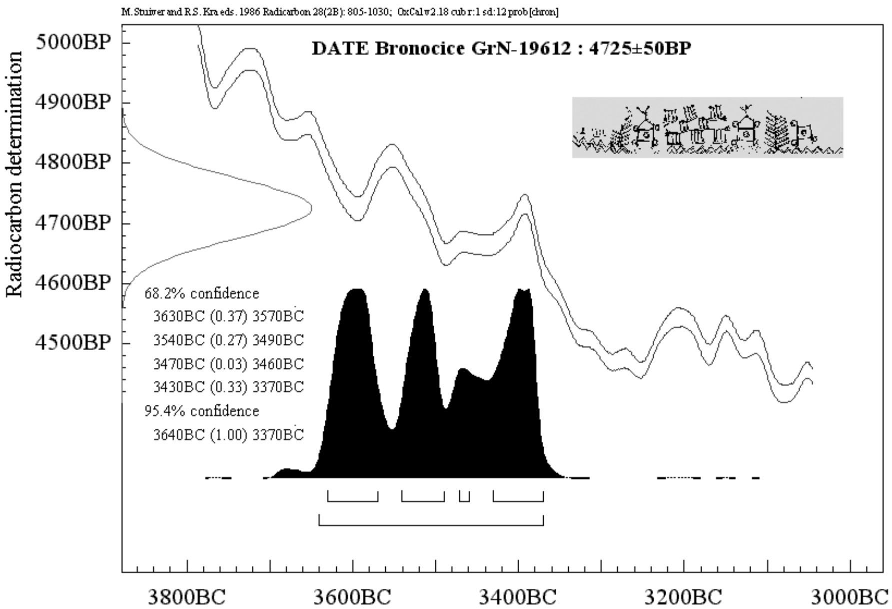

Figure 4. A calibration curve showing the "radiocarbon age" on the vertical axis and the calibrated "real age" on the horizontal axis. This graph shows the process of "wiggle-matching" in order to find the correct calibrated age. Notice the normal distribution on the right, indicating the age. This graph demonstrates that the possible age range of a given sample is normally distributed. Taken from http://www.comp-archaeology.org/SAA_Communication_Figs.htm (Anonymous, 1998).

noted above, no systematic analysis of radiocarbon in ancient geologic samples has been done to date, of which I am aware. My conclusion is reasonable but not exhaustive. It is my hope that this paper will stimulate more research into this subject as well as provide a basis for using the lognormal model in analyzing radioisotope data. This being said, the radiocarbon dating is still on the side of the creationist, and should be regarded a friend rather than a foe in the study of young-earth geology.

Summary and Conclusion

Many young-earth creationists believe that most of the carbon samples that were analyzed in this study were buried during or close to the time of the Flood. If this is in fact the case, we might expect that many of the samples would have approximately the same radiocarbon age. This radiocarbon age would not, of course, be the true age if the C-14/C-12 ratio before the Flood were different from what it is today. The actual age would not necessarily be accurate because we do not know what atmospheric conditions were like before the Flood, or whether the C-14 decay rate has changed. Based on our analysis of the sample ages, we conclude that the majority seems to follow a normal curve pattern, and we infer that this implies all of the samples date to approximately the same time. This conclusion is consistent with the young-earth position.

To clarify, this study does not rule out any trace of contamination in the samples tested, only that the pattern observed overall indicates that contamination is not responsible for all of the observed radiocarbon. More research is needed in this area to come to a definite conclusion regarding contamination. I suggest that an intensive research initiative could address the problem of contamination and intrinsic radiocarbon by testing across different sample types and ages, pre-test treatment regimens, and laboratories and then carefully analyzing the results. Unfortunately, this expensive solution will probably be necessary for the true nature of radiocarbon content and contamination in very old samples to be resolved in a satisfactory way for most people.

Radiocarbon studies have great potential in young-earth research to add to the body of evidence that favors the Biblical timescale and should be regarded as a friend rather than a foe. While one line of evidence will probably not convince secular scientists that the geological column is in error, radiocarbon dating is just one more demonstration that true science will always align with a proper understanding of God's Word. It is our task as creation scientists to find out how. It should also be remembered that study results and statistical reports always have a capacity for error, while the Bible is not subject to error when its message is understood correctly. As such, it is good to have a healthy skepticism of all scientific conclusions, while conclusions based on a sound exegesis of the Bible can be safely held without such apprehension.

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Appendix A: A Closer Look at the Lognormal Distribution

As we noted in the main body of the paper, the apparent radiocarbon levels found in geologically ancient carbon samples appear to be lognormally distributed. What does this actually mean? Of course, the most obvious point is that if the logarithm of every point is taken, a normal distribution will result (see Figure 2 for a comparison of the normal and lognormal distributions). Also, there are several important observations to make. For example, consider the histogram shown in Figure 1. First, note that there are no samples with a "zero" reading; the column above "0.0" on the graph shows those samples that are between 0.0 and 0.1 pMC. The minimum amount was 0.014 pMC. Second, most data points fall in a region close to but slightly greater than zero. Third, there are a few data points on the far right-hand side of the histogram, showing a few samples with unusually high C-14 levels. This is known as a "tail" in statistical lingo.

There are some important implications of using the lognormal model that future researchers, particularly those studying radiocarbon or other radioisotope dating methods, should keep in mind. The most important is that the standard parameters used to describe data, such as mean or average and standard deviation, cannot be used. This is because the equation that describes the lognormal curve contains a base *e* (other bases are certainly possible, but in dealing with radioisotopes the base will always be *e*).

Therefore, we must use parameters to describe lognormal data that are appropriate to the model. The geometric mean (designated by μ^*) and multiplicative standard deviation (σ^*) describes the shape of the distribution, rather than the typical additive mean or average (μ) and additive standard deviation (σ). These additive parameters are measures used to describe the *normal* distribution curve and should not be used to describe lognormal curves. Now, we can always take the natural logarithm of the data, produce a normal curve, and then apply our standard measures. This is certainly a valid option for researchers. However, we must be careful not to apply measures such as the additive mean to data that should be characterized as lognormal.

Because of the multiplicative nature of the lognormal parameters, we describe the spread of the data using the notation $\mu^* \cdot/ \sigma^*$ (geometric mean multiplied or divided by multiplicative standard deviation) to describe the shape of the curve, in contrast to the normal distributions, where we use $\mu \pm \sigma$. For a more thorough discussion of these parameters and how they are used to describe lognormal data, as well as contexts where the lognormal distribution is found in nature, see Limpert et. al. (2001).