

# Understanding and Minimizing Sources of Error in Radiocarbon Dating

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## Introduction

The issue pertaining to sources of error regarding conventional radiocarbon dating is nothing new. This poster is not designed to provide any new insight to the already considerable literature on the subject. Rather, this work presents a series of apparently anomalous radiocarbon dates from a single archaeological feature and serves as a practical, though somewhat hypothetical, illustration for determining (1) whether the dates reported are statistically imprecise and/or (2) what source of error may be responsible for the apparent imprecision of the dates obtained.

## Background

The conventional radiocarbon dating method has been used by archaeologists for more than 50 years. Radiocarbon dating is the primary means of establishing the necessary chronological framework for creating hypotheses and interpreting archaeological assemblages. The dates that archaeologists receive, however, must be viewed with the confines of certain methodological limitations. Taylor (1987) recognizes two basic components for evaluating the dates obtained from radiocarbon analyses. These components involve sample provenance factors and the degree to which theoretical assumptions are applied to a particular sample. The latter component is further broken down into “three sets of factors that impinge on the accuracy and precision of individual 14C estimates” (Taylor 1987:15). These factors are sample composition factors, statistical and experimental factors, and systemic factors (Table 1).

Systemic factors relate primarily to violations of the general assumptions of the radiocarbon method, including constancy in 14C concentrations in the living materials over time and within each of the carbon reservoirs (Taylor 1987). Variations in these concentrations are known to occur, and the effects can lead to inaccurate age calculations if not taken into account. This is why calibration curves were constructed and are used when calculating radiocarbon dates. This study, however, is concerned primarily with imprecision, rather than inaccuracy, and in the interest of space, the reader is referred to Aitken (1990) and Taylor (1987) for detailed explanations of the numerous sources of systemic error.

Statistical and experimental factors are primarily concerns for the laboratory. In most cases strict adherence to methodological protocols is the only means to minimize the affect of experimental factors, though some explanation of statistical factors is warranted. Taylor notes (1987:124) that the error reported with a radiocarbon date is occasionally misunderstood by those submitting samples for dating, leading to overconfidence that this value represents an estimate of overall precision. The error observed represents the probability that the date reported falls within the reported range 68% of the time, or 1 $\sigma$ . If this value is doubled (2 $\sigma$ ), the probability that the age reported falls within this range increases to 95%. Therefore, the date reported actually represents “the time interval within which there is a given probability that the 14C age equivalent of the actual 14C activity of a sample actually lies” (Taylor 1987:125). Laboratories report dates in this manner because of the inherent random nature of radioactive decay. This emphasizes why conventional laboratories count samples for extended periods of time (two days in the case of the laboratories used in this study) and why “one date is no date” (Aitken 1990:95).

Sample composition factors should be concerns for both the archaeologist and the laboratory technicians. One compositional factor is related to the natural variations in the stable carbon ratios of samples (13C/12C). These variations are due to which part of the carbon reservoir the samples derived from as well as differential metabolic fractionation of these isotopes by the organism in life. In terms of plant samples submitted for radiocarbon dating, the primary fractionation effects are related to differences in C3 and C4 metabolic pathways as well as, to a lesser degree, what portion of the plant is represented in the sample. The fractionation effect can be adjusted in the laboratory through the use of known  $\delta^{13}C$  ranges for the material being dated or, more directly, by measuring the exact ratio with standard mass spectrometry methods. Another sample composition factor is contamination. Contamination can affect the precision and accuracy of the date reported by the introduction of modern carbon or, in some cases, of the mixture of samples from one or more cultural events. The addition of modern carbon will produce an anomalously younger age for the sample, whereas the addition of older carbon will produce the opposite result. This effect is usually minor for Holocene samples (Taylor 1987) and most laboratory pretreatment protocols will eliminate much of any modern contaminants present in a submitted sample.

Table 1. Components affecting accuracy and precision of 14C ages.<sup>1</sup>

<i>Systemic Factors</i>
Reservoir Effects
Secular Variation Effects
<i>Statistical and Experimental Factors</i>
Dates as Time Intervals
Experimental Error
Instrument Error
Human Error
<i>Sample Composition Factors</i>
Fractionation Effects
Contamination Effects

<sup>1</sup>From Taylor (1987)

Table 2. Aliquot dating results.

Sample	Conventional Age	1 $\sigma$ Range (68%)	2 $\sigma$ Range (95%)
ISGS 5758	1060 $\pm$ 70yrBP	990-1130yrBP	920-1200yrBP
UTCAG 06-012 V1	1120 $\pm$ 70yrBP	1050-1190yrBP	980-1260yrBP
UTCAG 06-012 V2	1010 $\pm$ 70yrBP	940-1190yrBP	870-1150yrBP
UTCAG 06-005	1340 $\pm$ 70yrBP	1270-1410yrBP	1200-1480yrBP
UTCAG 06-011	1245 $\pm$ 70yrBP	1175-1315yrBP	1105-1385yrBP

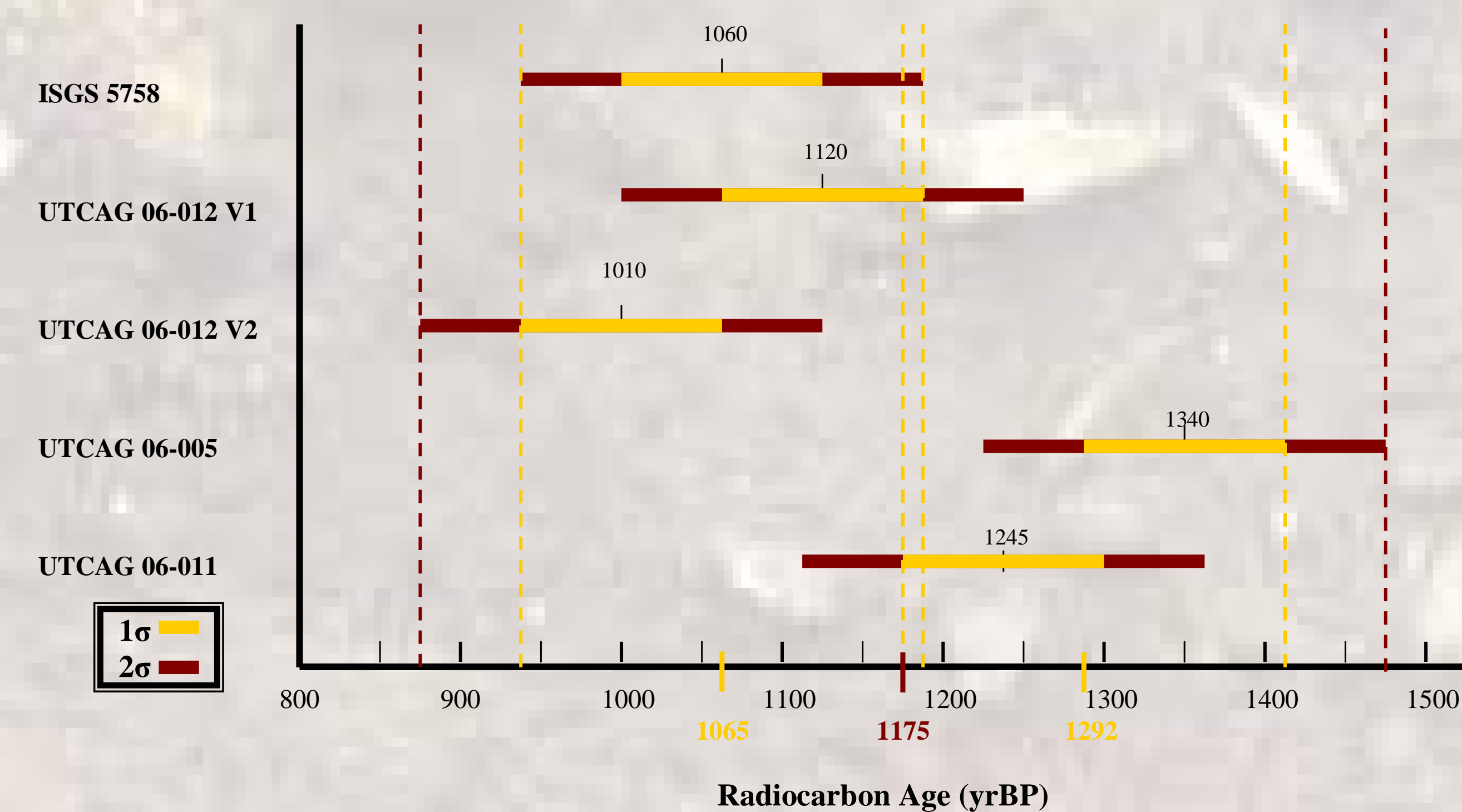


Figure 2. Radiocarbon age ranges for the examined aliquots.

## Materials and Methods

Five aliquots were created from a bulk charcoal sample obtained from a Late Woodland/Early Mississippian pit feature from a pre-contact archaeological site in east Tennessee (the name of the site has been intentionally omitted). The pit feature was encountered at 20cmbs, extended to 180cmbs and contained a mixture of charcoals, including the identified remains of maple (*Acer* sp.), walnut (*Juglan* sp.), and pine (*Pinus* sp.).

One aliquot (ISGS-5758) was sent to the Illinois State Geological Survey for conventional radiocarbon dating. This sample served as an interlaboratory comparative date for the remaining four aliquots. The remaining samples (UTCAG 06-005, 06-011, 06-012-V1, 06-012-V2) were dated at the University of Tennessee Center for Archaeometry and Geochronology conventional radiocarbon laboratory (Figure 1). Both laboratories utilize the liquid scintillation counting method.

All samples were pretreated using a standard acid/alkali/acid procedure. After oven-drying overnight, the samples were then combusted and converted to benzene, using a four-part conversion process. A small sample of carbon dioxide was taken from each sample prior to formation of lithium carbide for  $\delta^{13}C$  determination. The ISGS fractionation sample was measured at the ISGS stable isotope lab. The UTCAG samples were measured at the UT Department of Earth and Planetary Sciences stable isotope laboratory. Each of the benzene samples was counted 27 times for 100 minutes, over a period of two days. Background samples of spectrometer grade benzene were also counted a total of 2700 minutes, before and after each sample, to determine the necessary background counts for age determination. The ISGS sample was counted using a Packard TriCarb liquid scintillation counter. The UTCAG samples were counted in a Quantulus Ultra-Low Level liquid scintillation counter. Both laboratories use oxalic acid as the modern standard for age calculation.

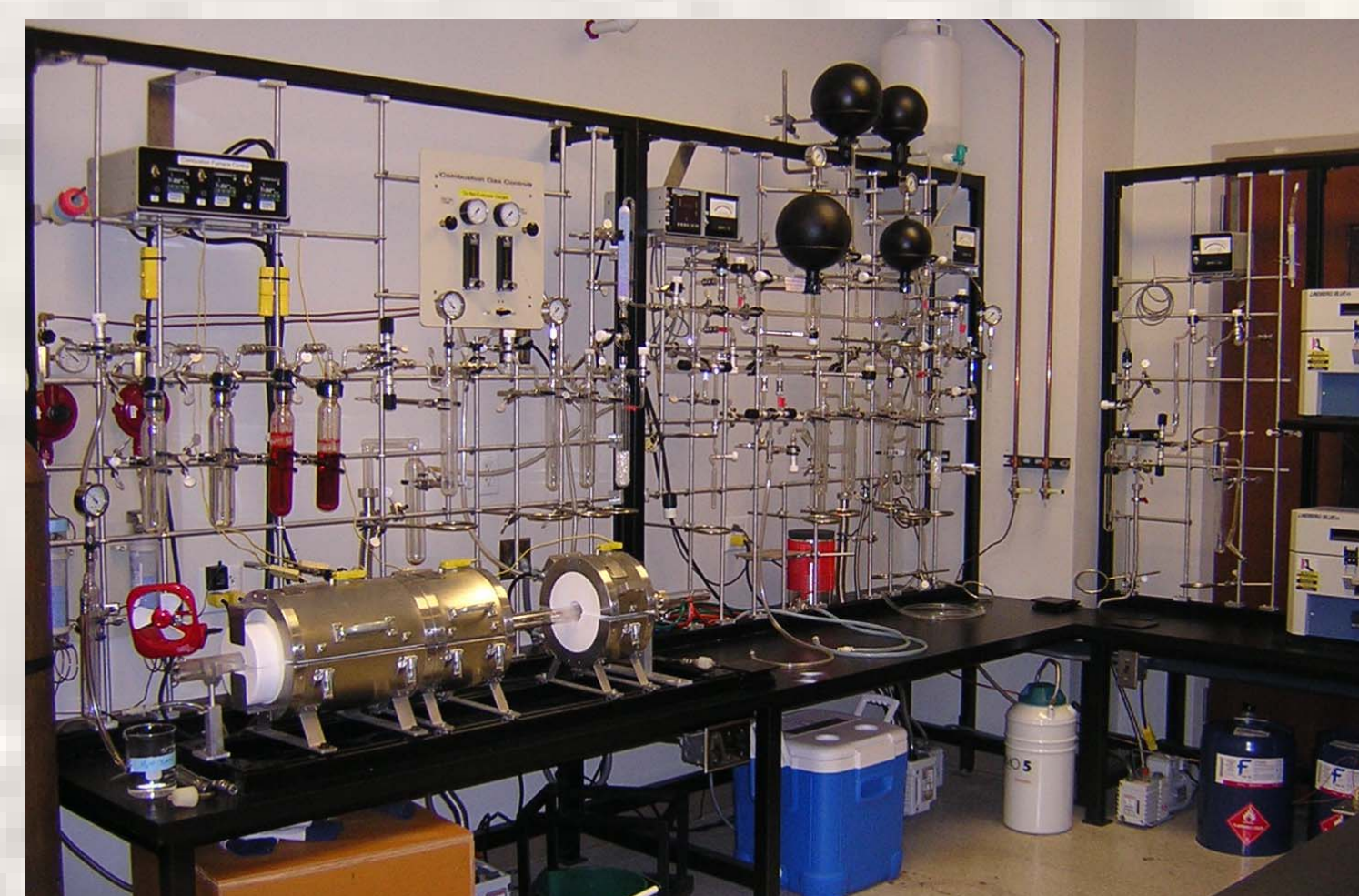


Figure 1. The UTCAG conventional radiocarbon dating laboratory.

## Results

The reported radiocarbon ages for the five aliquots and their associated 1 $\sigma$  and 2 $\sigma$  ranges are presented in Table 2. A  $\delta^{13}C$  value of -26.2‰ used for the fractionation correction for ISGS 5758, whereas a measured value of -26.1‰ was used for all of the UTCAG samples. When the age estimates are viewed together at the 2 $\sigma$  confidence interval ( $p = 0.95$ ), there appears to be a chain of overlapping ages from 870-1480yrBP (Figure 2). If the median of this range is taken as the accepted age of the sample, it would indicate that the feature was deposited approximately 1175yrBP. Upon closer examination, particularly at the 1 $\sigma$  range, this conclusion is less clear. Considerable overlap occurs between samples ISGS 5758, UTCAG 06-012-V1, and UTCAG 06-012-V2 and between samples UTCAG 06-005 and UTCAG 06-011. The median age for the combined ranges of these two groupings would be 1065yrBP for the former and 1292yrBP for the latter; a difference of more than 200 years. It could be argued, therefore, that the ages represent two separate depositional events.

It is also important to note that sample UTCAG 06-005 demonstrates no overlap with samples ISGS 5758 and UTCAG 06-012 V2, even at the 2 $\sigma$  level. As an individual sample UTCAG 06-005 would appear to be a considerable outlier when compared to the other two. It is not until all five aliquots are viewed together that sample UTCAG 06-011 can be identified as a ‘bridge’ to the other ages obtained. At the 95% confidence interval, however, this bridge connects a series of ages representing a 600 year time span. While statistically valid, a 600 year confidence interval provides little confidence to an archaeologist interested in dating a single feature.

## Discussion

The apparent imprecision of the dates raised concern and necessitated investigation. It was upon further questioning of the archaeologists responsible for the pit feature sample that it was discovered that an Archaic Period intrusion was identified in the predominantly Late Woodland/Early Mississippian feature. As previously mentioned, however, the sample was collected as a bulk sample and lacked reference to the precise location of the sampled materials from within the feature.

In a case study of archaeological sites from Scotland, Ashmore (1999) cites specific examples regarding the dangers associated with dating mixed charcoal samples. In one of the presented examples, dates from three features associated with the remains of a roundhouse (estimated to be between 1000 BC and the earliest 1st millennium AD) were compared. One bulk and three, single entity samples were dated from each of the three features. The single entity samples were submitted for accelerator mass spectrometry (AMS) dating. Based on the averaged age of the associated single entity AMS dates, the results suggested that the bulk samples from two of the features may have contained 8-10% charcoal from older contexts creating a 200 year error. The third feature indicated an opposite trend, with 15% of the bulk sample being made up of younger charcoal, producing an error of approximately 400 years when compared to the average age of the AMS dates.

As an exercise into the affect of possible contamination, we posed the question, “How much charcoal from the Archaic intrusion would have been necessary to create the approximately 300 year difference between the observed younger and older age groups in our sample?” Based on the work of Ashmore (1999) and Taylor (1987), if 1063yrBP (the average of the three youngest dates) is taken as the actual Late Woodland/Early Mississippian age of the feature and 4000yrBP as the age of the Archaic intrusion, a 92:8 mixture of young and old charcoal would have had to occur to produce the older group average of 1292yrBP. Although this explanation is plausible, an appeal to contamination may be unwarranted for the dates obtained in this study. With an average age for the five samples of ~1150 AD, the deposition of the feature would still have occurred during the late Woodland Period.

## Conclusion

It is more likely that the age ranges observed in this study are simply the result of the primary problem inherent to bulk samples. They are mixtures of an indeterminate variety of charcoals. The charcoal may have derived from several plant species, secondary and/or tertiary branches of trees, sapwood and/or heartwood, or may have in fact been deposited during multiple occupations of a site. All, or some, of these factors may have contributed to the *seemingly* imprecise results observed here. Further, if UTCAG 06-005 had been the only sample submitted for dating, the age of the depositional event may have been overestimated by at least 200 years. This emphasizes an important point for archaeologists when choosing samples for dating. Single entity samples are always best for helping to minimize the effects of the many factors responsible for inaccurate or imprecise radiocarbon dates. In some cases, however, bulk samples may be the only option. As this study demonstrates, it is in this instance that the researcher should be prepared to submit several aliquots of the bulk sample to obtain an average age for the feature or event of interest.

## References Cited

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