Scientific Approach in Radiocarbon Dating in Archaeology

N.S.P. Kumburage
Department of Social Sciences, Faculty of Social Sciences and Humanities, Rajarata University of Sri Lanka, Mihintale
randikumburage@gmail.com

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Introduction

Archaeology has a direct relation with natural sciences while it is a science of human behavior [1]. This paper expects to discuss the way of Natural Sciences carries direct relationship to Archaeology.

Technologies as radiocarbon dating, dendro chronology, luminescence dating are contributed to the archaeology for the date the physical remains uncover from the sites. All these came from natural sciences and among all the Radiocarbon dating has been having revolutionized archaeology. There are two techniques for measuring radiocarbon in samples through radiometric dating and by Accelerator Mass Spectrometry (AMS) [2]. Today the vast majority of radiocarbon laboratories utilize these two methods of radiocarbon dating. Of major recent interest is the development of the Accelerator Mass Spectrometry method of direct C14 isotope counting. The crucial advantage of the AMS method is that milligram-sized samples are required for dating.

The 14C Method

C12, C13 (both stable) and C14 (unstable or radioactive) are the three principal isotopes of carbon which occur naturally. The radiocarbon method is based on the rate of decay of the radioactive or unstable carbon isotope 14 (^{14}C), which is formed in the upper atmosphere through the effect of

cosmic ray neutrons upon nitrogen 14. The reaction is:

$^{14}N + n \Rightarrow {}^{14}C + p$

Where,

n- Neutron p- Proton

The formed ^{14}C is rapidly oxidized to $^{14}CO_2$ and enters the earth's plant and animal life ways through photosynthesis and the food chain. Plants and animals which utilize carbon in biological food chains take up ^{14}C during their life times. They exist in equilibrium with the ^{14}C concentration of the atmosphere, that is, the numbers of^{14}C atoms and non-radioactive carbon atoms stay approximately the same over time. As soon as a plant or animal dies, they cease the metabolic function of carbon uptake; there is no replenishment of radioactive carbon, only decay.

Libby, Anderson, and Arnold (1949) were the first to measure the rate of this decay [3]. They found that the initial ^{14}C amount in a sample woulddecay in half a time, took thesame time to decay in the rest sample to be half and so on.The half-life (t 1/2) is the name given to this value.As ^{14}C decays, it emits a weak beta particle (b), or electron, which possesses an average energy of 160keV. The decay can be shown:

$^{14}C \Rightarrow {}^{14}N + b$

Thus, the ^{14}C decays back to ^{14}N. There is a quantitative relationship between the decay of ^{14}C and the production of a beta particle. The decay is constant but spontaneous. That is, the probability of decay for an atom of ^{14}C in a discrete sample is constant, thereby requiring the application of statistical methods for the analysis of counting data. This is used the Bayesian statistics for the calculation. It follows from this that any material which is composed of carbon may be dated. Herein lies the true advantage of the radiocarbon method, it can be uniformly applied throughout the world.

The historical perspective on the development of radiocarbon dating is well outlined in Taylor's (1987) Libby and his team initially tested the radiocarbon method on samples from prehistoric Egypt In 1949.In this paper, they presented the first results of the C14 method, including the "Curve of Knowns" in which radiocarbon dates were

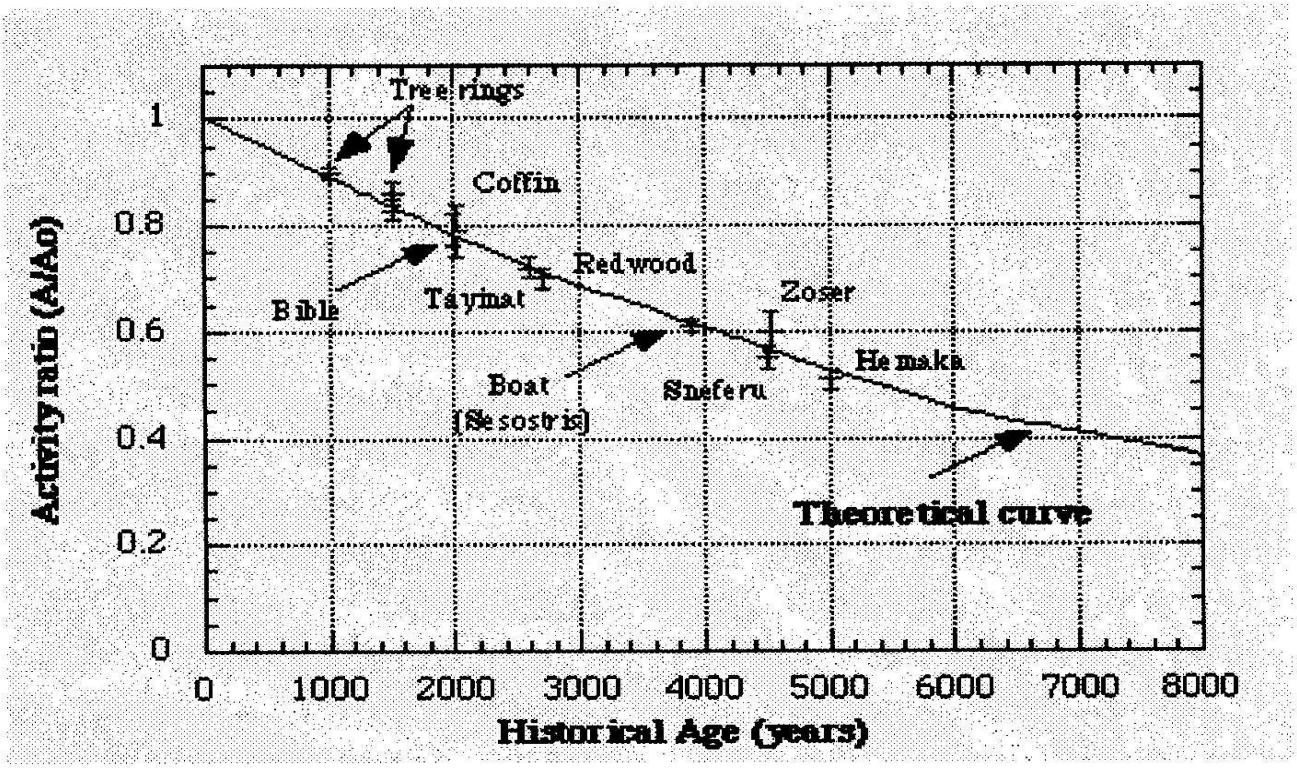

Figure 1: The "Curve of Knowns" after Libby and Arnold (1949).

compared with the known age historical dates (figure 1).

The major developments in the radiocarbon method up to the present day involve improvements in measurement techniques and research into the dating of different materials. The radiocarbon dating method remains arguably the most dependable and widely applied dating technique for the late Pleistocene and Holocene periods.

Radiocarbon calibration

At least the last decade and a half, an immense amount of effort has been invested in providing calibration curves, in ensuring and evaluating data quality, and in interpreting results. The sheer volume of information is bewildering, and much of it is seemingly complex, especially as new dataare often presented without reference to the implications for archaeological application. In this review only concerned with the calibration of radiocarbon dating results and

particularly with the status of recent calibration data and the emergent use of Bayesian statistics. It must be stressed that calibration is often viewed as a final step, requiring thought only after the radiocarbon results have been supplied by the laboratory.

Calibration methods

The calibrated dates can be faithfully represented only by probability distributions that fully take account of both the error term on the radiocarbon result and the effect of the wiggles in the curve; the wiggles indicate that any radiocarbon result can correspond to more than one calendar age range. Familiar from many calibration programs, but incorporating any additional chronological information available. Bayesian methodology also allows a variety of other inferences to be [4]. What are the practical implications of this type of approach for the archaeologist? Sets of results relating to the same event and shown to be contemporary can, generally speaking, be dealt with using existing calibration programs. Extending the Bayesian approach to dates relating to several events, linked stratigraphically or otherwise, however, requires more complex analysis. The mathematical formulation of the problem is not straightforward, and its solution requires extensive computing resources.

Radiocarbon dating by Accelerator Mass Spectrometry

The technique of measuring radiocarbon using Accelerator Mass Spectrometry (AMS) has been in existence for nearly 15 years, and radiocarbon dates have been produced by this method for over a decade. Although only about a quarter of these are archaeological dates.

The basis and significance of the AMS technique

To obtain a radiocarbon date, it is necessary and sufficient to measure the relative abundance of the carbon isotopes ^{12}C, ^{13}C, and ^{14}C in a suitable sample. The AMS method detects ^{14}C atoms independently of whether they radioactively disintegrate, measuring about 1% of all ^{14}C atoms and requiring samples of only 1 mg of carbon (and often less)[5]. The main outcome is that archaeologists now have far more

possibilities as to what samples can be dated. Therefore, the value of the technique depends very much on how well this choice is exercised. In other respects, the AMS method does not differ greatly from the conventional method. The cost is somewhat higher, the measurement error similar (though the results are more reliable due to better selection), and the age range much the same (though again, older dates are undoubtedly more reliable because samples have been better freed from modern contamination).

Advantages of greater selectivity

The advantages of much greater selectivity fall into two categories: an increase in the archaeological reliability of the date, and the generation of new chronological information. Rechecking dates. If alaboratory date seems questionable, for whatever reason, sufficient sample is often available for a second measurement, which might help to confirm that the original measurement was not in error. W hen only 1 mg of carbon is required for analysis, it is relatively easy to find material that can be better chemically characterized and/or be subjected to more stringent chemical procedures. Therefore, reasonably well-preserved bone has turned out to be the sample material of preferences. The question of chemical treatment becomes especially important for dates beyond 30,000 years and only consistent stratigraphic sequences can demonstrate its effectiveness.

Different sources of carbon in sediments can be sorted out using this approach. Of particular interest has been the comparison of the "charcoal" and "humic" fractions in charred carbonaceous material." Their agreement obviously strengthens the reliability of the date obtained. This approach has been used in several situations, In many ways, it is one of the most powerful methods available for establishing reliability, although, of course, the cost of dating is thereby increased.

Conclusions

Like any dating technique, the use of radiocarbon requires care in sample selection and measurement. Radiocarbon dating, however, has special problems in interpretation, because of the need for calibration. The continually growing body of

calibration data and the variety of statistical models used to deal with the calibration process are daunting to assimilate. These factors, however, underline the value of early and continued collaboration among archaeologists, radiocarbon scientists, and statisticians. Only through such cooperation can the potential of Bayesian analysis be realized, a technique that holds considerable promise because of its generality and its ability to incorporate archaeological data explicitlyRadiometric dating methods detect beta particles from the decay of carbon 14 atoms while accelerator mass spectrometers count the number of carbon 14 atoms present in the sample. Both carbon dating methods have advantages and disadvantages. The full archaeological potential of radiocarbon dating by AMS depends on a comprehensive grasp of how its selectivity may best be exploited. On the technical side, selectivity can be increased as smaller and smaller samples can be analyzed and as our understanding of the processes of organic degradation and environmental contamination improves. With deepening understanding, reliable dating beyond 50,000 years may eventually prove possible. To date, AMS's chief contributions have been to provide much greater reliability in radiocarbon dates and to forge a closer relationship between specifically archaeological information and chronological data.

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