# SOME RECENT RESEARCH IN ARCHAEOLOGICAL DATING IN THE UNITED STATES

by

Jan F. Simek

Department of Anthropology

University of Tennessee

Knoxville, Tennessee 37865

USA

## Introduction

I have been asked to provide a brief review of recent U.S. research on absolute dating techniques that might be of interest to archaeologists concerned with Upper Paleolithic prehistory in Europe. To be sure, a great deal of work has been done, and a great many important results achieved, over the past five years by physicists, chemists, and biologists developing and applying archaeometric dating techniques in laboratories around the world. I propose in this review to discuss a few major topics where laboratories in the United States have and/or will make important contributions to understanding Upper Paleolithic chronology and human adaptations.

Research into improving absolute dating methods in geology and archaeology is currently going on in many countries and is certainly not restricted to the United States of America. However, I will concentrate on work undertaken in U. S. laboratories as this is what I am personally most familiar with. In my discussion, I do not intend to provide a "laundry list" of Upper Paleolithic dates. Individual papers in this volume dealing with the Upper Paleolithic prehistory of specific regions, provide recent dates obtained in each area. I will confine my remarks to the techniques themselves.

## Dating Techniques

### Radiocarbon

Most archaeologists are well aware that the technology of radiocarbon has undergone a minor revolution in recent years due to the application of Accelerator Mass Spectrometry (AMS) to the measurement of carbon isotopes. Of particular import to paleolithic archaeologists, AMS dating requires smaller samples (c 1 mg of carbon) and provides more precise measurements allowing dating of more ancient materials than conventional $^{14}C$ techniques (to more than 40,000 years ago). These advances are possible because AMS dating can operate at the molecular level. The new technique also allows relatively direct assessment and elimination of sample contamination; this has made accurate dating of fossil bone and bulk sediment samples possible for the first time.

While AMS radiocarbon dating is far superior to conventional methods, it still suffers from certain problems. Therefore, much current U. S. research devoted to this technology lies in three realms: (1) improvement of sample preparation and dating technology, (2) improvement of calibration curves, and (3) improvement of information dissemination.

Improvement of sample preparation and dating is being approached in two ways. On the one hand, all radiocarbon laboratories, including those in the United States, constantly try to increase the purity of their sample preparation process and the cleanliness of their facilities in order to avoid contamination of samples being processed. For AMS dating, this involves refinement of graphite target fabrication and $CO_2$ handling. In addition, accuracy of dating is assessed, often using inter-laboratory comparisons where identical reference samples are dated in different laboratories and the causes of any observed variation identified. Refined laboratory protocols have led to ever-increasing precision in radiocarbon dating by AMS.

A second area of recent work designed to increase accuracy and precision is the dating of individual sample molecules. Radiocarbon dating at the molecular level typically involves extraction of specific organic compounds from a sample, either carbon molecules or, in the case of bone, amino acids contained in bone collagen. Dating individual molecules provides many advantages over traditional approaches: date accuracy can be objectively assessed using chemical means, impurities can be identified and removed, and contaminated samples can be rejected prior to dating (Stafford, et al. 1987). The "dating threshold" for radiocarbon has also been pushed back (finite dates of 42,000 bp have been obtained) through increased accuracy and decreased sample contamination. In addition, <u>very</u> small samples can be processed in this way.

Research on dating fossil bone through extraction of amino acids from collagen was pioneered by Wand (1981) and refined by Stafford and colleagues (Stafford 1988; Stafford, et al. 1982, 1987). It has been used in recent years to address a variety of chronological questions, including the antiquity of certain human skeletons associated with paleoindian artifacts in North America. Stafford has found that 12 of 18 amino acids present in collagen can be successfully extracted without contamination, and these can each be dated for the same sample, providing multiple individual dates. Multiple dates, in turn, yield increased statistical confidence, and ages with very low standard deviations ($\pm$40) can be obtained. Clearly, this technique is far more precise than previous $^{14}C$ methods, even those that employ AMS technology on samples prepared using traditional protocols. Moreover, recent work by Stafford and others (op cit.) indicates that non-destructive extraction of amino acids from bone may be possible; thus, loss of potentially important artifacts in the dating process may soon be eliminated.

Other AMS researchers have attacked the problem of dating bones that are depleted in collagen. Groups under the direction of A. Long at the University of Arizona and P. Hare at the Geophysical Laboratory in Washington, D.C. are at the forefront of this research (Long, et al. 1988). They have used amino acid racemization to determine a sample's suitability for amino acid extraction and dating, and have proposed some potential ways that collagen-depleted bone dates might be pursued.

In sum, accurate and precise AMS dating of fossil bone has become a reality through the extraction of specific amino acids. We can anticipate that, soon, such dates can be furnished without artifact destruction. Research into improved sample preparation and dating techniques continues at various laboratories, and promises to make important contributions to archaeology generally and Upper Paleolithic prehistory specifically in the near future.

Despite my emphasis on AMS-based dating, I do not mean to imply that conventional $^{14}C$ techniques are applied without critical assessment and attempts at improvement. Laboratories at the University of California (Riverside), the University of Colorado (Boulder) and Southern Methodist University (Dallas) all are undertaking research into purifying sample preparation protocols to avoid contamination (and thereby increase the precision) of radiocarbon methods using standard counters. This attention, and the advent of more accurate counting systems, has made it possible for Haas at Southern Methodist, for example, to date carbon-charged bulk sediment samples using conventional means.

The second area of ongoing radiocarbon research in the United States concerns calibration of radiocarbon dates to account for past variation in atmospheric $^{14}C$. Like improvements in sample preparation and dating, calibration research is being carried out at many laboratories around the world, not only in the United States, and many laboratories contribute to calibration studies if they do not perform basic research themselves. A center for basic calibration work is the radiocarbon laboratory directed by M. Stuvier at the University of Washington, Seattle, and that lab deserves special mention in any review of U. S. radiocarbon research.

Over the past five years, the Seattle laboratory (in collaboration with the Belfast laboratory) has been analyzing wood decadels derived from the German Main dendrochronological sample. Hundreds of sample analyses have pushed the Seattle calibration curve back to c 7000 years ago. In the coming years, continuing German Main Chronology studies should extend the calibration curve even further, to the end of the Pleistocene (c 10,000 years bp). As these studies are always performed in two different laboratories, assessments of dating accuracy are performed along with date production, and much information on inter-laboratory variability has been obtained as this project proceeds. A special calibration issue of the journal Radiocarbon (1986) reports on much of this work, and a computer program containing the Seattle calibration was distributed to over 250 individuals at the 13th International Radiocarbon Conference in Dubrovnik.

The third issue I will discuss concerning radiocarbon research in the United States is, in fact, exemplified by the Seattle laboratory's distribution of calibration programs: the availability and dissemination of information. Radiocarbon dating is now so widespread in archaeology (today it is a fundamental research tool for all archaeologists), that it has become nearly impossible to follow advances in technology, not to mention the dates themselves, as they are published in the literature. Efforts are currently underway to address this problem through the creation of an International Radiocarbon Data Base (IRDB) at the University of Arizona.

The journal Radiocarbon was founded in 1959 as a central information clearinghouse for radiocarbon research and the publication of dates. It has served admirably in that role until the present time, and will surely continue to provide the basic outlet for publication of $^{14}C$ dating information. However, over the past 30 years, more than 35 laboratories have been established world-wide, and a vast number of dates have been produced, reassessed, calibrated, etc. Unfortunately, for a variety of reasons these are not all readily available to the "consuming" public. The IRDB is designed to provide a global radiocarbon archive that can be accessed by any scholar desiring dating information. Currently under the direction of Renee Kra, the IRDB will be located at the University of Arizona Geophysical Laboratories radiocarbon dating facility. At the Dubrovnik 13th International Radiocarbon Conference, the IRDB was endorsed by participating facilities and scholars, and a Governing Committee was established (R. Kra, J. Evin, G. Frison, S. Gulliksen, H. Haas, F. Hole, A. Long, R. McNeely, W. Mook, B. Obelic, R. Otlet, M-F. Pazdur, H. Polach, E. Taylor, J-C. Vogel, J. Walker, J. Weinstein). In addition, a "minimum format" for a data base entry was approved. Clearly, an International Radiocarbon Data Base, comprising computerized and widely-accessible radiocarbon date information, is an idea whose time has come. We can anticipate that this facility will be of enormous utility to Upper Paleolithic archaeologists everywhere in a very few years time.

Thermoluminescence

In recent years, dating of archaeological materials by thermoluminescence (TL) has provided provocative new insights for Paleolithic archaeology. Specifically, TL dating of fossil hominid sites in the Near East and Europe, mostly carried out in French laboratories, (e.g., Valladas, et al. 1987) has significantly altered our perception of the relation between archaic Homo sapiens (particularly the "Neanderthals") and modern forms of that species. Dates for early modern Homo sapiens greater than 90,000 years ago now suggest that modern and archaic H. sapiens forms were contemporary (on a global scale, at least) for a very long time; this observation has, in turn, sparked heated debate about the evolutionary heritage of modern human populations.

As is the case for radiocarbon dating, research into TL properties is going on in many laboratories around the world, and in fact, most of the theoretical and technical development of TL dating has gone on outside the United States. The theory and techniques of TL have been well described in the literature (Aitken 1985). A major advantage of the method is that the TL signal can be acquired by a wide range of materials, including most minerals that have a crystal lattice structure (quartz, calcite, feldspars, etc.), and dating can be performed on a wide variety of archaeological artifacts and features-- ceramics, lithics, sediments, and other materials with such a structure. A disadvantage lies in the fact that the technique assumes that TL dose acquisition began at the specific time of interest (i.e., the date of archaeological production or deposition); this presumption, sometimes referred to as "zeroing" of the TL signal, is fundamental to the method's utility as a dating technique

(Huntley 1985) but must be assumed in the absence of empirical test procedures.

In the United States, TL research is widespread, but work specifically related to archaeology is being undertaken in two principle locations: the University of Maryland and the University of Washington. W. F. Hornyak and A. D. Franklin are performing basic research into the properties of TL at the University of Maryland with particular concern for the problem of signal origin and dose acquisition. Their work on bleaching of TL has shown that TL emissions can be greatly effected by the number of competing electron traps involved in generating TL signals and by the extent to which traps are occupied prior to analysis (Franklin & Hornyak n.d.a.). They have also shown that the slow bleaching peak TL glow curve can be influenced in its behavior by the rapid bleaching glow curve, indicating further caution is warranted in the dating process (n.d.b.). They continue research, however, into how basic kinetic properties of the TL emission process are to be understood.

At the University of Washington, T. G. Stoebe and R. C. Dunnell have established a TL laboratory designed to serve the archaeological community with need for TL measurement services. The University of Washington facility is the only TL service laboratory in the United States devoted to archaeological research, and seeks to educate the archaeological community in the United States on the potential and limitations of TL dating, as well as to provide a low cost dating service. The University of Washington laboratory is also performing basic research into

TL measurement with a specific concern for developing screening techniques that detect samples unsuitable for analysis before a date is produced. (At present, unsuitability can be determined only by carrying out the dating process). One approach being pursued involves three dimensional measurement of TL emissions to detect the effects of secondary luminescence sources that might influence primary source signals (e.g., mineral inclusions in quartz grains).

United States research into TL dating is only beginning, and it is often carried out in collaboration with laboratories in other countries. Still, by investigating basic properties of TL, these laboratories should soon make contributions to this potentially crucial dating method. This is especially important since recent TL dates have forced Paleolithic Archaeology to substantially alter its perception of the origin of modern humans and their culture.

Electron-spin Resonance

Electron-spin Resonance (ESR) dating is a technique related to thermoluminescence. Over time, crystals are bombarded by radiation, and free electrons are trapped in defects in the crystal lattice. An ESR spectrum will have a peak proportional to the number of trapped charges, and when the accumulated dose is compared to the environmental dose measured from surrounding sediments, a date can be calculated. Hydroxyapatite, a major constituent of bones and teeth, provides a suitable crystal environment for ESR dating, however for a variety of reasons, tooth enamel is preferable to dentine and bone (Grun & Schwarcz 1987; Grun, et al. 1987). Of course, tooth enamel is a common material recovered in archaeological sites, and this makes ESR dating particularly attractive to paleolithic archaeologists.

At present, only one laboratory in North America, directed by H. P. Schwarcz in the Department of Geology , McMaster University, is carrying out research on ESR dating of archaeological sites. The McMaster laboratory, working in conjunction with F. C. Howell of the University of California, has undertaken an ambitious program of dating paleolithic sites using ESR, and results are encouraging. Because the technique can be used to date materials up to several millions of years old, initial applications have stressed Lower and Middle Paleolithic sites in Europe, the Near East, and Africa. Included among these are Ambrona (Spain), La Micoque, Grotte Vaufrey, and La Chaise (France), Bilzingsleben (DDR), Sterkfontein and Swartkrans (South Africa), Vertesszolos and Erd (Hungary), Wadi Amud Cave and Qafzeh Cave (Israel), and Isernia de la Pineta (Italy). However, ESR dating has great potential for more recent sites, as well, and may provide useful comparisons for other dating methods (i.e., $^{14}C$, TL), especially in sites dating to the early part of the Upper Paleolithic where $^{14}C$ dates are least precise.

Amino Acid Racemization

Amino acid racemization (AAR) has fallen out of favor as a dating technique, primarily because of great variability in the rate that amino acids are leached from most organic materials. This rate varies depending on material and context, and this lack of constancy has resulted in the technique's use primarily for stratigraphic correlation only in very limited circumstances.

Recently, however, research carried out by a collaborative group headed by G. H. Miller of the University of Colorado has shown that at least one organic material, ostrich eggshell, comprises a closed system that retains 90 to 95% of the amino acids found in modern shells even after more than 100,000 years (Brooks et al. 1990). This is true even in laboratory simulations of extreme leaching environments. Thus, ostrich shells may provide one case where AAR can provide useful dates. By extension, the method may be valuable on other avian eggshells, as well. Miller and his associates have undertaken a project designed to test this method using data from Bir Tarfawi (Egypt), Olduvai Gorge (Tanzania), and sites ranging from the Early to the Upper Paleolithic in Africa and Asia. Where possible, AAR dates will be crosschecked by dating of the specific amino acids composing the shells (see above) by the University of Arizona AMS facility. While still in preliminary stages, this work promises to provide another possible means for dating Upper Paleolithic sites where bird eggshells are recovered.

<u>Conclusions</u>

I have tried to briefly describe what comprises, to me, the most important avenues of dating research currently underway in the United States that are of direct interest to archaeologists concerned with the Upper Paleolithic. I do not mean to imply that these are the <u>only</u> present efforts, nor that the United States the only source of innovation in archaeological dating. In fact, most research is collaborative and international, requiring as it does cooperation among several laboratories to develop techniques and replicate results. Current research in the United States does show, I think, how much archaeological dating has changed over the past few years and where it may go in the near future; developments such as AMS dating, amino acid extraction, TL and ESR, will dramatically affect how we view the Upper Paleolithic archaeological record. Given the new and rapidly evolving dating tools, I suspect that the next five years will be very interesting from a chronological point of view.

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