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ARCHAEOLOGIC SHERD DATING: COMPARISON OF THERMOLUMINESCENCE DATES WITH RADIOCARBON DATES BY BETA COUNTING AND ACCELERATOR TECHNIQUES

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ABSTRACT. Sherds can be dated by four independent methods: ^{14}C beta counting on associated material, accelerator mass spectrometry on carbon traces on and within the sherd, thermoluminescence studies on minerals within the sherd, and stylistic form. Age analyses of materials and sherds from several sites are shown in this work. Each technique has its own frequently encountered non-laboratory sources of error. A combination of at least two independent techniques is indispensable for the highest level of confidence.

INTRODUCTION

Often, the most plentiful artifacts found in archaeologic excavations are ceramic sherds. Potsherds, with their often recognizable, distinctive styles, can form the basis of useful chronologic sequences used to trace the development of a region or culture. They are used as markers to correlate widespread sites and summarize the overall development of diverse civilizations or cultures.

Table 1 illustrates four principal methods of dating archaeologic sherds. ^{14}C dating of associated charcoal was the first quantitative dating method for sherds and remains the most popular approach. Several studies have also been made by ^{14}C dating carbonaceous remains extracted from large quantities of sherds (De Atley, 1980; Delibrias & Evin, 1979; Evin, 1983; Tauber, 1970; Taylor & Berger, 1968).

More recently, reliable techniques for thermoluminescence (TL) dating of sherds were developed (Aitken, Zimmerman & Fleming, 1968; Zimmerman, 1971; Fleming, 1979) which permitted quantitative age determinations on the actual marker artifact. Finally, the development of accelerator mass spectrometry (AMS) made possible ^{14}C dating of very small amounts of food remains and other carbonaceous traces occasionally found on or within individual sherds (Bill *et al*, 1984).

The results of sherd dating from several archaeologic sites are presented here. Sites selected for sherd dating in south Florida were principally habitation mounds (Goggin, 1950; Doran, 1984; Carr & Beriault, 1984), all of Glades II period. Sherds from the Central Alpine region of Europe were from a variety of sites, stylistic descriptions of which were discussed previously (Bill *et al*, 1984). Comparisons of dates obtained with beta counting of associated charcoal, thermoluminescence of sherds, and AMS on included carbon are used to examine agreement among these methods.

TABLE 1
Comparison of principal archaeologic sherd dating techniques

Dating technique	Some advantages	Some disadvantages
Stylistic dating	1. Dating of actual object of interest 2. Done by archaeologist 3. Least expensive	1. Usually uses information based on ^{14}C dates, with the same errors of that method 2. Subjective
^{14}C dating: beta counting of associated charcoal or other carbonaceous materials	1. Extensive laboratory experience with method 2. Moderate expense 3. Objective	1. Does not date the actual object of interest 2. Material is generally older, by an unknown amount, than the associated sherd 3. Not always available in the site
^{14}C dating: AMS measurements on sherd soot, food remains, or included carbon	1. Dating of actual object of interest 2. Objective 3. Food remains avoid the "old charcoal" problem	1. Soot comes from firewood that is older, by an unknown amount, than the sherd 2. Sherds do not often contain soot or food remains 3. Most expensive
TL dating	1. Dating of actual object of interest 2. Avoids "old charcoal" problem 3. Moderate expense 4. Objective	1. Sherd may have been accidentally reheated after original firing 2. Sherd might not have been completely zeroed in inefficient firing 3. Some ceramics do not hold a TL signal

FLORIDA SITE DESCRIPTIONS

Addison Key

This represents the first attempt to excavate a deep stratigraphic black midden that could reveal an adequate sampling of the pottery sequence typical of the area in the Ten Thousand Island area of southwestern Florida. The only other ^{14}C dates from this area were on Onion Key (also in this paper). The ^{14}C and TL results correlate with the ceramic seriation sequence originally developed by Goggin (1950) and later expanded by Griffin (1984).

The mound is composed of shell with a black dirt midden (habitation mound) on top. The overall site consists of numerous mounds and ridges composed of shell which were dredged away in the early 1940s.

This site encompasses the Glades II period. There is a possibility of an earlier habitation period below the mound but this level is presently under water.

Rivermount Site

The site is composed of a black dirt midden on the New River in Broward Co, Florida. No ^{14}C dating had been done on this river system which is the largest in SE Florida and represents an important component of this prehistoric settlement system.

This site was selected to obtain data on one of the few remaining sites along the river, the majority of sites having been destroyed by construction. The site itself is an elevated ridge along the river bank. The elevation is due to extensive cultural activity for several hundred years.

Panther Mound

This site is located on an everglades tree island in the southern everglades area. The mound sampled is a black dirt occupation midden which rises 1m above the surrounding island.

The site was selected as part of a National Park Service project involving a systematic sampling of all sites in the Big Cypress Preserve. This particular site held a wealth of small ceramic fragments from the Glades II period.

Onion Key

This site was also sampled as part of a National Park Service project. Previous ^{14}C dates from this site (3) were anomalously old and indicated some type of contamination. A test pit was dug in the side of the mound from which charcoal and sherd samples were collected. The mound is composed of a shell base with a black dirt midden on top. This site and the Addison Key site are roughly contemporaneous.

EXPERIMENTAL

The benzene method was employed for the beta counting measurements (Polach & Stipp, 1967; Tamers, 1975). For AMS measurements, pretreated carbon samples were mixed with silver powder in a 1-to-5 ratio and pressed on copper targets (Bonani *et al,* 1984). General procedures of the ETH accelerator were described previously (Suter *et al,* 1984).

Thermoluminescence studies were made using the fine-grain technique (Zimmerman, 1971) with the 2 to 8μ size fraction. Radiation sensitivity was determined with calibrated ^{244}Cm and ^{90}Sr plack sources. Uranium and thorium contents were obtained by alpha counting, and potassium was analyzed chemically. The quoted errors for TL are enlarged to include uncertainties in the environmental contribution to the observed signal where data was unavailable and best estimates were necessary.

Pretreatment of associated charcoal was done by standard techniques—crushing, hot acid and alkali solutions interspersed with rinsings with hot distilled water. Shell was strongly acid-etched to remove outer layers and checked by X-ray. Included carbon in sherds (for AMS) was treated somewhat differently. Each sherd was dried, crushed, and placed in deionized water. The minerals sank, leaving tiny pieces of carbonized organics (animal fats, plant fibers, or charcoal used in the tempering process) floating on the surface. Carbonized organics were isolated by centrifugation and given HCl to remove carbonates. The samples were then given a 0.5% NaOH heated bath for 1 hour and a subsequent 0.5% HCl rinse.

TABLE 2
Sherds and charcoals from the Ten Thousand Islands area of southwest Florida

Level	Sample material	Sample no.	Beta counting ^{14}C dating (yr BP) $\pm 1\sigma$	$^{13}C/^{12}C$ ‰	Sample no.	TL dating (yr BP) $\pm 1\sigma$	Sample no.	AMS dating (yr BP) $\pm 1\sigma$	$^{13}C/^{12}C$ ‰
Addision Key, Test Pit #1									
3	Charcoal	UM-2532	800 ± 70	−24.77					
3	Charcoal	UM-2531	910 ± 110	−25.13	UMTL-845	860 ± 70	ETH-0285	1110 ± 130	−25.7
3	Shell	UM-2530	820 ± 100	−0.81					
4	Charcoal	UM-2529	870 ± 110	−26.11	UMTL-846	900 ± 80			
5	Shell	UM-2528	1080 ± 90	−0.57					
5	Charcoal	UM-2527	1030 ± 140	−25.02	UMTL-847	1100 ± 90			
6	Charcoal	UM-2509	1010 ± 150	−25.62	UMTL-848	1200 ± 90	ETH-0292	1090 ± 90	−24.1
9	Charcoal	UM-2523	1290 ± 140	−25.16					
9	Charcoal	UM-2522	1330 ± 130	−25.21	UMTL-849	1450 ± 130	ETH-0284	1520 ± 100	−25.2
9	Shell	UM-2519	1440 ± 90	−1.10					
10	Shell	UM-2516	1530 ± 110	−1.01					
10	Charcoal	UM-2515	1370 ± 100	−24.20	UMTL-850	1510 ± 120			
10	Charcoal	UM-2514	1410 ± 50	−24.52	UMTL-851	1410 ± 100			
Onion Key									
1	Charcoal	UM-3091	960 ± 150		UMTL-852	960 ± 110			
2	Charcoal	UM-3092	1000 ± 150		UMTL-853	930 ± 100	ETH-0295	1210 ± 140	−20.8
3	Charcoal	UM-3093	2050 ± 200		UMTL-854	970 ± 100	ETH-0221	1320 ± 140	−26.7
					UMTL-855	1010 ± 120			
4	Charcoal	UM-3094	950 ± 150		UMTL-856	1040 ± 120			
5	Charcoal	UM-3095	1220 ± 140		UMTL-857	1220 ± 140	ETH-0286	1520 ± 110	
Rivermount site									
3	Charcoal	UM-2405	1480 ± 100	−25.09					
4	Charcoal	UM-2404	1570 ± 170	−24.22	UMTL-842	1480 ± 100	ETH-0283	1550 ± 130	−28.0
5	Charcoal	UM-2403	1400 ± 90	−24.48					
6	Charcoal	UM-2401	1280 ± 140	−25.90					
7	Charcoal	UM-2398	1530 ± 110	−25.00					
8	Charcoal	UM-2399	1570 ± 170	−25.57	UMTL-843	1660 ± 140	ETH-0222	1080 ± 90	−27.3
9	Charcoal	UM-2402	1590 ± 170	−27.12	UMTL-844	1500 ± 100	ETH-0291	1650 ± 170	−25.7
Basal	Charcoal	UM-2400	1550 ± 120	−24.69					

TABLE 3
Panther Mound
Sherds and charcoal from Shark River Slough, Everglades National Park, Florida

Level	Sample material	Sample no.	Beta counting ^{14}C dating (yr BP) $\pm 1\sigma$	$^{13}C/^{12}C$ ‰	Sample no.	TL dating (yr BP) $\pm 1\sigma$	Sample no.	AMS dating (yr BP) $\pm 1\sigma$	$^{13}C/^{12}C$ ‰
1					UMTL-858	490 ± 60	ETH-0290	1110 ± 125	−21.4
2	Shell	UM-3090	1170 ± 140	−0.99			ETH-0220	1240 ± 240	−27.7

TABLE 4
Central Alpine region
Neolithic to Iron age sites in Europe*

Site	Sample no.	Beta counting ^{14}C dating (yr BP) $\pm 1\sigma$	$^{13}C/^{12}C$ ‰	Sample no.	TL dating (yr BP) $\pm 1\sigma$	Sample no.	AMS dating (yr BP) $\pm 1\sigma$	$^{13}C/^{12}C$ ‰
CH Egolzwil (LU) "Egolzwil 4"	KN-1021 H-228/276 H-229/277	5880 ± 250 5940 ± 300 5750 ± 225		UMTL-861	4660 ± 930	ETH-0236	5470 ± 240	−21.0
CH Egolzwil (LU) "Egolzwil 5"	B-2727 B-2728	5570 ± 200 5820 ± 200		UMTL-865	5850 ± 117	ETH-0133	5700 ± 150	−23.4
I Val di Pine "Acqua Fredda"	—			UMTL-866	2870 ± 570	ETH-0137	2970 ± 260	−23.1
FL Balzers "Runder Buchel"	B-3910	2330 ± 190		UMTL-862 (burned clay)	2500 ± 500	ETH-0138	2400 ± 180	−24.2
				UMTL-863 (sherd)	2340 ± 470			
FL Balzers "Areal Foser"	—			UMTL-867	2410 ± 480	ETH-0139	2580 ± 120	−24.0

* The AMS and beta counting ^{14}C dates have been reported previously (Bill *et al*, 1984), except for ETH-0236, which is a recent measurement.

After rinsing to neutral and drying, the samples were carbonized in ultrapure nitrogen to remove volatiles and adsorbed CO_2.

RESULTS AND DISCUSSION

Ages measured on contemporaneous materials from six archaeologic sites have been studied to compare the three independent dating techniques used to produce the dates. Results are shown in Tables 2–4. ^{14}C dates have been corrected for isotopic fractionation in nature with ^{13}C (Stuiver & Polach, 1977) and, in the case of marine shell samples, for a reservoir effect of 410 yr in Florida waters (Druffle & Linick, 1978). ^{14}C dates are based on the 5730 yr half-life and have been corrected for the De Vries effect (Klein *et al*, 1982). This is necessary for the comparison of the ^{14}C and TL results.

Results show that all three of the instrument dating approaches have produced at least one apparently anomalous date. In the Onion Key site, one beta counting ^{14}C measurement (UM-3093) is too old. A possible explanation might be original use of old wood (Smiley, pers commun). The three AMS measurements here are all a little older than the TL dates, but are within 2σ statistics. AMS dating of charcoal or soot on or in the sherds could also be affected by old wood or pitch in the fire. Also, the charcoal could have been used as temper in manufacture.

Panther Mound shows a TL date (UMTL-851) that is apparently too young. Although the reason is uncertain, the sherd may have been subjected to accidental reheating after its manufacture. This could have occurred by a brush fire or fire that burned after the stratum had been partially buried.

The Rivermount site shows an AMS date (ETH-0222) that appears somewhat young, the reason for which is also not apparent. However, the sherd may have been intrusive, which, likewise, could also explain the anomalous TL result in Panther Mound. The possibility of sampling intrusive material is particularly serious in archaeologic sherd dating. Often, the best sherds are kept for collections and stylistic identification. Sherds without distinctive markings are likely to be those sacrificed in the destructive processes of the TL or AMS dating.

The Central Alpine region dates are in general agreement. TL measurements show large errors since the sherds did not have associated soil samples available for measurement. In these cases, as with samples from museum collections, TL error terms of 20% are assigned to cover all reasonable possibilities of true water content and environmental radioactivity contribution to the TL signal. Nevertheless, Egolzwin 4 (UMTL-861) shows the possibility of an inconsistency.

CONCLUSION

Although radiochemical and radiophysical dating methods are now highly developed and efficient, discrepancies between dates and apparently indisputable archaeologic evidence regularly appear. The problems are usually not in laboratory measurements, but, rather, in the field. For example, in a disturbed site, charcoal found close to a sherd cannot confidently be associated with the sherd. Wood collected by indigens for their camp fire could be lying on the ground dead for hundreds of years before being used. Also, sherds could have been reheated by brush fires 1000 yr after manufacture.

The existence of significant undetermined errors cannot be excluded from any age determination. No method is immune to processing grossly incorrect dates when unknown problems may exist with the sample at the collection site. Our results illustrate that this situation can occur frequently. A combination of at least two independent dating techniques is indispensable for the highest level of confidence.

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