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

<table>
<thead>
<tr>
<th>Dating technique</th>
<th>Some advantages</th>
<th>Some disadvantages</th>
</tr>
</thead>
</table>
| 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
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

<table>
<thead>
<tr>
<th>Level</th>
<th>Sample material</th>
<th>Sample no.</th>
<th>Beta counting $^{14}$C dating (yr BP) $\pm 1\sigma$</th>
<th>$^{13}$C/$^{12}$C %</th>
<th>Sample no.</th>
<th>TL dating (yr BP) $\pm 1\sigma$</th>
<th>Sample no.</th>
<th>AMS dating (yr BP) $\pm 1\sigma$</th>
<th>$^{13}$C/$^{12}$C %</th>
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</thead>
<tbody>
<tr>
<td><strong>Addison Key, Test Pit #1</strong></td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td>Charcoal</td>
<td>UM-2532</td>
<td>800 ± 70</td>
<td>-24.77</td>
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<td>860 ± 70</td>
<td>ETH-0285</td>
<td>1110 ± 130</td>
<td>-25.7</td>
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<tr>
<td>3</td>
<td>Charcoal</td>
<td>UM-2531</td>
<td>910 ± 110</td>
<td>-25.13</td>
<td></td>
<td>UMTL-846 1100 ± 80</td>
<td>ETH-0292</td>
<td>1090 ± 90</td>
<td>-24.1</td>
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<td>4</td>
<td>Shell</td>
<td>UM-2530</td>
<td>820 ± 100</td>
<td>-0.81</td>
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<td>UMTL-846 900 ± 80</td>
<td>ETH-0292</td>
<td>1090 ± 90</td>
<td>-24.1</td>
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<td>Charcoal</td>
<td>UM-2529</td>
<td>870 ± 110</td>
<td>-26.11</td>
<td></td>
<td>UMTL-845 860 ± 70</td>
<td>ETH-0285</td>
<td>1110 ± 130</td>
<td>-25.7</td>
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<td>Shell</td>
<td>UM-2528</td>
<td>1080 ± 90</td>
<td>-0.57</td>
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<td>UMTL-845 860 ± 70</td>
<td>ETH-0285</td>
<td>1110 ± 130</td>
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<td>Charcoal</td>
<td>UM-2527</td>
<td>1030 ± 140</td>
<td>-25.02</td>
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<td>UMTL-847 1100 ± 90</td>
<td>ETH-0292</td>
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<td>-25.21</td>
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<td>UMTL-849 1450 ± 130</td>
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<td>UM-2519</td>
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<td><strong>Onion Key</strong></td>
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<td>1000 ± 150</td>
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<td>UM-3093</td>
<td>2050 ± 200</td>
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<td>UMTL-854 970 ± 100</td>
<td>ETH-0221</td>
<td>1320 ± 140</td>
<td>-26.7</td>
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<td>4</td>
<td>Charcoal</td>
<td>UM-3094</td>
<td>950 ± 150</td>
<td></td>
<td></td>
<td>UMTL-855 1010 ± 120</td>
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<td>Charcoal</td>
<td>UM-3095</td>
<td>1220 ± 140</td>
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<td>UMTL-856 1040 ± 120</td>
<td>ETH-0221</td>
<td>1320 ± 140</td>
<td>-26.7</td>
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<td><strong>Rivermount site</strong></td>
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<tr>
<td>3</td>
<td>Charcoal</td>
<td>UM-2405</td>
<td>1480 ± 100</td>
<td>-25.09</td>
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<td>UMTL-842 1480 ± 100</td>
<td>ETH-0283</td>
<td>1550 ± 130</td>
<td>-28.0</td>
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<tr>
<td>4</td>
<td>Charcoal</td>
<td>UM-2404</td>
<td>1570 ± 170</td>
<td>-24.22</td>
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<td>UMTL-842 1480 ± 100</td>
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<td>-28.0</td>
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<td>Charcoal</td>
<td>UM-2403</td>
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<td>Charcoal</td>
<td>UM-2401</td>
<td>1280 ± 140</td>
<td>-25.90</td>
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<td>UMTL-842 1480 ± 100</td>
<td>ETH-0283</td>
<td>1550 ± 130</td>
<td>-28.0</td>
</tr>
<tr>
<td>7</td>
<td>Charcoal</td>
<td>UM-2598</td>
<td>1530 ± 110</td>
<td>-25.00</td>
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<td>UMTL-843 1660 ± 140</td>
<td>ETH-0222</td>
<td>1080 ± 90</td>
<td>-27.3</td>
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<td>8</td>
<td>Charcoal</td>
<td>UM-2399</td>
<td>1570 ± 170</td>
<td>-25.57</td>
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<td>UMTL-843 1660 ± 140</td>
<td>ETH-0222</td>
<td>1080 ± 90</td>
<td>-27.3</td>
</tr>
<tr>
<td>9</td>
<td>Charcoal</td>
<td>UM-2402</td>
<td>1590 ± 170</td>
<td>-27.12</td>
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<td>UMTL-844 1500 ± 100</td>
<td>ETH-0291</td>
<td>1650 ± 170</td>
<td>-25.7</td>
</tr>
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<td>Basal</td>
<td>Charcoal</td>
<td>UM-2400</td>
<td>1550 ± 120</td>
<td>-24.69</td>
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<td>UMTL-844 1500 ± 100</td>
<td>ETH-0291</td>
<td>1650 ± 170</td>
<td>-25.7</td>
</tr>
</tbody>
</table>
### Table 3
Panther Mound
Sherds and charcoal from Shark River Slough, Everglades National Park, Florida

<table>
<thead>
<tr>
<th>Level</th>
<th>Sample material</th>
<th>Sample no.</th>
<th>Beta counting $^{14}$C dating (yr BP) ± 1σ</th>
<th>$^{13}$C/$^{12}$C %o</th>
<th>Sample no.</th>
<th>TL dating (yr BP) ± 1σ</th>
<th>Sample no.</th>
<th>AMS dating (yr BP) ± 1σ</th>
<th>$^{13}$C/$^{12}$C %o</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Shell</td>
<td>UM-3090</td>
<td>1170 ± 140</td>
<td>-0.99</td>
<td>UMTL-858</td>
<td>490 ± 60</td>
<td>ETH-0290</td>
<td>1110 ± 125</td>
<td>-21.4</td>
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<tr>
<td>2</td>
<td>Shell</td>
<td>UM-3092</td>
<td>1110 ± 140</td>
<td>-0.99</td>
<td>ETH-0220</td>
<td>1240 ± 240</td>
<td>ETH-0236</td>
<td>1220 ± 240</td>
<td>-27.7</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Site</th>
<th>Sample no.</th>
<th>Beta counting $^{14}$C dating (yr BP) ± 1σ</th>
<th>$^{13}$C/$^{12}$C %o</th>
<th>Sample no.</th>
<th>TL dating (yr BP) ± 1σ</th>
<th>Sample no.</th>
<th>AMS dating (yr BP) ± 1σ</th>
<th>$^{13}$C/$^{12}$C %o</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH Egolzwil (LU) &quot;Egolzwil 4&quot;</td>
<td>KN-1021</td>
<td>5980 ± 250</td>
<td>0.62</td>
<td>UMTL-861</td>
<td>4660 ± 930</td>
<td>ETH-0236</td>
<td>5470 ± 240</td>
<td>-21.0</td>
</tr>
<tr>
<td>H-228/276</td>
<td>5940 ± 300</td>
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<tr>
<td>H-229/277</td>
<td>5750 ± 225</td>
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<tr>
<td>CH Egolzwil (LU) &quot;Egolzwil 5&quot;</td>
<td>B-2727</td>
<td>5570 ± 200</td>
<td>1.01</td>
<td>UMTL-865</td>
<td>5850 ± 117</td>
<td>ETH-0133</td>
<td>5700 ± 150</td>
<td>-23.4</td>
</tr>
<tr>
<td>B-2728</td>
<td>5820 ± 200</td>
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<tr>
<td>I Val di Pine &quot;Acqua Fredda&quot;</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>FL Balzers &quot;Runder Buchel&quot;</td>
<td>B-3910</td>
<td>2330 ± 190</td>
<td>-1.0</td>
<td>UMTL-862 (burned clay)</td>
<td>2500 ± 500</td>
<td>ETH-0138</td>
<td>2400 ± 180</td>
<td>-24.2</td>
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<tr>
<td>FL Balzers &quot;Arca Foser&quot;</td>
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<td>FL Balzers &quot;Runder Buchel&quot;</td>
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<td>FL Balzers &quot;Arca Foser&quot;</td>
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</tbody>
</table>

* 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 CO₂.

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. ¹⁴C dates have been corrected for isotopic fractionation in nature with ¹³C (Stuiver & Polach, 1977) and, in the case of marine shell samples, for a reservoir effect of 410 yr in Florida waters (Druffle & Linick, 1978). ¹⁴C 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 ¹⁴C 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 ¹⁴C 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
Archaeologic Sherd Dating

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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