Measuring burn temperatures from charcoal using the reflectance method, first results from an Irish Bronze Age cremation site

Robyn Veal[1], Lorna O'Donnell[2] and Laura McParland[3]

1 Department of Archaeology, University of Sydney, NSW, 2006, Australia; robyn.veal@sydney.edu.au
2 Department of Archaeology, University College Dublin, Belfield, Dublin 4, Ireland; odonnell.lorna@gmail.com
3 Earth Science and Resource Engineering, CSIRO, NSW, 2113, Australia; laura.mcparland@csiro.au

Summary: *Reflectance is a method borrowed from coal studies which can estimate the absolute burn temperature of charcoals. Studies examining the usefulness of reflectance in archaeology are underway in a number of areas. This report details first results from reflectance testing of archaeological charcoals from known Irish Bronze Age cremations, which included calcinated bone. As calcination of bone occurs at 650 °C to ≥ 800 °C (Wahl, 1982), it was expected that the charcoals would reflect this temperature. This was not the case for identified charcoals > 2mm, nor for micro-charcoals of* ca*. 250 µm. Cultural depositional modalities, combustion completeness and taphonomic influences may have all played a part in this result which suggests that the usefulness of reflectance will depend on depositional circumstances and charcoal collection strategies.*

Key words*: Charcoal reflectance testing, taphonomy, micro-charcoals, charcoal collection strategies*

INTRODUCTION

Reflectance testing has been attested as a useful tool for demonstrating approximate burn temperatures of archaeological charcoal (McParland *et al.*, 2009a, b; McParland, 2010). McParland (2010) has in particular, demonstrated the nearly directly linear relationship between reflectance of specially prepared samples of charcoal across a range of wood species, temperatures, and charring times. Extensive testing over a range of archaeological depositional types however, has not yet been carried out, although results from a Roman hypocaust (bath) appeared to confirm the validity of the method. The testing in this study, in which charcoals of a range of size fractions were evaluated, was intended to be a control of the method as cremation temperatures for human bone are known.

ARCHAEOLOGICAL BACKGROUND

Charcoal was derived from excavations of Bronze Age sites along the N8 freeway from Cashel to Mitchelstown in Ireland (Mc Quade *et al.*, 2009), as part of O'Donnell's doctoral research. Soil contexts were bulk sampled and processed by flotation. Reflectance testing was used to address questions of burning temperature from three sites: a flat cemetery at Templenoe, a settlement site at Ballylegan and a *fulacht fiadh* (cooking pit) at Lissava, all excavated in County Tipperary.

In the Irish BA, bodies were either cremated; or burnt in funeral pyres consisting of raised wooden structures that would have ensured adequate air flow from beneath, or may have been sunk into the ground with oxygen being introduced via a series of flues (Buckley and Buckley, 1999: 25). From the site of Templenoe, two samples were selected from cremation pits with well cremated bone (indicated by white colour of remains) which contained *Quercus* sp. (oak) only. A further cremation pit dominated by Maloideae charcoal that included a low level of oak, was also selected. A cremation fill dominated by *Fraxinus* sp. (ash); and a further sample from mixed oak and pomaceous fruitwood pyres (a common occurrence at Templenoe) were also selected for testing. Templenoe is unusual in Ireland in that four possible pyres have also been discovered (in addition to the cremations). Samples from these provided the opportunity to compare burn temperatures of pyre material, with those of cremation pit charcoals. Taxa consisted mainly of *Quercus* sp. and some Maloideae, however, human bone was not actually identified in these contexts. A small number of features at Templenoe were considered to be non funerary pits and these were also tested as a comparison to the funerary contexts. These contained a wide variety of wood taxa and were dominated by *Corylus avellana,* hazel, which was not observed in the funerary contexts. Control samples from a domestic hearth at Ballylegan and from a trough fill at Lissava were also included.

METHOD

Charcoals > 2 mm, once identified taxonomically, were roughly crushed and mounted using one of two methods: cold set, or hot set epoxy resin blocks. The blocks were then ground and highly polished, and inspected under oil and a reflecting microscope for their reflectivity according to McParland (2010). Fifty measurements were taken and averaged for each sample. The hot and cold set epoxy methods have different utility depending on sample size and other factors, but a control test revealed results were not affected by setting method. Testing of samples of individual taxa was made, as well as of mixed taxa. The burn temperature results obtained did not demonstrate the high temperatures expected. Based on McParland's hypocaust work (McParland *et al.*, 2009b), which suggested material of much smaller dimensions would provide higher readings, some of the micro-charcoals from the same contexts, of 250 µm, ranging to 1 mm were further tested (without identification of taxa). Average reflectance measurements for each sample were then calibrated from the known linear relationship between reflectance and temperature (McParland *et al.*, 2009b; McParland, 2010), Figure 1 refers.

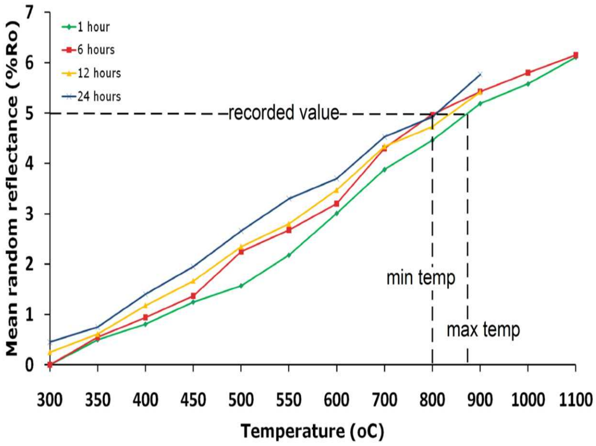

FIGURE 1. Calibration graph of reflectance vs. burn temperature

RESULTS

The average temperature ranges for the tested cremation samples varied from a low of 360-410 °C to a high of 390-450 °C, values well below that expected. Little differentiation in temperature was found for single taxon samples, as opposed to mixed taxa samples, i.e. wood type appeared to make little difference. The smallest fraction samples did show a slightly higher (*ca.* 15 °C) average temperature, and the maximum observed was about 550 °C. The open hearth samples, examined as a contrast, provided similar readings in the high range 390-450 °C.

DISCUSSION

The results show that charcoals collected from archaeological contexts may not always demonstrate the temperatures associated with the known cultural process in question. Because of the presence of the calcinated bone, the temperatures reached in the Bronze Age cremation samples had to have been in the vicinity of 650-800 °C (Wahl, 1982). The fact that no charcoals were measured at any temperature close to this range suggests that remainder archaeological charcoals in this case have not reached these temperatures, and instead reflect incompletely combusted fuel which has been at the periphery of the fire, and/or thrown on late in the cremation. While the smaller, (i.e. 250 µm) charcoals did reveal slightly higher temperatures, the results were not statistically significant. One possibility is that the higher temperatures may have been measureable from even smaller material, but this was not collected. It is not known if ash was deposited, and not collected; or if ash was deposited and lost in the surrounding soils. Combustion, once temperatures reach the high levels expected, may be wholly destructive, and it may not be possible to collect any remnant charcoals which have been exposed to the highest temperatures. However, it should be acknowledged that the flotation process for collecting the charcoals used a 250 µm mesh. Without testing of materials below this size the matter is still open.

CONCLUSIONS

The results suggest that reflectance will need to be applied in a selective manner and results interpreted carefully in terms of cultural burn modalities, combustion processes and taphonomy. Normal field collection of charcoal is by dry sieving over 4 or 5 mm mesh; and/or flotation over 250 µm or larger mesh. Size of charcoals for identification purposes is usually >2 mm. It will be useful in the future to collect un-sieved soil samples of ash and micro-charcoals (where present), and separate out the charcoal by gravimetric or other method for reflectance testing to further resolve this issue.

ACKNOWLEDGEMENTS

The authors acknowledge the support of the CSIRO, Sydney, and the Australian Centre for Microscopy and Microanalysis, University of Sydney. The excavations were carried out by Margaret Gowen & Co. Ltd, funded by the National Roads Authority in Ireland. Charcoal results are stored in the WODAN database at www.wodan.ie.

REFERENCES

BUCKLEY, L., BUCKLEY, V., 1999. Ashes to ashes? The archaeology of cremation. *Archaeology Ireland* 13 (50), 24-28.

MCPARLAND, L.C., 2010. *Utilisation of quantified reflectance values to determine temperature and processes of formation for human produced charcoals*. Ph.D. Thesis. Royal Holloway, University of London.

MCPARLAND, L.C., COLLINSON, M.E., SCOTT, A.C., CAMPBELL, G., 2009a. The use of reflectance values for the interpretation of natural and anthropogenic charcoal assemblages. *Archaeological and Anthropological Sciences* 1, 249-261.

MCPARLAND, L.C., HAZELL, Z., CAMPBELL, G., COLLINSON, M.E., SCOTT, A.C., 2009b. How the Romans got themselves into hot water: temperatures and fuel types used in firing a hypocaust. *Environmental Archaeology* 14, 176-183.

MC QUADE, M., MOLLOY, B., MORIARTY, C., 2009. *In the shadow of the Galtees. Archaeological excavations along the N8 Cashel to Mitchelstown*. Dublin: Wordwell.

WAHL, J., 1982. Leichenbranduntersuchungen. Ein Überblick über die Bearbeitungs — und Aussagemöglichkeiten von Brandgräbern. Berlin. *Prähistorische Zeitschrift* 57, 2-125.