

THE HEATED AND THE BROKEN: THERMALLY ALTERED STONE, HUMAN BEHAVIOR AND ARCHAEOLOGICAL SITE FORMATION

MICHAEL D. PETRAGLIA

Leverhulme Centre for Human Evolutionary Studies, University of Cambridge

ABSTRACT

Thermally altered stone is commonly found in archaeological contexts, but it remains an under-appreciated artifact class for deciphering many aspects of site formation.

Thermally altered stone can be used to provide information about site-use intensity and the sorting effects of natural processes and modern plowing. Different types of thermally altered stone arrangements may be conceptualized, including single- and multi-state evident features and latent patterns. Thermally altered stone features and patterns from a set of hunter-gatherer sites in the Mid-Atlantic region of the Eastern United States are analyzed relative to the hypothetical conceptualizations. The construction and formation of thermally altered stone features provide a comparative basis for the examination of evolutionary behaviors.

INTRODUCTION

Thermally altered stone is one of the most common artifact classes in Holocene-age hunter-gatherer sites of North America. Thermally altered stone occurs in varying arrangements, densities, and sizes in feature contexts and across depositional surfaces. Heated stone on archaeological sites may be the result of cooking and roasting meat and plants, fire bounding, boiling liquids, and warming stone for steam generation. Archaeologists pay significant attention to thermally altered stone where the material occurs in unusual densities and in spectacular forms, e.g., as large-scale features, such as burned rock mounds (e.g., Barfield and Hodder, 1987; Abbott and Frederick, 1990; Buckley, 1990; Hester, 1991; Hodder and Barfield, 1991). More routine attention to the typical range of thermally altered stone features and distributions occur in site excavation reports, although the artifact class and its spatial arrangement generally remain

unsystematically observed and poorly described in this literature. When reported, thermally altered stone is often described in terms of gross counts and weights, with little attention paid to physical properties and variability in feature formation. Few studies place analytical attention on this artifact class in order to discern site activity and formation processes. The lack of analytical study obscures the variability often preserved within the full range of thermally altered stone occurrences. In reporting thermally altered stone concentrations or fire-related features, archaeologists frequently consider function to be self-evident, typically assuming features to be related to domestic activity (e.g., a cooking hearth), or they shy away from any interpretation because of complicated use-life histories that are often difficult to discern from the patterns. In many site structural analyses, “hearths” in fact are used to assess feature-centered activities (e.g., Binford, 1983; Carr, 1991; Rapson and Todd, 1992) with very little attention to the actual formation history of the “hearth” itself.

Thermally altered stone may also be an important information source in the context of human evolution and fire related activities. The initial use and the eventual control of fire itself has important implications with respect to the origins of cooking, changes in hominid nutrition, and the structure of social interactions (e.g., Wrangham et al., 1999). Fire is also associated with the generation of warmth, the provision of light in the evenings, the protection of individuals from predators, the signaling of nearby groups, and the creation of focal places for the performance of various economic, social, and ceremonial activities. Yet, fired earth, charcoal, and heated stone are rarely found on Lower and Middle Pleistocene sites of Africa, and when they are identified, there is some question as to whether the material results from natural fires or purposeful, and controlled human activity (James, 1989). Although burning evidence, such as the presence of charcoal and ash is more frequently identified in Lower and Middle Paleolithic cave sites in Europe, supporting interpretations for the control of fire (Straus, 1989; Brace, 1995), the deliberate excavation and construction of hearths and the common use of stone for heating are often called into question (Mellars, 1996). The frequent and purposeful construction of hearths, the use of stone for cooking and roasting food, the heating of stones for boiling in containers, and the heating of stone for creating steam for conducting

ceremonies (e.g., in sweat lodges) may be signs of modern human behavior. Given this evolutionary background, it may be profitable to understand the scope of thermally altered stone occurrences on Holocene hunter-gatherer sites, as these provide a comparative basis to examine the nature of fire use in Pleistocene settings.

Archaeological site investigations and ethnographic observations of North American peoples demonstrate that heat-related or hearth-associated artifact assemblages provide valuable information on landscape use, site occupation histories, and economic, social and ceremonial activities (e.g., Guernsey, 1984; Stevenson, 1991; Wandsnider, 1997; Jensen et al., 1999; Smith and McNees, 1999).

Although thermally altered stone is one of the most ubiquitous artifact classes found on archaeological sites, much research remains to be conducted to understand the nature and formation of thermally altered stone distributions. This article focuses on thermally altered stone distributions found on Native American hunter-gatherer sites of the Mid-Atlantic region of Eastern North America. Particular attention is paid to how this artifact class may be used to assess the history of site formation, inclusive of short- and long-term cultural activities and spatial transformations caused by post-depositional processes. To assess the formation of thermally altered stone features and their spatial distributions, hypothetical situations are outlined, summarizing fire-related contexts that researchers might expect to identify in archaeological sites. These expectations are tested against the thermally altered stone distributions recovered at a series of archaeological sites in several geographic settings. The techniques and analyses that archaeologists may use to infer the cultural and natural processes responsible for the formation of fire-altered features and spatial distributions are demonstrated, and wider evolutionary implications are discussed.

As used here, the term, “thermally altered stone” denotes all pieces of stone that are discolored, crazed, cracked, or broken as a result of heating. The term, “fire-cracked rock” is used to specifically denote the cracked and broken component of such assemblages. Based on fracturing characteristics, fire-cracked rock is usually easier to identify in archaeological contexts, whereas in comparison, thermally altered stone may

be more difficult to detect as some material exhibits little in the way of physical modification or discoloration (Rapp et al., 1999).

FORMATIONAL HISTORY

Archaeologists are increasingly attempting to discern how the spatial arrangement of artifacts and features relate to activities and formation processes (e.g., Wandsnider, 1996). A variety of thermally altered stone features and patterns may be created by activities occurring during site occupation, after its abandonment, and in its subsequent reoccupation. Archaeologists may anticipate that this variation will be captured through morphological studies of feature types and analysis of the physical properties of heated and re-heated stone. A hypothetical distinction may be drawn between two thermally altered stone patterns that may be expected in the archaeological record: evident and latent (Leroi-Gourhan, 1972; Petraglia, 1993). As used here, evident features bear clear morphology and are easily recognizable during excavation due to visible structure and material content. Latent patterns occur as distributions that are not particularly obvious during excavation and may only emerge during subsequent analysis. Latent patterns may result from repeated site activities or post-depositional processes that alter original distributions to create relatively non-distinct archaeological signatures (e.g., through the re-use of occupation surfaces and features, trampling, natural sorting).

Evident Features

Evident features are those that retain form after use and site abandonment (Figure 1). Many ethnoarchaeological studies are able to delimit and map evident features, since they often represent single-use episodes that have not been subject to post-abandonment alteration (e.g., Yellen, 1977; Binford, 1978; Bartram et al., 1991). Among identifiable characteristics viewed in archaeological contexts are well-defined feature boundaries, often in combination with artifactual contents and eco-facts that can easily be separated from surrounding sediment matrices and artifact distributions. Thus, certain fire-related features may be relatively easy to identify since they contain an abundance of thermally altered stone, charcoal, and burned earth.

Evident features vary with respect to their functions and use-life histories, and they may be subdivided into two categories: single-state and multi-state. Single-state features are those for which a discrete activity event may be recognized or inferred, such as with the construction of a bounded ring-hearth. In contrast, multi-state features are those that are modified or used for several purposes. Fire-altered stones and other artifacts may, for example, have become incorporated into the feature as a result of behavior unconnected with its original function. As an example, site inhabitants might use an empty storage pit for the discard of refuse containing thermally altered stone. As the feature use-history becomes more complex, the relationship between the original function of the pit and the thermally altered stone becomes more difficult to define. Dumping behavior such as this may be identified based on morphological assessment of the pit, the range and size of the thermally altered stone, and the lack of in situ burning, thereby suggesting the burned rock was a product of secondary deposition. Multi-state evident features are more likely to be created as a consequence of increasing time spent at sites. These features may be remnants of a variety of cultural processes, including re-use behaviors, scavenging, maintenance, and trampling (Figure 2).

Latent Patterns

A range of cultural and natural processes may operate to sort or rearrange the elements of evident features to the point that they are no longer directly visible. Nonetheless, it may be possible to identify remnant patterns that are attributable to the original features. Latent patterns represent former activity constructions that are not readily apparent to the archaeologist in the field, as they do not show clearly detectable boundaries or clear artifact associations. Latent patterns are those that may result from cultural sorting behaviors, such as increased length of site occupation on a surface and re-occupations on the same surface, where re-use of features or processes such as trampling which have a strong effect on original patterns. These types of repetitive processes tend to alter original artifact positions, forming deposits that are overlapping accumulations of site activities (e.g., Gregg et al., 1991; Stevenson, 1991).

Evident features may be seriously modified by natural processes. Prior to burial, thermally altered stone may become disturbed by a variety of environmental agents such as flowing water and gravity. After burial, artifact distributions may be influenced by tree root action or burrowing animals. Modern plowing can also be implicated in altering original cultural patterning and redistributing thermally altered stone across a wider area. In any of these scenarios, thermally altered stone concentrations or features may no longer exhibit the discrete spatial structure of the original cultural context. Thermally altered stone may thus become redistributed horizontally across surfaces or vertically separated in buried contexts.

Archaeologists may identify latent patterns from archaeological sites through various types of analytical studies (Figure 3), including qualitative and quantitative spatial analyses (e.g., Rigaud and Simek, 1991; Petraglia, 1993). For instance, cluster analysis of assemblage distributions may identify intra-site spatial patterning not readily apparent in the field. Refitting is another useful analytical technique, where conjoins of fire-cracked rock may reveal patterns which help to identify spatial clustering and implied activity sets that are not obvious in the raw data.

ARCHAEOLOGICAL SITE CASE STUDIES

The utility of the hypothetical sub-divisions of thermally altered stone features may be compared against archaeological data sets from Eastern North America. Native American sites in this region commonly contain features with thermally altered stone (e.g., Kinsey, 1972; Ritchie and Funk, 1973). Archaeologists working in the region have taken different approaches to understanding the function of these features, through descriptive, morphological, and experimental studies (e.g., Stewart, 1977; Hatch and Stevenson, 1980; Cavallo, 1984; Pagoulatos, 1992; Petraglia et al., 1998a). What is often lacking, however, is an examination of the relationships between morphology, contents, and formation processes, although attempts are being made (Petraglia et al., 2002).

The case examples are from the Mid-Atlantic region of the United States, and include Native American sites located in Pennsylvania and Delaware (Figure 4). The sites are primarily Late Archaic to Middle Woodland in age, dating from about 3,000

B.C. to A.D. 1,000. The sites bear evidence of relatively short-term, semi-sedentary occupation, as opposed to long-term residence characteristics of sedentary village locales. Due to the relatively high level of settlement mobility implied by the sites, as well as the potential for re-occupation on the same surfaces, thermally altered stone features may be expected to be more ephemeral, or not as well-constructed as those at sedentary locales.

The Pennsylvania and Delaware sites were located in a deciduous vegetation zone, and relatively thin stratigraphic profiles have developed as a result of colluvial and aeolian contributions, and erosion on floodplain settings. The Connoquenessing site was located in western Pennsylvania, in the Upper Ohio Valley (Knepper and Petraglia, 1996). The archaeological assemblages at the site were found on a broad alluvial terrace, in an open agricultural field, where a number of sub-plow zone features were identified. The Kettle Creek East site was located in north central Pennsylvania, along the western fringes of the Appalachian Mountains (Petraglia et al., 1998a). The site was situated on a broad alluvial terrace, and archaeological assemblages were identified in plow zone and sub-plow zone contexts. The Lums Pond site was located in northern Delaware, situated in the High Coastal Plain (Petraglia et al., 1998b). The assemblages also were identified in plow zone and sub-plow zone contexts, as well as in more deeply buried contexts on the floodplain of a small stream.

Evident Features

Each of the Pennsylvania and Delaware sites contained evident features. The Connoquenessing and Kettle Creek East sites contained single-state evident types, which were the most common type of thermally altered stone feature encountered. Multi-state evident types were identified at the Connoquenessing site and at Lums Pond.

Single-State Evident Features

At the Connoquenessing site, well-delimited hearths with thermally altered stone were preserved. In one example, there was a hearth that retained its original morphology and contents, along with reddened subsoil, indicative of intense heating (Figure 5). Charcoal was concentrated within the feature, and heated rock was found in abundance.

Multiple refits of the fire-cracked rock further indicated the primary cultural nature of the feature.

In the Kettle Creek East site, there was a wide range of evident types. A large group of features were classed as hearths, so defined from their shallow basin shape and the amount of thermally altered stone associated with them. One hearth feature unique to the site was a wide, shallow basin filled with densely packed and heavily fractured rock (Figure 6). The thermally altered stone was brittle, as if extensively or repeatedly burned, and many pieces were fractured in place. A dark, charcoal-laden soil surrounded the thermally altered stone. The stone lay atop a layer of charcoal and ash, which was dark greyish brown and black in color. Another feature that retained its original shape (Figure 7) contained thermally altered stone that was generally angular and displayed low weights. This suggested repeated heating and rapid cooling of the material, perhaps associated with stone boiling. The feature contained reddened and fire-hardened sediment with a collection of thermally altered stone lying adjacent. A similar configuration has been described in ethnoarchaeological settings for stone boiling features where stones were laid beside the hearth to dry out prior to reheating.

Multi-State Evident Features

The sites preserved thermally altered stone features that may be classed as multi-state. In the Connoquenessing site, several features retained lenses of charcoal and cultural fill (Figure 8). There was no evidence of in situ heating. The thermally altered stone was likely in secondary context since there were only a few pieces of thermally altered stone present and few of the fragments refitted. In other cases, the presence of thermally altered stone may have been incidental. For example, one feature showed evidence of infilling during the normal course of site activity and not as a result of purposeful maintenance activity (Figure 9). The end-result was the same: a pit with scattered pieces of thermally altered rock and no evidence for in situ burning.

In the Lums Pond site in Delaware, a series of large, deep, rounded pits were fully exposed, overlapping radiocarbon dates indicating that they were formed at about the same time. Most of the pits were considered to have been storage features, based on size

and shape parameters and on ethnographic parallels. Archaeological support for this interpretation came from the lack of evidence of fire alterations, and from evidence for secondary infilling. In at least one case, the fill appeared to be derived from intentional and rapid refuse disposal, resulting in distinct charcoal lenses and a number of pieces of thermally altered stone (Figure 10). In other pits, the fill appeared to be the result of slower cultural processes occurring during site occupations. In either case, the pits may be classified as multi-state evident features, containing variable densities of thermally altered stone deposited as secondary refuse.

Latent Patterns

Latent patterns were identified in several areas of the Lums Pond site, particularly for several thermally altered stone distributions buried in alluvial deposits along the low stream terrace. During excavations, small and ephemeral scatters of thermally altered stone were noticed in a buried A-horizon (Figure 11). Once the artifact distributions were analyzed and the horizon was computer mapped, it was noted that the small scatters were part of a broader distribution of thermally altered stone. There were no definite and strict boundaries to this thermally altered stone distribution. A refitting study of the fire-cracked rock was conducted to examine the formation of this distribution. Refits were discovered within a concentration highlighted by cluster analysis, but fire-cracked rock fragments were also shown to refit across several excavation units. Refits of mendable heated and non-heated chipped stone indicated that firing happened after certain archaeological patterns were laid down, indicative of re-use of the surface. The wider spatial distribution of thermally altered stone also strongly implied that an original cultural feature was subsequently scattered as well.

Post-depositional Influences

Fire-cracked rock refits helped to identify post-depositional transformations of original cultural patterns at the Lums Pond site. At Lums Pond, refitting of fire-cracked rock showed the effects of natural processes on feature and artifact distributions. The vertical dislocation of fire-cracked rock was caused by post-burial processes, causing

fragments to be moved upward and downward in the profile (Figure 12). The effects of artifact size sorting were readily observable as the fire-cracked rock fragments, being larger and heavier than chipped stone artifacts, were not separated vertically as much as the chipped stone.

Thermally altered stone distributions played an important role in the search for cultural patterning in plow zone contexts at Lums Pond. Spatial analyses were conducted on the thermally altered stone in the plow zone as a means of locating latent patterns (Figure 13). In an area where subsurface pit features were preserved, there were thermally altered stone clusters apparent in the plow zone. This suggested that while plowing had redistributed the upper layers of artifacts, some of the original spatial patterning was preserved despite the disturbance. Moreover, a spatial association between the thermally altered stone and the subsurface features was implied, indicating that hearths may have been situated adjacent to the pits. Despite study of plow zone and sub-plow zone distributions at Connoquenessing and at Kettle Creek East, no discernable latent patterns could be ascertained apart from partially plowed up evident features, suggesting that no other features were present other than the evident ones.

DISCUSSION

An attempt has been made to demonstrate the value of targeted analysis of an important artifact type: thermally altered stone. Thermally altered stones and their contexts have an important role to play in fostering an understanding of archaeological site formation, including assessment of site occupation intensity and post-depositional transformations.

The Formation of Mid-Atlantic Sites

Analysis of thermally altered stone patterns on the Mid-Atlantic sites provides a better understanding of short-term and repeated activity events. None of the sites reviewed here had features that were all exclusively representative of single-state episodes, as might be found in ethnoarchaeological situations or very short-term occupation sites (Figure 14a). Such sites may only be anticipated where burial rapidly

covers features or in contexts where a group does not re-visit a locale. In examining a wide range of hunter-gatherer sites of the Mid-Atlantic region, a more common evidentiary situation is of the kind reported here (i.e., Figure 14b, c). The archaeological sites summarized herein contained variable numbers of evident features (i.e., both single- and multi-state) and latent patterns, although the degree to which they contained such features and patterns varied considerably. Together with other site structural data and temporal information drawn from radiocarbon dating and diagnostic artifact styles, the thermally altered stone evidence indicated that multiple activity sets and repeated occupations occurred in different intensity at each of the sites. In almost all cases, plowing had disrupted the original cultural patterning, hence it was sometimes difficult to examine the original formation of the site from spatial distributions. Nevertheless, various lines of evidence showed that the Connoquenessing site experienced sporadic and non-intensive use, an interpretation supported by the presence of evident features, the low number of spatially related features, the lack of overlapping features, and the lack of latent patterns. Although there was greater material evidence for occupation of Kettle Creek East, a cluster of features dated to discrete intervals within the Transitional period, and most of these features were single-state in formation. Although this was the case, discrete intra-site patterning slowly accumulated, as shown in a 8 x 12 m area, which had 10 separable features (Figure 15). The 7 dated features indicated repeated occupations over a 2,000 year range, occurring in at least three major episodes, between 1,630-1,470 B.C., 1,250-1,090 B.C., and 500 A.D. The study of thermally altered stone at Lums Pond was particularly instructive for ascertaining the re-use of a surface and demonstrating evidence for multi-state pit features. The combined use of contour plotting and refitting at Lums Pond, in particular, assisted in the understanding the cultural redistributions of artifacts along the low stream terrace. The identification of thermally altered stone in tightly dated pit features indicated the role of secondary behaviors during site occupation, and the study of heated stone in the plow zone led to the realization that former hearths may have been present alongside the pits. In all cases, then, the repeated, but short-term occupation of certain open-air locales resulted in variable situations for identification of evident features and latent patterns.

In considering the Late Archaic-Middle Woodland data, some differences in thermally altered stone would also be anticipated for earlier Holocene sites and later, more sedentary locales. For instance, in Early Archaic societies, where mobility and movement of locales was relatively high, it is anticipated that single-state thermally altered stone features will tend to be more common (although more ephemeral) as many sites were not occupied for long periods (Figure 14a). On the other hand, in long-term sedentary locales, it is expected that lower numbers of single-state features will be present, and there will be a larger quantity of re-used stones within or adjacent to main occupations (Figure 14c). It is anticipated that thermally altered stone features were re-used and scavenged by site inhabitants. The identification of multiple activity sets and repeated occupation surfaces would be further revealed by contour plotting. The overall dimensions of thermally altered stone features, the physical size of the stones, and the spatial distributions of material will be different in each of these situations. Taken together, this information reveals that thermally altered stone, and its spatial distribution, supplies potentially significant details useful for evaluating the intensity of site use.

Evolutionary Implications

The evidence summarized here, from a set of hunter-gatherer sites ranging from 3,000 B.C. to A.D. 1,000, is instructive from a comparative, evolutionary perspective. The most striking aspect of this study is that dense accumulations of thermally altered stone occur on repeatedly occupied, but relatively short-term and seasonal sites. Many arguments for the earliest Pleistocene sites in Africa surround the accurate identification of burning evidence itself and the cause of burning, i.e., whether it resulted from natural fires or deliberate human activities. These arguments will continue to be debated as the majority of sites prior to 200-300,000 years ago only include sporadic evidence for burned earth, charcoal, and clear cultural associations. For these situations, the most appropriate modern analogies will continue to be southern latitude hunter-gatherer sites in Africa and Australia, as hearths usually consist only of charcoal and ash, and formal stone filled hearths are rarer occurrences (e.g., see O'Connell 1987; Bartram et al. 1991). Compared to earlier sites, Middle Paleolithic localities of western Europe show more

deliberate use of fire, with some evidence for construction of stone lined hearths (Mellars, 1996). However, given the quantity of excavated Middle Paleolithic sites and the rare presence of hearths, it does not appear that the same intensity and range of stone-using and heating processes was established in comparison to the North American Holocene period sites. Rather, the infrequent construction of Middle Paleolithic hearths implies that this was an experimental and incipient behavior that was not fully elaborated upon. The presence of structured hearths, the variable use of the features, and the use of living space appears to be a special condition emerging in the Early Upper Paleolithic (e.g., Gamble, 1999). The frequent selection of stone for intended use in fires appears to be a specific activity associated with behavioral modernity. Stone may not have been used in relation to fire until humans recognized that this material was suitable for a variety of tasks, and once this was realized, the material was increasingly adopted for cooking, maintaining heat in fires, steaming, and for secondary uses (e.g., boiling). The construction of stone-lined features should not, however, be considered to be a universal modern behavior in the Paleolithic given considerable ethnographic variation in fire use around the globe. The construction of stone features appears to be a method that is favored in certain foraging societies and environments (e.g., see Binford 1978, 1983). As a consequence, if behavioral modernity emerged in Africa between 300-250,000 thousand years ago (McBrearty and Brooks, 2000), then formal selection of stone may not necessarily be present (although rare examples of stone-lined hearths do occur [Barham, 1996]). When recognized in future excavations, a formational approach to constructed Paleolithic features will be instructive in order to ascertain the degree to which they may represent intensity of site occupation and variable behaviors.

The paucity of evidence for early fire control is thought to relate to preservation conditions (Klein, 1999). Most of the earlier Paleolithic sites are in open-air situations where the survival of charcoal and lenticular concentrations are judged to be poor. Yet, in considering the evidence from modern hunter-gatherer sites in open-air situations presented here, it does not make sense to assume that preservation conditions alone account for the lack of firing information in early sites. If early humans were indeed controlling fire in any fashion, it would be reasonable to expect that scorched earth,

charcoal, and thermally altered stone would be found, as is the case in many Holocene sites. The construction of hearths and the use of stone may not be expected, but secondary and incidental associations would certainly be expected in larger frequency.

CONCLUSION

The results of the presented case studies suggest that there is value in the analytical approach taken here, and that archaeologists should make a concerted effort to examine the various cultural and natural processes that form distributions of thermally altered stone. It should be anticipated that there will be recurrent patterns in thermally altered stone features on certain hunter-gatherer sites, and that distinctions can be made among original, functional patterns and transformed distributions. The entire spectrum of formation processes, from initial feature construction and use to alterations resulting from later cultural and natural processes, can be extensive. From a methodological perspective, this discussion implies that careful excavation and detailed analyses are critical for an evaluation of the formation of thermally altered stone patterns. Detailed field recording -- e.g., feature size, soil burning, charcoal attributes, thermally altered stone attributes, material content -- are critical to evaluation of feature variability. Thorough analysis subsequent to fieldwork is necessary to fully understand site structure, such as the discovery and evaluation of patterns not clear in the field. The refitting of stone and spatial mapping are examples of project that provide a much richer evaluation of site formation. Thus it is necessary to treat thermally altered stone and related features explicitly in some level of analytical detail, rather than simply counting, or worse, discarding the stones after excavation. Analysts will then be in a stronger position to investigate the processes leading to observed spatial configurations and preservation conditions of these features in archaeological context. Moreover, analysis of Holocene archaeological sites and ethnoarchaeological observations in different environments and settings will provide a solid background to examine the origin and development of fire-related features in Pleistocene contexts.

ACKNOWLEDGMENTS

The excavations reported here were funded by the CNG Transmission Corporation and the Delaware Department of Transportation, as part of cultural resource compliance projects. Fellow archaeologists in the Cultural Resource Program at Parsons, particularly John Rutherford, Carter Shields, and Sulah Lee, provided their stalwart services in the field, laboratory, and office. Dennis Knepper deserves a special note of thanks as he was intimately involved in conducting major components of fieldwork and technical report writing. Dennis Knepper, Nicole Boivin, and LuAnn Wandsnider provided many useful comments on a draft of this article; I alone, however, am responsible for any errors or omissions.

REFERENCES

- ABBOTT, J.T., and C.D. FREDERICK
1990 Proton Magnetometer Investigations of Burned Rock Middens in West-Central Texas: Clues to Formation Processes, *Journal of Archaeological Science*, 17, pp. 535-545.
- BARFIELD, L., and M. HODDER
1987 Burnt Mounds as Saunas and the Prehistory of Bathing, *Antiquity*, 61, pp. 370-379.
- BARHAM, L.
1996 Recent Research on the Middle Stone Age at Mumbwa Caves, central Zambia, in *Aspects of African Archaeology*, edited by G. Pwiti and R. Soper, University of Zimbabwe Publications, Harare, pp. 191-200.
- BARTRAM, L.E., E.M. KROLL, and H.T. BUNN
1991 Variability in Camp Structure and Bone Refuse Patterning at Kua San Hunter-Gatherer Camps, in *The Interpretation of Archaeological Spatial Patterning*, edited by E.M. Kroll and T.D. Price, Plenum Press, New York, pp. 77-148.
- BINFORD, L.R.
1978 *Nunamiut Ethnoarchaeology*, Academic Press, New York.
1983 *In Pursuit of the Past*, Thames and Hudson, New York.
- BRACE, C.L.
1995 *The Stages of Human Evolution*, Prentice Hall, Englewood Cliffs.
- BUCKLEY, V. (editor)
1990 *Burnt Offerings: International Contributions to Burnt Mound Archaeology*, Wordwell Ltd., Academic Publishers, Dublin, Ireland.
- CARR, C.
1991 Left in the Dust: Contextual Information in Model-Focused Archaeology, in *The Interpretation of Archaeological Spatial Patterning*, edited by E.M. Kroll and T.D. Price, Plenum Press, New York, pp. 221-256.
- CAVALLO, J.A.
1984 Fish, Fires, and Foresight: Middle Woodland Economic Adaptations in the Abbott Farm National Landmark, Trenton, New Jersey, *North American Archaeologist*, 5, pp. 111-138.
- GAMBLE, C.
1999 *The Palaeolithic Societies of Europe*, Cambridge University Press, Cambridge.

GREGG, S.A., K.W. KINTIGH, and R. WHALLON

- 1991 Linking Ethnoarchaeological Interpretation and Archaeological Data, the Sensitivity of Spatial Analytical Methods to Postdepositional Disturbance, in *The Interpretation of Archaeological Spatial Patterning*, edited by E.M. Kroll and T.D. Price, Plenum Press, New York, pp. 149-196.

GUERNSEY, K.

- 1984 Ethnographic Review of Various Functions of Firepits, Appendix F, in *Final Report of Investigations along the Cities Service 12, 8, and 6 Inch Pipeline, Sweetwater County, Wyoming*, edited by W.R. Latady, Jr., Office of the State Archeologist, Laramie, Wyoming.

HATCH, J.W., and C. STEVENSON

- 1980 Functional Analysis of the Fisher Farm Features, in *The Fisher Farm Site: A Late Woodland Hamlet in Context*, edited by J.W. Hatch, The Pennsylvania State University, Department of Anthropology, Occasional Papers, No. 12, pp. 140-170.

HESTER, T.R. (editor)

- 1991 *The Burned Rock Middens of Texas: An Archeological Symposium*, Studies in Archeology 13, Texas Archeological Research Laboratory, The University of Texas, Austin.

HODDER, M.A., and L.H. BARFIELD (editors)

- 1991 *Burnt Mounds and Hot Stone Technology*, Sandwell Metropolitan Borough Council, West Midlands, Ireland.

JAMES, S.R.

- 1989 Hominid Use of Fire in the Lower and Middle Pleistocene, *Current Anthropology*, 30, pp. 1-26.

JENSEN, K., J. JENSEN, and C. CLEGG

- 1999 Inferring Intensity of Site Use From the Breakdown Rate and Discard Patterns of Fire-Cracked Rock at Playa View Dune. *Utah Archaeology*, 12, pp. 51-64.

KINSEY, W. F. III

- 1972 *Archaeology of the Upper Delaware Valley*, Anthropological Series of the Pennsylvania Historical and Museum Commission, No. 2, Harrisburg.

KLEIN, R.G.

- 1999 *The Human Career: Human Biological and Cultural Origins*, University of Chicago Press, Chicago.

KNEPPER, D.A., and M.D. PETRAGLIA

1996 Prehistoric Occupations at the Connoquenessing Site (36BV292), an Upland Setting in the Upper Ohio River Valley, *Archaeology of Eastern North America* 24, pp. 29-57.

LEROI-GOURHAN, A.

1972 Vocabulaire, in *Fouilles de Pincevent*, edited by A. Leroi-Gourhan and M. Brézillon, Paris, CNRS, pp. 321-327.

MCBREARTY, S., and A.S. BROOKS

2000 The Revolution that Wasn't: A New Interpretation of the Origin of Modern Human Behavior, *Journal of Human Evolution*, 39, pp.453-563.

MELLARS, P.

1996 *The Neanderthal Legacy: An Archaeological Perspective from Western Europe*, Princeton University Press, Princeton.

O'CONNELL, J.F.

1987 Alyawara Site Structure and its Archaeological Implications, *American Antiquity*, 52, pp. 74-108.

PAGOULATOS, P.

1992 The Re-Use of Thermally Altered Stone, *North American Archaeologist*, 13, pp. 115-129.

PETRAGLIA, M.D.

1993 The Genesis and Alteration of Archaeological Patterns at the Abri Dufaure: an Upper Paleolithic Rockshelter and Slope Site in Southwestern France, in *Formation Processes in Archaeological Context*, edited by P. Goldberg, D.T. Nash, and M.D. Petraglia, Prehistory Press, Madison, pp. 97-112.

PETRAGLIA, M., D. KNEPPER, and J. RISSETTO

1998a The Nature of Prehistoric Activities on Kettle Creek, *Journal of Middle Atlantic Archaeology*, 14, pp. 13-38.

PETRAGLIA, M., D. KNEPPER, J. RUTHERFORD, P. LAPORTA, K. PUSEMAN, J. SCHULDENREIN, and N. TUROSS

1998b *The Prehistory of Lums Pond: The Formation of an Archaeological Site in Delaware*, Delaware Department of Transportation Archaeology Series No. 155.

PETRAGLIA, M., S. BUPP, S. FITZELL, and K. CUNNINGHAM (eds)

2002 *Hickory Bluff: Changing Perceptions of Delmarva Archaeology*, Delaware Department of Transportation Archaeology Series, in prep.

- RAPP, G.R., JR., S. BALESU, and M. LAMOTHE
 1999 The Identification of Granitic Fire-Cracked Rocks using Luminescence of Alkali Feldspars, *American Antiquity*, 64, pp. 71-78.
- RAPSON, D.J., and L.C. TODD
 1992 Conjoins, Contemporaneity, and Site Structure: Distributional Analyses of the Bugas-Holding Site, in *Piecing Together the Past: Applications of Refitting Studies in Archaeology*, edited by J.L. Hofman and J.G. Enloe, BAR International Series, No. 578, pp. 238-263.
- RIGAUD, J.P., and J.F. SIMEK
 1991 Interpreting Spatial Patterns at the Grotte XV, a Multiple-Method Approach, in *The Interpretation of Archaeological Spatial Patterning*, edited by E.M. Kroll and T.D. Price, Plenum Press, New York, pp. 199-220.
- RITCHIE, W.A. and R.E. FUNK
 1973 *Aboriginal Settlement Patterns in the Northeast*, New York State Museum and Science Service, Memoir 20.
- SMITH, C.S., and L.M. McNEES
 1999 Facilities and Hunter-Gatherer Long-Term Land Use Patterns: An Example from Southwest Wyoming. *American Antiquity*, 64, pp. 117-136.
- STEVENSON, M.G.
 1991 Beyond the Formation of Hearth-Associated Artifact Assemblages, in *The Interpretation of Archaeological Spatial Patterning*, edited by E.M. Kroll and T.D. Price, Plenum Press, New York, pp. 269-299.
- STEWART, M.C.
 1977 Pits in the Northeast: a Typological Analysis, in *Current Perspectives in Northeastern Archaeology*, edited by R.E. Funk and C.F. Hayes III, Researches and Transactions of the New York State Archaeological Association, Vol. 17, No. 1, pp. 149-164.
- STRAUS, L.G.
 1989 On Early Hominid Use of Fire, *Current Anthropology*, 30, pp. 488-491.
- WANDSNIDER, L.
 1996 Describing and Comparing Archaeological Spatial Structures, *Journal of Archaeological Method and Theory*, 3, pp. 319-384.
- 1997 The Roasted and the Boiled: Food Composition and Heat Treatment with Special Emphasis on Pit-Hearth Cooking, *Journal of Anthropological Archaeology*, 16, pp. 1-48.

WRANGHAM, R.W., J.H. JONES, G. LADEN, D. PILBEAM, and N.L. CONKLIN-BRITTAIN

1999 The Raw and the Stolen: Cooking and the Ecology of Human Origins, *Current Anthropology*, 40, pp. 567-594.

YELLEN, J.E.

1977 *Archaeological Approaches to the Present: Models for Reconstructing the Past*, Academic Press, New York.

LIST OF FIGURES

Figure 1. Hypothetical types of evident features. In the single-state scenario, thermally altered stone and its arrangement results from discrete activity. In the multi-state scenario, thermally altered stone in features may be modified as a consequence of a range of activities. In both cases, archaeologists may readily identify these feature types because they are visibly distinct due to their form and material content.

Figure 2. The transformation of single-state to multi-state evident features. In this example, the result of various activities may lead to the addition and/or subtraction of thermally altered stone from an original locus. This may result in rearrangement, size sorting and the mixing of material from different activities.

Figure 3. Hypothetical types of latent patterns identified through computer mapping techniques and artifact refitting. In both cases, latent features are defined through analytical studies performed after the completion of fieldwork.

Figure 4. Location of archaeological sites used in this study.

Figure 5. Single-state evident feature, Connoquenessing site. This feature showed a well-delimited hearth with refittable fire-cracked rock.

Figure 6. Single-state evident feature, Kettle Creek East site. This feature showed densely packed thermally altered stone in a basin. The thermally altered stone was brittle as if heavily or repeatedly burned, and many pieces were fractured in place.

Figure 7. Single-state evident feature, Kettle Creek East site. This feature contained angular thermally altered stone which displayed low weights, suggesting the repeated heating and rapid cooling, perhaps associated with stone boiling.

Figure 8. Multi-state evident feature, Connoquenessing site. This feature retained lenses of charcoal and cultural fill without evidence of in situ heating. In this case the thermally altered stone appears to have been dumped in the feature.

Figure 9. Multi-state evident feature, Connoquenessing site. This feature showed infilling during the normal course of site activity and not as a result of purposeful maintenance activity, resulting in occasional pieces of thermally altered stone and no evidence for in situ burning.

Figure 10. Multi-state evident feature, Lums Pond. This feature showed fill as the result of intentional and rapid dumping behavior, resulting in distinct charcoal lenses and a number of fire-altered pieces.

Figure 11. Latent pattern, Lums Pond. Scatters of thermally altered stone noted across a horizon as a result of computer mapping. These patterns displayed no strict boundaries but there was some degree of clustering across units. The fire-cracked rock refits were joined across several excavation units. Some concentration of refits within several units was identifiable.

Figure 12. Vertical transformations, Lums Pond. A clear case for size sorting is established by comparing core/flake refits and fire-cracked rock refits. Smaller core/flake artifacts are moved to a much greater extent than larger fire-cracked rocks. In both cases, the vertical disturbances appeared to be caused by natural processes that occurred after burial, moving artifacts upward and downward in the profile.

Figure 13. Horizontal plow zone transformations, Lums Pond. Spatial plotting showed thermally altered stone clusters in the plow zone (above), possibly showing an association with the pit features (below).

Figure 14. Variability of thermally altered stone features anticipated as a consequence of site use intensity. In this hypothetical scenario, highly discrete features and activity areas over space (A) are only expected in ethnoarchaeological and archaeological situations that occur in the short term. In contrast, archaeological features and activity areas are more often accumulations on surfaces (B, C) varying as a result of intensity of site use, repeated visitation, and long term occupation. Slow burial of features and activity areas may also result in complex spatial arrangements.

Figure 15. Features in the Kettle Creek site showing spatially distinct patterning. The feature origins occurred within a particular time period, but they were the product of repeated events that gradually accumulated through time.

Direct reprint requests to:

Michael Petraglia
Leverhulme Centre for Human Evolutionary Studies
Department of Biological Anthropology
Downing Street
University of Cambridge
Cambridge CB2 3DZ England

MICHAEL PETRAGLIA received his Ph.D. from the University of New Mexico. He is currently a Lecturer in Human Evolution at the University of Cambridge. His research interests include hunter-gatherer peoples of North America, Old World Paleolithic archaeology, site formation, and bio-cultural evolution.