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Fire modified rock illuminated: Rediscovering the applications of hearth assemblages in site analyses

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Limited fire modified rock research has prevented archaeologists from analyzing sites to their full capacity. The level of burning, discoloration and fragmentation of fire modified rock can reflect the artifact's life stage while assemblage context may indicate function. The four main cooking functions of fire modified rock are distinguished as boiling, steaming, roasting, and baking (Thoms, 2008), which all have similar effects on heated stones as they are utilized during the cooking processes. Schiffer's (1972) artifact life cycle model is reviewed according to its application to cooking stone, after which a use-wear model for fire modified rock is presented. The physical attributes of fire modified rock are proposed to separate the tool into three use-wear levels under Schiffer's use stage of the consumption life cycle. Then, further explorations in this field of research are proposed, as any advancement in fire modified rock research could enhance our understanding of how past humans utilized the landscape.

Introduction

Fire modified rock (FMR) has been insufficiently represented in archaeological site analysis, and as a result no models have been developed for organizing FMR data. In this paper, I propose an ordinal use-wear model based on experimental data from Pagoulatos (2005), which may be used to implicate occupation duration. The proposed model allows archaeological practitioners to assess the extent of burning that each rock experienced in its use life based on the physical attributes the FMR sustained during the burn process. The level of burning, paired with other supporting data, may infer a site's occupation type.

Prior to proposing the model, I first evaluate previous theoretical, methodological, and experimental publications on FMR in order to introduce what is already known about the artifact. This background allows for the direct application of Schiffer's (1972) artifact life cycle model to FMR's life stages based on Thoms' (2008) overview of prehistoric cooking methods. Next, focusing on the consumption and recycling stages of the artifact life cycle, I develop and propose the three-stage use-wear model. This model is not an immediate fix to the lack of attention on FMR in the field of archaeology; rather, it is aimed at initiating a dialogue regarding its effective function in site analysis, with the hopes of persuading more practitioners to incorporate this artifact as a line of supporting evidence during site analysis and interpretation.

Background

In this text the term "fire modified rock" is used as opposed to the traditional term "fire cracked rock." The traditional terminology stems from the idea that the most identifiable markers of thermally altered rock are cracking and/or breakage. The problem with the traditional terminology is that, although cracking is typical for FMR, it is not inevitable. There are several other measurements by which we may identify

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burned rock, such as color change and spalling, hence the emphasis of the term modified as opposed to cracked.

Fire modified rocks are artifacts that were thermally altered by humans for several purposes. These purposes are generally related to cooking, but can also include other practical or spiritual uses. In historic and prehistoric periods, rocks were often used as the heating mechanisms for cooking, similar to coals for a barbeque or electric heat coils for a stove. The benefit of heating rocks is that "the relative non-combustibility and high density of rocks (i.e., heavy per unit volume) enable them to capture and hold heat for long periods of time" (Thoms, 2008, p. 444-445). In turn, rocks with more exposure to fire display more chemical and molecular damage. Similar to cutting, sawing, or piercing use-wear on stone tools, burning causes visually observable use-wear on FMR. The level of burning represents the level of consumption the artifact experienced during its systemic context.

In his article *Archaeological Context and Systemic Context*, Schiffer (1972) proposes two models; the first for durable elements, and the second for consumable elements. Durable elements were defined as "transformers and preservers of energy," while consumable elements were defined as "elements whose consumption results in the liberation of energy" (Schiffer, 1972, p. 157). Based on these definitions, FMR is a consumable element due to its absorption of heat from fire and subsequent release of heat. Due to its thermal degradation, FMR has a finite capacity for absorbing and releasing heat. The life cycle stages of Schiffer's model are: procurement, preparation, consumption, perhaps recycling, discard, and refuse. In his article, Schiffer only defines one of these terms. For the sake of this paper I will define the remaining terms in chronological order from the beginning to the end of the artifact life cycle.

Procurement refers to the process by which a raw material is acquired. Preparation is the process of modifying the raw material. Consumption is the process used to exploit that modified raw material. If, after consumption, the modified raw material is still functional, it can be recycled/reused. Discard is the moment when the artifact's owner either abandons it or is buried along with it. Refuse was defined as the "state of an element in the archaeological context" (Schiffer, 1972, p. 159).

In order to apply Schiffer's model to FMR, we need to better understand the artifact's functional purposes. These artifact life stages are better demonstrated in the diagram below, reproduced with permission, from Schiffer's 1972 article.

While fire modified rock can be used for ceremonial practices such as steam production in sweat lodges, this paper focuses on utilitarian food processing functions. In *The Fire Stones Carry*, Thoms (2008) describes the more typical uses of FMR by tribes of western North America through the evaluation of the ethnographic record.

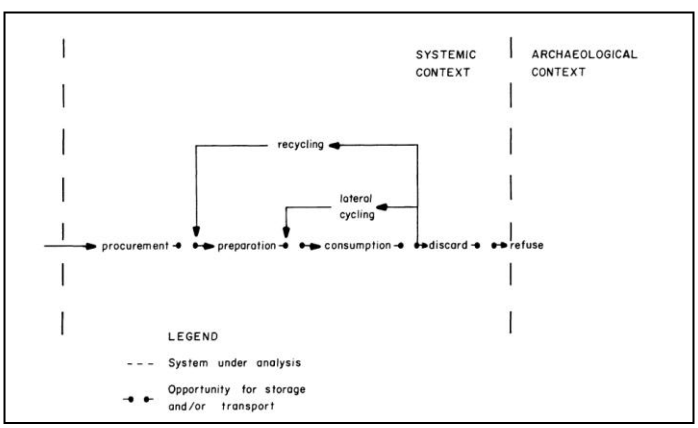

Figure 1. Life cycle flow model of consumable elements (Schiffer, 1972, p. 159).

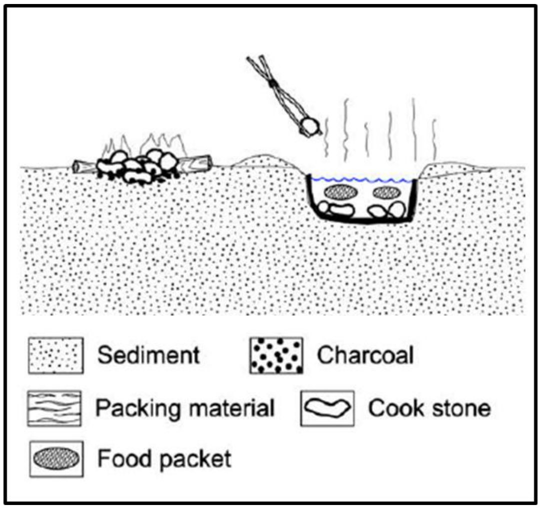

Figure 2. Stone Boiling Feature (Thoms, 2008, p. 446).

Table 1. Boiling Stone Life Cycle

Life Cycle Stage	**Boiling Stone FMR**
Procurement	Collect boiling stones
Preparation	Heat stones on a surface fire
Consumption	Place in water for boiling
Recycle	Depends on level of chemical and molecular damage from boiling
Discard and Refuse	At base of deep pit in context or in midden out of context

The four main functions he describes are: boiling, steaming, roasting, and baking. Although Thoms wrote detailed descriptions of cooking feature setups, he frames the article around the entire cooking mechanism, of which FMR is only one component. The following descriptions will highlight FMR's role within each cooking function. The details recorded for archaeological boiling, steaming, roasting, and baking processes are based on Smith's (1984, 2000) 1936-1937 ethnographic fieldwork on the Kalispel Reservation in northeast Washington. For each cooking function, the life cycle of FMR is broken down.

Boiling

Stones are heated on a surface fire and moved with wooden tongs to water-filled vessels or pits. The vessels can range from bark baskets and hide for small family or single-person use to small canoes for group use (Thoms, 2008, p. 450). The heated stones then boil the water at which point food can be processed (Figure 2).

Steaming

Steaming food using FMR generally took place in a closed pit. The rocks can be thermally altered on a surface fire and transported, probably with wooden tongs, to a shallow pit. The heat-treated rocks were covered by a layer of large leaves, then food, then leaves again. As displayed in Figure 3, the pit was topped with soil (for steam insulation) and water was poured into the pit (Thoms, 2008, p. 450).

Roasting

As demonstrated in Figure 4, roasting is conducted on a surface oven, a term used by Smith (2000), which consists of "an open-air, fired-in-situ cooking facility that was not sealed with an earthen lid but, rather, was covered by layers of green boughs" (Thoms, 2008, p. 449). Roasting can be conducted indoors or outdoors depending on seasonality and weather and is typically employed for roasting meat (Thoms, 2008, p. 450).

Baking

Earth ovens were created for the purpose of a prolonged baking (Figure 5). They can be manufactured a variety of ways for different purposes, but one consistent attribute of earth ovens when comparing methods between regional groups is closed pit cooking. Rocks can either be heated on a surface fire or at the base of the earth oven itself (Thoms, 2008, p. 448).

These summaries of four FMR functions do not include further details of the processing pits and ovens because specific attributes are highly variable between and among groups of people.

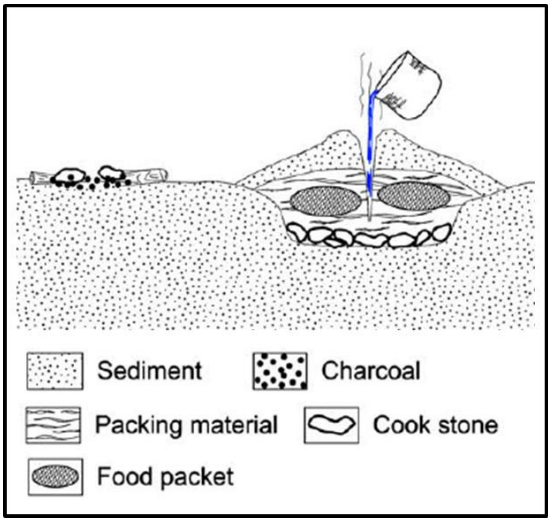

Figure 3. Stone steaming feature (Thoms, 2008, p. 446).

Table 2. Steam stone life cycle

Life Cycle Stage	**Steaming Stone FMR**
Procurement	Collect steaming stones
Preparation	Heat stones on a surface fire
Consumption	Place heated stones at base of pit and pour water into pit contents
Recycle	Depends on level of chemical damage from steaming
Discard and Refuse	At base of deep pit in context or in midden out of context

These explanations are used to demonstrate the patterns identified in western North America and are generalities. Variation can be due to regional, tribal, familial, hierarchical, and environmental differences, all of which could drastically alter an individual's decision regarding desired size of cooking feature or method of processing food. Due to the degree of equifinality of functional approaches resulting in similar archaeological deposits, archaeologists must be careful when making definitive statements about cooking features.

Although there is variability in stylistic rock experiments. He conducted experiments on pit feature experiments on limestone. This was one of very few publications on fire modified space and time: the rocks used for cooking were heated using fire. This point narrows our focus from FMR's entire life cycle, specifically to the consumption and recycling stages.

Fire Modified Rock Experiment

As previously noted, fire modified rock is chemically altered when burned. Regardless of

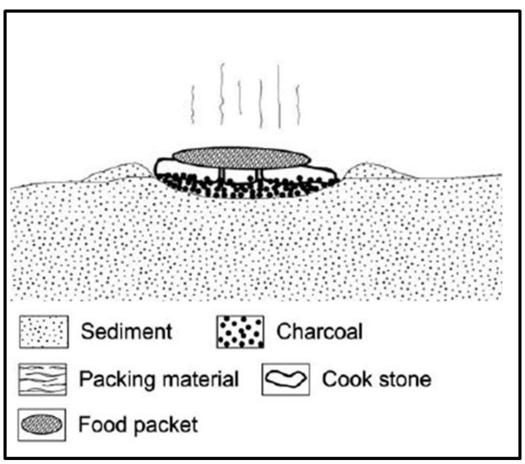

Figure 4. Stone roasting feature (Thoms, 2008, p. 446).

Table 3. Roasting stone life cycle

Life Cycle Stage	**Roasting Stone FMR**
Procurement	Collect roasting stones
Preparation	Heat stones in-situ on surface fire
Consumption	Heat food contents
Recycle	Depends on level of chemical damage from roasting
Discard and Refuse	On surface associated with evidence of in-situ burning or in midden out of context

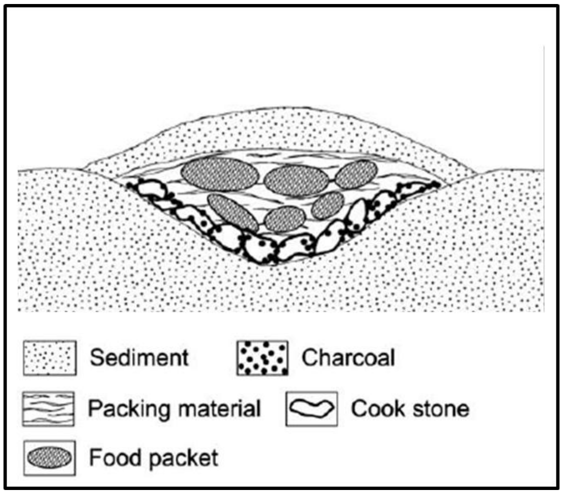

Figure 5. Stone baking feature (Thoms, 2008, p. 446).

Table 4. Baking stone life cycle

Life Cycle Stage	**Baking Stone FMR**
Procurement	Collect baking stones
Preparation	Heat stones in-situ or on surface fire
Consumption	Bake food contents for prolonged period
Recycle	Depends on level of chemical damage from baking
Discard and Refuse	At base of deep pit in context or in midden out of context

the activity (boiling, steaming, roasting, baking) the rock slowly degrades with every use. In 2005, Pagoulatos published data he collected from FMR pit feature experiments on limestone. This was one of very few publications on fire modified rock experiments. He conducted experiments on 12 burn pits (with 32-40 limestone cobbles per pit). These 12 burn pits were separated into four burn duration categories: 6-hour, 12-hour, 24-hour, and 48-hour. All of the pits were then burned three separate times at their designated burn intervals.

Pagoulatos took four pre- and post-burn measurements: total weight (g), the average weight of cobbles in each assemblage (kg), the average length of each assemblage's cobbles (cm), and the size range of the cobbles in the assemblage (cm). Once the experiments were complete, the author then conducted 19 post-burn measurements in order to identify thermal effects on limestone. These measurements include: the number of cobbles with observed color change, the average percent of surface color change on cobbles; the number of reddened, blackened and whitened cobbles; the percent of reddened whitened and blackened cobbles; the number of cracked cobbles; the total number of cracks on cobbles; the mean number of cracks per cobble (cm); the total linear crack length (cm); the mean length of a crack (cm); the number of cobbles spalled; the total number of spalls; the mean weight per spall (g); the spall size range (cm), and weight loss (Pagoulatos, 2005, pp. 296-297).

Based on the data published in Pagoulatos' paper, the majority of these measurements showed random effects, providing no correlation between thermal damage and burn time, although there were five variables which appeared to have trends.

Table 5 displays the five variables Pagoulatos measured which showed trends in damage based on the duration of thermal exposure. The five thermal effects which seem to demonstrate damage are: the mean percent surface color change, the percent of reddened cobbles, the percent of whitened cobbles, the mean weight per spall, and the mean size of each cobble. The data can be seen below, and each effect is discussed in the following paragraphs.

Mean Percent of Surface Color Change

The mean percentage of surface color change appears consistent around the 64% average throughout the 6-hour, 12-hour, and 24-hour burn time groups. Then, the average for the 48-hour burn time group increases to an 85%. This indicates that when FMR is burned for more than 24 hours at least three times, discoloration increases to cover most of the rock.

Percent of Reddened Cobbles

The percent of reddened cobbles is

Table 5. Derived from Pagoulatos (2005) data table (E# = experiment number, (- #) = categorical burn time)

Variable	E1-6	E2-6	E3-6	E4-12	E5-12	E6-12	E7-24	E8-24	E9-24	E10-48	E11-48	E12-48
Mean % surface color change	62	64	67	57	76	63	51	63	86	76	91	89
% of reddened cobbles	47	44	40	40	42	45	27	13	37	40	35	16
% of whitened cobbles	13	19	26	14	17	17	9	31	42	34	55	72
Mean weight per spall (g)	236	222	176	185	104	87	24	30	39	34	39	36
Mean size of each cobble (cm)	5.67	4.84	4.56	5.40	4.60	4.40	2.05	2.26	2.92	2.57	2.84	2.82

consistent around the 43% average in the 6-hour and 12-hour categories, which then decreases to a 31% average in the 24-hour and 48-hour categories. These numbers indicate that limestone can turn a reddish color when burned, but with a longer exposure to fire the reddening can decrease.

Percent of Whitened Cobbles

The percent of whitened cobbles remains at 19% when the 6-hour, 12-hour, and 24-hour categories are averaged together, then increases to a 54% average in the 48 hour burn time category. This pattern indicates that the majority of a limestone FMR tends to whiten with extensive burning.

Mean Weight per Spall in grams

The weight of spalls tended to decrease from the 6-hour category at a 211 kg average to the 12-hour category at a 125 kg average then levels out during the 24-and 48-hour categories, whose averages together were 33 kg. These patterns indicate that in the early stages of burning, limestone FMR spalls tend to be much larger than more extensively burned cobbles whose spalls are smaller.

Mean Size of Cobbles Post Burning

A decrease in the mean size of the cobbles appears to occur between the 12-hour and 24-hour burning periods. The averages are from 5.02 cm and 4.80 cm at the 6- and 12-hour categories which then reduce to 2.41 cm and 2.74 cm in the 24 and 48-hour categories.

Discussion

From his measurements, Pagoulatos found FMR use-wear patterns, but his article lacked an interpretive discussion of these findings. Using the data he collected, this section will discuss his results. Most of the measurements conducted yielded random results, but color change, spall weight, and average cobble size had clear patterns based on duration of thermal exposure. From these results we can conclude that with longer exposure to burning, rocks can become increasingly discolored and smaller.

Limestone will redden at first, but decrease in reddening when burning approaches the 48-hour category, and whitening increases when burning exceeds the 24-hour category. The rocks produce larger spalls in the 6- to 12-hour range then produce much smaller spalls in the 24- to 48-hour range. This could occur for several reasons. One possibility is the temperature decrease when burning for a long duration. Thoms has observed that, "initial temperatures soared to 800ºC, dropped to 400ºC within 2 h and to 200ºC after 10 h. Thereafter, temperatures tapered gradually, reaching 100ºC after 24 h and falling to about 60ºC after 48 h" (2008, p. 453). While these numbers are derived from Thoms' (1995) field school experiments in the Northern Rockies and may not have been reflected in Pagoulatos' (2005) experiments, they provide an understanding of the general cooling process that a fire feature goes through. This cooling process could affect the number and size of spalls that occurs over the cooking duration.

These burn duration and visual effect

relationships in an archaeological context are an implication of consumptive damage and can be directly transferred into an FMR use-wear model. A theoretical model based on experimental results could assist archaeologists in determining the extent to which the artifact had been used in systemic context.

FMR Use-Wear Model

As previously mentioned, fire modified rock models have not been developed for measuring the artifact's extent of use. Lithic reduction experiments and models in the 1970s and 1980s were iconic contributions to lithic analyses (Henry, Haynes, & Bradley, 1976; Magne & Pokotylo, 1981; Muto, 1971), because they proposed measureable methods to evaluate the level of consumption of any given lithic artifact from debitage to bifaces. These models were the foundation to the refinement of lithic analyses. This foundational stage has taken place for many artifact types, allowing archaeologists to conduct analysis consistently and efficiently for lithics, faunal remains, and botanicals, but not yet for fire modified rock. My review here shows that proper analysis for FMR is lacking in the literature; therefore, my motivation in this paper is to propose the necessary foundations for categorizing FMR based on use-wear.

Pagoulatos' (2005) experimental design allows us to directly plug his data trends into an ordinal model. This model will be generalized so it can be applied to most FMR raw material seen in the archaeological record. Since Pagoulatos only used one material type (limestone), this proposed model will use the results from his data as a rough guide, and not to strictly define each stage.

Similar to the lithic reduction stages developed by Muto (1971), I propose the formation of a similar model of FMR stages. The difference between these two concepts is that the lithic reduction falls within Schiffer's preparation stage, so the reduction occurs due to human alteration developing the tool for consumption, whereas FMR reduces during the consumption stage. The similarity is that raw materials are being reduced due to ancient human interaction with the natural world and reduction is measured through an ordinal scale. FMR use can be divided into three use-wear stages: light, moderate, and extensive.

Stage 1: Light Thermal Alteration

Light thermal alteration refers to FMR that has not been utilized to the end of its use life. Light use-wear can be identified by slight to moderate discoloration to the rock (<50% reddening, whitening, and blackening combination over total surface) and a potential for large spalls fragmented from the rock body (depending on the duration of burning). The rock may have cracks, which at this stage would likely be more shallow and shorter in length (>2 cm). Based on this definition, the rock could have been used up to several 6 to 12-hour burn periods.

Light wear may indicate that the artifact was only used once during a longer burn period or on a few occasions in a short-lasting fire. Depending on the rock's function, less invasive burning procedures would leave less use-wear over several use periods while more invasive burning procedures would leave more use-wear over fewer use periods. Unless the FMR assemblage is found as an evident feature, functional inferences should not be drawn. Archaeologically, if recovered as refuse where it was discarded, lightly altered FMR would likely be found in a hearth as it was not yet designated as trash because it had recycling potential.

Stage 2: Moderate Thermal Alteration

Moderate thermal alteration refers to FMR that has likely been utilized on more than one occasion with some remaining use life. Moderate use-wear can be identified by extensive discoloration to the rock (50%-100% reddening, whitening, and blackening combination over total surface) and potential for any size spalls fragmenting from rock body (depending on the duration of burning). The rock likely has cracks, which at this stage could be shallow to deep and could lead to breakage. Moderate wear may indicate that the artifact was used on several occasions (recycled) in a range of fire durations (6-hours to 24-hours).

Again, unless there is as an evident pattern in the record, the function of the rock should not be implied. Although, if the FMR feature is found as a latent pattern containing a large fire modified rock assemblage, one may infer function and life cycle stage of the feature as a whole prior to its collective deposition; data with provenience and context is always more credible than that which is found in a singular state outside of its assemblage. In the archaeological record, moderate use-wear FMR would be more commonly found in the context of a hearth feature or in a designated 'storage' space for hearth materials as it has recycling potential.

Stage 3: Extensive Thermal Alteration

Extensive thermal alteration is FMR which has reached the end of its use life and was very likely utilized on more than one occasion. Extensive use-wear can also be identified by extensive discoloration to the rock (50%-100% reddening, whitening, and blackening combination over total surface, with more whitening than average depending on material type) and potential for small spalls fragmenting from the rock body. The rock likely would contain large cracks, which at this stage could cause quite a bit of breakage. Extensive wear indicates recycling, either used in many short- or a few long-duration fires. In context, this use-wear stage is more likely found in a midden or dump context, as the artifacts have reached the end of their use life.

Through this proposed model, archaeologists now have a new classification system by which to categorize individual FMR in an assemblage using a low-power visual approach. For example, the presence of Stage Three FMR can imply long-term (sedentism) or multi-event (seasonal revisiting) use at the site since its damage is generally due to several long duration fires. Contrariwise, only identifying Stage One FMR throughout a site could contribute evidence to temporary use.

Conclusion

This paper demonstrated the level of research that has been conducted on FMR, and subsequently revealed room for expansion in fire modified rock analysis. Through examining how fire modified rock was used in the past, we were able to better understand its life stages in the systemic context, particularly the consumption and recycling stages. By developing a three-stage use-wear model, archaeologists now have a tool with which they can categorize the extent to which FMR was used in the consumption and recycling stages prior to its deposition. Based on the level of burning the FMR at a site experienced, an implication of occupation duration can be drawn, paired with other lines of evidence. Although there is little general interest in FMR, it nonetheless has the potential to contribute to our understanding of the past. The model I propose should encourage more archaeologists to consider including FMR interpretation in site analysis for a more holistic perspective of the past.

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