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Experiments in Late Archaic methods of heat-treating Ogallala Formation quartzarenite clasts along the Southern High Plains eastern escarpment of Texas

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ABSTRACT

World-wide, flintknappers typically reduced clasts into smaller packages (e.g., bifaces, flake blanks, preforms) prior to heat-treatment. Research along the eastern escarpment of the Southern High Plains of Texas (USA) uncovered evidence of a Late Archaic (4500–2000 radiocarbon years B.P.) industry that heat-treated whole Ogallala Formation quartzarenite clasts rather than smaller lithic packages. A series of controlled and outdoor replicative experiments were conducted to ascertain the temperature range and time necessary to heat-treat quartzarenite clasts effectively, and the possible techniques used to heat-treat whole clasts without thermal shock. Roughness (Ra) and color change (R/L) were measured to quantify the results of heat-treatment.
Results indicate that a minimum temperature range of 246–273 °C (475–525 °F) is necessary to heat-treat quartzarenite clasts. Successful heat-treatment requires placing the clasts directly on coals to achieve the necessary temperatures for heat-treatment. Avoidance of thermal shock requires that the temperature of the clasts be raised gradually. This procedure involves incrementally moving the clasts closer to the coals before directly placing the clasts on the coals. Heat-treatment results in a significant decrease in roughness (Ra) and moderate increase in cortical and interior redness. This study demonstrates that preparing smaller lithic packages for heat-treatment is not always necessary, and provides new insights into the process of heat-treatment.

1. Introduction

Experimental archaeology has been important to understanding the role of heat-treatment in lithic technology beginning with the seminal work of Crabtree and Butler (1964) and Bordes (1969) in the 1960s (Jeske et al., 2010:112). The goal of these studies has been to elucidate the techniques of how past people successfully thermally altered a wide range of lithic materials to understand better the flaked stone found in the archaeological record (Domanski and Webb, 2007).

Past work has documented that hunter-gatherers from around the world reduced clasts into smaller-sized cores, bifaces, or flake blanks prior to heat-treatment (Domanski and Webb, 2007; Wyckoff, 1994). Experimental studies have documented that reducing the size of lithic materials before heat-treatment decreased the chances of thermal shock as a result of too rapid increases or decreases in temperatures (Crabtree and Butler, 1964:2; Mercieca and Hiscock, 2008). Heat alteration experimental studies, as a result, have focused on the effects of heat-treating smaller prepared packages of lithic material rather than unaltered large pieces.

Research along the Southern High Plains eastern escarpment near Post, Texas (Fig. 1) has revealed a Late Archaic lithic industry that incorporated the use of controlled heat-treatment to enhance the flakeability of Ogallala Formation quartzarenite clasts. Known as Potter member quartzite in past literature (Hurst et al., 2010), this material is common in local gravels within the region and typically are the largest sized clasts within the gravel (Banks, 1990; Holliday and Welty, 1981; Hurst et al., 2010; Rebnegger, 2006).

In contrast to other documented studies of heat-treatment (Domanski and Webb, 2007; Mercieca and Hiscock, 2008), Late Archaic groups in this region regularly heat-treated large unaltered whole clasts (~350–3000 g) instead of preparing blanks or preforms to reduce the chance of thermal shock. The recovery of both heat altered large cores and early stage reduction debitage indicated controlled heat-treatment was used successfully to alter whole Potter quartzarenite clasts (Fig. 2).

Controlled heat alteration of whole clasts of coarse lithic material such as Potter quartzarenite may have been advantageous in initial flaking. Potter quartzarenite typically is irregular in shape, with that irregularity providing initial platforms 90° or less for detaching the preliminary cortical flakes to setup a core. The material, however, often is difficult to fracture even with suitable platforms (Hurst et al., 2010). Heat-treating whole clasts first would have been an effective means to avoid the difficulty of reducing this material in preparation for heat alteration.

This current work builds upon past experimental heat-treatment studies. It has a focus on ascertaining how hunter-gatherers effectively

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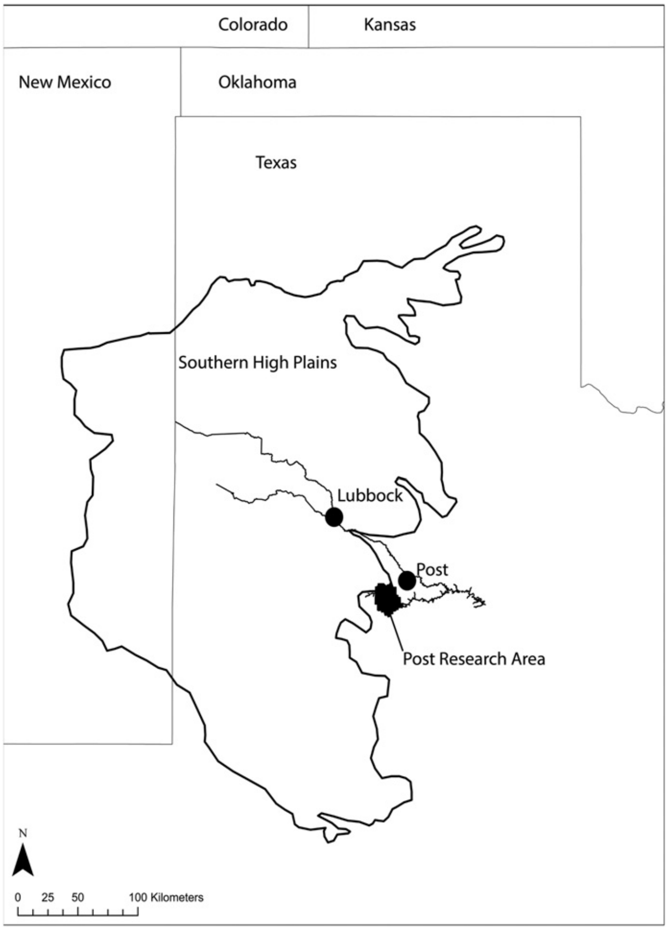

Fig. 1. Location of Post research area along the eastern escarpment of the Southern High Plains of Texas.

altered whole clasts and avoided the detrimental effects of thermal shock. Although the focus of this experimental study is regionally based, it has important world-wide research ramifications. Previous research has demonstrated that thermal shock results in crazing and unpredictable fractures that makes the material unusable for flaking (Purdy, 1975), and is a common result in attempts to heat-treat large pieces of lithic material (e.g., Backhouse and Johnson, 2007). The results of this experimental research demonstrate how past hunter-gatherers may have heat altered large clasts, and, therefore, adds to the growing body of experimental heat-treatment research. This heat alteration technique likely has been practiced elsewhere in the world. The results of this work provide a baseline for other researchers to identify the thermal alteration of unprepared lithic material in lithic assemblages.

1.1. Heat-treatment studies

Heat-treatment in many lithic technologies was often an important step to improve a lithic material's flakeability (Brown et al., 2009; Crabtree and Butler, 1964; Domanski and Webb, 2007; Purdy, 1974) and increase the sharpness of a stone tool's edge (Rick, 1978; Towner, 1985). Heat-treatment provided a means to increase the quality of stone, thereby reducing the need to trade or directly procure higher quality stone from great distances. The process of heat-treatment was discovered in many regions of the world (Domanski and Webb, 2007) and successfully used since the development of more advanced human cognition (Brown et al., 2009).

The success of heat altering flakeable stone requires the control of two variables. First, the correct temperature range must be obtained for the necessary transformation that leads to an increase in material hardness, that is correlated with fracture toughness (Schmidt et al., 2012:142) and subsequently, with more uniform and easily initiated fracture propagation (Domanski and Webb, 1992, 2007; Speers, 2010). The threshold temperature is dependent on the type of rock selected for heat-treatment (Crabtree and Butler, 1964; Domanski and Webb, 2007). For example in chert, color change, an increase in luster, and improvement in flaking typically occurs between 250 and 350 °C (482–662 °F) (Domanski and Webb, 2007:168). In contrast, silcrete requires temperatures that are 200 °C (392 °F) higher for successful heat alteration in comparison to chert (Schmidt et al., 2013:3529).

Secondly, the temperatures during heat-treatment must increase and decrease at rates that correlate to the specimen's volume (Crabtree and Butler, 1964; Mercieca and Hiscock, 2008) and material type (Schmidt et al., 2013). The threshold temperature can be reached faster with smaller specimens while larger specimens require an extended amount of time to avoid thermal shock (Crabtree and Butler, 1964; Mercieca and Hiscock, 2008; Schmidt et al., 2013). The type of cementing agent and amount of pore space also affect the rate of possible temperature change. For example, due to a larger network of pore space, silcrete can be heated more rapidly than chert (Schmidt et al., 2013).

Replicative studies have explored slow-and-steady and fast methods of thermal alteration (Mercieca and Hiscock, 2008). Slow-and-steady methods attempt to raise and lower temperatures gradually to avoid cracking and fracturing the rock (e.g., Crabtree and Butler, 1964; Domanski and Webb, 1992; Mandeville and Flenniken, 1974). In the slow-and-steady method, the specimens are protected from the direct source of heat by a layer of sediment and the temperatures are allowed to rise and fall gradually over great lengths of time.

Mandeville (1973), for example, placed lithic performs for heat-treatment within a 10 cm thick layer of sand that was sandwiched between two layers of coals built up between 30 and 35 cm in thickness over two two-hour periods and the pit then was capped with an additional 10 cm sand layer and allowed to cool for 20 h. This method required the construction of an elaborate pit (Mandeville, 1973), careful monitoring, and several days to complete (e.g., Domanski and Webb, 2007; Mercieca and Hiscock, 2008).

In the fast method of heat-treatment, the flakeable stone was placed in direct association with the heat source and temperatures allowed to change quickly (Griffiths et al., 1987; Mercieca and Hiscock, 2008). For example, Griffiths et al. (1987) successfully annealed flint preforms by placing them directly on the cooling ash of the fire and also caking some of the specimens with clay prior to placing them directly on the hot coals. Griffiths et al. (1987) found that this method works if the initial temperature change is limited. This method required little extra work and could have been incorporated easily into the maintenance activities of hearths. With this method, the main determinates in avoiding thermal shock were to limit specimen size (Mercieca and Hiscock, 2008) and select appropriate rock types more suitable to rapid temperature changes (Schmidt et al., 2013).

Several prior thermal alteration experiments have been conducted with Potter quartzarenite. Potter quartzarenite is very susceptible to thermal shock when placed directly into fire (Backhouse et al., 2009; Hurst and Rebnegger, 1999). A slow-and-steady method of heat-treatment also has been attempted with the construction of a pit with similar dimensions as Mandeville and Flenniken (1974). This method, however, has proven ineffective for heat altering quartzarenite (Hurst and Rebnegger, 1999).

2. Methodology

The experimental study began with a series of four controlled indoor kiln experiments to ascertain the temperature and time needed for the effective heat-treatment of Potter quartzarenite clasts. Then, four outdoor replication experiments were conducted to determine how quartzarenite clasts could be heated to an effective temperature for thermal alteration without rapid temperature change that would cause