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A previously undescribed organic residue sheds light on heat treatment in the Middle Stone Age

Patrick Schmidt [a,*], Guillaume Porraz [b,c], Ludovic Bellot-Gurlet [d], Edmund February [e], Bertrand Ligouis [f], Céline Paris [d], Pierre-Jean Texier [g], John E. Parkington [h], Christopher E. Miller [f], Klaus G. Nickel [i], Nicholas J. Conard [a]

[a] Eberhard Karls University of Tübingen, Department of Prehistory and Quaternary Ecology, Schloss Hohentübingen, 72070 Tübingen, Germany
[b] CNRS, USR 3336, UMIFRE 25, Institut Français d'Afrique du Sud (IFAS), Johannesburg, South Africa
[c] Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa
[d] Sorbonne Universités, UPMC Université Paris 6, MONARIS "de la Molécule aux Nano-objets: Réactivité, Interactions et Spectroscopies", UMR 8233, UPMC-CNRS, 4 place Jussieu, 75252 Paris Cedex 5, France
[e] University of Cape Town, Department of Biological Sciences, Rondebosch 7701, South Africa
[f] Eberhard Karls University of Tübingen, Institute for Archaeological Sciences, Rümelinstrasse 23, 72070 Tübingen, Germany
[g] CNRS, UMR 5199-PACEA, Université de Bordeaux 1, Talence, France
[h] University of Cape Town, Department of Archaeology, Rondebosch 7701, South Africa
[i] EberhardKarls University of Tübingen, Department of Geosciences, Applied Mineralogy, Wilhelmstraße 56, 72074 Tübingen, Germany

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ABSTRACT

South Africa has in recent years gained increasing importance for our understanding of the evolution of 'modern human behaviour' during the Middle Stone Age (MSA). A key element in the suite of behaviours linked with modern humans is heat treatment of materials such as ochre for ritual purposes and stone prior to tool production. Until now, there has been no direct archaeological evidence for the exact procedure used in the heat treatment of silcrete. Through the analysis of heat-treated artefacts from the Howiesons Poort of Diepkloof Rock Shelter, we identified a hitherto unknown type of organic residue — a tempering-residue — that sheds light on the processes used for heat treatment in the MSA. This black film on the silcrete surface is an organic tar that contains microscopic fragments of charcoal and formed as a residue during the direct contact of the artefacts with hot embers of green wood. Our results suggest that heat treatment of silcrete was conducted directly using an open fire, similar to those likely used for cooking. These findings add to the discussion about the complexity of MSA behaviour and appear to contradict previous studies that had suggested that heat treatment of silcrete was a complex (i.e., requiring a large number of steps for its realization) and resource-consuming procedure.

1. Introduction

In recent years, human origins research has focused on South Africa as a key region for the beginnings of 'modern human behaviour' during the Middle Stone Age (MSA). The suite of behaviours that archaeologists view as characterizing the emergence of modernity includes the production of standardized stone tool types (Clark, 1988; McBrearty and Brooks, 2000) and elaborate bone tools (Henshilwood et al., 2001; Backwell et al., 2008), the invention of compound adhesives (Wadley, 2010; Charrié-Duhaut et al., 2013), symbolic behaviour (Henshilwood et al., 2002, 2009; Texier et al., 2013) and heat treatment of silcrete, a local, fine-grained lithic raw material (Brown et al., 2009; Mourre et al., 2010). Because knapping heat-treated rock requires less force and allows better accuracy in obtaining the desired end-products (Crabtree and Butler, 1964; Purdy and Brooks, 1971; Inizan et al., 1976; Domanski et al., 1994; Schmidt et al., 2012) this knowledge may have been decisive in the evolutionary history of anatomically modern humans. Understanding the procedures used for lithic heat treatment, and the degree of complexity and investment associated with them, is thus of great importance. Some authors (Brown et al., 2009; Brown and Marean, 2010; Wadley, 2013; Wadley and Prinsloo, 2014) suggest a rather complicated procedure for heat treatment that is both time and resource consuming because it relies on slow, indirect heating in

* Corresponding author.
E-mail address: patrick.schmidt@uni-tuebingen.de (P. Schmidt).

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a sand-bath under a fire specially built for this purpose. Others (Schmidt et al., 2013) have argued that heat treatment of silcrete might have been a much faster and more efficient process using the glowing embers from regular domestic fires.

When silcrete is heated, it undergoes several readily identifiable physical changes. These changes include reddening (Schindler et al., 1982), occasional heat fracturing (Mercieca, 2000), the loss of porosity (Schmidt et al., 2013) and increased brittleness (Domanski and Webb, 1992). However, the identification of these characteristics does not directly imply intentional heating since, in post-depositional contexts, unintentional heating of artefacts can occur through indirect heating below a hearth or due to natural fires. Heat treatment may unambiguously be considered intentional only when one can demonstrate that an artefact was knapped after heating. This must be confirmed on the basis of technological arguments such as fracture pattern and sequence of flake negatives: fracture surfaces resulting from flakes removed after heat treatment (post-heating surfaces) are smoother or more glossy than fracture surfaces from before heat treatment (pre-heating surfaces) (Olausson and Larsson, 1982; Schmidt, 2013). This difference of fracture pattern is due to heat-induced transformations of the rocks' mechanical properties (Schmidt et al., 2012, 2013; Schmidt, 2013) and a comparison of the roughness allows one to determine whether a flake was knapped before or after heat treatment.

The scope of this work is to identify these markers of intentional heat treatment on silcrete artefacts from the Howiesons Poort of the South African MSA site of Diepkloof Rock Shelter (Western Cape, South Africa) and to compare them with experimental reference material. We also try to identify proxies that help us understand the procedures used for heat treatment in the MSA. In order to do so, we conducted heat treatment experiments using silcrete types recorded in the site and the wood of plant species growing in the vicinity of the shelter and documented in its MSA record (Cartwright, 2013). After a first study (Schmidt et al., 2013) that addressed the thermally induced structural and crystallographic transformations in South African silcrete, in order to understand the parameters necessary for heat treatment of this material, we aim in the present study to test the hypotheses about heat treatment procedures that resulted from our initial mineralogical study.

2. Materials and methods

2.1. Archaeological samples

We analysed all plotted silcrete artefacts from two Howiesons Poort (HP) stratigraphic units (SU) Frank and Frans. These two SUs were chosen because of their high proportion of silcrete artefacts (ca. 40% of all lithic material [Porraz et al., 2013]). They both belong to what has been called the 'intermediate HP', characterized technologically by the production of blades and bladelets and typologically by the production of backed tools and strangulated-notched pieces. All of the plotted silcrete artefacts coming from an excavated surface of 6 m^2 (squares N-M6, N-M7, N-M8 [Parkington et al., 2013]) were analysed and represent a total of 574 pieces for the SU Frank and 691 pieces for the SU Frans. Additionally, one unplotted silcrete artefact recovered from a profile collapse of the SUs John to Darryl (Intermediate and Late HP) was selected for destructive analyses.

2.2. Experimental heat treatment

For heat treatment experiments, we collected silcrete samples of good knapping quality from the Malmesbury area. Silcrete from this region is one of the materials that the MSA inhabitants of Diepkloof used extensively (Porraz et al., 2013). We built a set of outdoor camp fires using wood of four local southern African plant species that were reported in the charcoal record of the Diepkloof Howiesons Poort layers (Cartwright, 2013): *Heeria argentea* (Thunb.) Meissner, *Diospyros glabra* (L.), *Searsia laevigata* (L.) F.A. Barkley var. villosa (L.f.) Moffett and *Podocarpus elongatus* (Ait.) L' Herit. ex Pers. Three days before the heat treatment experiments, the wood of these four species was cut from living plants in the vicinity of the shelter. All fires used during the experiments were started in the same way: first, approximately 1–2 kg of the thinnest branches including green leaves was lit. When the leaves were burnt down and the thin branches became fine glowing embers, the thick white smoke caused by the leave's moisture disappeared and the first visible flames appeared. The thicker branches were then progressively added, building up a stable camp fire that could be sustained for several hours by adding more wood. This procedure allowed for the lighting of the freshly cut green wood without too much effort. Furthermore, this procedure allowed for the rapid formation of a cone of ash and embers at the base of the fire (up to 10 cm high at its centre) due to the burnt thin branches and leaves. The temperatures at different places within these camp fire structures (flames, glowing embers, ash cone at the base of the fires) were monitored using K-type thermocouples. Based on these fires, two experimental setups were used for heat treatment.

[Exp. 1]: As suggested by Schmidt et al. (2013), we scraped some glowing embers away from the bottom part of the camp fire and used these embers to cover a block of silcrete (at a distance of about 30 cm from the actual fire; Fig. 1a, b). The temperature evolution of three such silcrete/ember piles (*P. elongatus*, *S. laevigata* and *D. glabra*) was monitored with K-type thermocouples placed under the blocks before the experiment (the probes were placed beneath the blocks at >3 cm distance from the nearest glowing embers, measuring the effective heating rate in the silcrete). After four hours and 20 min the experiments were stopped and the silcrete was removed from the ashes that had cooled down.

[Exp. 2]: A second experiment was conducted in parallel using two of the fires (*S. laevigata* and *D. glabra*). For this, a block of silcrete was pushed directly into the ash-cone at the bottom of each fire (Fig. 1c, d). Measuring the temperature evolution within these blocks was not straightforward because the ash-cone already had an initial high temperature before the blocks were introduced. We therefore first placed a thermocouple at the bottom of the cone and then pushed the cold block of silcrete onto the probe. The blocks were left beneath the fires until these had stopped burning and cooled down but temperature recording beneath the blocks was stopped after two hours.

[Exp. 3]: We conducted a third set of experiments aiming to investigate the risk of overheating (Schmidt, 2014) of silcrete during the heat treatment procedure. This experiment did not aim to reproduce the actual conditions of heat treatment at Diepkloof but was designed to understand the relation between heat-induced fracturing (overheating) in different volumes of silcrete and high temperatures/fast heating-rates. For this, we tried to create 'extreme conditions' by applying temperatures and heating-rates to the silcrete that are higher than what can be expected using wood of the plant species identified from the charcoal at Diepkloof (Cartwright, 2013). Experiment 3 was therefore realized with the same procedure as Experiment 1 but using a southern African woody species, *Acacia erioloba* E.Mey, which is not endemic to Diepkloof but does produce particularly high temperatures and fast heating rates. When glowing, the embers of *A. erioloba* maintain a temperature above 500 °C for several hours without dying down, delivering a relatively high and constant amount of energy to the silcrete that is heated up to 550 °C with a ramp rate of 20 °C/min (a