

THE SYMBOLIC AND FUNCTIONAL EXPLOITATION OF OCHRE DURING THE SOUTH AFRICAN MIDDLE STONE AGE

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DECLARATION

I declare that this thesis is my own unaided work. It is being submitted for the Degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



Signature of candidate

10 May 2012

ABSTRACT

Ochre is a ubiquitous artefact in Middle Stone Age (MSA) contexts throughout Africa and the Near East. Archaeological evidence for the abrasive processing of ochre to extract pigment powder becomes increasingly prevalent after 100 ka. The habitual exploitation of ochre is interpreted as evidence for symbolism, a proxy for the origin of language and as a key element of 'symbolic' and 'modern' human behaviour. Evolutionary explanations agree that ochre and the products of its processing played a significant role in the adaptive strategies of early modern humans, but they differ in the functions assigned to it. I therefore ask the following question: What role did symbolic and functional applications of ochre play in the enhancement of prehistoric technology, and how may these have functioned to promote and maintain social relations within MSA *Homo sapiens* societies?

With the aim of answering this question, I follow a *chaîne opératoire* approach to elucidate the exploitation of ochre during the MSA. First, I present the results of an experimental study devised to infer the methods employed to process ochre. It is demonstrated that functional data derived from actualistic experiments can enhance our understanding prehistoric behaviour. Second, I describe one of the oldest instances of a deliberate engraving on ochre at 100 ka to 85 ka. I consider the possibility that specific types of raw material were selected for engraving purposes and expand on whether all engraved depictions inevitably functioned in 'symbolic' contexts. The third objective entails the evaluation of an often cited functional hypothesis for ochre, namely the use of red ochre as a 'hide-tanning' ingredient.

I also introduce and discuss three further functional hypotheses, namely those concerning the use of ochre as a form of mineral supplementation and detoxification agent, as a sun-protection element and as an insect repellent. Ethnoarchaeological research has proven to be informative in terms of revealing a range of functional uses for red ochre. I therefore consider how data derived from the Ovashimba of northern Namibia can enhance current understandings of ochre use in the MSA. I propose that in order to assess any hypothesis concerning the exploitation of ochre in the MSA methodically and in a scientific manner, it is necessary to engage with the theories and analytical methods of cognitive and technical sciences not normally viewed as applicable to archaeological enquiry.

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CHAPTER 1

INTRODUCTION

In this chapter I present an overview of the aims and scope of this thesis. I introduce the archaeological contexts and materials with which my research is concerned and provide a summary of the motivation for my research. I also provide and outline of the interpretative frameworks of archaeological ochre and explore the viability of viewing ochre as a proxy for symbolic behaviour.

1.1. Aims and scope

Given the current interest in the symbolic and utilitarian functions of ochre, an earthy material comprising anhydrous iron, and as the published information on the topic is relatively limited, the research I present here aims to address three interrelated sets of questions concerning the exploitation of ochre during the 100 000 to 70 000 years ago (ka) period of the southern African Middle Stone Age (MSA). Archaeological material recovered from the Still Bay and preceding archaeological units at Blombos Cave dated to 101 ± 4 ka (Henshilwood et al. 2011:219) provides the foundation for and forms the focal point of my research. The selected topics all pertain to the processing and subsequent functions or applications of ochre, and are not mutually exclusive.

- First, how was ochre processed and what may the uses of the resultant ochre powder and the remainder of the modified pieces have been? Are so-called ochre 'crayons' to be interpreted as such, or are these pieces simply the result of abrasive processing methods intended to extract pigment powder? What criteria can be used to discern between primary or processing and secondary or use wear traces on archaeological ochre?

- Second, is it possible to ascertain whether all engraved ochres operated in the same social or symbolic contexts? Could some engraved pieces simply have functioned as portable source of ochre powder, or were 'engravings' on ochre intended to reflect conventional designs with broad meanings, or more localised sets of symbolic information?

- Third, how effective is ochre in rendering unprocessed animal hide resistant to putrification and desiccation? Does the use of ochre to process animal hide constitute an actual tanning process? And should the ability to process or 'tan' animal hides be seen as forming part of the trend towards increasingly 'modern' technological and social advances during the Middle to Late Pleistocene?

The research objectives and structural arrangement of the thesis therefore follows a *chaîne opératoire* approach to exploring how ochre may have been processed and utilised during the MSA. The term *chaîne opératoire* was first used by Andre Leroi-Gourhan (1964:164) and further refined by, amongst others, Tixier (1978), Geneste (1985), Pelegrin (1986) and Haudricourt (1987) to refer to the study of lithic manufacturing 'technique' as a social product

and a founding element of the society which constitutes the technique (see Schlanger 1991; Lemonnier 2004; Soressi & Geneste 2011 for discussions). The concept has largely been applied to experimental research into European lithic technology denoting the '… incorporation of the process of production and use into classification and interpretation …' (Andrefsky 2005:38). I use the concept to both explore and describe the operational sequence of ochre from the raw material state to the point at which it is processed and subsequently applied for whichever purpose it may have initially been intended for. Chapter 3 deals with the operational sequence of ochre processing from an experimental and archaeological perspective, Chapter 4 with the problems inherent in interpreting engraved ochre as inevitably 'symbolic' and Chapter 5 focuses on the subsequent functions or uses of processed ochre as indicated by an actualistic experimental study.

My research protocols and analytical methods benefit from recent advances in microscopic analyses, experimental exploits and archaeometric analytical techniques. New discoveries from African MSA sites also present opportunities to explore the contexts in which ochre may have functioned during the MSA. This necessitates the conceptualisation of analytical methods designed to direct the interpretation of these new discoveries, and the engagement with theories and analytical methods of cognitive and technical sciences not normally viewed as applicable to archaeological enquiry. Separating the functional worth from the symbolic significance of ochre remains a highly challenging venture, particularly so in terms of understanding the motivations behind the sourcing, processing and consumption of ochre during the MSA.

1.1.1. Research focus

I address a number of interpretations concerning the symbolic and functional exploitation of ochre during the MSA. A broad definition for a 'symbol' is something that represents something else by association, resemblance or convention (see Jung & De Laszlo 1958; Savage-Rumbaugh 1986; Tomasello 2008 for a comprehensive range of definitions). A more strict definition such as that adopted by Henshilwood and d'Errico (2011:89) denotes a sign that has no connection or resemblance to its referent (Peirce 1998). The terms 'functional' and 'utilitarian' are used here to refer to ochre as capable of serving a particular function or use and as having a useful function pertaining to utility as distinguished from being expressive, emblematic, iconic, symbolic or representative of something. Archaeologists use the term 'ochre' to designate any earthy material comprising anhydrous iron (III - ferric or Fe3+) oxide such as red ochre (which includes unhydrated haematite or Fe_2O_3), partly hydrated iron (III) oxide-hydroxide such as brown goethite ($FeO(OH)$) or hydrated iron (III)

oxide-hydroxide such as yellow limonite (Fe2O3(OH) nH2O) (Cornell & Schwertmann 2003; Popelka-Filcoff et al. 2007; Easthaugh et al. 2008). Historically, 'ochre' has largely been used to refer to red earth pigments. That the term equates with the colour red can almost be assumed, even if no specific colour prefix is provided (Watts 2010:1). Rarer pigment forms frequently labelled 'ochre' include stibiconite (SB2O3(OH)2), uranium oxide (U2O3), molybdite (MoO3), plumbic ochre oxide (PbO3), tellurium oxide (TeO2), bismite (Bi2O3.3H2O) and annabergite (Ni3As2O2.8H2O) (Easthaugh et al. 2008:285).

Ochre is a ubiquitous archaeological artefact that is widespread in historic, Iron Age, Later Stone Age (LSA) and MSA contexts throughout Africa. By the Upper Pleistocene, when archaeological visibility in southern Africa is clearer, the exploitation of ochre had become commonplace and continues into the MSA, the LSA and the historical and ethnographic periods. The habitual exploitation of ochre is variously interpreted as evidence for colour symbolism (Watts 1999, 2002, 2009), as a proxy for the origin of language (Barham 2002; Knight 2008; Henshilwood & Dubreuil 2009; Watts 2009) and as one of the essential elements of 'symbolic' and, accordingly, 'modern' human behaviour (Knight et al. 1995; McBrearty & Brooks 2000; Watts 2002; d'Errico 2003; Henshilwood & Dubreuil 2009; Henshilwood et al. 2009; d'Errico et al. 2010; Henshilwood & d'Errico 2011). The gradual increase in ochre recovered from African MSA sites has therefore been employed to sustain the hypothesis that modern cognitive abilities arose in Africa.

Current evolutionary hypotheses agree that ochre and the products of its processing played a key role in the adaptive strategies of *Homo sapiens*, but they differ substantially in the functions assigned to it (Kuhn & Stiner 2007; d'Errico et al. 2009a, 2010; Wadley et al. 2009; Watts 2009). Symbolic interpretations (e.g. Knight 1991; Knight et al. 1995; Power & Aiello 1997; Power & Watts 1997; Watts 1999, 2002, 2009) essentially draw on ethnographic (Bleek & Lloyd 1911; Marshall 1961, 1976; Viegas Guerreiro 1968) and historical accounts (Campbell 1815; Burchell 1822; Methuen 1846; Stow 1905; Silberbauer 1965) of ochre use by extant hunter gatherer and pastoralist societies, and tend to focus on the use of red ochre to adorn the bodies of females or of ritual participants (Watts 2002, 2009).

Ethnographic analogy (see David & Kramer 2001; Denton 2002; Seetah 2008; Spriggs 2008 for definitions and discussions) is based upon the principle that people in similar cultural and environmental circumstances faced with similar goals, resources and constraints will behave in similar ways (Stanish 2008:1363). These analogues do not however explicitly reveal the causal relationships between human actions and what is observed archaeologically, especially so in terms of material recovered from temporally distant MSA contexts. Current

research suggests that ochre may also have functioned in utilitarian frameworks, and a number of functional hypotheses have been proposed to account for ochre recovered from MSA archaeological sites. Ochre may have been applied as a form of skin protection against the sun or from insects (Roper 1991; Wadley 2001), as a topical medicine or geophagic substance (Velo 1984, 1986; Johns & Duquette 1991; Mahaney et al. 1993), as a constituent in paint (Prinsloo et al. 2008), to knap bifacial foliate points (Soriano et al. 2009), as an ingredient in hafting mastics (Wadley et al. 2004, 2009; Wadley 2005, 2006; Lombard 2007b) and as a hide preservative (Keeley 1980; Audouin & Plisson 1982; Velo 1984; Couraud 1991; Wadley 2006).

1.2. Background

Over the past two decades, the behavioural and physical origins of modern humans have dominated palaeoanthropological dialogues. Until recently it was widely assumed that the production of symbolic material culture and its use to mediate social behaviour was a recent innovation and the result of a stochastic event that took place after 40 ka in Europe. It has subsequently been established that Africa is the evolutionary source of the earliest members of the genus *Homo* (McBrearty & Brooks 2000; Klein 2001; Wadley 2001; d'Errico 2003; Henshilwood 2004; White et al. 2003; McDougall et al. 2005; Mellars 2005, 2006; Krause et al. 2007; Berger et al. 2010; Manzi 2011; Shea 2011). It has also been confirmed that anatomically and behaviourally fully 'modern' *Homo sapiens* evolved during the extended span of the African Middle Stone Age (MSA) (Goodwin & Van Riet Lowe 1929), a lithic industry spanning the period between 285 and 25 ka (McBrearty & Tryon 2005:257; Wurz 2002:1013). Archaeological sites dating to this period record hominin expansions into new ecological niches, increasingly larger foraging ranges, the selection of finer-grained raw materials often derived from distant resources, the geographic patterning of artefact and artistic styles, a general broadening of the human dietary base, the use of sophisticated hunting techniques and evidence for symbolically mediated social behaviour (McBrearty & Brooks 2000; Henshilwood & Marean 2003, 2006; Henshilwood et al. 2009, 2011; Texier et al. 2010). Although not correlated directly with the initial emergence of anatomically modern *Homo sapiens*, these behavioural advances are significant because of their broad temporal and geographic coincidence with the evolution of our species. These behaviours, in some instances, also closely resemble the cognitive and linguistic abilities of contemporary *Homo sapiens* (Henshilwood et al. 2004, 2009; d'Errico et al. 2005; Mellars 2006).

The human origins debate has continually drawn on genetic data and theories concerning the evolution of modern human behaviour (Harpending & Rogers 2000; Enard et al. 2002;

Pääbo 2003; White et al. 2003; Tishkoff & Kidd 2004; McDougall et al. 2005; Wood et al. 2005; Krause et al. 2007; Li et al. 2008; d'Errico et al. 2009a, b; Henshilwood & Dubreuil 2009, 2011; Premo & Hublin 2009; Tishkoff et al. 2009). While these sources are significant, some researchers have additionally opted to focus on specific categories of cultural remains in their search for modernity, with the role and significance of 'ochre' receiving growing attention (Wadley 2001, 2005a, b, 2006, 2009, 2010; Barham 2000; 2002; Henshilwood et al. 2002, 2004; Watts 2002, 2010; Hovers et al. 2003; d'Errico et al. 2005, 2009, 2010; Lombard 2006, 2007a, b; Lombard & Wadley 2007; Soressi & d'Errico 2007; Henshilwood et al. 2009, 2011; Hodgskiss 2010).

1.3. The southern African Middle Stone Age

Several archaeologists contend that 'symbolically mediated behaviour', or behaviour that is '… mediated by socially constructed patterns of symbolic thinking, actions, and communication that allow for material and information exchange and cultural continuity between and across generations and contemporaneous communities … ' (Henshilwood & Marean 2003:635) evolved in Africa and that its origins are closely associated with the emergence of *Homo sapiens* during the MSA (Knight et al. 1995; Watts 1999, 2009; McBrearty & Brooks 2000; Henshilwood et al. 2002, 2004, 2009, 2010; d'Errico & Henshilwood 2011). The advent of modern cognitive behaviours in Eurasia is viewed as the consequence of an 'out of Africa' dispersal of an already symbolic species between 80 ka and 60 ka (Henshilwood & Marean 2003, 2006; Mellars 2006). Although the exact causes of this expansion of African *Homo sapiens* populations remains largely hypothetical (Mellars 2006:9383), recent genetic evidence, coupled with climatic and archaeological data is providing more information with which to clarify this event (Stringer 2003; Carto et al. 2009; Coop et al. 2009; Green et al. 2010; Krause et al. 2010; Henshilwood et al. 2011).

The out-of-Africa dispersal of *Homo sapiens* is preceded by changes in artefact types and technology that first occurred 300 to 260 ka and which underlies much more profound changes in human behaviour (McBrearty & Brooks 2000:488). The beginning of the MSA therefore reflects one of the most significant Middle Pleistocene archaeological events in Africa (McBrearty 2001; Tryon & McBrearty 2002). The MSA comprises prepared core technologies and blade and flake production that evolved out of the Acheulean after 300 ka and lasted until 25 ka in southern Africa (Clark 1997) and 45 ka in eastern Africa (Ambrose 1998). In contrast to the MSA, the preceding Acheulean is defined by the presence of large core-derived cutting tools such as handaxes and cleavers produced by *Homo erectus* or *Homo ergaster* (Rightmire 1990; McNabb et al. 2004; McPherron et al. 2010). Evidence from

Herto (White et al. 2003) indicates that the Acheulean persisted until 160 ka, implying that the transition from the Acheulean to the MSA spanned ~125 000 years. While the exact nature of the ESA to MSA transition remains unclear, current theories posit the gradual integration of novel MSA technologies, with the Acheulean being replaced by the Sangoan in tropical regions and by the Fauresmith elsewhere in Africa (Mercader 2002). Both of these industries were ultimately replaced by MSA lithic traditions which mark the innovation and appearance of composite technologies (Foley & Lahr 1997). Indicators of cognitively modern behaviour also become increasingly prevalent during the MSA and are manifest in social, technological, ecological and symbolic terms (Clark 1989; McBrearty 1993; McBrearty & Brooks 2000; Henshilwood et al. 2002, 2004, 2011; Henshilwood & Marean 2003; 2006; Mourre et al. 2010; Henshilwood & Dubreuil 2011).

1.3.1. The Still Bay and the Howieson's Poort

A range of terminologies have been used to describe the cultural divisions observed in the southern African MSA. At Klasies River, Singer and Wymer (1982:190) adopted the terms MSA I, MSA II, Howiesons Poort, MSA III and MSA IV. Volman (1981:280) proposed a revised version of this cultural stratigraphic scheme to include the MSA I, MSA 2a, MSA 2b, Howieson's Poort and Post-Howieson's Poort. Alternative terms have also been proposed (Wurz 2002:1013). Of the various MSA techno-traditions, the Howieson's Poort and Still Bay are essential for our understanding of the origins of human behavioural modernity.

The Still Bay Industry was officially described in the 1920s based on finds of bifacial foliate points at an open air site near the town of Still Bay (Henshilwood 2004:99). Sites containing the typical marker of the Still Bay, the bifacial foliate point, are however rare in southern Africa and include only nine known cave or shelter sites and five open air sites (Henshilwood & Dubreuil 2011). On account of excavations of layers at Blombos Cave containing artefacts that typify the Still Bay, namely foliate, bifacial lithic points, the term Still Bay re-entered the MSA debate. The finds from this time period, 78 ka to 72 ka, are contributing directly to the debate on the origins of behavioural modernity. Howieson's Poort sites are more numerous and geographically more widely distributed than Still Bay sites in southern Africa. The Howieson's Poort is represented by 32 archaeological sites, most of which occur south of the Zambezi River (Jacobs et al. 2008). Adequate descriptions are available for the Howieson's Poort (Wurz 1999) and this nomen therefore has validity.

The Still Bay and the Howieson's Poort techno-traditions appear in a relatively short period following the Marine Isotope Stage (MIS) 5 to 4 transition between 80 ka and 60 ka. They

were relatively short-lived, spanning some 6000 years each and separated by around 7000 years (Jacobs et al. 2008; Henshilwood et al. 2011). These complexes arguably represent some of the first explicit examples that suggest that *Homo sapiens* at this time had the capacity for symbolically mediated social behaviour (Henshilwood 2004:96; McCall 2007:13; Tribolo et al. 2009:730). Examples of artefacts that to form part of a 'symbolically mediated culture', or a culture in which '… individuals understand that artefacts are imbued with meaning and that these meanings are construed and depend on collectively shared beliefs …' (Henshilwood & Dubreuil 2011:368), include pressure-flaked bifacial foliate points (Mourre et al. 2010), engraved bone fragments (d'Errico et al. 2001; Henshilwood et al. 2002, 2009; Watts 2009), formal bone tools (Henshilwood et al. 2001), perforated shell beads (Henshilwood et al. 2004; d'Errico et al. 2005) and substantial amounts of ochre (Henshilwood et al. 2009, 2011; Watts 2009).

1.3.2. Middle Stone Age ochre occurrences

The first ochre occurrences span the transition from the Early Stone Age (ESA) Acheulean to the MSA (McBrearty 2001; Barham 2002; Cruz-Uribe et al. 2003; van Peer et al. 2004; McBrearty & Tryon 2006; d'Errico 2008). The initial use of ochre is reflected by isolated examples occurred during the Middle Pleistocene between 300 ka and 500 ka (de Lumley 1969; Barham 2002; Tryon & McBrearty 2002; Beaumont & Vogel 2006; Watts 2010). These precede the appearance of anatomically modern *Homo sapiens* dated to 195 ka at Omo Kibish (McDougall et al. 2005:736) and 160 ka to 154 ka at Herto in the Middle Awash Valley (White et al. 2003:747) in Ethiopia. The exploitation of ochre of variable colour and geological origin is therefore not restricted to modern *Homo sapiens* (Thévenin 1976; Koller et al. 2001; Zilhão 2001; Barham 2002; Grünberg 2002; Tryon & McBrearty 2002; d'Errico et al. 2003; van Peer et al. 2003, 2004; Bailey & Hublin 2006; Beaumont & Vogel 2006; Šajnerová-Dušková et al. 2010; Zilhão et al. 2010) (Table 1). The presence of ochre in MSA contexts does not therefore reflect a 'quantum leap' signifying a shift away from archaic to modern and symbolic patterns of behaviour (Conard 2005:310). The systematic sourcing and processing of manganese pigments by Neanderthals (Soressi & d'Errico 2007) indicate that, if it can be shown that Neanderthals used manganese for symbolic purposes, pigment use is not a species-specific behaviour and that the cognitive prerequisites of modern human behaviour existed prior to the emergence of biologically archaic and modern populations. Ochre could therefore have functioned 'symbolically' before the emergence of anatomically modern *Homo sapiens* ~195 ka and may in fact have had several functional uses 'early on' which subsequently evolved to comprise both symbolic significance and functional value.

Table 1. Archaeological ochre occurrences illustrating temporal and geographic variability in the exploitation of ochre by hominins over the past 1.5 million years.

Archaeological contexts	Geographic locations	Chronology	Associated lithic technologies	Hominin species[1]	References
Gadeb[2]	Ethiopia	1500 ka	Acheulean	*Homo ergaster*	Clark & Kurashina (1979)
Olduvai BK II[3]	Tanzania	1100 ka	Acheulean	*Homo ergaster*	Leakey (1958)
Wonderwerk Cave	South Africa	790 ka	Acheulean	*Homo ergaster*	Beaumont & Vogel (2006)
Olorgesaillie	Kenya	493 ka	Acheulean	*Homo ergaster*	Brooks (2006)
Terra Amata	France	380 ka	Acheulean	*Homo erectus*	de Lumley (1969)
Ambrona	Spain	350 ka	Acheulean	*Homo erectus*	Howell (1966)
Olorgesaillie	Kenya	340 ka	Acheulean	*Homo ergaster*	Brooks (2006)
Kathu Pan	South Africa	-	Acheulean	*Homo ergaster*	Beaumont & Vogel (2006)
Kabwe Cave	Zambia	300 ka	Charama	*Homo ergaster*	Barham (2002)
Duinefontein 2	South Africa	290 ka	Late Acheulean	*Homo ergaster*	Cruz-Uribe et al. (2003)
Kapthurin	Kenya	285 ka	Fauresmith / MSA	Archaic *Homo sapiens*	Tryon & McBrearty (2002)
Wonderwerk Cave	South Africa	276 ka	Fauresmith	Archaic *Homo sapiens*	Beaumont & Vogel (2006)
Nooitgedacht	South Africa	-	Fauresmith	Archaic *Homo sapiens*	Beaumont (1992)
Kathu Pan	South Africa	-	Fauresmith	Archaic *Homo sapiens*	Beaumont (1990)
Pniel 6	South Africa	-	Fauresmith / MSA	Archaic *Homo sapiens*	Beaumont (1999)
Twin Rivers	Zambia	266 ka	Early Lupemban	Archaic *Homo sapiens*	Barham (2002)
Kalambo Falls	Zambia	-	Lupemban	Archaic *Homo sapiens*	Clark (1974)
Maastricht-Belvedeer	Holland	250 ka	Middle Palaeolithic	*Homo erectus*	Roebroeks et al. (1988)
Achenheim	France	250 ka	Middle Palaeolithic	*Homo erectus*	Thévenin (1976)
Terra Amata	France	244 ka	Acheulean	*Homo erectus*	Falguères et al. (1991)
Border Cave	South Africa	227 ka	Middle Stone Age	Archaic *Homo sapiens*	Grün & Beaumont (2001)
Beçov	Czech Republic	222 ka	Middle Palaeolithic	*Homo erectus*	Šajnerová-Dušková et al. (2010)
Sai Island	Sudan	200 ka	Sangoan	*Homo sapiens?*	van Peer et al. (2003, 2004)
Mumbwa Cave	Zambia	172 ka	Middle Stone Age	*Homo sapiens?*	Barham (2000)
Pinnacle Point Cave	South Africa	164 ka	Middle Stone Age	*Homo sapiens*	Marean et al. (2007)
Es-Skhul	Israel	135 ka	Middle Palaeolithic	*Homo sapiens*	d'Errico et al. (2010)

Mumba Cave	Tanzania	132 ka	Middle Stone Age	*Homo sapiens*	Mehlman (1991)
Pomongwe	Zimbabwe	125 ka	Charama	*Homo sapiens*	Cooke (1963)
Bambata Cave	Zimbabwe	125 ka	Charama	*Homo sapiens*	Cooke et al. (1966)
Klasies River Cave	South Africa	110 ka	Middle Stone Age	*Homo sapiens*	Vogel (2001)
Blombos Cave	South Africa	100 ka	Middle Stone Age	*Homo sapiens*	Henshilwood et al. (2009)
Qafzeh Cave	Israel	92 ka	Mousterian	*Homo sapiens*	Bar-Yosef Mayer et al. (2009)
Grotte des Pigeons	Morocco	82 ka	Middle Stone Age	*Homo sapiens*	Bouzouggar et al. (2007)
Hollow Rock	South Africa	80 ka	Middle Stone Age	*Homo sapiens*	Högberg & Larsson (2011)
Olieboompoort	South Africa	80 ka	Middle Stone Age	*Homo sapiens*	Watts (1999)
Die Kelders Cave	South Africa	80 ka	Middle Stone Age	*Homo sapiens*	Tankard & Schweitzer (1976)
Apollo II	Namibia	70 ka	Middle Stone Age	*Homo sapiens*	Vogelsang et al. (2010)
Sibudu Cave	South Africa	58 ka	Middle Stone Age	*Homo sapiens*	Wadley (2010)
Cueva de los Aviones	Spain	50 ka	Charentian Mousterian	*Homo neanderthalensis*	Zilhão et al. (2010)
Cueva Anton	Spain	50 ka	Charentian Mousterian	*Homo neanderthalensis*	Zilhão et al. (2010)
Klein Kliphuis	South Africa	50 ka	Middle Stone Age	*Homo sapiens*	Mackay & Welz (2008)
Nelson Bay Cave	South Africa	50 ka	Middle Stone Age	*Homo sapiens*	Bernatchez (2008)
Enkapune Ya Muto	Kenya	46 ka	Nasampolai	*Homo sapiens*	Ambrose (1998)
Pech de l'Aze	France	43 ka	Mousterian	*Homo neanderthalensis*	Soressi & d'Errico (2007)
Geissenklösterle	Germany	43 ka	Aurignacian	*Homo sapiens*	Zilhão & d'Errico (2003)
Grotte du Renne	France	30 ka	Châtelperronian	*Homo neanderthalensis*	Caron et al. (2011)
Lagar Velho	Portugal	24 ka	Gravettian	*Homo sapiens*	Duarte et al. (1999)
Arene Candide	Italy	23 ka	Gravettian	*Homo sapiens*	Pettitt et al. (2003)
Matjes River	South Africa	12 ka	Albany	*Homo sapiens*	Louw (1960)
Byneskranskop	South Africa	2 ka	Wilton	*Homo sapiens*	Schweitzer & Wilson (1982)

[1] African *Homo erectus* specimens are classified as *Homo ergaster* and 'archaic' African *Homo sapiens* specimens as *Homo heidelbergensis* (formerly known as *H. rhodesiensis*). *Homo heidelbergensis* have been grouped into separate subspecies (Manzi 2011). *Homo heidelbergensis heidelbergensis* refers to the ancestral variant and include specimens from Bodo, Arago, Petralona and Ceprano. *Homo h. steinheimensis* refers to the European variant (Steinheim and Atapuerca), *H. h. rhodesiensis* to the African variant (Kabwe) and *H. h. daliensis* to the Asian variant of the species (Dali and Denisova).

[2] The basalt manuports at Gadeb showed no signs of use and the pigmentaceous material was identified simply as weathered cortex. But Clark and Kurashina (1979) notes that '… the occupation floor ... yielded several fragments of heavily weathered basalt which, when rubbed, give a red pigment. None of the pieces show unquestionable evidence of rubbing, but the possibility should not be ignored'.

[3] The two pieces of red ochre from Olduvai have subsequently been identified as reddened tuff but they do show signs of having been struck by a hammerstone (Dickson 1990:42).

1.4. A background to ochre and its applications

The term 'ochre' is a derivative of the Greek ὠχρός or *ochros* for *yellow* and adapted from the English *oker*, Old French *ocre*, and Latin *ōchra* (Barnett et al. 2005:466). Mineralogists categorise iron oxides into two sub-groups namely oxides and hydroxides, and oxide-hydroxides (Cornell & Schwertmann 2003). Iron most generally occurs in a ferrous (Fe II) form, and through processes of oxidation ferrous iron is converted to the ferric form (Fe III). Iron (II) oxide pigment is generally black, while iron (III) oxide is red. Because the foremost modern application of ochre is as a pigment, iron oxides have been studied to advance the manufacture of industrial pigments (Cornell & Schwertmann 2003; Elias et al. 2006). In archaeology, research tend to focus on the mineralogical characterisation of pigments used in rock art (Ospitali et al. 2006), the geological processes directing their formation or on the provenance ochre (Couraud 1991; Popelka-Filcoff et al. 2007).

One of the first securely dated instances of ochre exploitation by *Homo sapiens* involves red, yellow and black samples recovered from Sangoan (~200 to 182 ka) contexts at Sai Island in the Sudan (van Peer et al. 2003, 2004). Middle Pleistocene reports generally concern only red ochre, but at Sai Island yellow ochre is the predominant form. Following the emergence of *Homo sapiens* after 200 ka, a preference for red colourants appears to emerge. Ochre with a strong red hue frequently predominates in MSA contexts from 100 ka (Henshilwood et al. 2009:3), to 143 ka (Watts 2009:86, 90) and as early as 164 ka (Marean et al. 2007:906). Why there is a preference for these strong red colours remains debatable, one theory being the colour link with blood, fecundity and life (Watts 2009). But African MSA contexts also comprise yellow limonite, specular haematite, black manganese, green, yellow, pink, grey and purple shales, white kaolinite and brown goethite, often in significant quantities (Barham 2000; 2002; d'Errico 2008; Henshilwood et al. 2001, 2009; Wadley 2009; Watts 2009, 2010). Wear patterns are typically symptomatic of abrasive processing methods which suggest that the extraction of ochre powder was a foremost objective (Henshilwood et al. 2009; 2011). Ochre powder could however have been put to diverse symbolic and functional uses.

The recent publication of two ochre-processing tool-kits comprising grindstones, hammer-stones and two *Haliotis midae* shell containers with traces of red ochre, bone, charcoal and fat provides remarkable evidence of the ability of *Homo sapiens* to have sourced, combined and stored substances that may have enhanced technology or social practices 100 ka (Henshilwood et al. 2011). The discovery of these toolkits adds significant evidence for early technological and behavioural developments associated with MSA *Homo sapiens*. It also documents their deliberate planning, production and curation of an ochre-based compound

which may have functioned in various symbolic contexts and which was possibly used for numerous functional applications (Henshilwood et al. 2011:222).

1.4.1. Hypotheses concerning the exploitation of ochre

Ethnographically, red ochre is applied to human bodies and cultural artefacts in the course of generally symbolic practices (Rudner 1982; Watts 1999, 2002). Redness and brilliance are consistently associated with constructs of supernatural potency (Watts 1999). Menarcheal rituals are widely used as a template for other rites of passage in hunter-gatherer societies (Lewis-Williams 1981; Knight et al. 1995; Power & Watts 1997). Red body-paint was used during puberty and marriage rituals by San girls in Botswana in historic times (Marshall 1976:277), and /Xam San initiates presented the women of their band with haematite for decorating their cloaks and faces. Accounts by Burchell (1822), Methuen (1846), and Campbell (1853) also indicate that haematite was of considerable aesthetic value for southern African peoples of variable ethnic affiliation. The value of ochre is also illustrated by the association between ochre-filled ostrich eggshell containers and human burials (Humphreys 1974), the discovery of ceramic ware filled with powdered ochre in excess of 100 kilometres from the nearest source (Jacobson 1977) and reports that specular haematite was traded over distances of at least 500 kilometres (Beaumont et al. 1981).

Tangible evidence for the use of ochre as a 'body cosmetic' comes from the discovery of red ochre residues adhering to shell beads at the Grotte des Pigeons (Bouzouggar et al. 2007, d'Errico 2008) and at Blombos Cave (Henshilwood et al. 2004; d'Errico et al. 2005). At the latter site, more than 50 perforated *Nassarius kraussianus* shell-beads from layers dated to 75 ka (Jacobs et al. 2006) exhibit microscopic traces of red ochre. Since strung beads are most generally worn around the neck or wrists, the ochre residue may have been transferred from a human body onto the shells (d'Errico et al. 2005:3). Alternatively, red ochre may have been deposited onto the shells accidentally, perhaps whilst perforating the beads, if the shells came into contact with ochre in a type of container, because of the deliberate colouring of the beads, from rubbing against ochre-covered hide or from post-depositional contact with ochre in the sediment (d'Errico et al. 2005:3; d'Errico 2008:5). Although the Blombos beads may in fact provide stronger evidence of 'self-awareness' than of symbolism (Malafouris 2008:406), they present an indication of the ability to appreciate the perspectives of other individuals relative to oneself (Henshilwood & Dubreuil 2009:52).

The grounds for interpreting ochre in terms of colour symbolism, as symptomatic of the origin of language and as characteristic of symbolic and modern human behaviour are not

always explicit. With regards the link between ochre and language, specific frames of inferences have been proposed to refine the connection between language and elements of past symbolic material culture. A case in point involves the use of theories concerning the evolution of colour recognition and the linguistic outcomes thereof (Berlin & Kay 1969) to support the premise that the prehistoric exploitation of red ochre inevitably serves as an indication of complex systems of communication and semantic categories in prehistoric language (d'Errico et al. 2009:19; Watts 2009:64). Alongside complex technologies, regional trends in style, abstract and representational depictions, mortuary practices and personal ornaments, the systematic use of ochre is also considered as a non-linguistic 'phenotype' related to the emergence of language (d'Errico et al. 2009:14). The argument pertaining to the Blombos Cave shell beads is taken further to include the premise that, resembling such personal ornaments (Henshilwood et al. 2004; d'Errico et al. 2005; Vanhaeren 2005; Bouzouggar et al. 2007), decorated and some utilised ochre also comprise expressions of symbolically mediated behaviour (Henshilwood et al. 2009:1).

1.5. Overview of ochre-related research

In the absence of direct evidence, most archaeologists rely on ethnographic analogies (David & Kramer 2001; Denton 2002; Seetah 2008; Spriggs 2008), whether implicit or explicit in their accounts, to infer that ochre served primarily as a material for the production of pigments used for symbolic body decoration. That humans attached considerable symbolic value to red ochre is plainly illustrated by ethnographic examples, but these do not confirm that red ochre functioned exclusively in symbolic contexts, and it does not explain how the symbolic use of ochre arose (d'Errico et al. 2010:4). And since the decision of whether different cultural contexts are sufficiently similar to allow for the transfer of knowledge from the one to the other is central to the relevance of any analogy (Lewis-Williams 1984; Hodder 2004), the employment of ethnographic analogues is problematic in terms of explaining the use of ochre during the MSA (Kuhn & Stiner 2001).

Investigations into the symbolic versus utilitarian contexts of ochre therefore generally entail evaluation by ethnographic analogy instead of by direct scientific testing. Rigorous scientific practice involves the testing and falsification of hypotheses (Chalmers 1999:31; Ladyman 2002:70), and several studies (Semenov 1964; Keeley 1980; d'Errico 1988, 1989, 1992, 1993; d'Errico & Villa 1997; d'Errico & Nowell 2000; Backwell & d'Errico 2001; Henshilwood et al. 2001; Wadley 2005a, b; Soressi & d'Errico 2007; Wadley et al. 2009) demonstrate that methodical experimental archaeology can unlock formerly inaccessible information from the archaeological record (Trigger 1989:377; Outram 2008:1). The principles of experimental

research was acknowledged by the early 1960s (Ascher 1961a, b) and established by the time Coles (1979) wrote a seminal book on the subject (Seetah 2008:135). Notable progress was reported by Ingersoll et al. (1977), Bell (1994), Stone and Planel (1999) and recently by Mathieu (2002). The benefits of experimental approaches are numerous, provided that research is performed in a rigorous and scientific manner, experiments are replicable, follow an established protocol and provide qualitative and quantitative data. The provision of a testable hypothesis is not always explicit, but it is implicit and relates to the specific research question addressed by the experimental program. Wylie (1989) offers a description of archaeological practice in which hypotheses are proposed and then confronted with scientific evidence. Hypotheses are not then tested as such, but rather adapted to correspond with the evidence. This process is defined as one of 'tacking' between hypotheses and evidence. Theories are refined over time and customised in response to failures and successes in accounting for newly obtained data (Watson et al. 1984; Wylie 2002; Hodder 2004).

More recently, experimental research carried out by Brown et al. (2009) and Mourre et al. (2010) is worth mentioning. The former study confirmed that lithic raw materials were systematically manipulated with fire or 'heat-treated' to improve their flaking properties. Instances of heat treatment predominate among silcrete implements at 72 ka, and appear as early as 164 ka at Pinnacle Point (Brown et al. 2009:859). Through replication experiments, Mourre et al. (2010) determined that that heating and pressure flaking best explains the morphology of bifacial foliate points recovered from the 75 ka Still Bay levels at Blombos Cave. The pressure flaking of lithic implements that were heat treated has generally been considered to be an Upper Palaeolithic innovation dating to 20 ka, but this study indicates that this technology was conceived in Africa before its subsequent spread into other areas of the globe (Mourre et al. 2010:659).

A noteworthy example of the role of experimentation in the interpretation of archaeological ochre involves the work of Wadley (2005a, b, 2006; Wadley et al. 2009) and Lombard (2006, 2007a, b). Their research was prompted by the observation that MSA implements frequently had red ochre on their bases or non-working edges (Wadley 2005:1). Micro residue and use wear analyses of samples from Rose Cottage Cave and Sibudu Cave (Lombard 2004, 2005a, 2006, 2007a, b; Wadley et al. 2004, 2009; Williamson 2005) and replication and experimental work (Wadley 2005a, b, 2006a) have generated data that highlight the cognitive and technological skills implicated in hafting technologies, and which facilitates the investigation of changes in the use of ochre and of lithic adhesives over time (Lombard 2007b:406). Replication work on mastics and hafting corroborates previous suggestions that ochre is a suitable filler for use with either plant resins or wax (Wadley 2006:72; Wadley et

al. 2009:4). Since ochre was used in powder form in this application, the ground and scraped specimens associated with hafting technologies do not represent the outcome of explicitly symbolic behaviours. Whether this is the case for non-engraved ochre in general is arguable. It is therefore essential to demonstrate, and not simply assume, the symbolic and functional uses of ochre during the MSA.

In the case of the engraved ochres from Blombos Cave, symbolic behaviour can be inferred as the engravings are almost certainly the final outcome of the engraver's intention, and from the generally symbolic context in which these occur, as indicated by the ochre stained and perforated marine shell beads. But unless deliberately engraved, like many other substances often are (Parkington et al. 2005; Cain 2006; d'Errico & Henshilwood 2007; Texier et al. 2010), if specimens display clear signs of secondary use implicating the thoughtful intention of creating a 'design' (Soressi & d'Errico 2007) or if ochre is unequivocally implicated in the production of complex paint-like mixtures (Henshilwood et al. 2011), the presence of ochre in archaeological contexts cannot be viewed as indicative of symbolic behaviour. Ground and scraped pieces are therefore merely the by-products of a sequence of processing actions and subsequent usages that is difficult to reconstruct. This is why the interpretation of archaeological ochre is inherently controversial in nature (Wadley et al. 2009; Watts 2009; Wynn & Coolidge 2010).

1.6. The anthropogenic applications of ochre: A summary of research questions

1.6.1. Ochre crayons

The archaeological presence of crayon-shaped ochre pieces has prompted the suggestion that ochre may have been used, like modern crayons are, to 'draw' on surfaces to create coloured patterns. The terms 'crayon' or 'pencil' are widely used to designate archaeological ochre that resembles modern crayons. Although it has been demonstrated that crayons routinely result from grinding ochre to extract pigment powder (Wadley 2005), it has also been shown that crayons may indeed have been used to draw with (Soressi & d'Errico 2007). Since no direct evidence for this practice has yet been found in the MSA, it has been proposed that soft, organic and perishable objects such as leather, wood or human skin were the objects of decoration (d'Errico et al. 2003; Marshack 2003; d'Errico 2008).

Southern African MSA crayons typically comprise fine-grained sedimentary forms, but harder haematite and sandstone crayons also occur (Henshilwood et al. 2001:433; see Beaumont et al. 1978; Singer and Wymer 1982; Thackeray 2000; Clark & Brown 2001). Although many

ground pieces with convergent facets do qualify as crayons, many do not exhibit features suggestive of use as a crayon. Only if the morphology of processed crayons is not the result of intensive powder extraction, and if they have colour properties consistent with preferential selection, the use implied by their designation as crayons becomes plausible (Watts 2002:3; Wadley 2005a:8). This common inference for the use of faceted ochre as crayons indirectly links ochre crayons to art and, by implication, modern and symbolic human behaviour. This may be one of the reasons why crayons, and by association even unmodified ochre, are considered to exemplify symbolic behaviour (Wadley 2005:2). In order to clarify the use of ground ochre as crayons, it is essential to perform replicative experimental research and residual analyses of archaeological specimens (Loy & Hardy 1992; Lombard and Wadley 2007). The processes implicated in the formation of ochre 'crayons' is further explored in Chapter 3.

1.6.2. Engraved ochre

Painted and engraved abstract and representational depictions are traditionally considered key to assessing the modern character of human cultures (Conard 2008, 2010; Rossano 2010; Henshilwood & Dubreuil 2011). Engravings can also be formally described and their differences measured from a range of technological and metric perspectives (Bosinski et al. 2001; Henshilwood et al. 2009). But although engravings are afforded an important role in these debates, not all engraved patterns are likely to have operated in the same contexts or ways. Some pieces may have functioned to reflect conventional designs with broad meanings, while others may not have been intended to 'communicate' a specific message.

Parallel lines engraved on bone fragments have been recovered from Klasies River (Singer & Wymer 1982; d'Errico & Henshilwood 2007) and Sibudu Cave (Cain 2006). At Diepkloof Rock Shelter, 270 ostrich eggshell fragments engraved with abstract geometric patterns derive from Howieson's Poort levels dated to 60 ka (Texier et al. 2010). From Blombos Cave, 15 pieces of ochre exhibiting intentionally engraved abstract patterns have been recovered from levels ranging from 100 ka to 75 ka (Henshilwood et al. 2002, 2009). In Chapter 4, a fragmented ocherous pebble bearing a sequence of subparallel linear incisions and derived from MSA II levels of Klasies River Cave 1 is described. The archaeological units from which the piece derives are dated to between 100 ka and 85 ka, and it may therefore represent one of the oldest instances of a deliberate engraving. What has been interpreted as an 'engraving tradition' is therefore not limited to Blombos Cave and, in addition to the Klasies River specimen described here, also include engraved ochre from Klein Kliphuis (Mackay & Welz 2008) and Pinnacle Point (Watts 2010). Although the exact

purpose of ‘marking’ the object remains ambiguous, its detailed analysis adds relevant information to previously published occurrences of MSA engraved objects.

1.6.3. Ochre and hide tanning

Since the late 1970s, several practical hypotheses have been proposed for ochre. Foremost among these is the hide-preservation theory which draws on Mandl’s (1961) work on the preservative effects of iron oxides. Ochre has been shown to possess antibacterial properties (Mandl 1961; Velo 1984, 1986; Ellis et al. 1997), and the fact that it impedes collagenase is recurrently cited to support the hypothesis that red ochre was used to ‘tan’ hides in prehistory (Keeley 1980:172).

There is no deficiency of ethnographic information concerning the use of red ochre to dye material cultural items or to adorn human bodies. There are also many reports concerning hide-tanning experiments (Moss 1983; Sliva & Keeley 1994; Weedman 2002; Kleban & Bayer 2004; Covington 2008; Weedman-Arthur 2008; Püntener & Moss 2010) and analyses of wear traces on lithic scrapers (Semenov 1964; Broadbent & Knutsson 1975; Deacon & Deacon 1980; Dibble 1984; Kimura et al. 2001; Beyries & Rots 2008). But these do not provide explicit assessments of the efficacy of red ochre as a hide tanning ingredient.

The publication by Audouin and Plisson (1982) remains to be the most frequently cited reference concerning the efficacy of red ochre in preserving animal hides (Watts 1999, 2002, 2009; Wadley 2001, 2005a, 2006; Hodgskiss 2010). The authors established that treating hides with red ochre delays putrification and promotes dehydration. The experiments were however performed in France during the early 1980s and explored the efficacy of red and yellow ochre powder in treating a putrefied moose skin and an ox hide. It is believed that a revised assessment of the efficacy of ochre in tanning hide is essential, particularly in light of the current interest in the symbolic and utilitarian functions of ochre and in terms of performing actualistic experiments pertinent to local, southern African, circumstances. The experimental methodology of and the results obtained from such a revised assessment are presented in Chapter 5.

1.7. Further functional hypotheses

In Chapter 6 I introduce three additional functional hypotheses which are currently being explored. These entail evaluating the efficacy of ochre as a sunscreen, the capacity of ochre to provide essential mineral nutrients and the efficiency of ochre as an insect repellent. This

research is informed by ethnographic accounts and archaeological evidence which indicate that, as amongst contemporary Ovashimba (Namibia) and Hamar (Ethiopia) pastoralists, red ochre was in all probability used as a body cosmetic during the MSA. Whether this practice had strictly symbolic or functional significance remains debated (Wadley 2005, 2006; Watts 2002, 2009; d'Errico et al. 2005, 2008, 2009; Henshilwood et al. 2004, 2011).

The first paper is entitled *'Geophagy in prehistory: Implications for the interpretation of archaeological ochre'* and entails an appraisal of the ability of ochre to facilitate the adsorption of dietary toxins and to provide a source of mineral supplementation. Geophagy entails the deliberate ingestion of clay or soil and is the most common form of 'pica', the practice of ingesting non-food substances (Young et al. 2008). Geophagy has been attributed to the pursuit of mineral supplementation or to alleviate hunger (Brightsmith et al. 2008; Young et al. 2010). It has also been shown to counteract dietary toxins (Mahaney et al. 1995), resolve ionic imbalances (Jones & Hanson 1985), stabilise the pH in the digestive tract (Kreulen 1985), inhibit diarrhoea (Vermeer & Ferrell 1985), eradicate intestinal parasites (Knezevich 1998) and reduce bacterial activity (Williams et al. 2009).

The second paper, entitled *'Evaluating the protective effects of red ochre on human skin subjected to UV radiation'* is largely experimental and aims to evaluate the efficacy of ochre as a sunscreen. Epidemiological and experimental studies have established that excessive exposure to the sun leads to various deleterious cutaneous effects (Claerhout et al. 2005). Strategies for dealing with excessive exposure to harmful ultraviolet (UV) radiation must have been essential during human evolution, and may have comprised biological and behavioural coping mechanisms. Exposure of the human skin to the sun generally leads to darkening effects which serves a protective function via the increasing production of melanin (Gasparro 1999; Parra 2007; Jablonski & Chaplin 2010). This constitutes facultative skin color or 'tan' and involves the short-lived, immediate, and delayed tanning reactions elicited by exposure to UV radiation (Jablonski 2004). Another adaptive strategy entails the topical application of materials perceived to reduce the adverse effects of consistent exposure to the sun.

The third research paper currently in progress is entitled *'Red ochre, mosquitos and the emergence of modern human behaviour in Africa'* and entails an assessment of the capacity of ochre to act as a mosquito repellent. Mosquitoes transmit disease to more than 700 million humans per annum (Fradin & Day 2002; Kwiatkowski 2005) of which malaria is most significant. It is caused by five species of protozoan *Plasmodium* parasites. Of the species that infect reptiles, birds and mammals, *P. falciparum*, *P. vivax* and *P. ovale* are highly

anthropophilic. The most virulent is *P. falciparum* (Ollomo et al. 2009: 1). Besides malaria, Africa is also plagued by mosquito-borne diseases such as encephalitis (Lambrechts & Scott 2005), West Nile virus (Hubálek & Halouzka 1999; Lambrechts & Scott 2005), yellow fever (Gubler 2004; Severson et al. 2005), Dengue fever (Gubler 2004; Lambrechts & Scott 2005) and Rift Valley fever (Isaacson 2001).

Establishing the efficacy of red ochre as a sunscreen, a source of mineral supplementation and as an insect repellent may serve to confirm previously unexplored alternative functional applications of red ochre during the MSA. Such uses of ochre may have conferred a significant adaptive advantage to *Homo sapiens* in Africa, with groups who possessed such knowledge likely being much better equipped to withstand shifting environmental conditions.

CHAPTER 2

THESIS STRUCTURE

In this chapter I provide an overview of the structural organisation of this thesis. The chapter offers insight into the rationale of my research topic and presents a summary of the contents of Chapters 3 to 8. Synopses of the three central chapters of the thesis, Chapters 3 to 5 and which are presented as published research papers in their respective journal formats, are also provided.

2.1. Introduction

Ochre is most frequently recovered from archaeological sites in the form of residual powder, as rounded nodules, angular fragments or as inclusions within larger pieces of rock. Some examples display signs of grinding onto hard abrasive surfaces or scraping with sharp-edged implements, presumably to extract pigment powder. Ground pieces are often faceted to form a point, and in some cases exhibit grooves, striations and smoothed surfaces suggestive of abrasive processing (Wadley 2006:64; d'Errico 2008:4). The incidence of abrasive wear traces frequently correlate with geological derivation and with colour; red shale- or siltstone-derived ochre are the most frequently processed category (Watts 2009:88). Although ochre with a strong red hue appears to prevail in MSA contexts from as early as 164 ka, yellow, grey, white and green pastel or intermediate pieces also occur, often in large quantities. This, together with other hypotheses mentioned above, casts some doubt upon purely colour-related symbolic interpretations of MSA ochre.

If ochre was not only used for symbolic purposes, to what alternative functional uses may these mineral oxide specimens have been put? In particular, how and why was ochre utilised in the case of the relatively large quantities recovered from Blombos Cave (Henshilwood et al. 2002, 2004; 2009, 2011; Watts 2009) between 100 ka to 75 ka, from Sai Island at 200 ka (van Peer et al. 2003) or from Kapthurin (McBrearty 2001; McBrearty & Tryon 2005) and at Twin Rivers (Barham 1998, 2002) and Olorgesaillie (Brooks 2006) prior to the Acheulean / MSA transition at 280 ka to 250 ka? Given these new research questions and likelihood of alternative uses for ochre, it is understandable that the principally symbolic interpretations of archaeological ochre have been expanded to incorporate functional explanations for its presence in prehistoric contexts and especially in the MSA (Wadley 2005a, b, 2006; Lombard 2005, 2006, 2007a, b; Wadley et al. 2009). Evaluating the *chaîne opératoire* of ochre processing and its application is therefore important, especially in terms of how the inferences drawn from newly verified interpretations may relate to the debate about the origins of cultural modernity.

In this thesis I demonstrate that by employing diverse experimental protocols and analytical procedures to investigate the exploitation of ochre, the resulting interpretations can contribute to a more comprehensive understanding of the complexities of past human behaviour, both in symbolic and in functional or technological terms. I also reason that it is unwise to consider that the presence of ochre in archaeological contexts inevitably connotes ritual and symbolism (Riel-Salvatore & Clark 2001:459; Wadley 2001:204) and that it is

essential to establish, and not simply assume, the uses of ochre during the MSA - be they symbolic or functional.

2.2. Thesis structure

In accordance with the guidelines provided by the Faculty of Science at the University of the Witwatersrand for submission of a PhD thesis by publication, I present here three original research papers written, submitted for review and published in peer-reviewed journals during the period of registration. Completion of the thesis by published papers was preferred because of the range of related projects that could be addressed and also to accelerate the dissemination of information in a rapidly growing field of interest.

The core of my research comprises three papers published respectively in the *Journal of Anthropological Archaeology*, the *Journal of Archaeological Science* and the *Journal of African Archaeology*. The formatting of the papers is in accordance with the prescribed styles of the journals to which they were submitted. Each paper has its own reference list and the concluding reference list therefore applies only to the accompanying unpublished chapters. Following the three published papers presented as Chapters 3, 4 and 5, Chapter 6 introduces three on-going research projects dealing with the assessment of further functional uses of ochre during prehistory. Chapter 7 presents a summary and a discussion of the results obtained from the analyses of experimental and archaeological materials. Chapter 8 is the concluding chapter of the thesis, and summarises the principal conclusions reached in terms of inferring symbolic behaviour or functional use from processed archaeological ochre.

2.2.1. Chapter 3

Rifkin, R.F. 2011. Processing ochre in the Middle Stone Age: Testing the inference of prehistoric behaviours from actualistically derived experimental data. Journal of Anthropological Archaeology doi:10.1016/j.jaa.2011.11.004.

This paper is based on the premise that functional data derived from actualistic experiments can be employed to formulate more refined interpretations of prehistoric human behaviour (Hurcombe 1992:63; Odell 2001:62). The study draws inspiration from the research by Soressi and d'Errico (2007) which entailed the analysis of manganese (MnO_2) chunks from the Mousterian sites of Pech de l'Azé I and IV. Some 250 pieces from Pech de l'Azé I and 20 from Pech de l'Azé IV show clear signs of utilisation, with many specimens exhibiting traces of primary (processing) and secondary (use) modification (Soressi & d'Errico 2007:305). The

authors succeeded in demonstrating that *Homo neanderthalensis* prepared pigments by grinding them onto coarse abrasive surfaces before rubbing them onto smooth soft materials, possibly animal hide or human skin. Their study also shows that the multifaceted procedures implicated in the processing and subsequent use of pigments provides a strong argument in favour of the capacity of Neanderthals to have autonomously developed complex symbolic cultural practices (Soressi & d'Errico 2007:306). Apart from the recent publication by Hodgskiss (2010) and information provided by Wadley (2005a, 2006a, 2009, 2010), very few comprehensive studies relating to the formation of wear traces on MSA ochre exists. My objective was therefore to expand the existing but limited comparative references for the analysis of wear phenomena on archaeological ochre. The study entailed the experimental processing of 150 individual ochre specimens comprising 320 experiments. The purpose was to observe the development of primary or processing wear traces on ochre pieces subjected to various grinding or scraping activities. Although wear patterns indicative of abrasive processing methods prevail on archaeological specimens, many also exhibit traces not derived from grinding or scraping alone. Selected samples were therefore also subjected to secondary or use activities, the foremost of which comprised the employment of ochre as crayons to draw on and to colour in hard abrasive and soft non-abrasive surfaces.

Along with published archaeological and experimental observations (Wadley 2005a; Lombard 2006; Soressi & d'Errico 2007; d'Errico & Vanhaeren 2008; Henshilwood et al. 2009; Hodgskiss 2010; Watts 2010) the results obtained from this study presents a reliable empirical basis for developing expectations about the processes implicated in the formation of wear traces on archaeological ochre. The experiential appreciation of the link between wear traces and their causes is particularly important, and is expected to facilitate the formulation of testable ideas for the explanation of wear traces on archaeological ochre. The challenge is to transform these expectations into reliable middle-range arguments (Merton 1967; Binford 1977; Kosso 1993) that can link what has been established experimentally with what is observed archaeologically. In combination with comparative reference collections, it is believed that the analysis of wear phenomena on archaeological ochre can enhance the current understanding of how ochre was processed, the implements and materials that may have been used, the uses ochre powder may have been put to and the levels of cognitive skill implicated in such modern functional and symbolic behaviours.

As an initial appraisal of the capacity of the experimental database to achieve this goal, processed ochres derived from the Still Bay levels of Blombos Cave were examined macroscopically and microscopically, and compared to experimentally processed samples. Encouraging results were obtained, and the next envisaged step would be to initiate a

comprehensive analytical program of the remainder of the ochre assemblage recovered from the Still Bay and the earlier MSA levels of Blombos Cave.

2.2.2. Chapter 4

d'Errico, F., Garcia Moreno, R., Rifkin, R.F. 2011. Technological, elemental and colorimetric analysis of an engraved ochre fragment from the Middle Stone Age levels of Klasies River Cave 1, South Africa. Journal of Archaeological Science doi:10.1016/j.jas.2011.10.032.

Painted and engraved abstract and figurative depictions are widely considered a key to assessing the modern character of prehistoric human cultures (Conard 2010; Rosssano 2010; Henshilwood & Dubreuil 2011). Engravings are the result of cutting a design into a substance with the use of an implement, and comprise one of the few durable categories of material culture that represents the intended outcome of the actions performed by its executor. Engravings can also be formally described and their differences measured from a range of technological and metric perspectives (Bosinski et al. 2001; Henshilwood et al. 2009). Engravings on bone have been recovered from Blombos Cave and Klasies River (Singer & Wymer 1982; d'Errico & Henshilwood 2007) and on ostrich eggshell from Diepkloof (Texier et al. 2010). Engraved ochre is reported from Klein Kliphuis (Mackay & Welz 2008), Pinnacle Point (Watts 2009) and several undated MSA contexts across southern Africa. The most conspicuous assemblage of engraved ochre comprises the 15 pieces from 100 ka to 72 ka levels of Blombos Cave (Henshilwood et al. 2004, 2009).

This paper describes a fragmented ocherous pebble bearing a number of semi parallel linear incisions or engravings. The object derives from the Singer and Wymer (1982) excavations of the MSA levels of Klasies River Cave 1, and is dated to between 100 ka and 85 ka. Microscopic analysis reveals that the surface of the piece was first prepared by grinding before being engraved with a sequence of oblique and parallel multiple and single stroke lines. These marks are inconsistent with powder extraction and appear to instead represent examples of intended engravings. XRF and colorimetric analysis of the engraved piece, and of 12 other pieces from the same level, also suggests that the dark red colour and manganese-rich structure renders the engraved piece unique. This implies that a specific type of raw material may have been selected for engraving purposes. The piece is also contemporaneous with the older engraved specimens from Blombos Cave, signifying that broadly analogous cultural practices may have occurred over wider geographic spans than previously thought. The identification of engraved ochre from an additional MSA context complements the current database of artefacts widely viewed as

symptomatic of modern and symbolic behaviour. The study also demonstrates that the application of novel analytical techniques may become a valuable and potentially important avenue of analysis for ochre from MSA assemblages.

2.2.3. Chapter 5

Rifkin, R.F. 2011. Assessing the efficacy of red ochre as a prehistoric hide-tanning ingredient. Journal of African Archaeology 9 (2): 131-158.

It has been established that powdered ochre could have been put to diverse uses during the MSA and that processed ochre does not represent the direct outcome of specific functional or symbolic behaviours. A foremost functional premise for ochre from LSA and also MSA archaeological contexts is that it may have been used to process and preserve animal hides (Keeley 1980; Audouin & Plisson 1982; Velo 1984; Couraud 1991; Wadley 2006). Ochre has been shown to have antiseptic properties and to inhibit the bacterial production of collagenase, and these qualities are recurrently cited to support the hypothesis that red ochre was used to process, preserve or 'tan' animal hides in prehistory.

But as a general explanatory hypothesis, ochre use for tanning has been critiqued repeatedly (Knight et al. 1995; Power & Watts 1996; Watts 1999, 2002, 2009). The only scientific source cited by archaeologists as providing a chemical basis to the hypothesis are the experiments by Mandl (1961). These demonstrate that solutions of some metal ions may inhibit the breakdown of hide collagen by bacteria. While highly ferruginous or saline ochre might have a similar effect, it has not yet been demonstrated. A frequently cited experimental study is that by Audouin and Plisson (1982), who noted that the treatment of hides with red ochre is beneficial, especially in terms of preventing decay. Negative results were obtained for a specimen treated with yellow ochre as it remained rigid, thick and rough in contrast to a sample treated with red ochre which dried rapidly and became thin and soft. Phillibert (1994:450) suggests that the reason ochre appears to inhibit the breakdown of collagen is simply that it desiccates and consequently preserves the collagen fibres.

Given the absence of recent scientific evaluations of the tanning hypothesis, I present in this paper the results of an experimental study exploring the efficacy of ochre as a hide tanning ingredient. The intention of the experiments was not to challenge the premise that ochre was used as a pigment in symbolic contexts during the MSA, but to explore whether ochre may in fact comprise a suitable material for the preservation of animal hide. The methodology involved conducting actualistic experiments (Outram 2008:2) to determine the most likely

processes, methods and materials that might have been applied in the past. Experimental and XRF analytical results suggests that certain geological and elemental varieties of ochre may possess antibacterial, antifungal and desiccation properties, and that these may be linked to the ability of some ochres to inhibit collagenase and hide putrification. Archaeological (Rogachev & Sinitsyn 1982; Vasil'ev et al. 1987; Marks 1990; Loy & Hardy 1992; Boëda et al. 1996; Soffer et al. 2000; Henshilwood et al. 2001; d'Errico et al. 2003; Douka 2010; Gilligan 2010) and genetic (Kittler et al. 2004; Reed et al. 2004; Toups et al. 2011) evidence suggests that processes related to the manufacture of clothing appears to coincide with the emergence of complex social and symbolic behaviours during the MSA. The chemical and technological expertise implicated in hide tanning strategies may therefore have formed part of the progressive trend towards increasingly modern technological and social advances during the MSA.

2.2.4. Chapter 6

In this chapter, I explore the feasibility of drawing on the Ovashimba, agro-pastoralists of northern Namibia, as an ethnographic analogue for the interpretation of archaeological ochre. Recent ethnographic interviews conducted amongst the Ovashimba have proven to be informative in terms of revealing an extensive range of functional uses for red ochre. Whether a similarly broad range of applications existed during the LSA and MSA remains uncertain. Although acknowledging that the use of ethnographic analogies to infer the uses to which archaeological ochre may have been put may not be directly applicable to prehistory, I believe that this approach can provide a basis for the formulation and assessment of research questions.

Chapter 6 also presents a summary of three current experimental and analytical research projects not included in published format in this thesis. Time constraints, the theoretical and investigative broadening of research schemes and unforeseen analytical complications have resulted in the delay of the submission of these projects for publication. The topics covered in the above research also pertain to the processing and subsequent functions or applications of ochre, as do Chapters 3 to 5. The first topic explores the probability that geophagy, the deliberate ingestion of soil and clay, may have formed part of the human dietary repertoire during the MSA. If geophagy was practiced by early *H. sapiens* in Africa, it is likely to have formed an integral part of the trend towards increasingly 'modern' technological and social advances during the Late Pleistocene. The second and third projects aim to evaluate the efficacy of red ochre as a sun-protection element and as an insect repellent. These studies form part of the general research objectives of this thesis and

exemplify the degree of continuance following from the *chaîne opératoire* approach to exploring how ochre may have been processed and utilised during the MSA. It is anticipated that these research projects, which were commenced in 2010, will continue during 2012 and be completed by early 2013.

2.2.5. Chapter 7

This chapter provides a summary and a discussion of the principal conclusions reached in the preceding published and unpublished chapters. The results obtained from each study are discussed in terms of the theoretical and interpretative contributions of the published papers to current interpretations of ochre use in prehistory, and the ways in which future research may improve on what has been learnt from these studies. The chapter also explores the prospect of formulating innovative experimental protocols and employing novel analytical techniques to facilitate the evaluation of archaeological ochre assemblages that have not been subjected to scientific analyses. It provides an outline of the problems inherent in inferring either symbolic behaviour or functional uses from processed ochre, and proposes that sound scientific testing can provide conclusive empirical grounds for either accepting or rejecting hypothetical claims concerning the exploitation of ochre in the past.

I conclude that experimental research relating to utilitarian hypotheses proposed for MSA ochre can be used as an alternative to generate predictions that might illuminate the uses of ochre during the MSA. The results obtained from experimental research can therefore provide reliable empirical bases for developing expectations about the origin and morphology of wear traces on archaeological ochres. The challenge is to transform these expectations and ideas into reliable middle-range arguments that can link what has been established experimentally with what is recovered from the archaeological record.

2.2.6. Chapter 8

Chapter 8 is the closing chapter of the thesis. I conclude that by employing original and diverse experimental protocols and analytical procedures to investigate the prehistoric uses of ochre, it possible to attain a better understanding of the complexities of past human behaviour. In addition to providing my final thoughts on the role that symbolic and functional applications of ochre played in the enhancement of prehistoric technology and how these functioned to promote and maintain social relations within MSA *Homo sapiens* societies, I also explore the possibility of reconstructing the origins of ochre-related technologies.

2.3. Summary

As is the case for the interpretation of much archaeological evidence, current explanations concerning ochre use in the MSA represent only a glimpse of an MSA behavioural mosaic that culminated in the diasporas, at 80 ka to 60 ka, of a series of human expansions from Africa that introduced fully symbolic *sapiens* behaviour to Eurasia and the rest of the world (Henshilwood 2007:130). But how is ochre implicated in the emergence and persistence of symbolic *sapiens* behaviour?

Red ochre is associated with the very first explicit archaeological examples of the existence of fully modern human behaviour, and at least some of the technological advances brought about by the symbolic and practical applications of ochre must have functioned to facilitate increasingly complex social behaviours in the MSA. In symbolic terms, creating and using symbolic artefacts implies the ability to hold different perspectives of an object in the human mind. Enhanced cognition and memory would therefore have enabled the invention and maintenance of symbolic culture (Henshilwood & Dubreuil 2009:55). I aim to demonstrate that the same principle applies to more 'functional' technological advances, particularly those implicating ochre. The more a culture involves the use of complex symbolic behaviours, the more members of the group will need to establish formalised relationships and identify more formal social roles. Indeed, the selective pressure behind human cognitive evolution was primarily social (Henshilwood & Dubreuil 2011:363). However, even 'symbolic' behaviours do not only represent cognitive or social advances - they are also technological endeavours that stem from previous technological advances. The evaluation of the *chaîne opératoire* of ochre exploitation in the MSA is therefore essential, especially in terms of how the inferences drawn from newly substantiated interpretations may enrich the debate about the origins of cultural modernity.

CHAPTER 3

RIFKIN, R.F. 2011

PROCESSING OCHRE IN THE MIDDLE STONE AGE: TESTING THE INFERENCE OF PREHISTORIC BEHAVIOURS FROM ACTUALISTICALLY DERIVED EXPERIMENTAL DATA

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Processing ochre in the Middle Stone Age: Testing the inference of prehistoric behaviours from actualistically derived experimental data

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ABSTRACT

The increase in the presence of 'ochre' in African Middle Stone Age contexts has been employed, together with changes in human biology and behaviour, to support the hypothesis that 'modern' cognitive abilities arose in Africa. The consistent exploitation of ochre is interpreted as evidence for colour symbolism, a proxy for the origin of language and a defining aspect of 'modern' human behaviour. That humans attached considerable symbolic value to red ochres in particular is illustrated by ethnographic examples. Research has shown that wear patterns indicative of abrasive processing methods prevail, but many archaeological specimens also exhibit wear traces not derived from grinding or scraping alone. Building on former research, I present here the results of an experimental study devised to infer the methods employed to extract powder from ochre during the African Middle Stone Age. The prospect of ascertaining at least some of the likely uses to which ochre may have been put, is also explored. I conclude that functional data derived from actualistic experiments can be used to enhance our understanding of some aspects of prehistoric behaviour.

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Introduction

Over the past decade, the behavioural and physical origins of *Homo sapiens* have dominated palaeo-anthropological dialogues. Initially centred on the fossil record, and more recently also drawing on genetic data and the evolution of modern behaviour (Harpending and Rogers, 2000; Enard et al., 2002; Pääbo, 2003; White et al., 2003; McDougall et al., 2005; Wood et al., 2005; Krause et al., 2007; Li et al., 2008; d'Errico et al., 2009a; Henshilwood and Dubreuil, 2009; Premo and Hublin, 2009), the exploitation of earth pigments or 'ochre' have received increasing academic consideration (Barham, 2002; Hovers et al., 2003; Soressi and d'Errico, 2007; d'Errico et al., 2009a, 2010; Henshilwood et al., 2009; Wadley, 2009, 2010; Watts, 2010). In addition to the manufacture of abstract engravings and personal ornaments, the habitual exploitation of ochre is interpreted as evidence for colour symbolism (Watts, 1999, 2002, 2009), a proxy for the origin of language (Barham, 2002; Knight, 2008; Henshilwood and Dubreuil, 2009; Watts, 2009) and one of the essential elements of 'symbolic' and therefore 'modern' human behaviour (Knight et al., 1995; McBrearty and Brooks, 2000; Watts, 2002; d'Errico, 2003; Henshilwood and Dubreuil, 2009; Henshilwood et al., 2009; d'Errico et al., 2010). Modern human behaviour is here defined as "... behaviour that is mediated by socially constructed patterns of symbolic thinking, actions, and communication that allow for material and information exchange and cultural continuity between and across generations and contemporaneous communities" (Henshilwood and Marean, 2006, p. 9).

Ochre is ubiquitous in historic, Iron Age, Later Stone Age (LSA) and Middle Stone Age (MSA) archaeological contexts throughout southern Africa. Specimens are usually unmodified, but some are faceted, exhibiting striations and grooves (Henshilwood et al., 2001, p. 432), polish (Wadley, 2009, p. 167) and incisions and signs of flaking (MacKay and Welz, 2008, p. 1526; Henshilwood et al., 2009, p. 30). Rarer forms of modification include deliberately engraved lines (Henshilwood et al., 2002, 2009; d'Errico et al., 2011) and edge-notching (Evans, 1994). Although the intentionality of ochre processing during the MSA, spanning 285,000–22,000 years ago (Wurz, 2002, p. 1013; McBrearty and Tryon, 2005, p. 257), has been questioned in the past (Wadley, 2001; Klein and Edgar, 2002) analytical advances have largely warranted the acceptance of deliberate intent (see Soressi and d'Errico (2007), d'Errico and Vanhaeren (2008), and Henshilwood et al. (2009) for examples). But because ground or scraped ochres do not represent the direct outcome of specific functional or symbolic activities, the behaviours that these finds represent remain controversial (Wadley, 2006a, p. 64; d'Errico et al., 2009a, p. 20).

It would therefore be beneficial if functional data derived from the experimental processing and utilisation of ochre can be utilised to improve current readings of prehistoric behaviour. This can be accomplished by determining what types of wear traces result

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from which types of processing motions, materials and applications. This is best achieved by controlled actualistic experiments (e.g., Hurcombe, 1992, p. 61; d'Errico and Nowell, 2000, p. 128; Soressi and d'Errico, 2007, p. 297; Christidou, 2008, p. 746), which aim to produce wear patterns which "... most likely replicate wear patterns in antiquity" (Keeley, 1980, p. 15). These results then function as a type of 'middle range' analogue (after Binford, 1977; see also Merton, 1967; Raab and Goodyear, 1984; Kosso, 1993) that can be employed to facilitate the inference of the methods used to process (extract pigment powder from) archaeological ochres. Once the methods of processing and means of use have been ascertained, it becomes feasible to hypothesise about the cognitive skills and behaviour implicated in the processing and utilisation of ochre in the past (e.g., Henshilwood et al., 2002, 2004, 2009; Soressi and d'Errico, 2007; Henshilwood and Dubreuil, 2009; Wadley et al., 2009).

Objective

The objective is to expand existing comparative references (e.g., Wadley, 2005a; Hodgskiss, 2010) for the analysis of wear phenomena on archaeological ochres by: (1) exploring the range of mechanisms and implements involved in experimental ochre processing, (2) investigating the development of primary processing wear features on specimens and (3) observing the formation of wear traces resulting from the secondary use of specimens. In addition to macroscopic and microscopic morphological information, the database comprises detailed written comments and more than 1500 digital photographs. This catalogue will be employed for the comparative analysis of archaeological ochres from Blombos Cave (Henshilwood et al., 2002, 2004, 2009; d'Errico et al., 2003, 2005; d'Errico and Henshilwood, 2007; Henshilwood, 2007; Henshilwood and Dubreuil, 2009) and several additional MSA and LSA contexts in the Western Cape Province of South Africa.

This paper is structured to provide insight into the history of research concerning the analysis of wear traces on archaeological ochres, and to clarify the experimental methodology applied in this study. All the experiments were actualistic and aimed to investigate activities that might have occurred in the past using the methods and materials that would actually have been available (Outram, 2008, p. 2).

The most recent analysis of wear traces on ochre is that by Hodgskiss (2010). As with this paper, the study focuses on the formation of grooves and striations as a result of subjecting experimental specimens to diverse grinding, scoring or incising and secondary use activities. Attention is also paid to the prevalence of edge flaking or chipping and the formation of surface polishes and lustres. This study differs from that by Hodgskiss in that it does not fully explore the effects that depositional and trampling wear may have on the formation of wear phenomena. Instead, and in addition to the formation of grooves, striations and striae, the focus is on exploring the development of prehensile wear traces on processed ochres, the variability in extracted powder colour as derived from different processing methods and the formation and identification of what is generally referred to as ochre 'crayons'. These two studies are complementary and should be seen as presenting a comprehensive description of the processes responsible for the formation of wear traces on experimentally processed ochres.

Experimental results are presented in the form of macroscopic observations made during the experiments (Supplementary File 1), and as microscopic observations subsequent to primary and secondary experimental activities (Supplementary File 2). To evaluate the feasibility of the experimental database to augment the assessment of ochre derived from archaeological contexts, a preliminary analysis of processed ochres derived from Blombos Cave is presented. Ultimately, the results are explored in terms of the wider implications that the identification of different primary processing and secondary use activities on archaeological specimens may have for MSA research. I conclude that once the methods of processing and means of use of archaeological ochres have been determined, it becomes feasible to theorise about the cognitive skills implicated in sourcing processing and utilising ochre during the African MSA.

Archaeological ochre

Mineral substances recovered from archaeological contexts are generally referred to as 'ochre', a term derived from the Greek *ὠχρός* or *ochros* for 'yellow' and adapted from the Middle English *oker*, Old French *ocre*, and Latin *ōchra* (Barnett et al., 2005, p. 466). The narrow sense of the term refers to rocks which derive their colour from two specific minerals, namely haematite (α – Fe_2O_3) and goethite (α – FeOOH) (Easthaugh et al., 2008, p. 170, 183). Ochre is typically composed of these two forms of iron oxide (Fe_2O_3 and FeO) mixed with clays, silicates and an extensive range of mineral elements (Cornell and Schwertmann, 2003: Table 1.1; Barnett et al., 2005, p. 466; Popelka-Filcoff et al., 2007, p. 17; Easthaugh et al., 2008, p. 285).

African MSA archaeological sites often contain red ochre and red haematite, but yellow limonite, specular haematite, black manganese, green, yellow, pink, grey and purple shales, white kaolinite and brown goethite also occur (Henshilwood et al., 2001, 2009; Barham, 2002; d'Errico, 2008; Wadley, 2009; Watts, 2009, 2010). Wear patterns symptomatic of abrasive processing are common, indicating that the extraction of pigment powder was a principal objective during the MSA (Henshilwood et al., 2009, p. 29; Wadley, 2006a, p. 64). Preliminary analyses of processed ochres from Blombos Cave (Henshilwood et al., 2001, 2002, 2004, 2009; Henshilwood, 2007; Henshilwood and Dubreuil, 2009) indicate that specimens frequently exhibit wear traces not conclusively derived from grinding or scraping alone, suggesting that activities other than the extraction of pigment powder also occurred.

Diverse interpretations have been proposed for the use of ochre recovered from archaeological sites. Whereas symbolic readings (e.g., Knight, 1991; Knight et al., 1995; Power, 2001; Power and Aiello, 1997; Power and Watts, 1997; Watts, 1999, 2002, 2009) draw largely from ethnographic (Bleek and Lloyd, 1911; Marshall, 1961, 1976; Viegas Guerreiro, 1968) and historical accounts (Campbell, 1815; Burchell, 1822; Methuen, 1846; Stow, 1905; Silberbauer, 1965), functional interpretations (e.g., Keeley, 1980; Velo, 1984; Roper, 1991; Mahaney et al., 2000; Riel-Salvatore and Clark, 2001; Wadley et al., 2004, 2009; Lombard, 2007; Arocena et al., 2008; Prinsloo et al., 2008; Chambers, 2010) derive mainly from archaeological evidence and experimental results.

Ochre has been found inside perforated shell beads from several African MSA sites ranging from 92,000 to 70,000 years ago (d'Errico et al., 2005, 2008; Bouzouggar et al., 2007). These residues have been interpreted as (possibly) signifying the use of ochre as a body cosmetic with symbolic intent (d'Errico et al., 2005, 2008; Bouzouggar et al., 2007; d'Errico, 2008). The shell beads from Ifri n'Ammar, Taforalt and Rhafas in Morocco (92,000–60,000 years ago) were incorporated in beadwork designs and this was deliberately covered with red pigment (d'Errico et al., 2009b, p. 5). In the above examples ochres with the strongest red hues were selected, which challenges a purely functional interpretation for the presence of ochre (Watts, 2002, 2009). It is nevertheless imprudent to presuppose that the mere presence of ochre in archaeological contexts implies it was always connected with ritual activities and that it had symbolic significance (Riel-Salvatore and Clark, 2001, p. 459; Wadley, 2001, p. 204, 2005a, p. 3). But the possibility

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remains that seemingly secular activities may also have carried symbolic meaning (Lombard, 2007, p. 415).

Ethnographic records show that people attached considerable symbolic value to ochre. But they do not confirm that red ochre functioned exclusively in symbolic contexts, and do not explain how the symbolic use of ochre arose (d'Errico et al., 2010, p. 4). The exploitation of ochre of variable colour and geological origin is not limited to *H. sapiens* (see for example Koller et al., 2001; Grünberg, 2002; Soressi and d'Errico, 2007; Zilhão et al., 2010 for ochre exploitation by *H. neanderthalensis*) and its use does not reflect a 'quantum leap' from archaic to 'modern' patterns of behaviour (Conard, 2005, p. 310). The habitual exploitation of red ochres (see Watts (2002, 2009) for detailed explanations) may however represent a species-specific behavioural trait for *H. sapiens* (Henshilwood et al., 2009, p. 3; Watts, 2010, p. 393). Following the emergence of *H. sapiens* some 200,000 years ago (see White et al., 2003, p. 747; McDougall et al., 2005, p. 736) a noticeable preference for red colourants emerges (see Barham, 1998, 2002; Deino and McBrearty, 2002 for earlier red ochre occurrences). Ochres with a strong red hue predominate in MSA contexts from 100,000 years ago (Henshilwood et al., 2009, p. 3), to 143,000 years ago (Watts, 2009, p. 86, 90) and as early as 164,000 years ago (Marean et al., 2007, p. 906). Why there is such a striking preference for these strong red colours remains debatable (see Wadley et al., 2009; Watts, 2009).

Experimental archaeology

The analysis of pigments processed by *Homo neanderthalensis* in Europe and the Middle East presents a multifaceted approach in assessing the prehistoric use of ochre. The study by Soressi and d'Errico (2007) entailed an analysis of black manganese (MnO_2) chunks from the French Mousterian sites of Pech de l'Azé I and IV. At least 250 pieces from Pech de l'Azé I and 20 from Pech de l'Azé IV show clear signs of utilisation. Many of these exhibit traces of both primary (processing) and secondary (use) modification (Soressi and d'Errico, 2007, p. 305). Through experimentation, microscopy and profilometry the authors were able to conclude that, at 43,000 years ago, Neanderthals prepared pigments by grinding on coarse stone surfaces before rubbing them onto smooth soft materials such as animal hide or human skin. The study shows that careful analyses of archaeological ochres can expand our current understanding of the largely theoretical link between pigment use and the emergence of modern and symbolic behaviours. Although several studies have been published on ochre-use in southern Africa (Henshilwood et al., 2002, 2009; Watts, 2002, 2009, 2010; Wadley, 2005a, 2005b, 2006a, 2009, 2010; Lombard, 2006, 2007; Wadley et al., 2009; Hodgskiss, 2010), it is essential to subject pigments from South African MSA contexts to similar analytical procedures.

Experimental materials

In my experimental research, I used only materials and methods that were available or possibly used by MSA people (Wadley et al., 2009; Hodgskiss, 2010). These materials include sandstone, quartzite, mudstone and slate grinding stones, tanned gemsbok (*Oryx gazella*), springbok (*Antidorcas marsupialis*) and goat (*Ovis* species) hides, mixing agents (animal fat and charcoal), *Patella* sp. and *Donax* sp. shell mixing containers, silcrete, quartzite and quartz lithic implements, bone tools and marine shells. These materials were acquired from local resources and none were from archaeological sites.

The experimental ochres were sourced from four geological formations (Fig. 1). Shales, mudstones and weathered haematites were collected from the Groenkloof Nature Reserve in Pretoria and derive from the Timeball Hill deposits of the Transvaal Supergroup (Catuneanu and Eriksson, 2002). Ochre was also sourced from the De Hoop Nature Reserve and the adjacent Verfheuwel and Wydgelëe agricultural farms, the Cape Point Nature Reserve, Blomboschfontein Nature Reserve, and from exposed deposits between Bredasdorp and Napier in the Western Cape Province. These derive from the Bokkeveld Group deposits of the Cape Supergroup (Vorster, 2002), and are the most likely source of ochre at Blombos Cave (Henshilwood et al., 2009, p. 3). Ochre was also sourced from the Sevilla Nature Reserve in the Cederberg Mountains; the red shales derive from the Bokkeveld and Nardouw Groups deposits

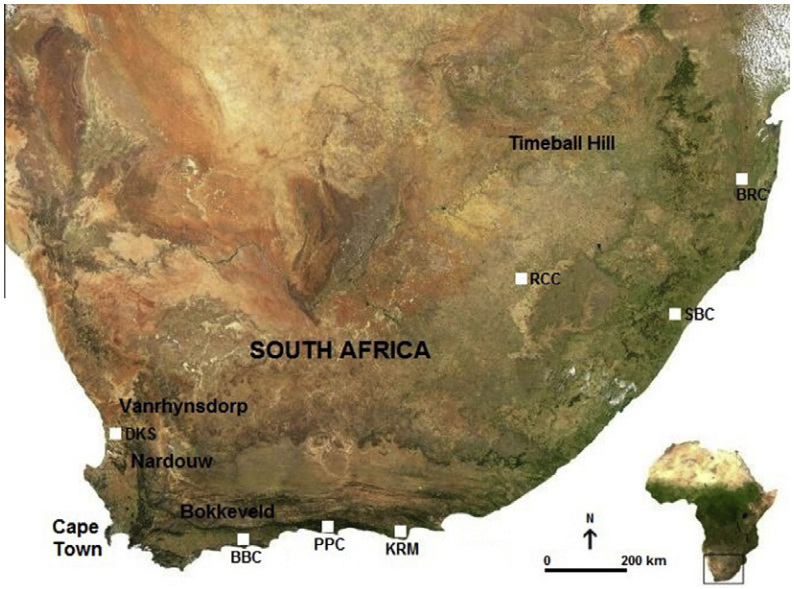


Fig. 1. Map of South Africa indicating archaeological contexts referred to in the text and the geological sources (the Timeball Hill, Vanrhynsdorp, Nardouw and Bokkeveld formations) from which the experimental pigment was obtained. Archaeological sites shown are: Blombos Cave (BBC), Border Cave (BRC), Diepkloof Rock Shelter (DRS), Klasies River Mouth (KRM), Pinnacle Point Cave (PPC), Rose Cottage Cave (RCC) and Sibudu Cave (SBC). (Map modified from satellite image courtesy Jacques Descloitres, MODIS Land Group, NASA Goddard Space Flight Centre.)

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of the Cape Supergroup, and the haematites from the Vanrhynsdorp Group deposits of the Gariep Supergroup.

Whilst sourcing ochre samples it was noted that the external surfaces of ochre seldom correlate with the colour and consistency of their internal contents. The weight of some pieces relative to others may provide an indication of iron content and colour, as heavier pieces are likely to contain more haematite from which the deep red hues of ochres derive. But frequently a heavy and seemingly iron-rich sample may be too hard to yield any powder. One way to ascertain whether a piece has the capacity to render fine pigment powder is to 'test' specimens by scraping them on hard rock, for example quartzite. Several MSA specimens exhibit what may represent traces of streak-testing (see Barham, 1998, p. 707; Henshilwood et al., 2009, p. 38), suggesting that ochres were consciously selected in the past according to specific criteria (such as hardness or colour). Given the efforts to extract and transport preferred ochres, these should comprise the bulk of samples recovered from archaeological contexts.

In the Still Bay and preceding MSA units at Blombos Cave, fine-grained sedimentary shales and siltstones are more common than coarse-grained sandstones and haematites (Henshilwood et al., 2009, p. 30). The incidence of abrasive wear traces on ochre correlates with geological derivation and with colour, with softer red shales being the most frequently processed category (Watts, 2009, p. 88). At Pinnacle Point Cave 13B, sedimentary shales and siltstones predominate over harder sandstones and haematites, and the incidence of wear traces is also markedly correlated with geological derivation and with colour (Watts, 2010, p. 408). Similar to the occupants at Blombos Cave, the inhabitants of Pinnacle Point appear to have favoured certain types of red ochres from known sources (Watts, 2010, p. 397). At 90 ka at Qafzeh Cave, Israel, local ochres were ignored in favour of more remote, but fine-grained and red sedimentary shales and siltstones (Hovers et al., 2003, p. 502; d'Errico et al., 2010, p. 6). Most of the ochre pieces chosen for my experiments were selected for their colour and hardness since they most closely represent those ochre pieces recovered from MSA sites.

Methodology

Functional data based on actualistic experiments can be utilised to formulate more refined interpretations of prehistoric behaviour (Hurcombe, 1992, p. 63; Odell, 2001, p. 62). Experimental activities were based on observations of wear traces (striations, grooves, faceting, polishes and residues) on and the morphology of processed ochres recovered from the Still Bay and preceding MSA levels of Blombos Cave. Wear patterns indicative of abrasive processing predominate, suggesting that the extraction of pigment powder was a principal objective (Henshilwood et al., 2009, p. 29). In my experiments I therefore concentrated on identifying the marks left on ochre after it was processed to obtain pigment powder. This was done by cutting ochre samples with stone and bone tools, scraping them with stone, bone and shell, grinding ochre onto stone surfaces and by grinding ochre between stone surfaces. The results showed that primary wear traces appear as a result of processing. Secondary traces of use wear emerged when ochre pieces were used for other purposes after pigment powder was extracted. Traces of primary (processing) and secondary (utilisation) wear were generated while varying four main parameters:

1. The type of processed raw material (shale, haematite, sandstone and mudstone).
2. The type of processing or contact material (quartzite, quartz, silcrete, slate, bone, shell, human skin and animal hide).
3. The method of processing employed (direct grinding, pounding, scraping, incising, cutting, rubbing and drawing).
4. The duration (in minutes) of the primary processing and secondary use actions.

The recording protocol followed during the experiments entailed: (1) allocating an experimental number to each specimen and the materials associated with that particular experiment; (2) noting the source and geological affinity for each sample; (3) recording the length and width (mm) and the mass (g) of samples prior and after processing; (4) noting the method of processing as well as the materials with which the specimen came into contact; (5) documenting the duration of the entire experiment (including photographic documentation) and the duration of the actual processing action, and (6) recording the amount of powder extracted from each specimen (g).

Definition of terms

Grooves, striations and striae are the most frequently observed wear marks on processed ochres. They are formed by the removal of the surface of the ochre and these marks generally form a linear pattern (e.g., Del Bene, 1979, p. 169; Del Bene and Shelley, 1979, p. 252; Diamond, 1979, p. 164; Hurcombe, 1992, p. 8). They occur as a result of abrasion through either direct grinding (defined as the manual processing of an ochre sample by grinding it directly onto a coarse grindstone surface) or applied scraping (when an ochre surface is abraded with the edge of a lithic implement held in one hand whilst the other hand secures the piece).

In lithic studies, linear wear traces exhibiting depth are called scratches, grooved scratches, furrows, sleeks, linear depressions and abrasion tracks. Superficial wear features are described as chatter marks or abraded lines (Vaughan, 1985, p. 12). In this study, I define grooves, striations and striae as follows: (1) 'striations' are straight or undulating, fine or deep, longitudinal marks often arranged parallel in groups and recurrently covering entire processed surfaces. Striations are visible to the naked eye and are therefore fairly substantial in terms of depth. Striations are multiple parallel grooves that are regularly formed by grinding against or scraping with a hard material (e.g., Hodgskiss, 2010, p. 4); (2) 'striae' refers to a finer and more superficial type of striation. Striae may vanish when processed specimens are brushed clean or rubbed against soft non-abrasive materials, such as animal hide or human skin. Striae are termed 'micro-striations' by Hodgskiss (2010: 4), and are defined as microscopically visible parallel striations which occur within grooves or on the surfaces of rubbed pieces; (3) 'grooves' refer to more robust linear wear features and occur more frequently than striations and striae. A groove is a broad category and includes any wide or narrow (and deep or shallow) linear furrow, including incisions, substantial striations and 'scratches'. No method of creation is implied by the term (e.g., Hodgskiss, 2010, p. 3). Grooves may completely cover facets and occur in groups or bands of several parallel features.

Polishes are defined as any shiny or glossy area that appears on ochre surfaces following secondary use (see Hodgskiss, 2010, p. 4). The formation of polishes can be ascribed to either additive (i.e., when sweat and skin oils are deposited onto ochre surfaces) or transformative (when ochre surfaces are slightly abraded and truly polished) processes. Polishes can however be mistaken for what is termed 'metallic lustre'. Although lustre is suggestive of metals, it describes the way in which light is reflected from the surface of any mineral (Malins and Tonge, 1999, p. 401). Sub-metallic lustres occur in near-opaque minerals with high refractive indices. Reported reflectivity is 55% for pyrite, 21% for magnetite and 28% for haematite, hence the suitability of these mineral elements for the manufacture of mirrors in Pre-Columbian South American contexts (Nelson et al., 2009, p. 1).

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Discernable grooves, striations, striae and polishes in particular do not however always occur ochres processed by grinding. Apart from the contact material, the geological composition of the specimen including grain size, hardness and the nature of the matrix, determines the formation and visibility of wear phenomena.

Experimental protocol

The experimental component of this study comprises 150 (numbered E1 to E150) experiments (Supplementary File 1). These consist of single processing events (e.g., experiments 1–7 and 15–21) when a specimen is only ground or scraped to extract pigment powder, and not rubbed onto animal hide or used to draw with. The primary and secondary activities comprise 320 individual experiments. When more than one processing action was performed during an experiment (e.g., experiments 33–36 and 76–82), or when supplementary (secondary use) activities were carried out after primary (processing) activities, experiments were labelled a, b, c, etc.

In the experiments discussed here, powder was extracted from ochres by grinding, scraping and cutting with shell, bone and lithic implements. Additional experiments explored the incidence of residue and polish on grinding stones, the nature of traces left by pigment powder, the surface covering capacity of powder and water mixtures and the abrasive capacity of ochre powder. It was found that the extraction of powder is best achieved by grinding ochres directly onto hard, coarse-grained grinding stones. Fig. 2 provides an indication of the steps involved in extracting powder from a shale-derived specimen by direct grinding (a primary processing action) onto a coarse quartzitic sandstone grindstone.

Secondary wear features occur when specimens are employed for additional purposes following the initial extraction of pigment powder. Secondary experiments were therefore carried out following the grinding of ochre on hard grindstone surfaces. The aim of these experiments was to produce traces of utilisation wear by rubbing ground specimens onto tanned animal hide and human skin, and colouring and drawing linear designs on tanned hide and stone plaques. A distinction is therefore made between primary processing-wear and secondary use-wear. Several specimens were subjected secondary processing activities during microscopic analysis. The formation of secondary traces could therefore be observed and documented whilst they occurred. Some specimens were subjected to circumstances that imitate depositional conditions and that of being transported in a leather pouch (Fig. 3).

Conditions that replicate depositional settings (e.g., Levi Sala, 1986; Grace, 1989) and 'transport wear' generally result in the removal of excess powder and the formation of a slight but unpolished 'sheen' (see Hodgskiss, 2010). Some ochre from Pinnacle Point Cave appears to have undergone prolonged curation and repeated processing. One sample was utilised over 90% of its surface and exhibits 14 small facets. The proximal end is the least utilised, with a few short scraping striae on an area inaccessible to grinding. The piece would have required prolonged processing to acquire this morphology, possibly over several episodes of use (Watts, 2010, p. 405).

Archaeologically, the processing of ochre appears to have occurred within social and residential settings. In the Still Bay, ranging from 78 ± 6 to 72.7 ± 3.1 ka (Jacobs et al., 2003; Tribolo et al., 2006), and preceding MSA levels of Blombos Cave, presently dated to a limit of 98.9 ± 5.5 ka (Jacobs et al., 2006), ochre grinding and scraping exhibits a random distributional pattern. There is currently no distinctive spatial separation between ochre grindstones, marine shells and lithic implements covered in ochre residue, processed ochres and the remains of hearths, terrestrial or marine species and lithic knapping activities. At Rose Cottage Cave (Wadley, 2006b, p. 289) and Sibudu Cave (Wadley, 2010, p. 2403) the distribution of artefacts associated with ochre processing also appears to be random. The experimental processing of ochre to generate wear traces may not therefore correspond entirely to the functional or social circumstances in which it occurred during the MSA. How

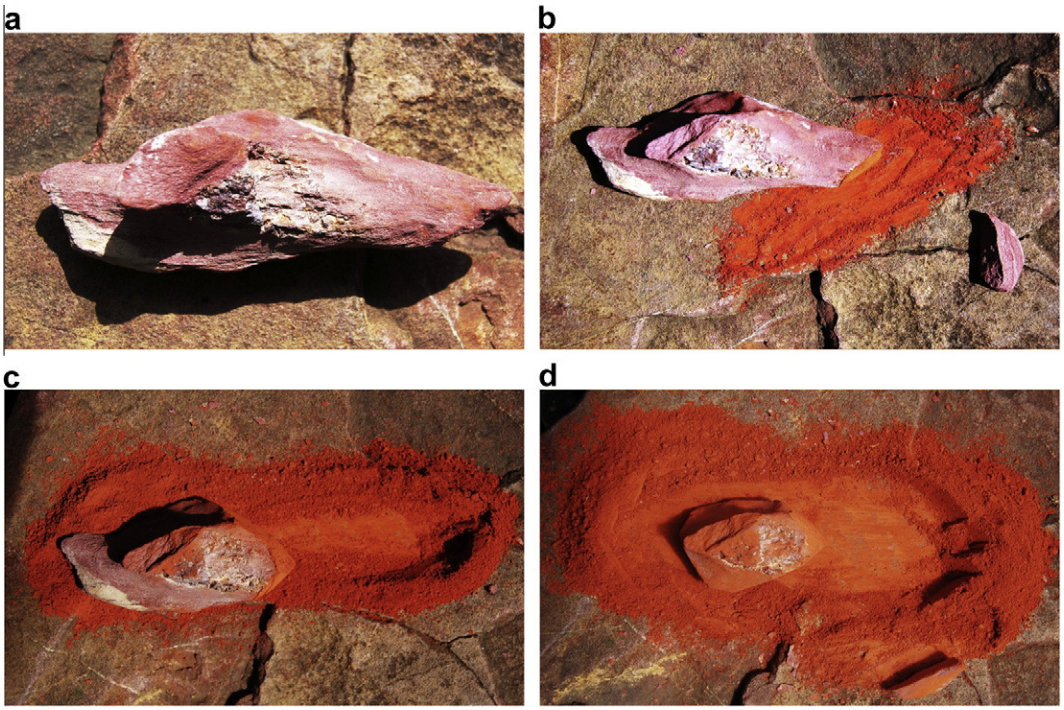


Fig. 2. The gradual reduction of a shale-based ochre specimen when ground directly onto a hard quartzitic sandstone grindstone. The specimen was processed as experiment number 46 (E46) for 33 min after which 22 grams of fine bright red powder was extracted: (a) the experimental sample as sourced and prior to processing; (b) after 2 min of processing the pointed end of the sample fractures; (c) after 19 min of processing fine red powder accumulates around the sample; (d) after 27 min of processing the samples acquires several converging facets and exhibits a crayon-like shape.

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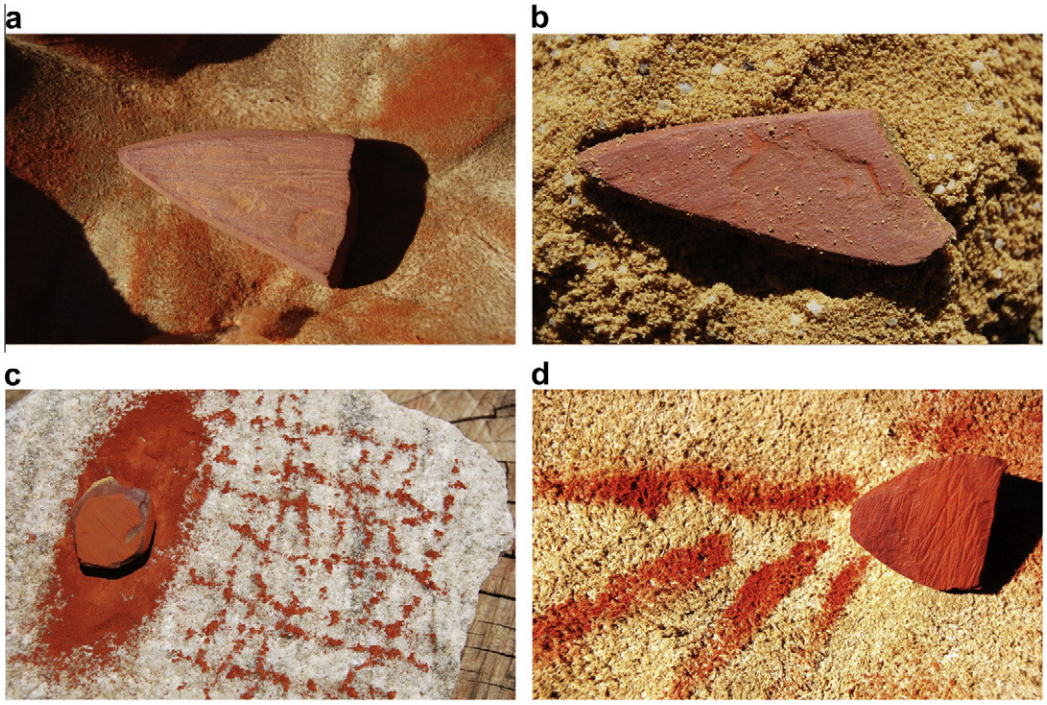


Fig. 3. The intentional generation of traces of secondary wear on processed specimens: (a) a shale-derived 'crayon' was carried in a leather pouch for 7 days during which most residual powder was removed from its surface and the angular edges acquired a 'clean' polished appearance (E36 C); (b) a shale-based 'crayon' was subjected to 7 days in a sand-filled sealed plastic container during which most residual powder was removed from its surface (E36 E); (c) after direct grinding a ground shale nodule was used to draw linear designs on a hard quartzite plaque during which several smaller adjacent or isolated striated facets developed (E85); (d) a processed shale specimen was used to draw lines on a soft tanned oryx hide during which most powder was transferred to the hide and the specimen acquired a 'clean' glossy appearance (E34).

this may influence the formation of wear traces on experimental ochres is uncertain, although the pace of processing may also have been either more intense or more leisurely, depending on the demand for ochre powder at any one time (see d'Errico and Vanhaeren, 2008; Henshilwood et al., 2009; Watts, 2010).

An additional variable that could not be observed during my experiments is the effect that post-depositional factors may have on: (1) the obstruction of original primary and secondary wear traces and (2) the formation of new non-anthropogenic wear traces. These issues are addressed by Hodgskiss (2010), and several additional studies (Vaughan, 1985; Grace, 1989; Levi Sala, 1986; Hurcombe, 1992; Shea and Klenck, 1993) have also demonstrated that natural processes can variably eradicate or result in the formation of marks that closely resemble, and in some cases are identical to, culturally generated wear traces. The interpretative potential of the database created by my experiments does not take into account the effects of unidentified taphonomic processes. For example, different post-depositional contexts, including varying depositional matrices and depths, the presence or absence of hearths, excessive or negligible amounts of lithic debitage, faunal remains or marine shell, differences in soil salinity, pH and moisture content, and the former and present positions of drip-lines and talus slopes may result in the variable preservation or eradication of wear traces on ochres. Although not addressed here, these issues are of importance and will be explored in terms of the unique taphonomic contexts from which respective ochre assemblages derive.

Macroscopic analysis of wear traces

Methodology

Macroscopic observations recorded during experimentation include: (1) the incidence of tactilely perceivable heat generated by frictional motion (i.e., when a specimen is ground directly onto a coarse hard surface), (2) the occurrence of damage (in the form of flaking or chipping) to the edges of processed facets, (3) the incidence of prehensile wear such as surface smudging or finger polish (areas smoothed and polished by the skin of the fingers), (4) the calculated frequency and nature (parallel, transverse, depth and profile) of striations striae and grooves and (5) the number and nature (concave and convex) of facets formed during processing.

Results

The incidence of macroscopic features noted during experimentation is listed in Supplementary File 1. Allocated numerical values (with 0 indicating the absence of a particular feature, 1 representing a limited (restricted) presence, 2 signifying a conspicuous presence and 3 indicating an extensive presence) were converted into percentages indicative of the frequency of incidence of certain features on processed and utilised specimens. The results are illustrated in Fig. 4.

The formation of facets is a distinctive feature of ochre grinding. Ground facets are typically even or slightly undulating in profile and covered in striations or grooves. Convex facets occur more frequently than concave facets (at 77.5% and 32.2% respectively). When raw materials contain coarse hard inclusions, these may be either abraded even or ripped from the processed surface. This results in the formation of rough, pitted surface 'scarring'. When grinding bone, flat or slightly convex facets covered by multiple fusiform striations develop (d'Errico and Nowell, 2000; Backwell et al., 2008). This is also the case for ochre, although the slight convex shape may in fact comprise two or more seemingly singular but separate facets. Single flat facets predominate when the raw material lends itself to grinding large flat areas. But when nodules are shaped irregularly, two or more adjacent facets may develop on the same processed plane. Not all the processed ochre nodules

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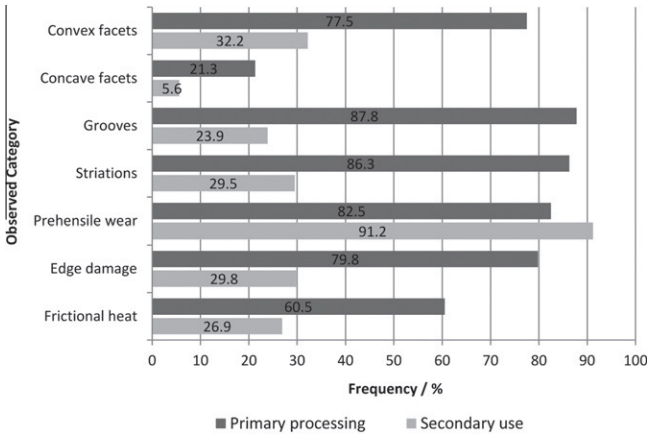


Fig. 4. Histogram indicating the prevalence of frictional heat, edge damage, prehensile wear traces, striations, grooves and concave and convex facets as observed macroscopically on primary processed (ground and scraped in dark grey shading) and utilised (in light grey) ochre specimens ($n = 320$).

formed converging facets (e.g., Hovers et al., 2003, p. 503). Most specimens retained their irregular shapes, reflecting the nature of the samples prior to processing. When specimens are roughly triangular before processing, a crayon-like shape develops without any effort on the part of the person grinding the ochre (e.g., experiment 36 a–j) (see also Wadley, 2005a, p. 5 for similar observations). Specimens are also most easily ground by frequent rotation, and this recurrently results in the formation of a crayon-like (triangular or elongated and generally pointed) shape. Scraping does not usually result in the formation of facets in the true sense. Instead, wide and generally concave zones with indications of associated (parallel) but individual (superimposed) instances of abrasion (i.e., grooves and striations) occur. In general terms, the formation of convex and concave facets typifies processing by grinding and scraping respectively. Convex facets are also a characteristic feature of ochres which are used to draw with on coarse hard materials, whilst concave facets are not a distinctive secondary attribute.

The formation of grooves and striations are typical of primary processing activities. Grooves and striations do not readily result form secondary use activities (except for when specimens are applied to hard abrasive surfaces such as quartzite) but are most likely to be obscured by slight abrasive forces and the deposition of fine pigment powder residue (resulting from rubbing on and drawing onto soft surfaces such as animal hide or human skin) into formerly visible grooves and striations. Whereas the prevalence of prehensile wear traces increases slightly during secondary activities (due to the increased amount of time spent physically manipulating the specimens), the incidence of frictional heat and damage to the edges of specimens occurs in less than 50% of the cases involving secondary use actions.

During most experiments involving hard iron-rich haematites, and to a lesser extent ochres derived from hard shales and sandstones, there was a distinct incidence of heat (60.5%) on the surfaces of processed specimens. In many instances (experiments 6, 17, 38, 50, 57, 64, 89, 93, 105, 112 and 128), it became difficult to grasp the samples without experiencing some discomfort. It was necessary to cease grinding for at least 30 s so that the specimen could cool down before proceeding with the experiment. Even at a macroscopic level, it was clear that specimens acquired a dark, glossy sheen or 'metallic lustre' (see also Hodgskiss, 2010, p. 6).

Semenov (1964, p. 14) termed abrasive wear associated with heat 'frictional wear'. The role of frictional heat in the formation of wear features on lithic implements has been a topic of discussion since the 1970s (Del Bene, 1979, p. 170, 174; Diamond, 1979, p. 162; Hayden and Kamminga, 1979, p. 7; Keeley, 1980, p. 166). Witthoft (1967, p. 384) was the first to suggest that frictional heat may be sufficient to 'melt' the surfaces of flint tools, thereby giving implements a fluid polished appearance. It is known that some of the friction that occurs during lithic manufacture and use dissipate as heat, and that high energy densities on small surface areas may be sufficient to render raw materials, such as quartz, pliable and prone to the development of highly polished sheens (Knutsson, 1988, p. 67). Thermal gloss is also a characteristic feature of heated lithic implements (Clemente-Conte, 1997, p. 530; Brown et al., 2009, p. 860), and there is some evidence that a high localised temperature is an important factor in the polishing processes of metals (Diamond, 1979, p. 163). It appears that these processes may also be responsible for the formation of metallic sheens or lustres on ground haematite specimens.

The incidence of edge flaking, and to a lesser extent edge fracturing, also characterises the processing of ochres by grinding. Most ochres are soft (using Moh's hardness scale) since they derive from sedimentary shales and siltstones. This renders them prone to the pressures of harder contact materials such as quartzite and sandstone. Harder haematites rarely exhibit instances of flaking or fracturing. During direct grinding, shale-derived ochres typically flake along their anterior and lateral ventral edges. Flake scars vary in size and most are visible to the naked eye. The extent of flaking depends on the edge angle of the specimen, the contact angle and the amount of pressure exerted. Flaking rarely occur at posterior ends where prehensile smoothing is more prevalent. While feather- and hinge-like terminations do occur, step terminations are the most common. These range from one to 25 mm in length and terminate abruptly, leaving steep sloping or stepped negative scars. Like flaking, fracturing most frequently occurs along natural flaws in the raw material (e.g., Lawn and Marshall, 1979, p. 66). Archaeologically, hard shales and harder haematites may have been purposely flaked prior to processing (see Barham, 1998, p. 706; Hovers et al., 2003, p. 500; Henshilwood et al., 2009, p. 31). As established by these experiments, this exposes the softer interior regions of the nodules from which fine powder may be more easily extracted by grinding.

Although macroscopic observations are informative, they do not provide comprehensive insight into the processes implicated in wear formation. The examination of wear traces on ochres therefore also benefit from the analytical techniques applied to lithic implements (Semenov, 1964; Keeley, 1980; Odell, 2003), grinding stones (Dubreuil, 2004; Hamon, 2008), bone implements (d'Errico, 1993; d'Errico and Villa, 1997; Backwell and d'Errico, 2001; d'Errico and Henshilwood, 2007) and shell beads and other forms of art (d'Errico, 1988, 1989, 1992; d'Errico and Nowell, 2000; d'Errico et al., 2005, 2009a, 2009b; Henshilwood et al., 2009).

Microscopic analysis of wear traces

Methodology

The aim of the microscopic examination was to identify and describe both the most prevalent and the most unusual primary (processing) and secondary (use) wear traces. The analysis of traces derived from different processing techniques and secondary uses depends largely on visual observation (see Soressi and d'Errico, 2007 for the use of profilometric surface measuring techniques), and in this study I used visual microscopy to examine wear traces left on ochre after they had been processed. Processed samples were observed with a Leica M125 stereo zoom microscope, and microphotographs were taken with a Leica DFL 295 colour digital camera.

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Attributes recorded during the microscopic analysis of the processed ochres include: (1) the nature and number of facets, (2) the prevalence of prehensile wear, (3) the types and nature of striations, (4) the presence of fine striae, (5) the types and nature of grooves and (6) the incidence of secondary wear traces. These variables differ from those recorded macroscopically in that changes in the morphology of specimens can be observed and described in a more detailed manner. For example, the profile shapes of grooves and striations are generally not discernable with the naked eye, but microscopic analyses have led to the recognition of rounded U-shaped, sharp V-shaped and angular or square (angular) U-shaped profiles.

Microwear formation

Microwear is formally defined as the progressive loss of substance from the surface of a body occurring as a result of motion (Burroni et al., 2002, p. 1279). Several causal phenomena have been identified, including adhesion, transfer, abrasion, plastic deformation, corrosion, chemical degradation and melting abrasion (see Rabinowicz, 1965; Sarkar, 1976; Zum Gahr, 1987; Arnell et al., 1991; Ludema, 1996; Anderson et al., 1998; Barceló et al., 2001 for detailed studies).

Although all these factors contribute to the formation of wear features of ochres (see for example Soressi and d'Errico, 2007; d'Errico and Vanhaeren, 2008; Hodgskiss, 2010; Watts, 2010), the microstructure of the raw material is also important to understanding morphological variability in processing wear traces. Sedimentary ochres are composite materials which, when compared to harder metamorphic materials such as quartzite or silcrete, exhibit substantial heterogeneity and brittleness. Models describing abrasive wear in modern composites are based on the 'equal wear rate assumption' which postulates that, at a steady state, different elements wear at an equal rate through the redistribution of abrasive pressures (Garrison, 1982; Axen and Jacobson, 1994). In the case of ochre, abrasive mediums affect harder and softer constituents alternatively and at different rates (Lee et al., 2002, p. 324). The levelling of processed surfaces, the removal of soft surface material to produce striations and grooves, and the removal of hard inclusions resulting in the formation of small 'pits' are mechanical abrasive actions. Additive tribochemical actions, for example the formation of surficial residues such as residual polishes or sheens (Hamon, 2008, p. 1508), also contribute to the formation of primary and secondary use wear phenomena (Buchely et al., 2005; Gluchy et al., 2008).

Processed archaeological ochres generally exhibit negligible traces of powder residue on their surfaces. This is due to the cleaning effect of the surrounding depositional environment which gradually removes excess powder residue from ochre surfaces (Levi Sala, 1986; Grace, 1989). To facilitate the optimal inspection of wear features, experimental samples were cleaned by dusting with a fine feather duster and by blowing the remaining powder residue from the processed surfaces with a camera lens-cleaning blower. This exerted the least amount of impact on the morphology, arrangement and visibility of processing and use wear traces (e.g., Evans and Donahue, 2005; Králík and Nejman, 2007).

Primary wear features

Primary wear or processing traces comprise the formation of surface features derived specifically from the processing of ochres by direct grinding or scraping. The most common types of processing wear traces observed include the development of grooves, striations and fine striae, the smoothing and polishing of interstitial ridges, the presence of unprocessed depressions or plateaus, the formation of flake scars on the edges and the presence of 'pitting' on processed surfaces. All these wear traces are essentially 'abrasion tracks' (Del Bene, 1979, p. 167; Keeley, 1980, p. 23; Hurcombe, 1992, p. 8), and occur either parallel, perpendicular or transversely in relation to the central axis of processed specimens. These features are illustrated photographically in Fig. 5.

The incidence of prehensile wear traces on processed specimens is a recurrent and inescapable phenomenon. Traces of prehensile wear have been observed on various archaeological objects (Králík and Nejman, 2007; Moran, 2007). On lithic implements this is manifest as glossy spots and light 'scarring' (Rots, 2005, p. 64, 2009, p. 40; Soressi, 2005, p. 400). It is argued that it is not the skin that determines polish formation but the material on which the implement is used (Rots, 2005, p. 65). Prehensile traces occur on the proximal ends of processed ochres, even when the experimenter's hands are clean and the specimen is the first to be processed during an experimental session (e.g., Del Bene, 1979, p. 170; Diamond, 1979, p. 160). This normally takes the form of either dull or glossy smooth, polished or smudged areas on the proximal ends of processed specimens. In some instances, the impression of the thumb or forefinger still retains an oily residue and traces of the fingerprints are visible.

In these experiments, prehensile wear traces (e.g., experiments 57, 46, 60, 64, 68, 84, 86, 98, 101, 127, 141 and 143) entail the formation of smoothed or polished areas derived from oily residues from the fingertips, and from smudging from sustained pressing onto specimen surfaces. Some prehensile traces should therefore be interpreted as primary processing related features since many of these polishes in fact comprise surface alterations and are not merely additive (e.g., Hurcombe, 1992, p. 13). The four principal types of prehensile wear traces (surface smoothing, deposited residues, surface smudging and the incidence of polish on interstitial ridges) are illustrated in Fig. 6.

The identification of these four different prehensile wear types may not however be as clear-cut on archaeological ochres. The prehensile wear traces identified on experimental specimens comprise freshly produced phenomena, the formation of which could also be observed during processing and secondary activities. Apart from substantial amounts of prehensile residue, it is unlikely that superficial prehensile traces (especially surface smudging and polishing) will survive the abrasive effects of most post-depositional environments.

Secondary wear features

Secondary wear traces are defined as surface features which emerge when processed specimens are employed for additional purposes following the initial extraction of pigment powder by grinding or scraping. Although secondary features are variable in nature, they persistently result in the alteration or elimination of primary processing features. The two foremost secondary activities explored include the use of ochre specimens as 'crayons' to draw on and to colour in hard abrasive and soft non-abrasive materials (Fig. 7).

The presence of crayon-shaped ochres in archaeological contexts has prompted the suggestion that ochre was, on occasion, used like modern crayons to draw on surfaces to create coloured patterns (e.g., Soressi and d'Errico, 2007). If the morphology of processed crayons is not simply the result of intensive powder reduction, and if they have colour properties consistent with preferential selection, then the use implied by their designation as crayons becomes plausible (e.g., Watts, 2002, p. 3; Wadley, 2005a, p. 8).

When specimens are rubbed clean on animal hide, most powder residue is removed resulting in a slightly polished appearance. When rubbed on human skin, specimens may acquire a residual (greasy) glossy sheen. These surface alterations are most prominent on elevated areas such as interstitial ridges and unprocessed

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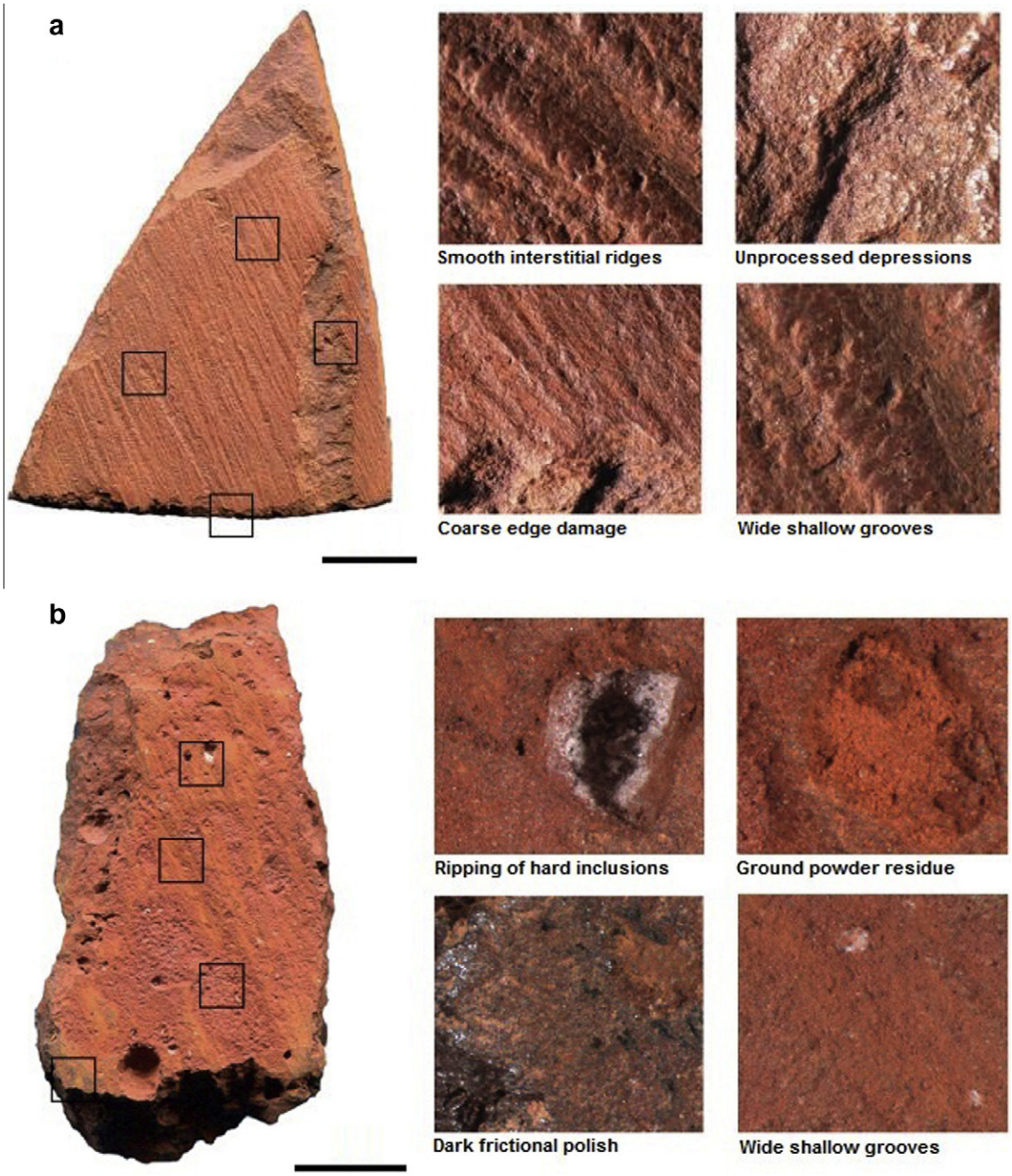


Fig. 5. The incidence of primary processing traces on experimental specimens (at 10× magnification). Features are indicated clockwise from the top towards the centre: (a) smoothed interstitial ridges unprocessed depressions coarse edge damage and wide shallow grooves on a hard shale-derived sample processed by direct grinding onto a coarse sandstone grindstone (E30); (b) the incidence of surface pitting powder residue dark frictional polish and wide shallow grooves on a hard coarse-grained haematite sample processed by direct grinding onto a coarse quartzite grindstone (E103) (scale bars represent 1 cm).

plateaus. Small amounts of excess powder residue may be forced into deeper wear features such as grooves, pits and unprocessed depressions, and the direction of the rubbing action can often ascertained from the angle at which powder residue fills these depressions (e.g., Figs. 5 and 7b).

Results

In order to measure the frequency of incidence of wear features on processed and utilised ochres, an ordinal evaluation scale, such as that employed by Rots and Williamson (2004, p. 1290) to assess the incidence of wear traces on lithic scrapers, was formulated. Ordinal scales (Stevens, 1946) assign values to features which represents the rank order of the assessed entities in relation to each other. For example, colour can be measured in accordance with a perceptual colour model, the Natural Colour System®© (NCS) in which each colour is assigned a unique code based on hue, blackness and chromaticness. Although the differences between allocated values each of which represents a different colour are not quantifiable, each value is representative of a very specific shade, tint or hue. Apart from standardised ordinal systems such as the NCS colour code, results for ordinal scale assessments can usually not be compared among different studies. The concept of order is nevertheless significant, and ordinal measurements can provide

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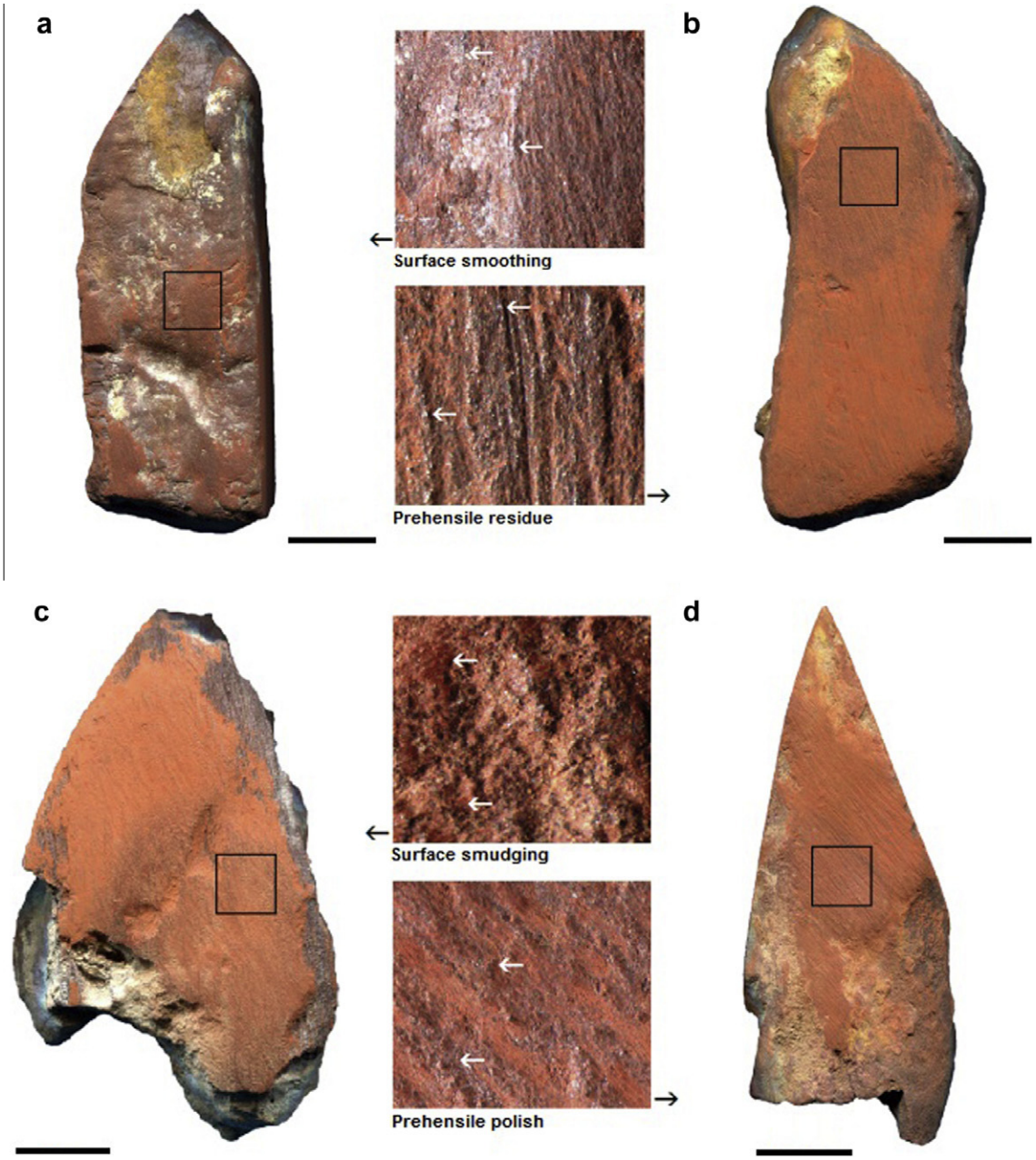


Fig. 6. The incidence and nature of prehensile wear traces on experimentally processed specimens (at 8× magnification): (a) surface smoothing on the unprocessed face of a hard fine-grained shale specimen (E57); (b) prehensile residue on the formerly processed facet of a hard haematite sample (E64); (c) surface smudging on a coarse-grained shale specimen (E68); (d) prehensile polish on s soft shale derived specimen (E98) (scale bars represent 1 cm).

an accurate assessment of variation within a single study (see Jamieson, 2004, p. 1217).

The ordinal values allocated to the recorded attributes (i.e., the nature and number of facets, the prevalence and types of prehensile wear, the types and nature of striations, fine striae and grooves, the incidence of secondary wear traces and the rounding of edges and interstitial ridges) are indicated in Supplementary File 2. For the purpose of analysis, numerical values (with 0 indicating the absence of a particular feature, 1 representing a limited (restricted) presence, 2 signifying a conspicuous presence and 3 indicating an extensive presence) were converted into percentages indicative of the frequency of incidence of features on processed and utilised specimens. The results are illustrated in Fig. 8.

Resembling the results presented in Figs. 5–7, the frequencies of incidence vary in terms of primary processing activities and the secondary use of specimens for colouring soft non-abrasive materials (human skin and animal hide) and harder abrasive substances (quartzite and sandstone surfaces). In the striation category, U-, V- and angular U-shaped profiles, and the parallel arrangement of striations, recurrently occur as a result of primary processing (grinding and scraping) activities. Only transverse (obliquely arranged in relation to the central axis of the processed specimen) striations occur most frequently following secondary use (drawing or rubbing) activities. The same pattern of frequency applies to the formation of grooves small pit-like structures and the presence of powder residue. Conversely, the smoothing of processed surfaces, the rounding of specimen edges and the occurrence of prehensile wear and surface 'polishes' predominate following secondary use activities. Fig. 9 provides a more explicit representation of the tendencies displayed by the data presented in Fig. 8.

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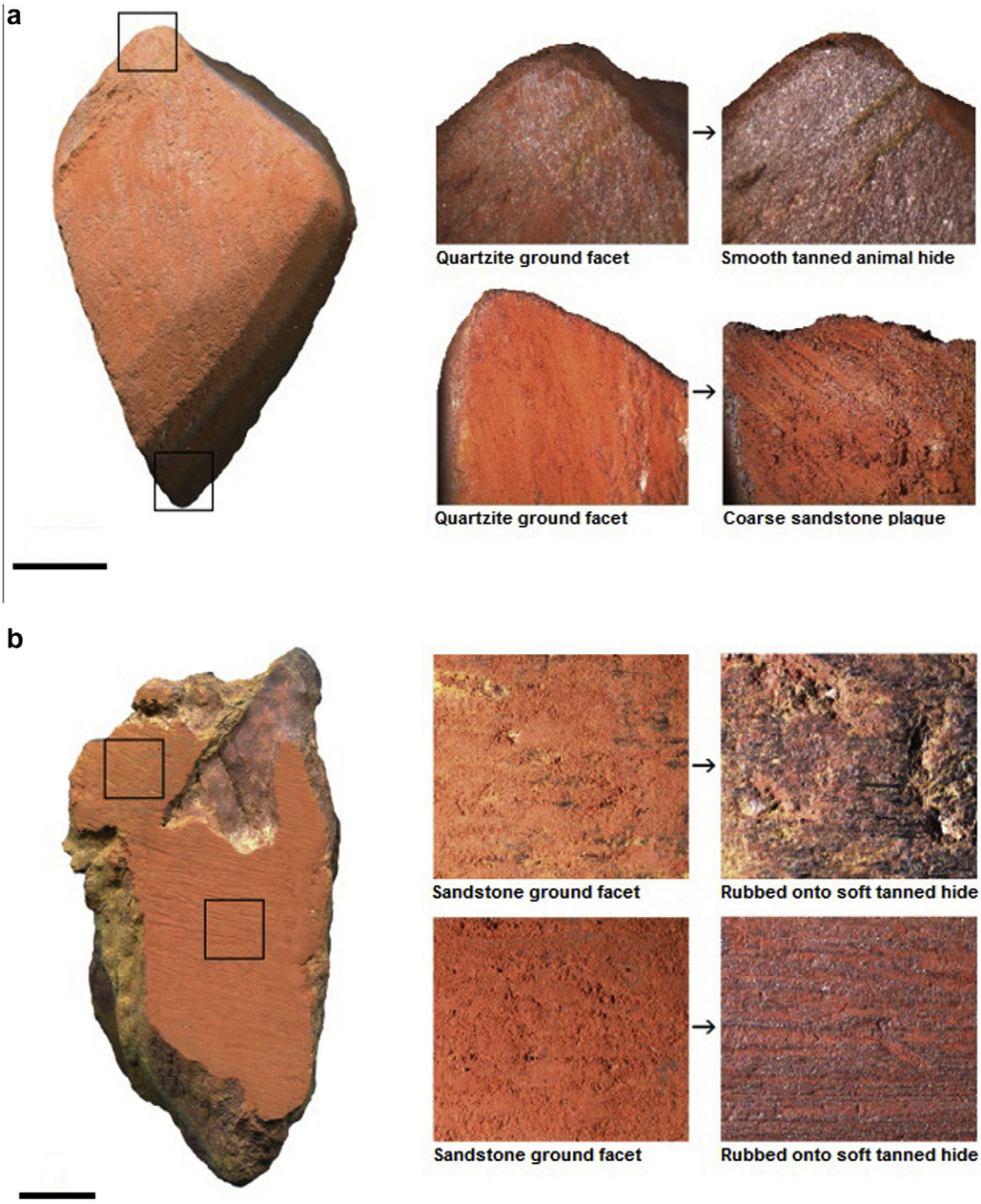


Fig. 7. The incidence and nature of intentionally produced secondary traces of use on experimentally processed specimens: (a) drawing linear designs on soft smooth tanned animal hide (top) and on a coarse sandstone plaque (bottom) (at 4× magnification) (E52); and (b) rubbing the ground sample onto soft tanned animal hide until no powder residue remains (at 6× magnification) (E99) (scale bars represent 1 cm).

Following the use of processed specimens for secondary purposes such as drawing on or rubbing onto coarse hard surfaces, there is a perceptible increase (9.6%) in the frequency of transverse (linear) wear features (grooves, striations and striae). When specimens are rubbed onto or used to draw on soft smooth surfaces, slight transverse striae may develop along with the oblique displacement of residual powder into striations, grooves and unprocessed depressions. The secondary application of processed ochres to soft surfaces also results in an increase in surface smoothing (by 30.3%), edge rounding (75.2%), prehensile wear formation (11.8%) and the development of 'polishes' or 'sheens' (41.5%). Although the incidence of metallic lustres is not indicative of specific processing activities, haematite is particularly prone to acquiring metallic sheens or lustres when ground onto hard surfaces; 70% ($n = 24$) of processed haematite specimens display these features. Polishes can be identified by their sheen, but this is not silver like a metallic lustre and it does not form an opaque layer on top of the processed surface (Hodgskiss, 2010, p. 12).

Using four individual experiments as representative examples, Fig. 10 provides additional insight into the morphological changes

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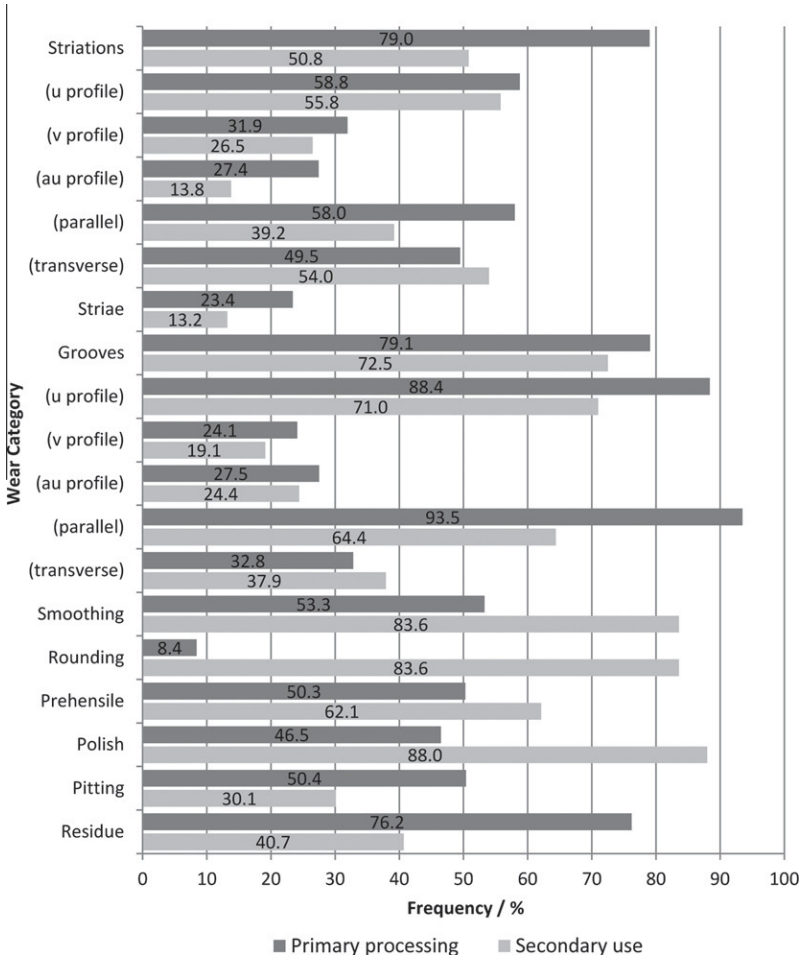


Fig. 8. Histogram indicating the prevalence of primary processing (in dark grey shading) and secondary use (in light grey) wear traces as observed microscopically on experimentally processed specimens ($n = 320$).

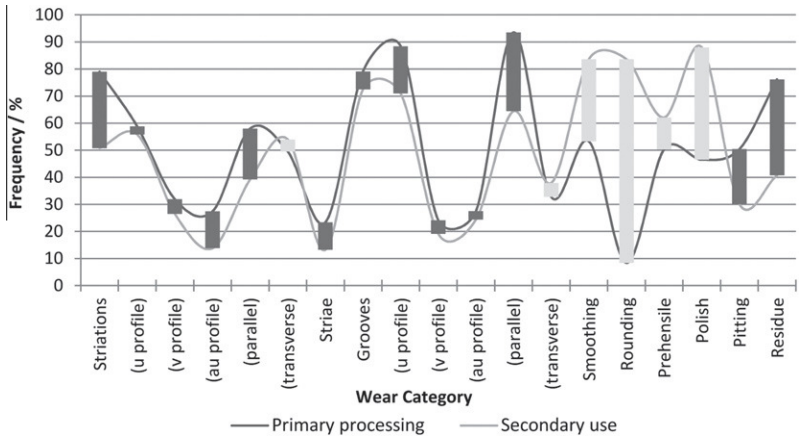


Fig. 9. Histogram indicating the relationship between the incidence of primary (vertical bars in dark grey colour) and secondary (unfilled bars) wear traces as observed microscopically on processed specimens ($n = 320$).

that occur when processed specimens are used for secondary activities such as drawing and colouring on either hard or soft materials. Further information on these and other primary and secondary processes is provided in Tables 1 and 2.

During primary processing activities (indicated by dark grey shading), an average of 2.6 facets ($n = 209$) formed on specimens. Facets were covered in parallel (but also some transverse) grooves, striations and striae. Processed surfaces exhibited only minimal traces of surface smoothing, surface (predominantly edge) rounding and prehensile polish formation. The presence of traces of prehensile wear was noted in 50% of all instances. Surface pitting was common on coarse-grained specimens with hard inclusions and substantial amounts of pigment residue remained present on processed surfaces.

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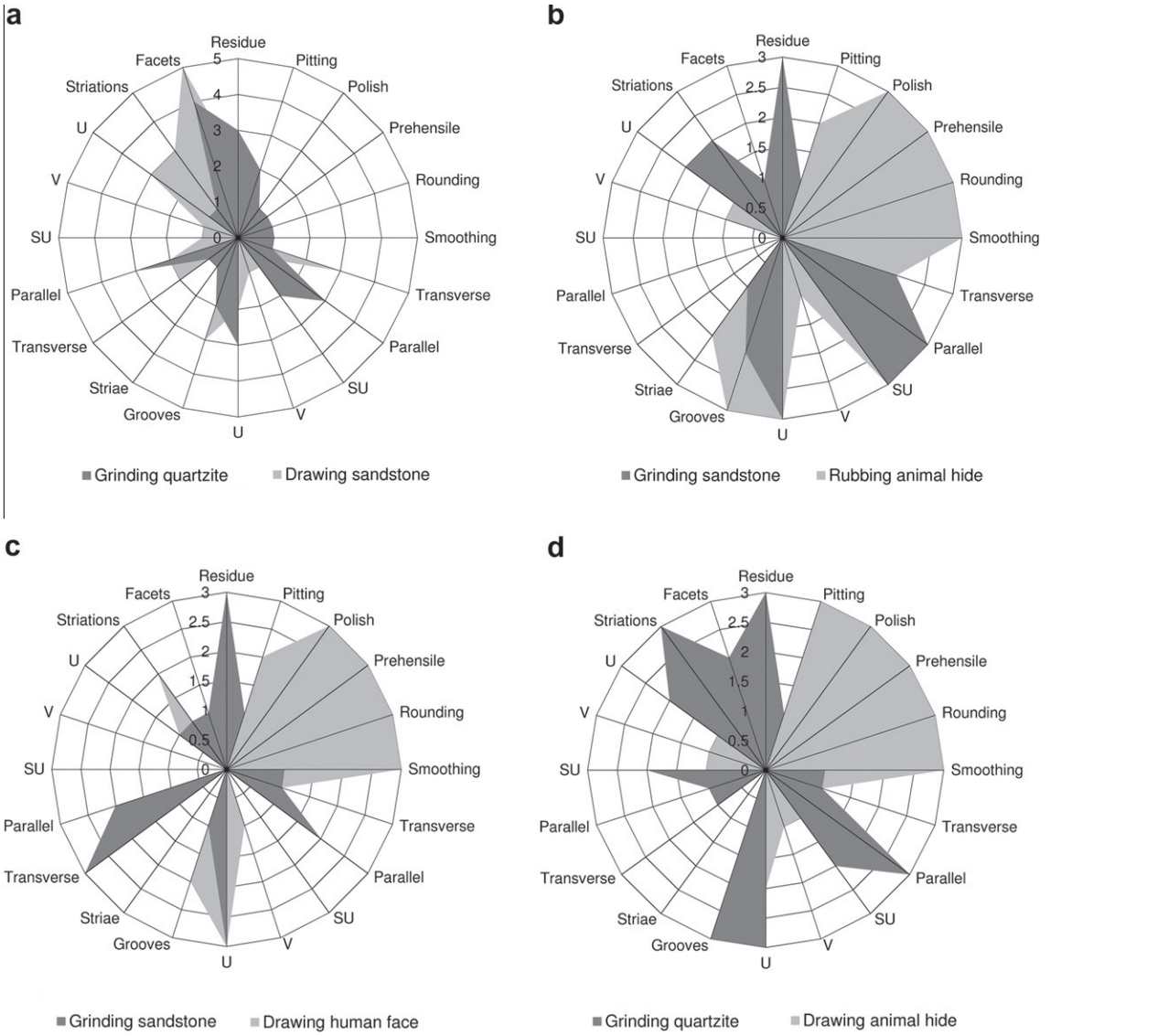


Fig. 10. Polar radial plots of data recorded for four individual experiments which illustrates the changes that occur as a result of subjecting processed samples to secondary use activities: (a) grinding a piece of ochre on a coarse-grained quartzite grindstone and then using it in a bidirectional manner to draw linear designs on a sandstone plaque (E52); (b) grinding an ochre specimen on a coarse sandstone grindstone and then colouring soft tanned animal hide by rubbing the piece onto the hide until 'clean' (E79); (c) processing an ochre sample on a coarse sandstone grindstone and then using it to draw broad linear patterns on the experimenters face (E89); (d) grinding a piece of ochre on a coarse quartzite grindstone and then using it to draw unidirectional linear designs on soft tanned animal hide (E108).

Secondary processing activities (indicated in light grey shading) resulted in both an increase and a decrease in the formation of (principally convex) facets. Whereas drawing on hard materials resulted in the formation of 2.8 facets per specimen ($n = 21$), drawing on soft materials, such as tanned animal hide and human skin, resulted in the creation of 1.6 facets ($n = 15$). No additional facets were derived from rubbing processed specimens on soft pliable materials such as tanned animal hide and human skin, although primary wear traces (such as striations striae and grooves) were either partially obliterated or removed completely. At the same time, there was an increase in the frequency of surface smoothing and edge rounding. The prevalence of prehensile wear traces (polished areas and residual deposition) and the formation of polishes or sheens were also amplified. Most residual pigment powder was removed from the surfaces and displaced onto the contact material. Instances of surface pitting remained visible, although many such traces were obscured by the displacement of residual powder into these features.

Table 1 provides a summary of the principal characteristics and the major variations in primary wear features as observed on experimentally processed specimens.

Despite these characteristic attributes, there exists a fair degree of variability in the traces produced by grinding scraping and incising. That different processing traces arise from different types of grindstone surfaces is illustrated by experiments 48, 130 and 131. Experiment 48 comprised grinding four pieces of shale-derived ochre (removed from a single larger piece) onto coarse sandstone, medium-grained mudstone, smooth slate and very coarse quartzite surfaces. Experiments 130 and 131 also tested the effects of different grinding surfaces on wear formation and powder extraction. The intensity of wear traces (grooves and striations) corresponds to the coarseness of the processing surfaces; the more coarse-grained a processing surface, the more prominent the wear traces on the specimens. Grainy quartzitic sandstone surfaces prove to be the most efficient in terms of extracting pigment powder. In most instances the powder is

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Table 1
Principal characteristics and major variations in primary wear features observed on pigment samples processed during this study.

Process	Characteristic features
Grinding	Grinding can be inferred where surfaces are abraded to smooth and generally convex facets bearing multiple parallel striations, striae or grooves. Grooves are usually wide and shallow with flat or vertical striated and frequently polished interior surfaces. The edges of grooves may be either jagged or smooth, depending on the coarseness of the processing material. Grooves may also occur as single long or shorter abrupt transverse features. Deeper V-shaped grooves may derive from incisions or if processing surfaces are especially coarse. The frequency of striations and fine striae depends on how coarse or smooth the processing surfaces are. U-shaped groove profiles are the most common, followed by angular U and deeper V-shaped profiles. Various forms of 'polish' do occur occasionally but mostly in the form of dark lustres or shiny sheens. These most likely result from frictional wear. Glossy residual polish is uncommon on ground pieces but do occur erratically. Facets are a characteristic feature of grinding and may converge to form pointed tips and crayon-like specimens. The number of facets depends on how often a specimen is rotated (due to discomfort or to avoid hard inclusions and target soft zones). Ground specimens usually retain their original shape, but when ground directly until exhausted (when too small to grasp) thin crayon-like shapes prevail. Wet grinding is not a suitable powder-producing method and results in the formation of dark muddy substances. Grinding traces display a variety of profile shapes due to variability in processing materials (e.g., coarse sandstone or smooth quartzite) which differ in the number and sizes of hard protruding features (e.g., Hodgskiss, 2010)
Scraping	Repeated applications of a scraping tool to the same area results in wide grooved and concave areas (e.g., Hovers et al., 2003, p. 502; Henshilwood et al., 2009, p. 30). Scraping produces parallel features of different width and depth resulting from projections on the contact surface of the implement used (e.g., Henshilwood et al., 2001, p. 432). With scraping, striations are generally less evenly aligned, less densely packed and shallower than those resulting from grinding. Scraping with shell and lithic implements also produce shallow or deep striated grooves arranged in wavy parallel patterns. Wear traces (striations and grooves) usually do not reach the ends of processed facets. Scraping produces sufficient amounts of pigment powder which is most often coarser than powder extracted by conventional direct grinding. As opposed to direct grinding, scraping does not result in edge flaking or chipping. Scraping traces display a range of profile and facet shapes which depends on the materials used and on the intensity of the scraping process. Scraped surfaces are mostly convex in profile but may also be present along and around the edges of specimens
Incising	Grooves resulting from cutting and incising generally incorporate several fine striations and striae along their interior semi-vertical edges. The elevated interstitial ridges that develop between striations and grooves may be either rounded or coarsely angular. Incisions generally leaves several unprocessed interstitial ridges and plateaus, and the sequence of individual actions may be determined with relative ease (e.g., Henshilwood et al., 2009). When organic materials are used to incise specimens (shell or bone) some residue nearly always remain in the grooves. Deliberately engraving juxtaposed lines (e.g., Henshilwood et al., 2009) produces very little pigment powder and differs markedly from repetitive incisions which are made to extract pigment powder. Repetitive incisions with a lithic implements generally produces little pigment powder and results in the formation of distinctive deep V-shaped grooves with internal micro-striations. These usually do not reach the ends of processed facets

Table 2
Principal characteristics and major variations in secondary wear features observed on ochre specimens processed during this study.

Process	Characteristic features
Drawing	The formation of additional smaller facets on the tips of contact edges is a characteristic feature of drawing or colouring harder abrasive substances. Drawing on hard materials (quartzite and sandstone) resulted in the formation of 2.8 facets ($n = 21$) per specimen. Drawing on soft materials (animal hide and human skin) does not normally produce additional facets although this did result in the formation of in 1.6 facets per specimen ($n = 15$). This relates mostly to tanned animal hide and not to human skin (the arm or face). which cleans and polishes but does not abrade ochre specimens. Drawing on very coarse materials usually produce wear traces analogous to that of grinding, i.e., parallel and transverse grooves, striations and fine striae. Pitting may also occur and substantial amounts of powder residue accumulates in these regions. The presence of several small additional facets concentrated at or around the tip of what may represent a crayon is the most diagnostic feature of drawing. The processed planes of these facets usually exhibit wear traces (grooves and striations) transversely or perpendicular to those derived from the initial grinding or processing action
Rubbing	Rubbing seldom modifies the surface shape of pieces but some may become either flat or slightly convex (e.g., Hodgskiss, 2010). Rubbing rarely results in the formation of facets. Rubbing on hard materials (such as quartzite and sandstone plaques) resulted in the formation of 1.3 facets ($n = 86$) per specimen. No additional facets were derived from rubbing processed specimens on soft pliable materials such as tanned animal hide and human skin. These facets do however experience substantial rounding and smoothing. Polishes and residues are also fairly common but depends on the materials on which the specimens are rubbed (e.g., human skin and animal hide). Rubbing on hide cleans the processed surfaces and usually result in the formation of smoothed interstitial ridges that may appear shiny or polished. Rubbing on human skin or the human face result in shiny smoothed facets that appears very 'polished' and which may contain some for of skin residue (oils or sweat). Most wear traces in fact become more visible, especially deeper grooves, striations and unprocessed surfaces. Superficial wear races such as fine striae and striations may disappear completely. Rubbing produces few grooves or diagnostic wear traces unless grainy debitage result in auto-abrasion. This is however very rare and most rubbed pieces are smoothed, polished to different degrees and exhibit both a loss of wear traces and the emergence of formerly invisible wear features (e.g., pits and deepgrooves)

fine-grained and of an intense colour. Smooth grindstone surfaces are less suitable for extracting fine-grained powder from ochres (e.g., Wadley, 2005a, p. 5). The use of a combination of processing techniques in antiquity seems plausible, depending on the hardness of the ochre and the availability of suitable grinding surfaces or crushing stones.

Excessive and moderate grinding pressures (e.g., experiments 17, 18 and 45) also bring about the formation of noticeably different wear phenomena. Whereas the prevalence and permanence of wear traces (e.g., grooves, striations, edge flaking, specimen fracturing and surface pitting) increases with excessive grinding pressures, moderate grinding results in the formation of clear linear wear traces (grooves and striations), but without the same frequency of edge damage and sample fracturing.

When ochres are processed by indirect grinding or pounding (e.g., experiments 28, 44, 71 and 95), marked differences in powder consistency (grain size) and colour occurs. Apart from outwardly dissimilar colours, differences in extracted powder colour result either from internal inconsistencies (e.g., Barham, 1998, p. 705) or from different methods of processing. Conventional grinding entails applying pressure to a pigment sample by placing it between an upper and lower grindstone surface (see for example Gooch, 1882; van Damme et al., 1922; Mason, 1951; Deacon et al., 1978; Rudner, 1982, 1983; Sealy et al., 2004; Youngblood, 2004; Sadr and Fauvelle-Aymar, 2006 for archaeological and ethnographic examples). The experiments revealed that it is often necessary to crush hard haematites to gain access to the softer interior, but the resultant powder is usually of a coarse consistency and of a less intense hue than when ground directly. There is also substantial wastage in terms of the amount of powder and small flakes that fall to the ground, and more time is required to grind all the minute fractured pieces into a powder.

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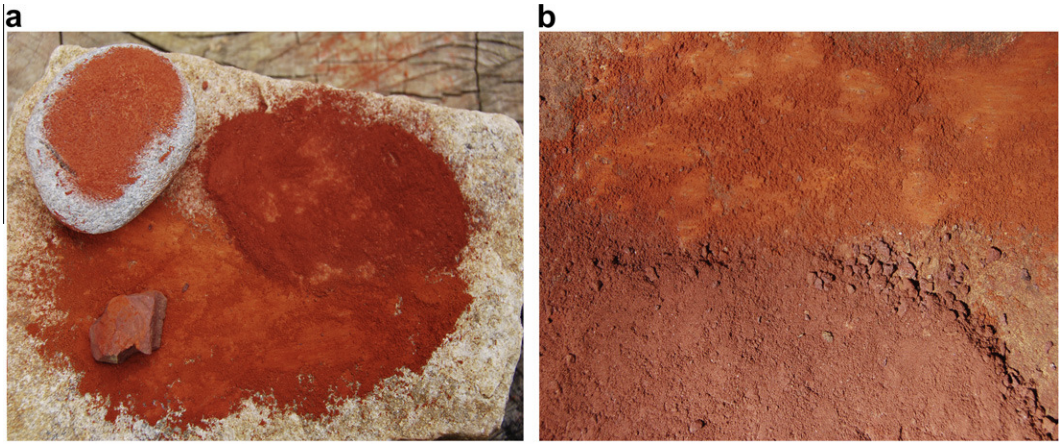


Fig. 11. Differences in powder colour and brightness resulting from either direct or indirect means of processing: (a) direct (at bottom with ochre specimen) and conventional (at top with quartzite cobble) grinding methods result in powder of differential grain size and colour (E71); (b) in several instances there is a marked colour difference between the powder extracted by conventional (dull coarse powder at bottom) or direct (bright fine powder at top) grinding (E44).

Direct grinding is the most efficient method to extract fine powder from softer shales and siltstones. A specimen sourced from shale deposits in the Cape Point Nature Reserve was processed as experiment 71 (Fig. 11 a). It was ground on a quartzite grindstone for three minutes, and then between a quartzite grindstone and a quartzite cobble for six minutes. During direct grinding it was possible to select which facets to grind according to the arrangement of natural sedimentary layers and the size of the surface area exposed. Grinding along its natural sedimentary grain produced more fine-grained powder than grinding transversely to natural layers. Whether archaeological specimens were also ground in this manner remains to be ascertained. There was also less wastage in terms of edge flaking, and less resistance. The specimen did not 'wobble' across the grindstone surface, less pressure had to be applied to extract powder and the fingertips were not prone to accidental grinding.

Besides the amount of iron, crystal structure and the degree of cementation, the colour of ground ochres also depends on the sizes of individual grains (Torrent and Barron, 2003, p. 309; Marshall et al., 2005, p. 240; Elias et al., 2006, p. 74; Legodi and de Waal, 2007, p. 162, 167; Wadley, 2009, p. 166; Mastrotheodoros et al., 2010, p. 53). Haematite is dark purple at 0.4 μm, but at 0.1 μm it appears to be maroon (Lane et al., 2002, p. 2). Goethite also increases in darkness and redness as crystal size decrease from 0.8 μm to 0.05 μm (Scheinost and Schwertmann, 1999, p. 1468). Archaeologically, ochres were frequently heated to obtain more desirable redder hues (e.g., Hovers et al., 2003; Godfrey-Smith and Ilani, 2004; Wadley, 2009). This occurs when exposure to temperatures in excess of 300 °C alters the crystalline structure of goethite and 'limonite' (a poorly defined term used to refer to yellowish rocks at least partially composed of goethite or other hydrated iron minerals), resulting in what is termed 'disordered haematite'. In essence, the mineral crystals become smaller during heating, resembling that of normally crystallised haematite (Helwig, 1997, p. 42).

In addition to the variability displayed by primary wear phenomena, there are also some shared similarities with secondary use phenomena. Table 2 provides a summary of the principal characteristics and variations in secondary wear features observed on processed specimens.

Activities comprising single (primary) processing events, such as grinding, scraping or incising, can be identified with reasonable accuracy. But multiple and consecutive processing activities (i.e., secondary uses) are more difficult to interpret, even when it appears possible to trace the various processing steps and sequences of wear formation (see Hodgskiss, 2010, p. 14). This is so because the abrasive methods implicated in the processing of (extracting powder from) ochres are reductive processes during which the majority of former processing traces are eradicated, leaving very few superimposed traces for the analyst to examine.

Discussion

The experiments carried out for this research were designed to investigate the formation of primary and secondary wear patterns on ochres processed by methods and materials that were likely available during the MSA. As demonstrated by Hodgskiss (2010, p. 14), different processing techniques and secondary uses result in the formation of largely distinctive wear phenomena on ochres. It must be noted that this conclusion is rooted in the experiential nature of ochre-processing and -use experiments. Without the practical awareness derived from the observation of the actions and processes implicated in the formation of wear phenomena, the interpretation of wear traces on archaeological specimens is much less likely to be accurate. The next step is establishing whether the database that resulted from the experiments could be used for the analysis and interpretation of wear traces that occur on ochres derived from archaeological contexts. Several processed specimens derived from Blombos Cave were examined macroscopically and microscopically, and compared to experimentally processed samples.

Archaeological contexts

The Still Bay (units CA, CB, CC, CD, CFA, CFB/CFC and CFD), and preceding MSA levels of Blombos Cave comprises a broad range of artefacts, some of which provides information concerning the development of complex social and symbolic behaviours over time. These artefacts include perforated ochre-stained *Nassarius kraussianus* shell beads (d'Errico et al., 2005), delicately fashioned bone implements (d'Errico and Henshilwood, 2007) and complex lithic manufacturing technologies (Mourre et al., 2010). The incidence of deliberately engraved juxtaposed lines on several ochres (Henshilwood et al., 2009), the presence of ochre crayons and the preferential modification of the most saturated red ochres permits the conclusion that the principal role of ochre at Blombos Cave was as an earth pigment (Henshilwood et al., 2001, p. 445).

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The ochre specimens illustrated in Fig. 12 derive from four Still Bay units at Blombos Cave. These specimens exhibit the majority of wear traces that are observed on experimentally processed ochres.

As indicated by Tables 1 and 2, grooves and striations are the most frequently observed phenomena on ground and scraped ochres, while the formation of convex and concave facets typifies processing by grinding and scraping respectively. The wear features interpreted as percussive pitting (Fig. 12h) and trampling wear (Fig. 12i) were not observed on any of the experimental specimens. The first interpretation is based on an observation of the processes responsible for the formation of similar pit-like structures when representational images are engraved (pecked) into hard dolerites and quartzites (Rifkin, 2009). The second draws from the study by Hodgskiss (2010, p. 8) and the results obtained for trampling experiments.

Ground specimens exhibiting three or more facets which converge to a point are widely referred to as crayons. Archaeological crayons mostly comprise fine-grained sedimentary forms, but haematite and sandstone crayons also occur (Henshilwood et al., 2001, p. 433; see also Beaumont et al., 1978; Singer and Wymer, 1982; Thackeray, 2000; Clark and Brown, 2001). Harder haematites and ochres are not however prone to develop into crayon-like forms, but fine-grained shales are inadvertently ground into crayons. The morphology and faceting of several crayons from Blombos Cave suggest that they may have been applied directly to abrasive surfaces to produce defined areas of colour, perhaps consistent with a design (Henshilwood et al., 2001, p. 433). The morphological characteristics of four ochre crayons are illustrated in Fig. 13.

The archaeological crayons illustrated in Fig. 13 suggest that the use of general morphology (i.e., when specimens exhibit three or more facets which converges to a point) as a defining descriptive measure for ochre crayons is problematic. Although many ground pieces with convergent facets certainly do qualify as crayons, many do not exhibit any features suggestive of use as a crayon. This widespread inference for the use of faceted (pointed) ochres as crayons indirectly links ochre crayons to 'art' and, by implication, modern and symbolic human behaviour. This may be one of the reasons why crayons, and by association even unmodified ochres, are considered to exemplify symbolic behaviours when they are found in archaeological contexts (Wadley, 2005a, p. 2). But the morphology of at least two of the specimens illustrated above (Figs. 13 c and d) suggests that their crayon-like shape is not sim-

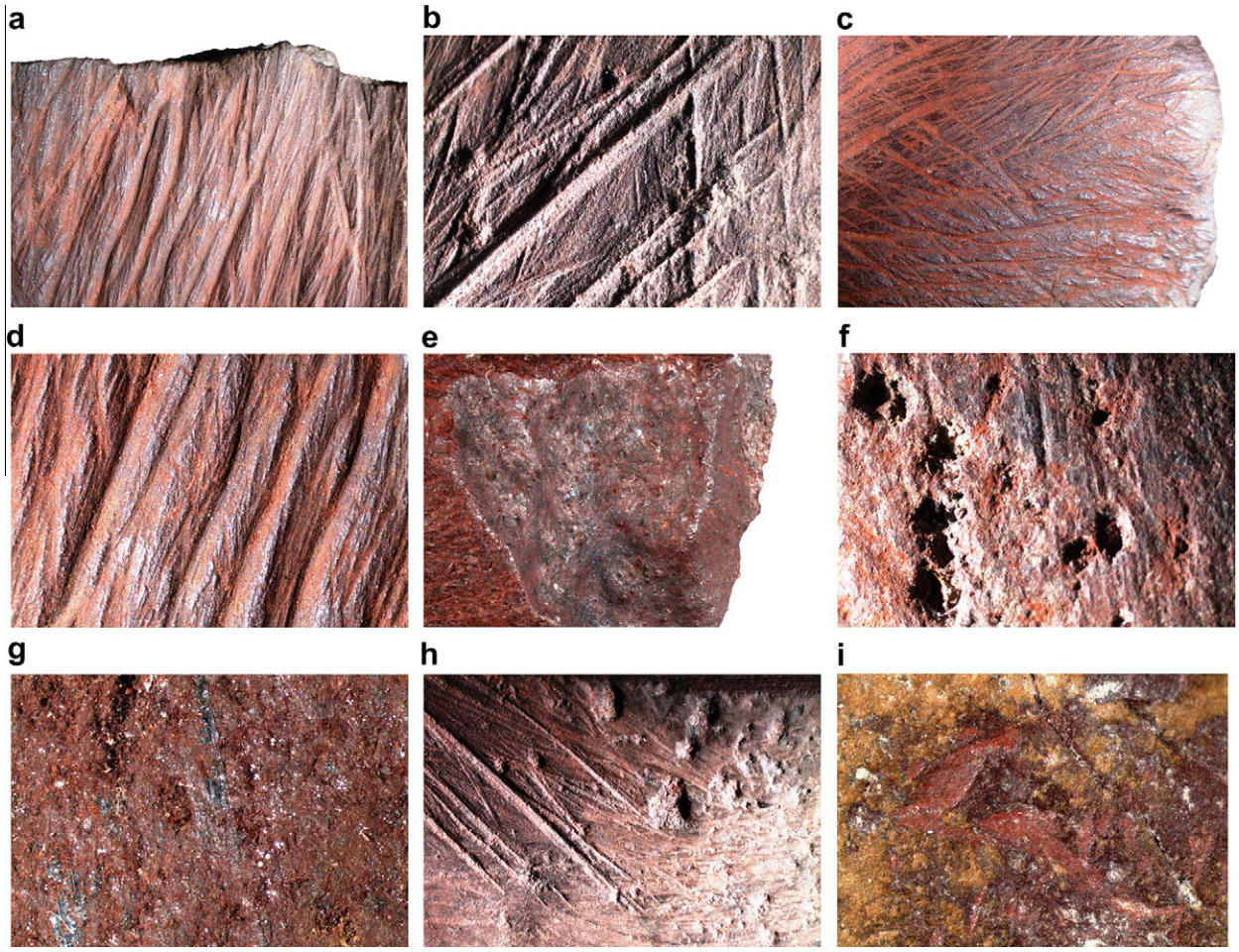


Fig. 12. Primary wear features observed on archaeological ochres from Blombos Cave: (a) deep parallel grooves fine pigment powder residue and 'polished' interstitial ridges on a soft scraped shale-derived specimen (unit CFB/CFC); (b) striations and transverse grooves with fine striae on a hard scraped shale-derived specimen (CFA); (c) wavy parallel grooves and surface 'polish' on a large even facet of a soft scraped shale-derived ochre specimen (CFB/CFC); (d) powder residue parallel grooves and interstitial 'polish' on a facet of a hard scraped shale-derived specimen (CFB/CFC); (e) a large scar formed by the removal of a flake (possibly due pressure exerted by direct grinding) on the edge of a hard shale-derived ochre specimen (CD); (f) parallel grooves surface pitting dark dull 'polish' and fine powder residue on a coarse-grained ground ochre specimen (CFA); (g) dark metallic lustre surface pitting and coarse powder residue on a hard sandstone-derived ground specimen (CFA); (h) deep parallel grooves and what appears to comprise impact scars from percussive pitting on a soft shale-derived ochre sample (CB); (i) broad abrupt transverse 'scratched' scars possibly attributable to post-depositional 'trampling' (CFA). Scales represent 1 cm.

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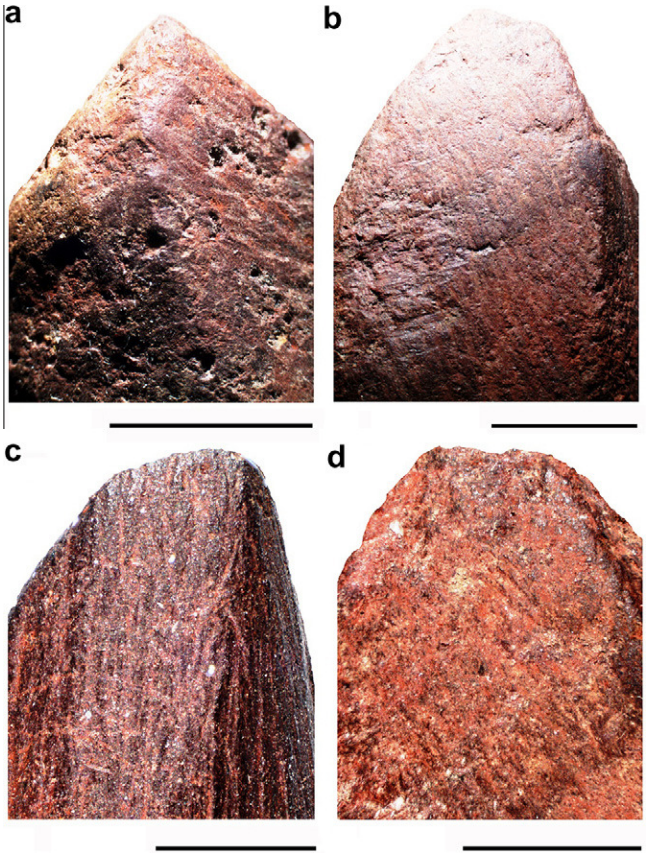


Fig. 13. Morphological characteristics of four ochre 'crayons' derived from the Still Bay units of Blombos Cave: (a) this specimen appears to have retained 'sharply' convergent facets derived from direct grinding onto a coarse hard surface; it may not therefore have been used as a 'crayon' although, the transverse nature of the grooves suggest that it may have been deliberately shaped (ground) to form a pointed tip (unit CA); (b) the morphology of this specimen suggest that it may have been applied to a hard surface subsequent to grinding (note the deep parallel grooves), although the worn tip may also derive from post-depositional wear (CA); (c) the convergent, parallel and transverse grooves, and 'polished' interstitial ridges on the rounded tip and of this sample, provides convincing evidence that it was used to produce defined areas of colour, consistent with a design (like a 'crayon'), on a coarse hard surface (CFA); (d) the near-complete disappearance of the 'tip' of this specimen, along with the coarse nature of the contact edges suggest that it was used to create an area of colour consistent with a linear design on a hard and especially coarse surface (CFA). Scales represent 1 cm.

ply the result of concentrated powder extraction. These samples also possess colour properties consistent with the preferential selection of red ochres, implying that the classification of these as crayons is a fairly credible presumption (see Wadley, 2005a, p. 8; Watts, 2002, p. 3).

As illustrated by the experiments, drawing on and colouring hard materials recurrently generate several additional smaller facets exhibiting clear grooves and striations. These may be aligned perpendicular or transversely to primary wear features which occur on or as larger processed facets. Softer materials such as animal hide do not normally abrade the ochre and simply result in the smoothing and rounding of existing facets. Wear traces on soft shales and siltstones and even harder sandstone-based specimens may vanish completely, leaving only a smooth undulating surface with slight indications of wear traces that were formerly prominent. In order to clarify the use of ground ochres as crayons, it is essential to perform residue analyses on archaeological specimens (e.g., Loy and Hardy, 1992; Lombard, 2005; Lombard and Wadley, 2007).

As observed experimentally, it is indeed possible to discern instances of prehensile wear (smoothing and polish) and residue (oily sheens and residual substances) on archaeological ochres. The two samples illustrated in Fig. 14 exhibit traces of prehensile wear analogous to those observed on experimentally processed ochres.

The first example (Fig. 14 a and inset) appears to have been held in the palm of the hand whilst being scraped with a sharp-edged lithic implement. The piece measures 45 mm by 70 mm, and exhibits extensive, deep superimposed sets of parallel and transverse grooves and striations. This resulted in the formation of a fairly substantial (~8 mm deep) concave (oval-shaped) facet on the processed (scraped) face. On the opposite side, prehensile polish is limited to elevated plateaus (low-lying depressions do not display any polish) and the convex ridge that runs lengthways across the underside of the specimen. Traces of fine bright red pigment powder remains visible in concave areas which have not been polished. The 'polish' is manifest as a bright, smooth and flowing glossy sheen.

The second illustrated sample (Fig. 14 b and inset) appears to have been grasped between the fingers (most likely the thumb and the forefinger) and ground directly onto a smooth but hard stone surface. The two converging processed facets are covered in slight parallel grooves and striations (owing to the hardness of the haematite) and display some surface pitting and a striking specular element. These features are characteristic of processing

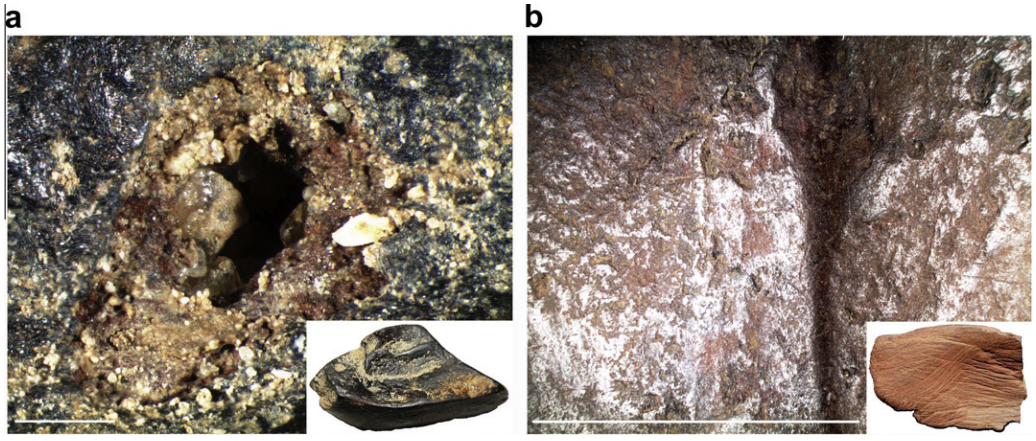


Fig. 14. Prehensile wear and residual traces observed on two processed ochre specimens derived from the Still Bay units at Blombos Cave: (a) a soft scraped shale-derived specimen (unit CFB/CFC) and (b) a hard ground haematite sample (CFA). Scales represent 1 cm in figure a and 1 mm in figure b.

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by direct grinding. The observed residue covers an area of 2.55 mm and comprise a mass of bright red[1] (most likely fine pigment powder), white (perhaps a bone fragment), yellow and brown (which may represent natural oils derived from the skin or animal fat) and quartz granules (presumably sand grains) which have been forced into a natural hollow on the surface of the specimen. The residue was most probably moist and malleable when it was deposited into the concavity, as it appears to have been moulded (by pressure exerted by a grasping finger) to follow the natural topography of the unprocessed surface of the specimen. Traces of human handling have also been reported on a bone awl from Blombos Cave and a notched bone from Klasies River (d'Errico and Henshilwood, 2007). These finds provide a rare instance of contact with the actual people who lived in the cave nearly 80 ka, somewhat similar to seeing the footprints left behind at Laetoli (Leakey and Hay, 1979), Langebaanweg (Roberts and Berger, 1997) and at Nahoon (Roberts, 2008).

As indicated by the specimens illustrated in Fig. 14, the prime factor influencing the probability of a piece being scraped rather than ground appears to be hardness (Henshilwood et al., 2009, p. 30). For the total sample of analysed archaeological ochres from Blombos Cave ($n = 1534$), 21.1% were softer than hardness three (adapting Moh's hardness scale). Among scraped specimens ($n = 106$), this percentage increases to 36.8%, compared to only 7.4% of ground examples ($n = 163$). Softer pieces are less likely to be particularly iron-oxide enriched, and when compared to ground pieces, scraped pieces represent a higher proportion of lighter rather than saturated or deep red nuances.

Conclusion

Along with published archaeological and experimental observations (Wadley, 2005a; Lombard, 2006; Soressi and d'Errico, 2007; d'Errico and Vanhaeren, 2008; Henshilwood et al., 2009; Hodgskiss, 2010; Watts, 2010) the results obtained from this study presents a reliable empirical basis for developing expectations about the origin and morphology of wear traces on archaeological ochres. The theoretical and experiential appreciation of the link between wear features and their causes should facilitate the formulation of testable ideas for the interpretation of wear traces on archaeological ochres. The challenge is to transform these expectations and ideas into reliable middle-range arguments that can link what has been established experimentally, with what is observed archaeologically. Such middle-range theories can be formulated and assessed in terms of primary, associational and behavioural interpretative levels.

On a primary interpretative level, even a single piece of ochre provides information on the preferred types of raw material, colour partiality and the principal methods of processing. Although there is substantial variability in the types of ochres recovered from southern African and specifically South African MSA contexts, there is a general preference for deep red sedimentary (and generally shale-derived) ochres. The variability in and trends towards particular pigment preferences during the African MSA and LSA has been attended to by Watts (2002, 2009, 2010).

In terms of ochre processing, different methods bring about diverse powder consistencies and colour intensities. This may relate to the functional or symbolic uses to which processed archaeological ochres may have been put. Small scraped pieces (e.g., Fig. 14 a) better fits the hypothesis that the resulting minimal quantities of pigment powder were used in symbolic contexts, such as face- or body-marking, instead of utilitarian contexts usually proposed to counter the symbolic interpretation of ochre use, such as the 'tanning' of raw animal hides (e.g., d'Errico and Vanhaeren, 2008). Similarly curated ochre crayons have been described from pre-Aurignacian contexts at Piekary II (d'Errico and Vanhaeren, 2008). The objects served as portable reusable sources of ochre powder, as well as decorated artefacts intended for visual display. The former use is demonstrated by the differentially worn traces of scraping left by multiple tools and motions. In most of instances, only a few strokes were applied to undecorated facets to produce small amounts of red powder. This behaviour concurs with the hypothesis that the resulting small quantities of pigment was most likely used in symbolic activities such as face-marking, rather than in the utilitarian contexts traditionally put forward to counter the symbolic interpretation of ochre use, such as hide tanning (d'Errico and Vanhaeren, 2008, p. 10). In order to cover an intact unprocessed animal skin in 4 mm to 6 mm of red shale-derived ochre, 2.1 kg of ochre powder is required for a medium- (springbok or impala) antelope, and 4.4 kg for a large-sized (such as a wildebeest or kudu antelope) hide (Rifkin, 2011). During these experiments, 690 grams of fine red ochre powder was extracted after 10 h of grinding shale-derived specimens ($n = 113$). It would therefore necessitate 30.4 h of grinding to extract enough ochre powder to tan a small antelope, and 63.7 h to process a large antelope hide. The extraction of haematite powder is an even more labour intensive process. After 79 min of grinding haematite samples ($n = 22$), only 49.1 grams of pigment powder was extracted. It would require 55.3 h of grinding to extract enough pigment powder to cover a medium-sized antelope hide, and 115.8 h to cover a large-sized hide to a depth of 4 to 5 mm.

In associational terms, the distances of ochre sources from archaeological sites offers a way of looking at sourcing strategies and the level of planning employed by MSA people when acquiring ochre (e.g., Gould and Saggers, 1985; Wilson, 2007; Henshilwood et al., 2009). Was the acquisition of preferred ochres a key objective of an excursion away from a site, or could additional resources also be obtained along the way? Did MSA people not perhaps acquire ochre on their way to the next cave or shelter? Why should they make deliberate journeys for ochre if they know where the sources were and they walked past those sources in the course of their regular movement across the landscape? In the context of Blombos Cave, the incidence of *Nassarius kraussianus* molluscs and exposed Bokkeveld shales along the same riverbank, present an example of how sought after resources could have been obtained during a single excursion or at least at the same time when they were in this area. Association also implies the recognition of the contexts from which utilised ochres derive. Specific types of processing methods and means of utility may be associated with particular lithic industries, such as the Still Bay or the Howieson's Poort, with different but contemporaneous archaeological contexts or with artefacts that are symptomatic of symbolic behaviours (Henshilwood et al., 2009; Wadley, 2010; Watts, 2010).

The evidence obtained from primary and associational contexts can be combined to generate a more coherent picture of the social contexts in which pigments functioned. This provides a basis for theorising about the causal factors responsible for the occurrence of utilised ochre. Why and how were ochres processed, and what may have been the use of these modified pieces? The morphological and traceological characteristics illustrated by some ochre crayons (Fig. 13a–d) and small scraped and ground pieces (Fig. 14 a and b) suggest that these were 'curated' and processed only when limited quantities of pigment powder were required (e.g., d'Errico and Vanhaeren, 2008). Small ground haematite pieces may therefore also fit the premise that the minute quantities of deep red powder extracted by grinding functioned in symbolic contexts (such as face- or body-marking) instead of utilitarian contexts such as hide tanning.

[1] For interpretation of colour in Figs. 1–3, 5–7, and 11–14, the reader is referred to the web version of this article.

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Once the methods of processing and means of use have been determined, it becomes progressively more feasible to theorise about the social and technological processes implicated in sourcing, processing and utilising ochre (Henshilwood et al., 2002, 2004, 2009; Soressi and d'Errico, 2007; Henshilwood and Dubreuil, 2009; Wadley et al., 2009). In the future, interpretative accuracy could be improved by defining new microscopic diagnostic criteria at higher magnifications together with tribological modelling and the expansion of experimental reference collections (e.g., Hamon, 2008, p. 1519). In combination with comparative reference collections such as the sample described here, the analysis of wear traces on archaeological pigments can enhance the current understanding of how pigments were processed, the uses these may have been put to and the levels of cognitive skill implicated in such 'modern' functional and symbolic behaviours.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jaa.2011.11.004.

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CHAPTER 3

RIFKIN, R.F. 2011

PROCESSING OCHRE IN THE MIDDLE STONE AGE: TESTING THE INFERENCE OF PREHISTORIC BEHAVIOURS FROM ACTUALISTICALLY DERIVED EXPERIMENTAL DATA

Table 2 (Supplementary Table 1)

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CONTENTS

Supplementary Table 1

Morphological characteristics, experimental details, and macroscopic data for pigment samples processed during the experimental study. In the duration category the (m/m) denomination pertains firstly to the duration of the experiment (including written and photographic documentation etc.), and secondly to the actual duration of the processing action (e.g. grinding, scraping, notching etc.).

#	Source	Geology	Mass (g)	Length (mm)	Width (mm)	Action	Contact	Duration (m\m)	Powder (g)	Heat generated	Edge damage	Handling wear	Striations	Grooves	Facets	Concave	Convex
1	Timeball	Shale	211.8	83.4	73.5	Grinding	Sandstone	35 \ 14	24.4	yes	yes	yes	yes	yes	5	yes	yes
2	Timeball	Shale	82.3	72.8	43.4	Grinding	Sandstone	18 \ 3	14.2	yes	no	yes	yes	yes	4	yes	no
3	Timeball	Haematite	92.5	69.2	32.8	Grinding	Quartzite	15 \ 5	1.9	yes	yes	no	yes	yes	1	no	yes
4	Timeball	Haematite	63.8	62.7	26.4	Grinding	Quartzite	11 \ 5	1.3	yes	yes	yes	yes	yes	3	no	yes
5	Timeball	Shale	39.2	69.0	33.9	Grinding	Quartzite	18 \ 10	9.6	yes	yes	yes	yes	yes	2	yes	no
6	Timeball	Shale	32.1	46.1	29.8	Grinding	Quartzite	26 \ 15	7.0	yes	yes	yes	yes	yes	3	no	yes
7	Timeball	Sandstone	26.7	31.9	26.3	Grinding	Sandstone	4 \ 1	1.4	yes	no	yes	yes	yes	2	yes	yes
8	Timeball	Sandstone	20.5	33.8	30.2	Grinding	Quartzite	9 \ 5	6.7	yes	yes	yes	yes	yes	3	no	yes
a			-	-	-	Rubbing	Animal hide	1	-	yes	no	yes	no	no	0	no	no
9	Timeball	Sandstone	43.7	59.6	35.5	Grinding	Quartzite	15 \ 5	1.2	yes	yes	yes	yes	yes	4	no	yes
10	Timeball	Sandstone	54.6	68.8	35.8	Grinding	Quartzite	35 \ 8	13.8	yes	yes	yes	yes	yes	5	no	yes
11	Timeball	Shale	79.0	81.3	31.4	Grinding	Quartzite	17 \ 3	8.6	yes	yes	yes	yes	yes	2	no	yes
12	Timeball	Shale	23.7	56.8	23.7	Grinding	Quartzite	10 \ 6	2.9	yes	no	yes	yes	yes	5	no	yes
13	Timeball	Shale	53.4	56.6	36.7	Grinding	Quartzite	13 \ 8	24.3	no	no	yes	yes	yes	7	yes	yes
14	Timeball	Shale	43.1	63.4	33.0	Grinding	Quartzite	11 \ 2	19.7	no	yes	yes	yes	yes	3	no	yes
a			-	-	-	Rubbing	Human arm	1	-	no	no	yes	no	no	0	no	no
15	Timeball	Shale	56.3	83.9	42.3	Grinding	Quartzite	15 \ 7	13.4	yes	yes	yes	yes	yes	4	no	yes
16	Timeball	Shale	61.1	48.6	36.9	Grinding	Quartzite	14 \ 4	11.3	no	no	yes	yes	yes	3	no	yes
17	Timeball	Shale	43.9	39.7	36.4	Grinding	Quartzite	4 \ 1	1.6	yes	yes	yes	yes	yes	2	no	yes
18	Timeball	Shale	45.7	44.3	29.1	Grinding	Quartzite	5 \ 1	3.5	yes	yes	yes	yes	yes	2	no	yes
19	Timeball	Shale	20.2	52.6	26.6	Grinding	Quartzite	22 \ 9	5.2	no	yes	yes	yes	yes	3	no	yes
20	Timeball	Shale	20.6	38.1	27.8	Grinding	Quartzite	40 \ 19	11.7	no	yes	yes	yes	yes	6	no	yes
21	Timeball	Shale	44.5	69.2	36.5	Grinding	Quartzite	20 \ 6	15.9	yes	no	yes	yes	yes	3	no	no
22	Timeball	Shale	67.2	110.3	25.3	Grinding	Quartzite	45 \ 18	3.7	yes	yes	yes	yes	yes	11	yes	yes
a			-	-	-	Drawing	Animal hide	1	-	no	no	yes	no	no	0	no	no
23	Timeball	Sandstone	53.0	43.8	26.5	Grinding	Quartzite	14 \ 4	6.8	no	yes	yes	yes	yes	1	no	yes
24	Timeball	Sandstone	464.7	119.5	56.7	Grinding	Quartzite	5 \ 3	2.3	no	yes	yes	yes	yes	2	no	yes

a			-	-	-	Incising	Quartzite	13 \ 8	4.3	no	yes	yes	no	yes	0	no	no
25	Timeball	Shale	237.6	115.6	105.2	Incising	Quartzite	13	19.8	no	no	yes	no	yes	0	no	no
26	Timeball	Shale	141.6	74.5	53.8	Incising	Quartz	18	1.7	no	no	yes	no	yes	1	no	yes
27	Timeball	Shale	140.8	91.2	62.1	Scraping	Quartzite	17 \ 9	5.2	no	no	yes	yes	yes	1	yes	yes
28	Timeball	Shale	6351	180.9	140.7	Pounding	Quartzite	11 \ 8	28.8	no	yes	yes	no	no	-	-	-
a			-	-	-	Grinding	Quartzite	19 \ 11	10.3	yes	yes	yes	yes	yes	6	yes	yes
29	Timeball	Shale	89.2	98.6	52.6	Grinding	Sandstone	14 \ 6	5.4	yes	yes	yes	yes	yes	4	no	yes
30	Timeball	Shale	64.6	54.3	44.7	Grinding	Sandstone	50 \ 22	26.9	yes	yes	yes	yes	yes	5	no	yes
31	Timeball	Shale	34.9	39.7	30.2	Grinding	Quartzite	11 \ 7	3.2	yes	no	yes	yes	yes	2	no	yes
32	Timeball	Shale	69.2	64.1	34.4	Grinding	Quartzite	35 \ 20	15.4	yes	yes	yes	yes	yes	4	no	yes
33	Timeball	Haematite	-	-	-	Cutting 1/3	Steel blade	4	-	-	-	-	-	-	-	-	-
a			16.8	24.7	17.0	Grinding	Sandstone	11 \ 2	1.7	yes	yes	yes	yes	yes	3	no	yes
			-	-	-	Control	None	-	-	-	-	-	-	-	-	-	-
b			36.4	42.3	26.9	Grinding	Sandstone	8 \ 2	1.4	yes	yes	yes	yes	yes	2	no	yes
			-	-	-	Rubbing	Human arm	1		yes	no	yes	no	no	0	no	no
c			33.5	36.9	26.6	Grinding	Sandstone	10 \ 2	1.8	yes	yes	yes	yes	yes	3	no	yes
			-	-	-	Rubbing	Animal hide	1	-	yes	no	yes	yes	no	0	no	no
34	Timeball	Shale	-	-	-	Cutting 1/3	Steel blade	8	-	-	-	-	-	-	-	-	-
a			13.8	34.0	33.8	Grinding	Sandstone	12 \ 2	2.2	yes	yes	yes	yes	yes	3	yes	yes
			-	-	-	Control	None	-	-	-	-	-	-	-	-	-	-
b			10.2	39.4	21.3	Grinding	Sandstone	8 \ 2	2.7	yes	yes	yes	yes	yes	1	no	yes
			-	-	-	Rubbing	Human arm	1	-	no	no	yes	no	no	0	no	no
c			9.5	43.7	21.7	Grinding	Sandstone	11 \ 2	2.5	yes	yes	yes	yes	yes	3	no	yes
			-	-	-	Rubbing	Animal hide	1	-	yes	no	yes	no	no	0	no	no
35	Timeball	Sandstone	-	-	-	Cutting 1/3	Steel blade	6	-	-	-	-	-	-	-	-	-
a			30.7	42.5	30.1	Grinding	Sandstone	9 \ 2	1.4	yes	yes	yes	yes	yes	5	no	yes
			-	-	-	Control	None	-	-	-	-	-	-	-	-	-	-
b			33.6	44.7	33.9	Grinding	Sandstone	11 \ 2	1.6	yes	yes	yes	yes	yes	2	no	yes
			-	-	-	Rubbing	Human arm	1	-	no	no	yes	no	no	0	no	no
c			20.9	35.9	20.2	Grinding	Sandstone	9 \ 2	1.3	yes	yes	yes	yes	yes	3	no	yes
			-	-	-	Rubbing	Animal hide	1	-	yes	yes	yes	no	no	0	no	no
36	Timeball	Shale	-	-	-	Cutting 1/10	Steel blade	4	-	-	-	-	-	-	-	-	-
a			6.5	34.7	6.7	Grinding	Quartzite	10 \ 9	4.0	yes	yes	yes	yes	yes	7	no	yes
			-	-	-	Drawing	Quartzite	1	-	no	yes	yes	yes	yes	3	yes	yes
b			9.7	36.1	8.4	Grinding	Quartzite	12 \ 9	3.4	yes	yes	yes	yes	yes	4	no	yes

			-	-	-	Drawing	Animal hide	1	-	no	no	yes	yes	no	1	no	yes
c			8.4	33.8	8.6	Grinding	Quartzite	9 \ 6	5.7	yes	yes	yes	yes	yes	4	no	yes
			-	-	-	Transport	Animal hide	14400	-	no	no	yes	no	no	0	no	no
d			19.3	50.6	9.2	Grinding	Quartzite	11 \ 9	7.8	yes	yes	yes	yes	yes	9	yes	yes
			-	-	-	Control	None	-	-	-	-	-	-	-	-	-	-
e			12.4	54.4	6.4	Grinding	Quartzite	13 \ 8	5.3	yes	yes	yes	yes	yes	7	no	yes
			-	-	-	Transport	Sand	14400		no	no	yes	no	no	0	no	no
f			11.7	34.2	4.7	Grinding	Quartzite	10 \ 7	8.6	yes	yes	yes	yes	yes	5	no	yes
			-	-	-	Control	None	-	-	-	-	-	-	-	-	-	-
g			10.6	26.7	10.2	Grinding	Quartzite	11 \ 8	7.2	yes	yes	yes	yes	yes	4	no	yes
			-	-	-	Drawing	Animal hide	1	-	no	yes	yes	no	no	4	no	yes
h			6.3	33.1	7.4	Grinding	Quartzite	9 \ 6	9.7	yes	yes	yes	yes	yes	5	no	yes
			-	-	-	Drawing	Human arm	1	-	no	no	yes	no	no	0	no	no
i			10.8	27.9	5.8	Grinding	Quartzite	9 \ 8	11.6	yes	yes	yes	yes	yes	4	no	yes
			-	-	-	Drawing	Quartzite	1	-	no	yes	yes	yes	yes	5	no	yes
j			10.1	27.6	7.6	Grinding	Quartzite	8 \ 6	8.6	yes	yes	yes	yes	yes	4	no	yes
			-	-	-	Soaking	Water	14400	-	no	no	yes	no	yes	0	no	no
37	Timeball	Shale	53.4	93.5	40.8	Grinding	Quartzite	12 \ 9	19.4	yes	yes	no	no	yes	3	no	yes
38	Timeball	Haematite	56.7	56.6	27.0	Grinding	Quartzite	20 \ 11	4.7	yes	yes	yes	yes	yes	4	no	yes
a			-	-	-	Drawing	Animal hide	1	-	no	no	yes	yes	no	0	no	no
39	Timeball	Haematite	21.3	37.8	22.6	Grinding	Quartzite	15 \ 9	1.5	yes	yes	yes	yes	yes	3	no	yes
40	Timeball	Haematite	41.5	52.6	21.3	Grinding	Quartzite	8 \ 3	1.8	yes	yes	yes	yes	yes	2	no	yes
41	Timeball	Various	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a		Shale	67.0	65.6	30.2	Soaking	Water	10	-	no	no	no	no	no	0	no	no
			-	-	-	Grinding	Quartzite	1	2.7	no	yes	yes	yes	yes	1	yes	no
b		Haematite	30.8	49.7	22.5	Soaking	Water	10	-	no	no	no	no	no	0	no	no
			-	-	-	Grinding	Quartzite	1	2.3	yes	yes	yes	yes	yes	2	no	yes
c		Sandstone	32.6	41.9	35.4	Soaking	Water	10	-	no	no	no	no	no	0	no	no
			-	-	-	Grinding	Quartzite	1	2.8	no	yes	yes	yes	yes	1	no	yes
42	Timeball	Shale	81.4	70.3	50.4	Cutting 1/2	Steel blade	3	-	-	-	-	-	-	-	-	-
a			-	-	-	Cutting	Dry bone	20 \ 6	4.2	no	yes	yes	yes	yes	6	yes	no
b			-	-	-	Notching	Dry bone	24 \ 8	4.6	no	yes	yes	yes	yes	8	yes	no
43	Timeball	Shale	49.6	63.4	31.2	Scraping	Dry bone	24 \ 7	4.1	yes	yes	yes	yes	no	5	yes	no
44	Timeball	Sandstone	233.8	70.0	52.9	Grinding	Quartzite	4 \ 3	9.0	yes	yes	yes	yes	yes	2	no	yes
a			-	-	-	Pounding	Quartzite	10 \ 7	17.8	yes	yes	no	no	no	0	no	no

45	Timeball	Shale	-	-	-	Cutting 1/2	Steel blade	3	-	-	-	-	-	-	-	-	-	-
a			146.4	100.3	58.6	Grinding	Quartzite	7 \ 5	9.7	no	yes	yes	yes	yes	1	no	yes
b			103.9	79.1	59.7	Grinding	Quartzite	11 \ 8	6.4	no	yes	yes	no	yes	1	no	yes
46	Napier	Shale	55.7	98.7	18.1	Grinding	Sandstone	33 \ 24	22.5	yes	no	yes	yes	yes	6	yes	yes
a			-	-	-	Drawing	Animal hide	1	-	no	no	yes	no	no	0	no	no
b			-	-	-	Drawing	Sandstone	1	-	no	yes	no	yes	yes	2	no	yes
47	Napier	Shale	54.9	124.4	22.8	Grinding	Sandstone	36 \ 31	20.6	yes	no	yes	yes	yes	8	yes	no
a			-	-	-	Drawing	Animal hide	1	-	no	no	yes	no	no	0	no	no
b			-	-	-	Drawing	Quartzite	1	-	no	yes	no	yes	yes	4	no	yes
48	Napier	Shale	146.3	71.8	41.5	Cutting 1/4	Steel blade	6	-	-	-	-	-	-	-	-	-
a			-	-	-	Grinding	Sandstone	1	6.7	yes	no	yes	yes	yes	2	yes	yes
b			-	-	-	Grinding	Sandstone	1	4.7	yes	no	yes	yes	yes	1	yes	no
c			-	-	-	Grinding	Slate	1	5.3	yes	no	yes	yes	yes	3	no	yes
d			-	-	-	Grinding	Quartzite	1	3.9	yes	no	yes	yes	yes	1	yes	yes
49	Napier	Shale	9.7	23.6	11.5	Grinding	Sandstone	6 \ 3	2.7	yes	no	yes	yes	yes	2	yes	no
a			-	-	-	Rubbing	Human arm	1	-	no	no	yes	no	no	0	no	no
50	Napier	Shale	12.2	44.7	12.8	Grinding	Sandstone	11 \ 5	3.6	yes	no	yes	yes	yes	3	yes	yes
a			-	-	-	Rubbing	Human arm	1	-	no	no	yes	no	no	0	no	no
51	Napier	Shale	13.6	30.1	8.4	Grinding	Sandstone	7 \ 4	2.2	yes	yes	yes	yes	yes	3	no	yes
a			-	-	-	Rubbing	Human arm	1	-	no	no	yes	no	no	0	no	no
52	Napier	Shale	21.7	40.0	21.9	Grinding	Sandstone	9 \ 4	3.7	yes	yes	yes	yes	yes	4	no	yes
a			-	-	-	Drawing	Animal hide	1	-	no	no	yes	no	no	0	no	no
b						Drawing	Sandstone	1	-	no	yes	yes	yes	yes	5	no	yes
53	Napier	Shale	21.2	39.4	15.3	Grinding	Sandstone	13 \ 7	11.9	no	no	yes	yes	yes	4	yes	yes
a			-	-	-	Rubbing	Human arm	1	-	no	yes	yes	yes	yes	0	no	no
54	Napier	Shale	8.7	48.6	11.2	Grinding	Sandstone	9 \ 6	4.6	no	no	yes	yes	yes	4	no	yes
a			-	-	-	Rubbing	Human arm	1	-	no	no	yes	no	no	0	no	no
55	Napier	Shale	16.1	36.2	16.7	Scraping	Quartz	8 \ 5	2.3	no	no	yes	yes	yes	1	yes	no
56	Napier	Shale	28.4	67.9	14.4	Notching	Quartzite	11 \ 7	2.8	no	yes	yes	yes	yes	8	yes	no
57	Napier	Shale	53.5	70.4	13.6	Grinding	Sandstone	19 \ 12	5.8	yes	yes	yes	yes	yes	3	no	yes
a			-	-	-	Rubbing	Hand	1	-	no	no	yes	no	no	0	no	no
58	Napier	Shale	18.4	47.8	14.3	Grinding	Sandstone	5 \ 1	0.4	no	yes	yes	no	yes	1	no	yes
a			-	-	-	Rubbing	Human face	1	-	no	no	yes	no	no	0	no	no
59	Napier	Shale	16.7	35.5	17.8	Grinding	Sandstone	5 \ 1	2.4	no	yes	yes	yes	yes	1	yes	yes
a			-	-	-	Rubbing	Hand	1	-	no	no	yes	no	no	0	no	no

60	Napier	Haematite	41.2	43.9	17.0	Grinding	Sandstone	13 \ 4	0.7	yes	yes	yes	yes	yes	2	no	yes
			-	-	-	Drawing	Animal hide	1	-	no	no	yes	no	no	0	no	no
61	Napier	Shale	21.8	39.7	26.4	Grinding	Sandstone	6 \ 1	4.6	yes	yes	yes	yes	yes	1	yes	no
a			-	-	-	Rubbing	Animal hide	0.5	-	yes	no	yes	no	no	0	no	no
62	Napier	Shale	26.4	51.6	14.3	Grinding	Sandstone	4 \ 1	4.1	no	yes	yes	yes	yes	1	no	yes
a			-	-	-	Rubbing	Human arm	0.5	-	no	no	yes	no	yes	1	no	no
63	Napier	Shale	25.6	53.4	14.7	Grinding	Sandstone	3 \ 1	3.5	no	yes	yes	yes	yes	1	no	yes
a			-	-	-	Drawing	Animal hide	1	-	no	no	yes	no	no	0	no	no
b			-	-	-	Drawing	Sandstone	1	-	no	yes	no	yes	yes	5	no	yes
64	Napier	Shale	39.7	51.8	16.9	Grinding	Sandstone	12 \ 6	2.3	yes	no	yes	yes	yes	2	no	yes
65	Napier	Shale	26.9	36.7	17.2	Grinding	Quartzite	9 \ 3	7.9	yes	no	yes	yes	yes	2	no	yes
a			-	-	-	Rubbing	Animal hide	1	-	yes	no	yes	no	no	0	no	no
66	Napier	Shale	24.5	46.1	22.3	Grinding	Sandstone	5 \ 1	3.1	no	yes	yes	yes	yes	3	no	yes
a			-	-	-	Rubbing	Animal hide	0.5	-	no	no	yes	no	yes	0	no	no
67	Napier	Shale	30.7	44.7	16.8	Scraping	Dry bone	7 \ 5	6.4	no	yes	yes	yes	yes	4	yes	no
68	Napier	Shale	43.8	61.8	16.4	Grinding	Sandstone	14 \ 9	4.2	yes	yes	yes	yes	yes	2	no	yes
69	Napier	Shale	30.7	39.8	22.8	Grinding	Sandstone	6 \ 1	4.9	yes	yes	yes	yes	yes	1	no	yes
a			-	-	-	Scraping	Shell	11 \ 8	1.8	no	no	yes	yes	yes	3	yes	no
70	Napier	Shale	34.2	42.1	19.4	Grinding	Sandstone	7 \ 4	3.6	yes	no	yes	yes	yes	2	no	yes
a			-	-	-	Rubbing	Hand	1	-	no	no	yes	no	no	0	no	no
71	Cape Point	Shale	13.4	29.7	14.6	Grinding	Quartzite	4 \ 3	3.2	yes	yes	yes	yes	yes	1	yes	no
a			-	-	-	Pounding	Quartzite	8 \ 6	17.0	no	yes	no	no	no	0	no	yes
72	Cape Point	Shale	35.2	35.9	22.7	Cutting 1/2	Steel blade	4	-	-	-	-	-	-	-	-	-
a			-	-	-	Grinding	Quartzite	6 \ 2	2.5	yes	yes	yes	yes	yes	1	no	yes
b			-	-	-	Grinding	Sandstone	6 \ 2	2.1	yes	yes	yes	yes	yes	1	no	yes
73	Cape Point	Shale	42.9	53.5	19.5	Scraping	Quartzite	11 \ 6	3.9	no	yes	yes	yes	yes	1	no	yes
a			-	-	-	Cutting	Quartzite	5 \ 2	1.7	no	yes	yes	yes	yes	1	no	yes
74	Cape Point	Shale	11.3	36.8	10.3	Grinding	Sandstone	14 \ 8	3.5	yes	yes	yes	yes	yes	3	no	yes
a			-	-	-	Drawing	Human arm	1	-	no	no	yes	no	no	0	no	no
b			-	-	-	Drawing	Quartzite	1	-	no	yes	no	yes	yes	4	no	yes
75	Cape Point	Shale	11.5	41.8	13.9	Scraping	Dry bone	8 \ 4	1.9	no	yes	yes	yes	no	1	yes	no
76	Cape Point	Shale	17.7	44.1	8.6	Grinding	Sandstone	7 \ 4	3.1	yes	yes	yes	yes	yes	1	no	yes
a			-	-	-	Rubbing	Human arm	0.5	-	no	no	yes	no	no	0	no	no
77	Cape Point	Shale	42.5	46.7	18.2	Grinding	Sandstone	3 \ 2	2.7	yes	yes	yes	yes	yes	1	no	yes
a			-	-	-	Drilling	Quartzite	1	-	no	yes	no	no	yes	0	no	no

b			-	-	-	Drilling	Quartz	1	-	no	yes	no	no	yes	0	no	no
c			-	-	-	Drilling	Shell	1	-	no	yes	no	no	yes	0	no	no
d			-	-	-	Drilling	Shell	1	-	no	yes	no	no	no	0	no	no
e			-	-	-	Drilling	Dry bone	1	-	no	yes	no	no	yes	0	no	no
f			-	-	-	Drilling	Dry bone	1	-	no	yes	no	no	no	0	no	no
g			-	-	-	Drilling	Steel drill	0.5	-	yes	yes	no	no	no	0	no	no
78	Cape Point	Shale	30.8	74.6	9.1	Grinding	Sandstone	6	19.6	no	yes	yes	yes	yes	1	no	yes
a			-	-	-	Mixing	Shell, water	8	-	-	-	-	-	-	-	-	-
b			-	-	-	Mixing	Shell, water	11	-	-	-	-	-	-	-	-	-
c			-	-	-	Mixing	Shell, water	18	-	-	-	-	-	-	-	-	-
d						Rubbing	Human face	1	-	no	no	yes	no	no	0	no	no
79	Cape Point	Haematite	17.8	32.5	20.0	Grinding	Sandstone	5 \ 2	0.6	yes	no	no	yes	yes	1	no	yes
a			-	-	-	Drawing	Human face	1	-	no	no	yes	no	no	0	no	no
b			-	-	-	Drawing	Quartzite	1	-	no	yes	no	yes	yes	6	no	yes
80	Cape Point	Shale	40.1	54.7	14.9	Grinding	Sandstone	3	3.4	yes	yes	yes	yes	yes	1	no	yes
a			-	-	-	Incising	Dry bone	5	-	no	yes	yes	yes	yes	-	no	no
b						Incising	Silcrete	4	-	no	yes	yes	yes	yes		no	no
81	Cape Point	Shale	40.6	70.5	24.2	Grinding	Sandstone	9	2.0	yes	yes	yes	yes	yes	1	no	yes
a			-	-	-	Incising	Quartz	6	-	no	yes	yes	yes	yes	-	no	no
b			-	-	-	Incising	Shell	7	-	no	yes	yes	yes	yes		no	no
82	Cape Point	Shale	23.4	36.7	12.9	Grinding	Sandstone	7	2.5	yes	yes	yes	yes	yes	1	no	no
a			-	-	-	Incising	Quill	2	-	no	yes	yes	yes	yes	-	no	yes
b			-	-	-	Incising	Quill	3	-	no	yes	yes	yes	yes	-	no	no
83	Cape Point	Shale	10.8	42.1	13.6	Grinding	Sandstone	18 \ 5	2.7	yes	yes	yes	yes	yes	3	no	yes
84	Cape Point	Shale	42.5	51.6	18.7	Grinding	Quartzite	15 \ 3	1.5	yes	no	yes	yes	yes	2	no	yes
85	Cape Point	Shale	15.3	32.6	13.0	Grinding	Sandstone	7 \ 3	1.8	yes	no	yes	yes	yes	1	no	yes
a			-	-	-	Drawing	Sandstone	3	-	no	yes	yes	yes	yes	4	no	yes
86	Cape Point	Shale	17.6	52.3	14.9	Grinding	Sandstone	3 \ 1	2.5	yes	no	yes	yes	yes	1	no	yes
a			-	-	-	Scraping	Shell	7 \ 2	0.9	no	yes	yes	yes	yes	9	yes	no
87	De Hoop	Shale	25.8	33.8	16.4	Grinding	Quartzite	18 \ 11	12.7	yes	yes	yes	yes	yes	3	no	yes
88	De Hoop	Shale	28.9	45.2	29.6	Grinding	Sandstone	4 \ 1	11.2	yes	yes	yes	yes	yes	1	no	yes
a			-	-	-	Scraping	Quartzite	8 \ 3	1.3	no	yes	yes	yes	yes	3	yes	no
89	De Hoop	Haematite	23.3	42.7	14.1	Grinding	Sandstone	7 \ 3	2.1	yes	no	yes	yes	yes	1	no	yes
a			-	-	-	Rubbing	Animal hide	2 \ 1	-	no	no	yes	no	no	0	no	no
90	De Hoop	Haematite	37.8	44.6	22.9	Grinding	Sandstone	11 \ 8	3.5	yes	yes	yes	yes	yes	2	no	yes

91	De Hoop	Haematite	19.7	26.1	24.5	Grinding	Quartzite	13 \ 6	3.0	yes	no	yes	yes	yes	3	yes	yes
92	De Hoop	Shale	34.4	42.7	17.7	Grinding	Sandstone	6 \ 2	2.6	yes	yes	yes	yes	yes	1	no	yes
a			-	-	-	Scraping	Quartzite	11 \ 7	2.1	no	yes	yes	yes	yes	1	yes	no
93	De Hoop	Haematite	13.7	31.6	23.1	Grinding	Sandstone	15 \ 11	2.7	yes	no	yes	yes	yes	3	no	yes
a			-	-	-	Drawing	Sandstone	1	-	no	yes	yes	yes	yes	5	no	yes
b			-	-	-	Rubbing	Animal hide	1	-	yes	no	yes	no	no	0	no	no
94	De Hoop	Haematite	46.0	44.9	21.8	Grinding	Quartzite	11 \ 3	0.7	yes	no	yes	yes	yes	1	no	yes
95	De Hoop	Shale	27.8	70.2	16.6	Cutting 1/2	Steel blade	2 \ 1	-	-	-	-	-	-	-	-	-
a			-	-	-	Grinding	Quartzite	7 \ 5	12.3	no	no	no	no	no	3	no	yes
b			-	-	-	Grinding	Shell	11 \ 7	10.8	no	no	no	no	yes	2	no	yes
96	De Hoop	Ochre	31.2	32.1	20.0	Grinding	Sandstone	13 \ 3	1.6	yes	no	yes	yes	yes	1	no	yes
a			-	-	-	Rubbing	Human arm	1	-	yes	no	yes	no	no	0	no	no
97	De Hoop	Shale	13.5	34.4	25.0	Grinding	Quartzite	7 \ 2	3.9	no	yes	yes	yes	yes	1	no	yes
a			-	-	-	Rubbing	Human arm	1	-	no	no	yes	no	no	0	no	no
98	De Hoop	Shale	96.8	97.5	41.0	Grinding	Quartzite	21 \ 6	8.4	yes	yes	yes	yes	yes	3	no	yes
a			-	-	-	Rubbing	Human face	1	-	yes	no	yes	no	no	0	no	no
99	De Hoop	Ochre	71.5	61.2	24.0	Grinding	Quartzite	11 \ 4	3.5	no	yes	yes	yes	yes	1	no	yes
a			-	-	-	Rubbing	Animal hide	1	-	yes	no	yes	no	no	0	no	no
100	De Hoop	Ochre	68.7	54.7	21.0	Grinding	Quartzite	7 \ 2	11.7	no	no	yes	yes	yes	1	no	yes
a			-	-	-	Abrasive	Bone / hide	10 \ 3	-	yes	no	yes	yes	no	-	-	-
101	Cederberg	Shale	30.4	30.7	24.3	Grinding	Sandstone	12 \ 3	4.3	no	yes	yes	yes	yes	3	no	yes
a			-	-	-	Rubbing	Animal hide	1	-	yes	no	yes	no	no	0	no	no
102	Cederberg	Shale	26.1	42.3	33.1	Grinding	Quartzite	11 \ 4	2.7	yes	yes	yes	yes	yes	1	no	yes
a			-	-	-	Rubbing	Human arm	1	-	no	no	yes	no	no	0	no	no
103	Cederberg	Ochre	18.2	44.8	23.5	Grinding	Quartzite	9 \ 1.5	3.3	yes	yes	yes	yes	yes	1	no	yes
a			-	-	-	Rubbing	Animal hide	1	-	yes	no	yes	no	no	0	no	no
104	Cederberg	Shale	37.6	43.6	28.8	Grinding	Sandstone	11 \ 5	4.8	yes	no	no	yes	yes	2	yes	no
a			-	-	-	Rubbing	Hand	1	-	no	no	yes	no	no	0	no	no
105	Cederberg	Ochre	31.9	42.3	34.2	Grinding	Quartzite	7 \ 2	0.7	yes	no	no	yes	yes	2	no	yes
106	Cederberg	Shale	29.3	48.6	28.7	Grinding	Quartzite	10 \ 3	2.9	yes	no	no	yes	yes	1	no	yes
a			-	-	-	Rubbing	Hand	1	-	no	no	yes	no	no	0	no	no
107	Cederberg	Haematite	15.4	28.1	22.6	Grinding	Quartzite	6 \ 1	2.4	yes	no	no	yes	yes	3	no	yes
108	Cederberg	Mudstone	50.8	53.0	18.9	Grinding	Quartzite	9 \ 3	6.3	yes	no	no	yes	yes	1	no	yes
a			-	-	-	Drawing	Animal hide	1	-	no	no	yes	no	no	0	no	no
109	Cederberg	Haematite	107.0	75.7	25.9	Grinding	Quartzite	4 \ 1	0.4	yes	no	no	yes	yes	1	no	yes

110	Cederberg	Shale	111.6	74.8	16.2	Grinding	Quartzite	8 \ 2	2.7	yes	no	no	yes	yes	1	yes	yes
a			-	-	-	Drawing	Human arm	1	-	no	no	yes	no	no	0	no	no
b			-	-	-	Drawing	Quartzite	1	-	no	yes	no	yes	yes	3	no	yes
111	Cederberg	Haematite	36.7	39.7	29.7	Grinding	Quartzite	4 \ 1	0.9	yes	no	yes	yes	no	1	no	yes
112	Cederberg	Haematite	42.9	41.4	35.8	Grinding	Sandstone	11 \ 3	2.9	yes	yes	no	yes	no	1	no	yes
a			-	-	-	Rubbing	Human arm	1	-	yes	no	yes	no	no	0	no	no
113	Cederberg	Haematite	42.3	44.7	16.6	Grinding	Quartzite	6 \ 2	0.7	yes	no	no	yes	no	2	yes	yes
114	Cederberg	Haematite	23.8	38.6	14.2	Drawing	Sandstone	6 \ 2	-	no	yes	yes	yes	yes	5	no	yes
115	Cederberg	Haematite	23.3	33.1	27.9	Drawing	Quartzite	6 \ 2	-	no	yes	yes	yes	yes	5	no	yes
116	De Hoop	Haematite	22.5	36.9	16.4	Grinding	Quartzite	3 \ 1	0.5	yes	no	no	yes	no	1	no	yes
117	De Hoop	Ochre	41.4	43.2	29.5	Grinding	Sandstone	5 \ 2	3.5	yes	no	yes	yes	yes	2	yes	yes
a			-	-	-	Scraping	Shell	2 \ 1	0.9	no	yes	yes	yes	yes	1	yes	no
b			-	-	-	Scraping	Shell	2 \ 1	1.3	no	yes	yes	yes	yes	1	yes	no
118	De Hoop	Ochre	35.7	40.7	20.1	Grinding	Sandstone	4 \ 2	0.7	yes	no	no	yes	yes	2	no	yes
a			-	-	-	Scraping	Shell	2 \ 1	1.7	no	yes	yes	yes	yes	1	yes	no
b			-	-	-	Scraping	Shell	2 \ 1	1.6	no	yes	yes	yes	yes	1	yes	no
119	De Hoop	Haematite	21.8	31.2	21.6	Grinding	Quartzite	11 \ 3	12.8	yes	no	no	yes	yes	1	no	yes
120	De Hoop	Ochre	50.4	47.8	30.7	Grinding	Sandstone	4 \ 2	2.4	yes	no	no	yes	yes	1	no	yes
121	De Hoop	Shale	68.9	58.6	41.3	Grinding	Quartzite	7 \ 2	4.0	no	yes	yes	yes	yes	1	no	yes
a			-	-	-	Rubbing	Animal hide	1	-	yes	no	yes	no	no	0	no	no
122	De Hoop	Sandstone	69.3	48.5	36.5	Grinding	Quartzite	11 \ 3	3.2	yes	no	no	yes	yes	1	no	yes
a			-	-	-	Rubbing	Human arm	1	-	yes	no	yes	no	no	0	no	no
123	De Hoop	Sandstone	229.2	100.2	48.7	Grinding	Quartzite	14 \ 3	9.6	no	yes	no	yes	yes	1	no	yes
a			-	-	-	Rubbing	Human arm	1	-	yes	no	yes	no	no	0	no	no
124	De Hoop	Sandstone	73.4	51.6	30.8	Grinding	Sandstone	9 \ 2	2.8	yes	no	no	yes	yes	1	no	yes
125	De Hoop	Sandstone	120.7	66.8	31.6	Grinding	Quartzite	8 \ 2	0.8	yes	yes	no	yes	yes	1	no	yes
a			-	-	-	Rubbing	Animal hide	1	-	yes	no	yes	no	no	0	no	no
126	De Hoop	Sandstone	77.4	54.3	36.1	Grinding	Quartzite	8 \ 2	2.5	yes	yes	no	yes	yes	1	no	yes
127	De Hoop	Shale	151.6	80.7	54.5	Grinding	Quartzite	12 \ 2	2.3	yes	yes	yes	yes	yes	2	yes	yes
a						Drawing	Quartzite	1	-	no	yes	yes	yes	yes	4	no	yes
128	De Hoop	Haematite	92.0	58.6	35.4	Grinding	Quartzite	13 \ 4	3.8	yes	no	yes	yes	yes	3	no	yes
a			-	-	-	Rubbing	Hand	1	-	yes	no	yes	no	no	0	no	yes
129	De Hoop	Sandstone	307.8	84.6	66.2	Grinding	Sandstone	13 \ 2	11.2	yes	yes	yes	yes	yes	2	no	yes
130	De Hoop	Sandstone	300.4	90.3	68.7	Grinding	Various	13 \ 3	-	-	-	-	-	-	-	-	-
a			-	-	-	Grinding	Slate	3 \ 1	0.5	yes	yes	yes	yes	yes	1	no	yes

b			-	-	-	Grinding	Sandstone	4 \ 1	0.3	yes	yes	yes	yes	no	1	no	yes
c			-	-	-	Grinding	Quartzite	3 \ 1	0.7	yes	yes	yes	yes	yes	1	no	yes
131	Cape Point	Shale	78.9	65.4	19.7	Cutting 1/2	Steel blade	3 \ 2	-	-	-	-	-	-	-	-	-
a			-	-	-	Grinding	Sandstone	2 \ 1	1.5	no	yes	no	yes	yes	1	no	yes
b			-	-	-	Grinding	Sandstone	2 \ 1	1.8	no	yes	no	yes	yes	1	no	yes
c			-	-	-	Rubbing	Hand	1	-	no	no	yes	no	no	0	no	yes
132	Blombosch	Shale	168.3	84.6	58.5	Grinding	Sandstone	7 \ 2	6.1	no	yes	yes	yes	yes	2	yes	yes
a			-	-	-	Rubbing	Human arm	2 \ 0.5	-	yes	no	yes	no	no	2	no	yes
133	Blombosch	Shale	141.7	83.4	51.2	Grinding	Quartzite	4 \ 2	3.4	no	no	yes	yes	yes	2	no	yes
a			-	-	-	Scraping	Shell	2 \ 1	2.2	no	yes	yes	yes	yes	1	yes	no
b			-	-	-	Scraping	Shell	2 \ 1	2.7	no	yes	yes	yes	yes	1	yes	no
134	Blombosch	Kaolinite	87.5	61.9	55.3	Grinding	Quartzite	5 \ 2	2.1	no	yes	yes	yes	yes	2	no	yes
a			-	-	-	Rubbing	Human arm	2 \ 0.5	-	no	no	yes	no	no	2	no	yes
135	Blombosch	Shale	143.7	89.7	66.9	Grinding	Quartzite	3 \ 2	0.8	no	yes	yes	yes	yes	1	yes	yes
136	Blombosch	Shale	32.3	56.6	20.3	Grinding	Quartzite	3 \ 1	0.3	no	yes	yes	yes	yes	2	no	yes
a			-	-	-	Rubbing	Hand	1	-	no	no	yes	no	no	0	no	no
137	Blombosch	Shale	27.5	53.8	25.7	Grinding	Quartzite	3 \ 1	0.6	no	yes	yes	yes	yes	2	no	yes
138	Blombosch	Kaolinite	31.7	56.2	42.0	Grinding	Slate	3 \ 1	0.5	no	yes	yes	yes	yes	1	no	yes
a			-	-	-	Rubbing	Hand	1	-	no	no	yes	no	no	0	no	no
139	Blombosch	Shale	30.9	49.9	32.2	Grinding	Quartzite	3 \ 1	0.6	no	yes	yes	yes	no	1	no	yes
140	Blombosch	Kaolinite	15.3	30.6	29.8	Grinding	Sandstone	3 \ 1	0.4	no	yes	yes	yes	yes	1	yes	no
141	Napier	Shale	38.1	75.8	24.5	Cutting 1/2	Steel blade	1 \ 2	-	-	-	-	-	-	-	-	-
a			-	-	-	Grinding	Quartzite	4 \ 9	5.4	no	yes	yes	yes	yes	4	no	yes
b			-	-	-	Grinding	Quartzite	4 \ 8	4.7	no	yes	yes	yes	yes	4	no	yes
c			-	-	-	Rubbing	Human arm	1 \ 3	-	no	no	yes	no	no	4	no	yes
142	Cape Point	Shale	44.6	38.9	7.5	Cutting 1/2	Steel blade	1 \ 2	-	-	-	-	-	-	-	-	-
a			-	-	-	Grinding	Quartzite	4 \7	7.5	no	yes	yes	yes	yes	7	no	yes
b			-	-	-	Drawing	Quartzite	2 \ 5	-	no	yes	yes	yes	yes	4	no	yes
143	Napier	Shale	35.4	48.7	21.6	Cutting 1/2	Steel blade	1 \ 2	-	-	-	-	-	-	-	-	-
a			-	-	-	Grinding	Quartzite	2 \ 5	3.3	no	yes	yes	yes	yes	4	no	yes
b			-	-	-	Grinding	Quartzite	2 \ 3	3.1	no	yes	yes	yes	yes	4	yes	no
c			-	-	-	Rubbing	Animal hide	1	-	no	no	yes	no	yes	4	no	yes
144	Napier	Shale	27.5	42.5	23.6	Cutting 1/2	Steel blade	1 \ 2	-	-	-	-	-	-	-	-	-
a			-	-	-	Grinding	Sandstone	6 \ 2	8.7	yes	yes	yes	yes	yes	3	no	yes
b			-	-	-	Grinding	Sandstone	6 \ 2	5.4	yes	yes	yes	yes	yes	3	no	yes

c			-	-	-	Rubbing	Human arm	2 \ 4	-	no	no	yes	no	no	0	no	no
145	Cederberg	Shale	36.1	39.4	26.1	Cutting 1/2	Steel blade	1 \ 2	-	-	-	-	-	-	-	-	-
a			-	-	-	Grinding	Quartzite	1 \ 3	1.9	no	yes	yes	yes	yes	1	no	yes
b			-	-	-	Grinding	Quartzite	1 \ 2	1.3	no	yes	yes	yes	yes	1	no	yes
c			-	-	-	Rubbing	Animal hide	1	-	no	no	yes	no	no	0	no	no
146	Blombosch	Shale	42,3	96.7	11.4	Cutting 1/2	Steel blade	1 \ 2	-	-	-	-	-	-	-	-	-
a			-	-	-	Grinding	Sandstone	1 \ 3	0.8	no	yes	yes	yes	yes	1	no	yes
b			-	-	-	Grinding	Sandstone	1 \ 3	2.6	no	yes	yes	yes	yes	1	no	yes
c			-	-	-	Rubbing	Animal hide	1	-	no	no	yes	no	no	1	no	no
147	Cape Point	Shale	18.6	46.2	6.8	Cutting 1/2	Steel blade	1 \ 2	-	-	-	-	-	-	-	-	-
a			-	-	-	Grinding	Quartzite	1 \ 3	0.6	no	yes	yes	yes	yes	1	no	yes
b			-	-	-	Grinding	Quartzite	1 \ 3	0.9	no	yes	yes	yes	yes	1	no	yes
c			-	-	-	Rubbing	Animal hide	1	-	no	no	yes	no	no	1	no	no
148	Napier	Shale	28.5	37.3	18.6	Cutting 1/2	Steel blade	1 \ 2	-	-	-	-	-	-	-	-	-
a			-	-	-	Grinding	Quartzite	1 \ 3	3.0	no	yes	yes	yes	yes	2	no	yes
b			-	-	-	Rubbing	Animal hide	1	-	no	no	yes	no	no	2	no	yes
c			-	-	-	Grinding	Quartzite	1 \ 3	0.4	no	yes	yes	yes	yes	2	no	yes
d			-	-	-	Rubbing	Animal hide	1	-	no	no	yes	no	no	2	no	yes
149	Napier	Shale	39.0	56.7	28.2	Cutting 1/2	Steel blade	1 \ 2	-	-	-	-	-	-	-	-	-
a			-	-	-	Grinding	Sandstone	1 \ 3	3.5	no	yes	yes	yes	yes	1	no	yes
b			-	-	-	Grinding	Sandstone	1 \ 2	3.2	no	yes	yes	yes	yes	1	yes	yes
c			-	-	-	Rubbing	Animal hide	1	-	no	no	yes	no	no	1	no	yes
150	Cape Point	Shale	31.6	62.9	8.6	Cutting 1/2	Steel blade	1 \ 2	-	-	-	-	-	-	-	-	-
a			-	-	-	Grinding	Quartzite	3 \ 5	9.7	yes	yes	yes	yes	yes	3	no	yes
b			-	-	-	Drawing	Quartzite	1 \ 2	-	no	yes	yes	yes	yes	3	no	yes

CHAPTER 3

RIFKIN, R.F. 2011

PROCESSING OCHRE IN THE MIDDLE STONE AGE: TESTING THE INFERENCE OF PREHISTORIC BEHAVIOURS FROM ACTUALISTICALLY DERIVED EXPERIMENTAL DATA

Table 3 (Supplementary Table 2)

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CONTENTS

Supplementary Table 2

Results of microscopic analyses of pigment samples processed during the experimental study. Numerals represent allocated values and indicate particular features as: 0 - absent; 1 - limited presence; 2 - extensive presence; and 3 - macroscopically visible.

#	Action	Contact	Mass (g)	Facets	Striations	U	V	AU	Parallel	Transverse	Striae	Grooves	U	V	AU	Parallel	Transverse	Smoothing	Rounding	Prehensile	Polish	Pitting	Residue
1	Grinding	Sandstone	80.9	5	3	1	1	0	2	2	1	3	3	1	0	3	1	1	0	1	1	2	2
2	Grinding	Sandstone	64.4	4	3	2	1	2	1	3	0	1	2	0	0	2	1	1	0	3	1	2	0
3	Grinding	Quartzite	91.8	1	2	3	2	1	2	2	1	3	3	1	0	3	1	2	0	0	3	1	2
4	Grinding	Quartzite	62.1	3	3	1	1	0	2	2	1	1	3	1	0	3	1	2	0	1	3	1	0
5	Grinding	Quartzite	29.4	2	3	2	2	1	1	3	0	3	3	1	0	3	1	1	0	2	1	2	1
6	Grinding	Quartzite	25.9	3	3	2	1	2	1	3	0	1	2	0	0	2	1	2	0	1	2	2	3
7	Grinding	Sandstone	24.4	2	3	2	1	1	2	1	1	3	3	1	1	3	1	2	1	2	2	1	3
8	Grinding	Quartzite	16.6	3	3	1	1	0	2	2	1	3	3	1	0	3	1	2	0	1	1	3	3
a	Rubbing	Animal hide	16.2	0	1	1	1	0	2	2	0	3	3	1	0	3	1	3	3	3	3	0	0
9	Grinding	Quartzite	41.7	4	1	3	2	1	2	2	1	1	3	1	0	3	1	1	0	0	0	3	3
10	Grinding	Quartzite	47.6	5	2	2	1	2	1	3	0	1	2	0	0	2	1	2	0	1	1	3	3
11	Grinding	Quartzite	71.9	5	3	2	1	1	2	1	1	3	3	1	0	3	1	2	0	2	3	1	1
12	Grinding	Quartzite	20.9	8	3	2	2	1	1	3	0	3	3	1	0	3	1	2	1	3	0	3	3
13	Grinding	Quartzite	28.4	7	3	2	1	2	1	3	0	1	3	1	1	3	1	3	0	3	1	1	3
14	Grinding	Quartzite	23.9	3	3	3	2	1	2	2	1	3	2	0	0	2	1	3	0	3	1	3	3
a	Rubbing	Human arm	23.1	0	1	2	1	0	2	2	0	3	2	0	0	2	1	3	3	3	3	3	0
15	Grinding	Quartzite	41.9	4	3	1	1	0	2	2	1	3	3	1	0	3	1	3	0	2	0	3	3
16	Grinding	Quartzite	49.3	3	3	2	1	2	1	3	0	1	3	1	0	3	1	2	0	1	1	2	3
17	Grinding	Quartzite	41.2	2	3	2	2	1	1	3	0	3	3	1	0	3	1	2	0	0	1	3	1
18	Grinding	Quartzite	42.1	2	3	1	1	0	2	2	1	3	2	0	0	2	1	2	0	1	1	3	1
19	Grinding	Quartzite	13.3	3	3	3	2	1	2	2	1	3	3	1	1	3	1	2	1	1	2	1	3
20	Grinding	Quartzite	7.1	6	3	3	2	1	2	2	1	3	3	1	0	3	1	2	0	3	0	2	3
21	Grinding	Quartzite	28.3	3	3	2	1	1	2	1	1	3	3	1	1	3	1	3	0	3	2	1	3
22	Grinding	Quartzite	38.9	11	3	1	1	0	2	2	1	3	3	1	0	3	1	2	0	3	0	1	3
a	Drawing	Animal hide	38.0	2	0	1	1	0	2	2	0	2	3	1	0	2	2	3	3	3	3	3	0
23	Grinding	Quartzite	48.1	1	1	2	2	1	1	3	0	1	3	1	0	3	1	1	0	1	0	3	3
24	Grinding	Quartzite	459.8	2	3	2	1	2	1	3	0	1	3	1	0	3	1	2	0	1	1	3	3
a	Incising	Quartzite	456.1	-	3	1	3	1	3	0	1	3	3	0	1	3	1	2	0	1	2	3	0

25	Incising	Quartzite	222.6	-	3	1	3	1	3	0	2	3	3	0	1	3	1	1	0	1	0	1	1
26	Incising	Quartz	141.4	-	3	1	3	1	3	0	2	3	3	0	1	3	1	1	0	2	2	1	3
27	Scraping	Quartzite	130.6	1	3	2	0	2	3	0	2	3	1	2	2	3	1	2	0	2	2	1	3
28	Pounding	Quartzite	589.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Quartzite	102.7	1	3	3	2	1	2	2	1	3	3	1	0	3	1	2	0	1	0	3	3
29	Grinding	Sandstone	39.9	4	3	2	1	2	1	3	0	1	2	0	0	2	1	3		2	2	0	3
30	Grinding	Sandstone	37.0	6	2	2	1	1	2	1	1	3	3	1	0	3	1	2	0	2	3	1	2
31	Grinding	Quartzite	31.5	3	1	3	0	2	3	1	0	1	3	1	0	3	1	1	0	1	1	3	3
32	Grinding	Quartzite	54.1	4	3	2	1	2	1	3	0	1	3	1	0	3	1	1	0	1	2	2	3
33	Cutting 1/3	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Sandstone	15.1	4	3	2	2	1	1	3	0	3	3	1	0	3	1	2	0	0	3	3	0
	Control	None	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
b	Grinding	Sandstone	34.9	3	3	1	1	0	2	2	1	3	2	0	0	2	1	2	0	0	2	1	3
	Rubbing	Human arm	34.1	0	1	1	1	0	2	2	1	2	2	0	0	2	1	3	3	0	3	1	0
c	Grinding	Sandstone	32.7	4	2	2	1	2	1	3	0	1	3	1	1	3	1	2	0	0	3	1	3
	Rubbing	Animal hide	32.1	0	1	1	1	1	1	2	0	2	2	1	1	2	1	2	3	0	3	1	0
34	Cutting 1/3	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Sandstone	12.3	4	3	3	2	1	2	2	1	3	3	1	0	3	1	3	0	1	3	0	3
	Control	None	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
b	Grinding	Sandstone	9.3	2	2	3	2	1	2	2	1	3	2	0	0	2	1	2	0	1	2	1	3
	Rubbing	Human arm	9.0	0	1	1	2	1	1	1	0	3	1	0	0	1	1	3	3	1	3	1	1
c	Grinding	Sandstone	4.2	5	2	2	1	2	1	3	0	1	3	1	0	3	1	2	0	1	3	1	3
	Rubbing	Animal hide	3.9	0	1	1	1	1	2	3	0	3	2	1	0	2	1	3	3	1	3	1	1
35	Cutting 1/3	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Sandstone	30.4	5	3	3	1	0	0	1	3	3	3	1	0	3	1	2	0	1	2	1	3
	Control	None	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
b	Grinding	Sandstone	28.2	2	3	1	1	0	2	2	1	3	2	0	0	2	1	2	0	1	2	1	3
	Rubbing	Human arm	27.7	0	1	1	1	0	2	1	0	3	2	0	0	2	1	3	3	1	3	1	1
c	Grinding	Sandstone	18.1	3	3	3	2	1	2	2	1	3	3	1	1	3	1	2	0	1	2	1	3
	Rubbing	Animal hide	17.7	0	3	2	1	0	2	2	0	3	1	0	0	2	1	3	3	1	3	1	1
36	Cutting 1/10	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Quartzite	6.8	7	3	1	1	0	2	2	1	3	3	1	0	3	1	1	0	1	1	1	2
	Drawing	Quartzite	5.8	3	2	1	1	0	2	2	1	3	3	1	0	2	1	1	3	2	1	1	2
b	Grinding	Quartzite	10.0	4	3	2	1	1	2	1	1	3	2	0	0	2	1	1	0	1	1	1	1
	Drawing	Animal hide	9.3	1	2	1	1	0	1	1	0	3	2	0	0	2	1	3	3	2	3	1	0

c	Grinding	Quartzite	8.2	4	3	3	2	1	2	2	1	3	2	0	0	2	1	1	0	1	1	1	1
	Transport	Animal hide	8.0	0	3	3	2	1	2	2	0	3	2	0	0	2	1	1	1	2	3	1	0
d	Grinding	Quartzite	16.9	9	3	1	1	0	2	2	1	3	3	1	0	3	1	1	0	1	1	1	2
	Control	None	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
e	Grinding	Quartzite	11.1	7	3	3	1	0	0	1	3	3	3	1	1	3	1	1	0	1	1	1	1
	Transport	Sand	10.9	0	3	3	1	0	0	1	1	3	3	1	1	3	1	2	1	0	2	0	2
f	Grinding	Quartzite	10.2	5	3	3	1	0	0	1	3	3	3	1	0	3	1	1	0	1	1	1	1
	Control	None	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
g	Grinding	Quartzite	9.4	4	3	3	1	0	2	1	3	3	3	1	1	3	1	1	0	1	1	1	3
	Drawing	Animal hide	9.1	0	1	2	0	0	1	1	0	2	2	1	0	2	1	3	3	1	3	1	0
h	Grinding	Quartzite	6.9	5	3	1	1	0	2	2	1	3	2	0	0	2	1	1	0	1	1	1	2
	Drawing	Human arm	6.6	0	1	1	1	0	1	1	0	3	2	0	0	1	1	2	3	1	3	1	0
i	Grinding	Quartzite	9.4	4	3	3	2	1	2	2	1	3	3	1	0	3	1	1	0	1	1	1	2
	Drawing	Quartzite	9.1	5	2	3	2	1	2	3	0	3	3	1	3	1	3	1	0	2	1	1	3
j	Grinding	Quartzite	8.9	4	3	2	1	2	1	3	0	2	3	1	1	3	1	1	0	1	1	1	3
	Soaking	Water	8.3	0	3	2	1	2	1	3	0	2	3	1	1	3	1	2	0	1	2	2	0
37	Grinding	Quartzite	13.7	3	3	1	1	0	2	2	1	3	2	0	1	3	2	2	0	1	3	0	1
38	Grinding	Quartzite	53.8	4	2	2	2	1	1	3	0	1	3	1	0	3	1	2	0	0	3	2	1
a	Drawing	Animal hide	53.2	0	1	1	1	1	0	2	0	2	2	0	0	2	1	3	3	0	3	1	0
39	Grinding	Quartzite	18.8	3	1	2	1	0	0	2	1	1	2	0	0	2	1	3	0	1	3	0	1
40	Grinding	Quartzite	39.7	2	3	1	1	0	2	2	1	1	3	1	0	3	1	3	0	0	3	0	1
41	Cutting 1/3	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Soaking	Water	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Grinding	Quartzite	66.5	1	1	3	1	0	0	1	3	1	3	1	1	3	1	3	0	1	0	0	1
b	Soaking	Water	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Grinding	Quartzite	28.6	2	3	2	2	1	1	3	0	3	3	1	2	3	1	2	0	1	0	0	3
c	Soaking	Water	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Grinding	Quartzite	26.5	1	2	2	1	0	0	2	1	1	3	1	0	3	1	2	1	1	1	1	1
42	Cutting 1/2	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Cutting	Bone	75.1		1	0	0	1	0	0	3	3	2	2	0	1	2	1	0	1	2	0	0
b	Notching	Bone	58.1		3	2	1	2	3	0	0	3	3	1	2	3	1	2	1	1	1	3	0
43	Scraping	Bone	43.1	5	1	0	0	1	0	0	3	3	2	1	0	3	3	0	1	1	0	3	0
44	Grinding	Quartzite	158.4	2	2	1	0	1	2	2	0	2	3	1	1	3	1	0	0	1	0	3	0
a	Pounding	Quartzite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45	Cutting 1/2	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

a	Grinding	Quartzite	136.8	1	3	2	1	0	0	2	1	1	3	1	0	3	1	1	0	1	0	2	1
b	Grinding	Quartzite	98.0	1	3	1	1	0	2	2	1	3	3	1	1	3	1	1	0	1	0	2	1
46	Grinding	Mudstone	32.5	6	3	2	2	0	3	1	2	3	3	1	0	3	1	1	1	3	1	3	3
a	Drawing	Animal hide	29.7	1	1	0	1	0	1	0	1	1	1	0	0	0	0	2	3	3	3	1	3
b	Drawing	Sandstone	29.6	2	3	1	1	0	2	2	1	0	1	1	3	2	1	1	0	3	1	2	3
47	Grinding	Mudstone	29.3	8	3	0	1	1	3	1	2	3	3	0	3	3	1	1	1	1	1	3	3
a	Drawing	Animal hide	29.0	0	0	1	1	0	1	1	0	0	2	0	0	2	1	3	3	3	3	0	3
b	Drawing	Quartzite	28.3	4	3	3	1	1	2	2	1	3	3	1	1	2	2	1	1	3	1	1	2
48	Cutting 1/4	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Sandstone	26.5	2	2	0	1	0	3	0	1	3	3	1	1	3	1	2	1	1	1	0	2
b	Grinding	Mudstone	42.0	1	1	0	1	0	2	1	1	2	3	0	2	3	1	1	1	1	0	1	2
c	Grinding	Slate	23.9	3	2	1	0	0	2	1	0	3	3	0	1	2	1	1	1	1	0	1	3
d	Grinding	Quartzite	24.7	1	2	1	2	1	3	0	1	3	3	2	2	3	0	1	1	1	2	1	3
49	Grinding	Sandstone	8.7	2	1	2	1	0	3	2	1	2	3	0	1	3	2	1	0	1	1	1	3
a	Rubbing	Human arm	8.5	0	3	1	1	0	3	1	0	3	3	0	1	3	1	3	3	3	3	3	0
50	Grinding	Sandstone	9.8	3	1	1	1	0	2	0	1	2	3	0	1	3	1	1	1	1	2	2	3
a	Rubbing	Human arm	9.7	0	3	1	1	0	2	0	0	3	2	0	1	2	1	3	3	1	3	0	3
51	Grinding	Sandstone	9.9	3	2	1	0	0	2	1	1	2	3	0	2	3	1	1	1	2	0	1	3
a	Rubbing	Human arm	9.7	0	3	0	0	0	2	1	0	3	2	0	2	3	1	3	3	3	3	0	3
52	Grinding	Quartzite	16.4	4	1	1	0	0	2	1	1	2	3	0	2	3	1	2	1	2	0	1	2
a	Drawing	Animal hide	16.1	0	2	0	0	0	0	0	0	2	2	0	1	2	1	3	3	2	3	0	3
b	Drawing	Sandstone	15.6	5	3	3	1	1	2	2	1	3	3	1	1	2	2	1	1	3	1	1	3
53	Grinding	Sandstone	10.2	4	1	2	1	0	3	0	0	2	3	0	1	3	1	1	1	1	0	2	3
a	Rubbing	Human arm	10.0	0	0	1	0	0	2	0	0	1	2	0	0	2	1	3	3	1	3	0	2
54	Grinding	Sandstone	3.3	4	2	1	1	0	0	0	1	3	2	0	0	3	0	1	0	1	0	2	3
a	Rubbing	Human arm	3.2	0	1	0	0	0	0	0	0	1	1	0	0	2	3	3	3	1	3	2	3
55	Scraping	Quartz	13.7	1	3	1	2	1	3	3	2	3	2	1	3	3	3	1	1	2	2	0	2
56	Notching	Quartzite	23.8	8	3	2	1	0	3	0	0	3	3	1	3	3	0	1	0	2	0	1	3
57	Grinding	Sandstone	47.7	3	3	3	1	0	3	1	1	3	3	0	2	3	1	1	1	3	2	1	3
a	Rubbing	Human hand	47.6	0	3	3	1	0	2	1	1	3	3	0	2	3	1	3	3	3	3	0	2
58	Grinding	Sandstone	16.2	1	3	1	0	0	3	3	1	3	3	0	2	3	3	1	0	3	0	3	3
a	Rubbing	Human hand	16.0	0	0	1	0	0	3	3	0	1	3	0	2	3	3	3	3	3	2	0	3
59	Grinding	Sandstone	14.2	1	2	1	1	0	2	1	1	3	2	0	1	2	1	1	0	3	1	2	3
a	Rubbing	Human hand	14.1	0	0	1	1	0	1	1	0	2	2	0	0	2	1	3	3	3	3	0	3
60	Grinding	Sandstone	40.2	2	3	2	0	0	2	1	1	3	2	0	1	2	1	2	1	3	0	1	3

a	Rubbing	Human hand	39.9	0	2	1	0	0	2	0	0	1	2	0	0	2	1	3	3	1	3	0	2
61	Grinding	Sandstone	16.7	1	2	2	1	0	3	1	1	3	3	1	1	3	1	1	0	2	0	2	3
a	Rubbing	Animal hide	16.3	0	1	1	0	0	1	0	0	2	1	0	0	1	0	3	3	2	2	2	3
62	Grinding	Sandstone	21.9	1	3	2	0	1	3	0	2	3	3	0	2	3	0	1	0	2	2	2	2
a	Rubbing	Human arm	21.7	0	3	1	0	0	2	0	0	3	3	0	1	2	0	3	3	2	2	3	3
63	Grinding	Sandstone	20.3	1	3	2	1	1	3	0	1	3	3	0	2	3	0	2	0	3	1	2	2
a	Drawing	Animal hide	20.1	1	1	1	0	0	2	0	0	1	2	0	1	2	0	3	3	3	3	1	3
b	Drawing	Sandstone	19.3	5	3	3	1	1	1	3	1	1	3	2	2	1	3	2	0	3	2	1	3
64	Grinding	Sandstone	36.9	2	3	2	1	1	3	0	0	3	3	2	0	3	1	2	0	3	3	0	3
65	Grinding	Quartzite	66.9	2	3	2	1	1	3	1	1	3	3	1	1	3	1	2	0	1	0	0	3
a	Rubbing	Animal hide	66.7	0	1	1	0	0	1	0	0	3	3	0	3	3	1	3	3	1	2	3	3
66	Grinding	Sandstone	20.0	3	1	2	1	1	3	1	0	2	3	1	2	3	1	1	0	1	1	3	3
a	Rubbing	Animal hide	19.9	0	1	1	0	0	2	0	0	1	2	0	1	1	0	3	3	1	2	0	3
67	Scraping	Bone	23.2	4	3	3	1	1	1	3	1	3	3	0	3	1	3	2	1	1	1	0	2
68	Grinding	Sandstone	39.1	2	3	2	1	1	3	1	1	3	3	1	1	2	1	2	1	3	3	0	3
69	Grinding	Sandstone	28.9	1	1	3	1	1	3	1	0	2	3	1	0	3	0	2	0	1	2	0	3
a	Scraping	Shell	25.6	1	3	3	3	0	3	0	2	3	3	0	3	0	0	1	0	1	0	1	3
70	Grinding	Sandstone	30.9	2	3	2	1	1	2	1	1	3	3	3	0	3	1	2	0	2	0	0	2
a	Rubbing	Human hand	30.6	0	3	1	0	0	1	1	1	3	2	2	0	2	1	3	3	2	2	0	2
71	Grinding	Quartzite	9.8	1	3	3	1	1	2	1	1	3	3	1	0	3	1	1	1	2	2	3	2
a	Pounding	Quartzite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
72	Cutting 1/2	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Quartzite	19.9	1	3	2	0	0	2	1	1	3	3	0	1	3	1	1	0	3	2	1	3
b	Grinding	Sandstone	11.2	1	3	3	0	0	2	1	1	2	2	0	1	3	1	1	0	3	1	3	3
73	Scraping	Quartzite	46.7	1	3	2	0	0	2	1	1	3	3	0	1	3	1	1	0	2	0	2	3
a	Cutting	Quartzite	38.6	1	3	2	2	2	2	2	3	3	3	2	3	3	3	1	0	2	0	1	2
74	Grinding	Sandstone	7.9	3	3	2	1	2	2	1	1	3	3	0	1	3	2	1	0	3	3	0	3
a	Drawing	Human arm	7.7	1	1	1	1	1	1	0	0	1	2	0	0	2	1	3	3	3	3	0	3
b	Drawing	Quartzite	7.1	4	2	3	1	3	1	3	1	2	3	0	0	2	3	2	0	3	2	1	3
75	Scraping	Bone	10.4	1	2	2	0	0	2	0	1	0	1	0	0	2	2	2	2	1	3	0	3
76	Grinding	Sandstone	13.6	1	2	1	1	2	1	1	3	3	3	0	3	1	2	0	2	0	0	3	2
a	Rubbing	Human arm	13.2	0	1	1	0	1	1	1	0	1	2	0	2	0	1	3	3	1	3	0	3
77	Grinding	Sandstone	36.9	1	3	2	1	1	3	0	0	3	3	2	0	3	1	2	0	3	3	0	2
a	Drilling	Quartzite	-	0	3	1	1	2	3	0	2	3	3	0	2	3	0	1	1	3	0	0	2
b	Drilling	Quartz	-	0	1	1	1	2	3	0	1	3	3	0	2	3	0	1	1	3	0	0	3

c	Drilling	Shell	-	0	2	2	1	1	3	0	1	2	2	0	1	3	0	1	1	3	2	0	3
d	Drilling	Shell	-	0	1	2	1	2	3	0	1	0	2	0	2	3	0	1	0	3	1	0	3
e	Drilling	Bone	-	0	1	1	2	3	3	0	1	1	3	0	2	3	0	1	1	3	0	0	3
f	Drilling	Bone	-	0	1	2	2	2	3	0	0	0	2	0	1	3	0	1	1	3	0	0	2
g	Drilling	Steel bit	24.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	0	0	3
78	Grinding	Sandstone	35.9	1	2	2	1	1	3	0	0	3	3	2	0	3	1	2	0	3	3	0	3
a	Mixing	Shell, water	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
b	Mixing	Shell, water	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
c	Mixing	Shell, water	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
d	Rubbing	Human face	35.4	0	3	2	1	0	2	0	0	3	3	2	0	2	1	3	3	2	2	3	2
79	Grinding	Sandstone	17.2	1	1	1	0	0	2	3	0	1	3	0	0	2	1	1	0	1	0	1	3
a	Drawing	Human face	16.7	0	2	1	0	0	1	1	0	2	3	1	0	1	1	3	3	3	3	2	0
b	Drawing	Quartzite	16.1	6	3	1	0	0	1	3	1	2	1	0	0	1	3	2	0	3	1	2	2
80	Grinding	Sandstone	39.9	1	1	2	0	1	2	0	1	2	3	0	1	3	1	2	0	1	0	3	2
a	Incising	Bone	37.4	-	1	1	0	0	1	0	0	3	1	3	0	3	3	1	0	1	0	1	3
b	Incising	Silcrete	36.2	-	1	1	0	0	1	0	0	3	1	3	0	3	3	1	0	1	0	0	3
81	Grinding	Sandstone	39.4	1	3	2	1	1	3	0	0	3	3	2	0	3	1	2	0	3	0	2	2
a	Incising	Quartz	36.9	-	3	1	0	0	3	0	2	3	1	3	1	3	3	1	0	1	0	1	2
b	Incising	Shell	34.6	-	3	1	0	0	3	0	2	3	1	1	3	3	3	1	1	1	0	1	2
82	Grinding	Sandstone	21.4	1	3	2	1	1	3	0	0	3	3	2	0	3	1	3	0	1	3	0	3
a	Incising	Quill	20.7	-	2	1	0	1	3	1	0	3	1	0	2	3	3	1	2	1	2	2	2
b	Incising	Quill	20.2	-	2	1	0	1	3	1	0	3	1	0	2	3	3	1	2	1	2	2	3
83	Grinding	Sandstone	7.3	3	3	1	0	1	2	2	1	1	2	0	1	3	3	1	1	3	3	3	3
84	Grinding	Quartzite	34.3	2	3	1	0	0	2	1	1	3	3	0	1	3	1	2	0	1	3	1	2
85	Grinding	Sandstone	13.6	1	3	1	0	0	2	0	1	3	3	0	3	3	2	1	1	3	3	1	3
a	Drawing	Sandstone	12.7	4	3	1	1	1	3	0	1	3	3	1	3	3	0	2	0	3	2	1	2
86	Grinding	Sandstone	13.9	1	2	3	1	1	3	1	0	2	3	1	0	3	0	2	0	1	1	0	3
a	Scraping	Shell	13.5	9	2	2	1	2	3	0	1	1	2	0	0	3	0	1	3	2	3	0	3
87	Grinding	Quartzite	10.8	5	2	3	0	1	3	2	0	3	3	0	2	3	2	2	1	2	0	1	3
88	Grinding	Sandstone	16.6	1	2	2	1	1	2	1	0	1	3	0	1	3	2	2	0	2	0	1	3
a	Scraping	Quartzite	15.8	3	3	1	0	0	3	1	2	3	1	0	3	3	1	1	2	2	0	1	3
89	Grinding	Sandstone	22.9	1	2	2	0	0	2	0	1	2	3	0	3	3	2	0	0	1	0	1	3
a	Rubbing	Animal hide	22.7	0	1	1	0	0	1	0	2	3	3	0	3	3	2	3	3	3	3	2	0
90	Grinding	Sandstone	36.5	2	2	1	0	0	3	1	0	3	3	0	2	3	1	1	0	3	2	0	2
91	Grinding	Quartzite	15.7	3	2	1	0	1	2	1	2	3	3	0	1	3	2	2	0	3	2	0	2

92	Grinding	Sandstone	28.8	1	2	1	1	2	1	1	1	3	3	0	3	1	2	1	0	1	1	2	3
a	Scraping	Quartzite	28.4	1	2	2	0	1	3	0	1	3	3	0	3	3	0	1	2	1	0	3	2
93	Grinding	Sandstone	10.7	2	2	1	0	1	3	1	0	3	3	0	1	3	0	1	0	1	1	2	3
a	Drawing	Quartzite	10.1	5	2	1	1	1	2	3	0	3	3	0	3	1	3	0	0	3	0	0	3
b	Rubbing	Animal hide	9.7	0	1	1	0	0	1	2	0	0	3	0	3	3	3	3	3	3	3	0	2
94	Grinding	Quartzite	45.3	1	2	2	0	1	2	1	0	1	3	0	1	3	1	3	0	3	3	0	3
95	Cutting 1/2	Steel blade	58.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Quartzite	46.6	3	3	2	0	1	3	1	2	0	3	0	2	3	1	2	0	1	3	0	3
b	Grinding	Shell	35.8	2	2	1	0	0	2	1	0	3	0	0	0	0	0	2	3	1	2	1	2
96	Grinding	Sandstone	29.2	1	3	1	0	0	3	0	1	3	1	0	3	3	1	3	0	3	3	3	3
a	Rubbing	Human arm	28.9	0	1	1	0	0	1	0	0	1	1	0	3	3	1	3	3	3	3	0	3
97	Grinding	Quartzite	9.7	1	3	1	2	0	2	1	2	3	0	2	3	3	1	1	0	3	1	1	3
a	Rubbing	Human arm	9.4	0	1	1	1	0	1	0	0	2	0	2	3	3	1	3	3	3	3	0	3
98	Grinding	Quartzite	75.6	3	1	1	0	1	3	0	2	3	1	0	3	3	1	3	0	3	2	1	3
a	Rubbing	Human arm	75.2	0	1	0	0	1	1	0	0	1	1	0	3	3	1	3	3	3	3	0	2
99	Grinding	Sandstone	65.6	1	1	1	0	1	1	1	2	3	2	0	2	3	1	2	0	2	1	1	3
a	Rubbing	Animal hide	65.1	0	1	1	0	1	1	1	0	1	2	0	2	3	1	3	3	3	3	0	3
100	Grinding	Quartzite	66.7	1	1	2	0	0	2	0	1	3	3	0	2	3	1	1	0	2	3	1	2
a	Abrasive	Bone / hide	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
101	Grinding	Sandstone	26.0	3	1	1	0	0	1	1	1	3	2	0	0	2	0	3	0	2	1	1	2
a	Rubbing	Animal hide	25.7	0	1	1	0	0	1	0	0	1	1	0	0	1	0	3	3	3	3	0	0
102	Grinding	Quartzite	23.9	1	2	2	0	0	2	1	0	3	3	0	1	2	1	2	0	2	1	2	3
a	Rubbing	Human arm	23.4	0	1	1	0	0	1	1	0	1	2	0	1	2	1	3	3	3	3	1	3
103	Grinding	Quartzite	14.4	1	1	1	0	0	1	1	0	3	2	0	2	3	1	2	0	1	3	2	3
a	Rubbing	Human face	14.1	0	0	0	0	0	0	0	0	1	1	0	1	2	1	3	3	3	3	1	3
104	Grinding	Sandstone	33.2	2	1	1	0	1	1	0	1	3	3	0	2	3	1	1	0	1	1	3	2
a	Rubbing	Human hand	33.0	0	1	1	0	1	1	0	0	0	2	0	2	3	1	3	3	3	3	1	0
105	Grinding	Quartzite	30.0	2	1	1	0	1	3	0	0	1	0	2	3	3	1	2	1	0	3	1	3
106	Grinding	Quartzite	26.1	1	3	1	0	1	3	0	1	3	0	2	3	3	1	1	0	3	1	2	3
a	Rubbing	Human hand	25.8	0	1	3	1	1	0	3	1	1	0	0	2	3	1	3	3	3	3	1	0
107	Grinding	Quartzite	12.8	3	1	1	1	0	2	0	0	1	3	1	0	3	0	2	0	0	3	1	2
108	Grinding	Quartzite	46.6	2	3	2	1	2	1	3	0	3	3	0	2	3	1	1	0	1	0	1	3
a	Drawing	Animal hide	45.2	1	1	1	0	1	0	2	0	1	3	0	0	2	1	3	3	3	3	3	0
109	Grinding	Quartzite	102.8	1	1	1	1	0	2	0	0	1	3	1	0	3	0	1	0	0	3	1	3
110	Grinding	Quartzite	57.9	1	1	1	1	0	2	0	0	3	3	0	2	3	1	1	0	0	2	2	2

a	Drawing	Human arm	57.4	0	1	1	1	0	2	0	0	1	2	2	2	0	2	1	3	3	3	1	0
b	Drawing	Quartzite	56.7	3	1	3	1	1	0	2	2	1	3	1	1	0	2	1	0	3	1	1	3
111	Grinding	Quartzite	36.3	1	1	1	1	0	2	0	0	0	3	1	0	3	0	2	0	1	3	1	2
112	Grinding	Sandstone	39.5	1	1	1	1	0	2	0	0	0	3	0	2	3	1	2	0	1	3	3	3
a	Rubbing	Human arm	39.1	0	1	3	1	1	0	3	1	1	3	2	2	0	2	1	3	3	3	1	3
113	Grinding	Quartzite	42.3	2	1	2	1	2	1	3	0	0	3	0	2	3	1	1	0	3	2	3	3
114	Drawing	Sandstone	22.7	5	1	3	1	1	0	2	2	1	3	0	2	2	1	2	0	1	3	2	3
115	Drawing	Quartzite	22.7	5	1	2	1	1	0	2	2	1	3	3	0	1	3	2	0	1	3	2	2
116	Grinding	Quartzite	20.4	1	0	2	1	2	1	3	0	0	3	1	0	3	0	3	0	0	3	3	3
117	Grinding	Sandstone	40.6	2	1	1	1	0	2	0	0	1	0	2	3	3	1	3	0	1	3	1	1
a	Scraping	Shell	39.7	1	3	2	0	1	3	0	1	2	3	1	3	3	0	1	2	1	2	3	2
b	Scraping	Shell	39.1	1	3	2	0	1	2	0	1	2	3	1	3	3	0	1	2	1	3	3	2
118	Grinding	Sandstone	34.9	2	1	2	0	1	0	3	0	2	3	0	2	3	1	1	0	2	0	2	2
a	Scraping	Shell	33.2	1	3	3	0	1	3	0	0	3	3	0	3	3	0	1	2	2	3	3	3
b	Scraping	Shell	31.6	1	3	2	0	1	3	0	0	3	3	1	3	3	0	1	2	2	3	3	2
119	Grinding	Quartzite	10.3	1	1	2	1	2	1	3	0	1	3	0	2	3	1	1	0	1	3	3	3
120	Grinding	Sandstone	47.2	1	1	1	1	0	2	0	0	1	3	1	0	3	0	1	0	2	3	3	3
121	Grinding	Quartzite	63.7	1	3	2	1	2	1	3	0	3	0	2	3	3	1	1	0	3	3	3	2
a	Rubbing	Animal hide	63.1	0	1	3	0	0	0	2	1	1	0	2	2	0	2	1	3	3	3	1	0
122	Grinding	Quartzite	65.2	1	1	2	1	2	1	3	0	3	3	1	0	3	0	2	0	3	1	1	3
a	Rubbing	Human arm	64.9	0	1	3	1	1	0	3	1	2	2	2	2	0	2	1	3	3	3	0	0
123	Grinding	Quartzite	219.6	1	1	2	0	1	0	3	0	2	3	0	2	3	1	1	0	1	1	3	2
a	Rubbing	Human arm	219.2	0	1	3	1	1	0	3	1	2	2	2	2	0	2	1	3	3	3	1	1
124	Grinding	Sandstone	72.9	1	2	2	0	1	0	3	0	3	3	1	0	3	0	1	0	3	3	3	3
125	Grinding	Quartzite	117.8	1	3	2	1	2	1	3	0	3	3	0	2	3	1	2	0	1	3	3	3
a	Rubbing	Animal hide	117.6	0	0	3	0	0	0	2	1	2	2	1	2	0	2	1	3	3	3	1	0
126	Grinding	Quartzite	73.2	1	3	3	0	1	1	3	1	3	0	2	3	3	1	1	0	3	2	3	1
127	Grinding	Quartzite	146.5	2	2	2	1	2	3	1	1	3	3	1	0	3	0	1	0	1	1	3	3
a	Drawing	Sandstone	145.3	4	2	3	1	1	1	3	0	3	3	0	2	2	3	0	0	3	0	0	3
128	Grinding	Quartzite	79.9	3	1	1	1	0	2	0	1	3	3	0	2	3	1	1	0	3	1	0	3
a	Rubbing	Human hand	79.7	0	1	3	1	1	0	3	1	1	2	0	1	1	0	3	3	3	3	0	1
129	Grinding	Sandstone	116.1	2	1	2	0	1	0	3	0	1	3	1	0	3	0	1	0	2	0	3	2
130	Grinding	Various	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Slate	107.4	1	1	2	0	1	0	3	0	1	3	2	0	3	1	1	2	2	1	3	2
b	Grinding	Sandstone	59.9	1	2	2	1	2	1	3	0	0	3	1	0	3	0	1	0	2	2	3	2

c	Grinding	Quartzite	115.0	1	1	1	1	0	2	0	0	1	3	0	2	3	1	1	0	2	1	3	3
131	Cutting 1/2	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Sandstone	43.5	1	3	2	0	1	0	3	0	3	3	1	0	3	0	3	0	2	1	1	3
b	Grinding	Sandstone	32.2	1	1	1	1	0	2	0	1	3	3	2	0	3	1	2	0	2	1	1	3
c	Rubbing	Human hand	31.8	0	2	3	0	0	0	2	1	1	2	1	0	2	1	3	3	3	3	0	0
132	Grinding	Sandstone	162.9	2	2	3	0	1	1	3	1	2	3	0	2	3	1	1	0	2	0	3	2
a	Rubbing	Human arm	162.4	0	3	3	1	1	0	3	1	3	2	0	1	2	1	3	3	2	2	0	1
133	Grinding	Quartzite	141.2	2	1	1	1	0	2	0	0	2	3	0	2	3	1	1	0	1	0	1	3
a	Scraping	Shell	136.2	1	3	2	0	0	2	0	1	3	3	2	0	3	1	1	2	1	0	0	3
b	Scraping	Shell	133.4	1	3	2	0	0	2	0	1	3	3	0	2	3	1	2	2	1	0	0	3
134	Grinding	Quartzite	83.2	2	2	2	1	2	1	3	0	3	0	2	3	3	1	1	0	1	0	3	2
a	Rubbing	Human arm	81.8	0	3	3	0	0	0	2	1	3	0	2	2	2	1	3	3	1	0	0	1
135	Grinding	Quartzite	141.4	1	1	1	1	0	2	0	0	3	3	0	2	3	1	2	0	2	1	1	3
136	Grinding	Quartzite	30.1	2	3	2	0	1	0	3	0	3	3	1	0	3	0	1	0	2	1	1	3
a	Rubbing	Human face	29.7	0	1	3	1	1	0	3	1	2	3	0	2	3	0	3	3	3	3	0	0
137	Grinding	Quartzite	27.5	2	3	2	1	2	1	3	0	3	3	0	2	3	1	1	0	2	1	3	1
138	Grinding	Slate	27.8	1	1	1	1	0	2	0	2	3	3	0	2	3	0	2	1	1	0	1	3
a	Rubbing	Human hand	27.5	0	1	3	0	0	0	2	1	1	2	0	1	2	0	3	3	3	3	0	0
139	Grinding	Quartzite	28.3	1	1	1	1	0	2	0	0	0	3	0	2	3	1	3	0	1	2	3	3
140	Grinding	Sandstone	13.3	1	1	1	1	0	2	0	1	3	3	1	0	3	0	1	0	0	2	3	2
141	Cutting 1/2	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Quartzite	13.0	4	3	2	0	1	0	3	0	3	3	0	2	3	1	1	0	3	2	1	3
b	Grinding	Quartzite	24.8	4	3	2	1	2	1	3	0	3	3	2	0	3	1	1	0	3	2	1	2
c	Rubbing	Human arm	24.5	0	0	3	1	1	0	3	1	0	2	2	0	2	1	3	3	3	3	0	0
142	Cutting 1/2	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Quartzite	11.7	7	1	1	1	0	2	0	1	3	3	0	2	3	1	1	0	2	0	1	2
b	Drawing	Quartzite	10.9	4	3	2	0	1	2	2	1	3	3	2	0	3	1	1	1	2	1	1	2
143	Cutting 1/2	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Quartzite	16.4	4	1	1	1	0	2	0	2	3	3	0	2	3	1	2	0	2	3	1	3
b	Grinding	Quartzite	11.9	4	3	2	1	2	1	3	0	3	3	1	0	3	0	2	0	2	3	1	3
c	Rubbing	Animal hide	11.1	0	3	3	0	0	0	2	1	3	2	1	0	2	0	3	3	2	3	0	0
144	Cutting 1/2	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Sandstone	25.2	3	1	1	1	0	2	0	1	3	3	1	0	3	0	1	0	2	0	1	3
b	Grinding	Sandstone	20.0	3	3	2	0	1	0	3	0	3	3	2	0	3	1	1	0	2	0	1	2
c	Rubbing	Human arm	19.2	0	3	3	1	1	0	3	1	3	2	2	0	2	0	3	3	2	2	0	0

145	Cutting 1/2	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Quartzite	16.1	1	3	2	1	2	1	3	0	3	3	1	0	3	0	2	0	2	3	1	3
b	Grinding	Quartzite	14.8	1	1	1	1	0	2	0	1	3	3	2	0	3	1	2	0	2	3	1	3
c	Rubbing	Animal hide	14.1	0	0	3	1	1	0	3	1	1	2	2	1	2	0	3	3	2	3	0	0
146	Cutting 1/2	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Sandstone	23.4	1	3	2	0	1	0	3	0	2	3	1	0	3	0	1	0	1	1	3	2
b	Grinding	Sandstone	15.6	1	3	3	0	1	1	3	1	2	3	2	0	3	1	1	0	1	1	3	3
c	Rubbing	Animal hide	14.9	0	0	3	1	1	0	3	1	0	2	2	1	2	0	3	3	1	3	1	1
147	Cutting 1/2	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Quartzite	8.8	1	3	2	1	2	1	3	0	3	3	1	0	3	0	2	0	2	1	0	3
b	Grinding	Quartzite	7.1	1	1	1	1	0	2	0	2	3	3	2	0	3	1	2	0	2	1	0	2
c	Rubbing	Animal hide	6.5	0	3	3	0	0	0	2	1	3	2	2	0	3	1	3	3	2	3	0	0
148	Cutting 1/2	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Quartzite	12.7	2	1	1	1	0	2	0	1	3	3	2	0	3	1	1	0	1	0	2	3
b	Rubbing	Animal hide	11.8	0	2	3	1	1	0	3	1	3	2	2	0	3	1	3	3	1	3	0	1
c	Grinding	Quartzite	11.9	2	3	2	1	2	1	3	0	3	3	2	0	3	1	1	0	1	0	1	2
d	Rubbing	Human hand	11.4	0	2	3	0	0	0	2	1	3	2	1	0	3	1	3	3	1	3	3	1
149	Cutting 1/2	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Sandstone	19.9	1	2	2	0	1	0	3	0	3	3	2	0	3	1	1	0	1	1	2	3
b	Grinding	Sandstone	11.8	1	1	1	1	0	2	0	1	3	3	1	0	3	0	1	0	1	1	2	3
c	Rubbing	Human arm	11.3	0	1	3	0	1	1	3	1	1	2	1	0	2	0	3	3	1	3	0	0
150	Cutting 1/2	Steel blade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a	Grinding	Quartzite	8.9	3	3	2	1	2	1	3	0	3	3	1	0	3	0	3	0	1	2	1	2
b	Drawing	Quartzite	15.8	3	1	3	0	1	0	2	2	3	3	0	2	3	0	3	1	1	3	1	0

CHAPTER 4

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TECHNOLOGICAL, ELEMENTAL AND COLORIMETRIC ANALYSIS OF AN ENGRAVED OCHRE FRAGMENT FROM THE MIDDLE STONE AGE LEVELS OF KLASIES RIVER CAVE 1, SOUTH AFRICA

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My contribution as a co-author to this paper included arranging access and permits to facilitate the analysis of ochre specimens recovered from the MSA levels of Klasies River Cave 1, the editing of photographs and the generation of maps and illustrations, formatting the basic structure of the paper, writing the *Introduction* and the *Archaeological context* sections and of editing the paper prior to submission to the *Journal of Archaeological Science*.

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Technological, elemental and colorimetric analysis of an engraved ochre fragment from the Middle Stone Age levels of Klasies River Cave 1, South Africa

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ABSTRACT

It is generally accepted that abstract and iconographic representations are reflections of symbolic material culture. Here we describe a fragmented ocherous pebble bearing a sequence of sub-parallel linear incisions. These were produced by a lithic point and may represent one of the oldest instances of a deliberate engraving. The object was recovered from Middle Stone Age II levels of Klasies River Cave 1, South Africa, and is dated to between 100,000 and 85,000 years ago. Microscopic analysis reveals that the surface of the object was ground until smooth before being engraved with a sequence of sub-parallel lines made by single and multiple strokes. X-ray fluorescence and colorimetric analysis of the object and a sample of twelve additional ochre pieces from the same level reveals that the brown colour and Manganese-rich composition renders the engraved piece distinct. This suggests that a particular type of raw material may have been selected for engraving purposes. Although the purpose of marking this object remains uncertain, its detailed analysis adds relevant information to previously published occurrences of Middle Stone Age engraved objects and contributes to clarify their distribution through time and space.

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1. Introduction

Recent archaeological, anthropological and genetic discoveries are radically changing our knowledge concerning the chronology of the emergence of modern cultural and anatomical traits. For most of the last century, the remarkable evidence of the complexity of Cro-Magnon behaviour in Europe convinced the scientific community that modern features had a sudden origin coinciding with the commencement of the Upper Palaeolithic some 40,000 years ago (ka) (Stringer and Gamble, 1993; Klein, 1995, 1999, 2000; Mellars, 1996a,b; Mithen, 1996; Bar-Yosef, 1998, 2002; Conard and Bolus, 2003). This view was challenged in the first decade of this century by authors supporting the scenario of a gradual emergence of modern culture in Africa during the Middle Stone Age (MSA). This would have occurred as a direct consequence of and in combination with the emergence of our species (McBrearty and Brooks, 2000; Henshilwood et al., 2002, 2004; Henshilwood and Marean, 2003, 2006). Others have argued that modern cognition was largely in place among the ancestors of Neanderthals and modern humans, and that we have to invoke demographic factors, perhaps triggered by climatic changes, to account for the discontinuous nature of the archaeological evidence for early forms of modern behaviour (Deacon and Wurz, 2001; Zilhão, 2001; d'Errico, 2003; d'Errico et al., 2003; d'Errico and Stringer, 2011; Lombard and Parsons, 2011; d'Errico and Henshilwood, 2011). This latter scenario is consistent with the recent finding that Siberian Middle Palaeolithic and Neandertal-derived genes account for between 2% and 8% of the ancestry of modern Eurasian humans (Green et al., 2010; Krause et al., 2010; Reich et al., 2010). As with our present genetic diversity, modern cultural features may not comprise a single 'package' with a unique African origin in one time, place and population, but rather a composite one whose elements appeared at different times and places, including some outside the African continent, either shared or as a result of a form of convergent evolution.

Unsurprisingly, the first instances of symbolic material culture play a major role in testing these scenarios. They arguably signal the emergence of the first societies in which social conventions, beliefs and knowledge about the outside world are coded, stored and

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transmitted using conventional signs. It has already been noted, however, that the criteria archaeologists use to infer cognition from past actions do not necessarily offer the same quality of information to enable the identification of human societies comparable to ours (McBrearty and Brooks, 2000; Kuhn and Stiner, 2001; Henshilwood and Marean, 2003, 2006; d'Errico et al., 2009; Henshilwood and Dubreuil, 2009, 2011). Pigments found at archaeological sites in the form of modified chunks (Barham, 2002; Hovers et al., 2003; Van Peer et al., 2004; Wadley, 2006; Henshilwood et al., 2009) or residues adhering to objects (Lombard, 2006, 2007; Wadley et al., 2009; Henshilwood et al., 2011) are generally the by-products of a sequence of actions that is difficult to reconstruct. It is for this reason that the interpretation of early pigment use is often controversial in nature (Wadley et al., 2009; Watts, 2009; Rossano, 2010; Wynn and Coolidge, 2010).

Evidently, different actions, with or without symbolic intent, may have similar consequences. Personal ornaments found at habitation sites can be described as the disposed elements of an irreversibly broken but originally meaningful string of signs. They represent clear proof of symbolically mediated behaviour (d'Errico et al., 2009: 19). However, the degree of complexity of those arrangements on the human body is lost forever, as are the ornaments made of perishable material that were included in that arrangement. A close reading of primary and secondary burials may help to reconstruct funerary practices (Duday et al., 1990; Pearson, 1999; Duday, 2010), but ethnographic data on those practices demonstrate that archaeology can only provide a minimalistic account of the actions associated with death and burial. Technological complexity and the morphological standardisation of stone and bone implements may be of assistance in evaluating the cognitive abilities of our ancestors (Ambrose, 2001; Foley and Lahr, 2003) but it is often difficult, when it comes to assessing the symbolic dimensions of tool production, to disentangle stylistic and symbolic aspects from functional constraints.

Painted, engraved and carved abstract and depictional representations are traditionally considered key to assessing the modern character of human cultures (Conard, 2008, 2010; Rossano, 2010; Henshilwood and Dubreuil, 2011). The former category may be heavily affected by taphonomic processes (Langley et al., 2011) and the durability of the latter depends largely on the raw material on which carvings are made. Engravings, the result of cutting a design into any substance with the use of an implement, comprise the only durable category of potentially symbolic early material culture that represents the complete end product of the actions performed by its executor. As with drawings, engravings explicate the deepest subconscious state of mind of the artist (Freeman and Cox, 1985; Thomas and Silk, 1990) while, at the same time, visually 'organising' a shared culture (Cox et al., 2001). Contrary to other early symbolic manifestations, engravings can be formally described, compared and their differences measured from a range of technological and metric perspectives (Bosinski et al., 2001; Henshilwood et al., 2009).

The microscopic analysis of engraved patterns may provide discrete information on the intentions of the engraver. The shape of the terminations of an incised line, changes in its depth, direction and internal morphology, divulge, by comparison with experimentally engraved lines, information concerning directionality, precision, strength of motion and the location of the engraver and his or her hand in relation to the incised surface (d'Errico, 1996; Fritz, 1999). Analysis of multiple lines and patterns, including intersections, also provide evidence for the chronology of motions, the use of single and multiple tools, engraver laterality and possible changes in the orientation of the engraved surface between the production of different incisions. By combining these details, it is possible to evaluate the technical competence of the engraver, his or her degree of determination and, to some extent, the mental template behind the physical appearance of the product of the engraver's actions.

In this study we describe, for the first time, an engraved piece of ochre derived from MSA II layers of Klasies River Cave I (Singer and Wymer excavation). Technological analyses are performed and the elemental composition and colorimetric values of the object are compared with a sample of 12 additional pigment pieces recovered from the same level. The analyses confirm the anthropogenic and deliberate nature of the markings, and reveals that a particular type of raw material was selected by the MSA engraver. This object adds to recently published evidence of similar and broadly coeval behaviours expressed on the same media (Mackay and Welz, 2008; Chazan and Horwitz, 2009; Henshilwood et al., 2009; Watts, 2009). This study also highlights the importance of complementing the visual analysis of engraved objects with non-destructive and objective colorimetric and elemental characterisations of the selected mediums.

1.1. Early engravings

Several sites in Africa and Europe older than 40 ka have yielded convincing evidence for the intentional production of engravings. The archaeological evidence for southern African MSA engravings reveals a complex pattern with several sites yielding several isolated pieces, and only a few providing consistent evidence. A banded ironstone slab with some superficial scratches has recently been reported from the Fauresmith levels of Wonderwerk cave (Excavation 6) dated to at least 187 ka (Chazan and Horwitz, 2009). The random orientation and shallow nature of the lines suggest, however, that they may be the result of trampling rather than

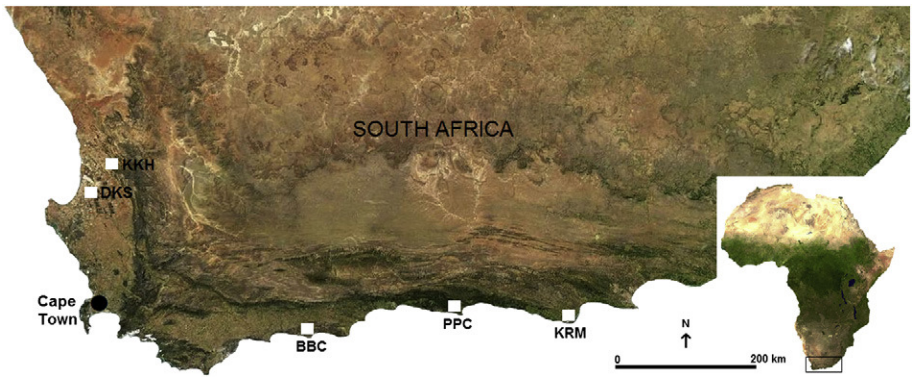


Fig. 1. Location of Klasies River and other key Middle Stone Age sites from Southern Africa referred in the text.

engraving. One piece of ochre from Pinnacle Point Cave levels dated to 164 ka (Marean et al., 2007; Marean, 2010) has also been argued to have been decorated with a chevron pattern (Watts, 2010).

Dendritic and convergent line motifs have been recovered from 100 ka contexts at Pinnacle Point in the Western Cape (Watts, 2009), and parallel linear engravings are reported from an undated MSA context at Bushman Rock Shelter in Mpumalanga Province (Watts, 1998). A cross-hatched pattern is engraved on a small ochre slab from Klein Kliphuis in the Western Cape (Mackay and Welz, 2008), and an engraved stone fragment recovered by Sydow in 1963 at a site containing only MSA lithics near Palmenhorst and Rossing in the Swakop Valley, Namibia (Wendt, 1975), also exhibits a cross-hatched pattern. Engraved patterns also appear on an ochre fragment recovered near the Cape Hangklip Rock Shelter (Minichillo 2005), and at Apollo II in southern Namibia (Vogelsang et al., 2010). Parallel lines engraved on bone fragments are found at Klasies River (d'Errico and Henshilwood, 2007) and Sibudu Cave (Cain, 1996). The most conspicuous collections of engraved items comprise the engraved ochres from Blombos Cave and engraved ostrich eggshell fragments from Diepkloof Rock Shelter in the Western Cape Province of South Africa. At Blombos Cave, fifteen pieces exhibit intentionally engraved abstract patterns from levels ranging from 100 ka to 75 ka (Henshilwood et al., 2002, 2009). At Diepkloof, some 270 ostrich eggshell fragments engraved with abstract geometric patterns has been recovered from Howieson's Poort levels dated to 60 ka (Texier et al., 2010).

Numerous engravings are reported from Acheulean and Mousterian sites in Europe and the Near East. A number of purported engravings on bone have been shown to be natural. This is the case with the Pech-de-l'Aze II rib and objects from Cueva Morin, Stranska Skala, Schulen, and Molodova IV (d'Errico and Villa, 1997; Nowell and d'Errico, 2007). Other objects appear to be engraved, but require closer analysis to verify these hypotheses, ascertain the antiquity of the marks, and evaluate the degree of 'deliberateness' behind them. Cases in point for the Lower Palaeolithic are the sequentially notched long bone shaft fragments from the Lower Pleistocene site of Kozarnika (Guadelli and Guadelli, 2004) and a mammoth shaft fragment from Bilzingsleben which exhibits a 'fan-like' engraved motif (Mania and Mania, 1988; Behm-Blancke, 1983; Steguweit, 1999). Among the objects found at Mousterian sites, the Tata nummulite which has a cross formed by a line perpendicularly crossing a natural crack (Vértes, 1964; Marshack, 1976), sequential incisions from Suard (Crémades, 1996), Saint Anne I (Raynal and Seguy, 1986), Vaufrey (Vicent, 1988), Oldisleben 1 (Günther, 1994), Le Moustier (Peyrony, 1930), Lartet (Debénath and Duport, 1971), Marillac (Duport, 1973), Le Petit Puymoyen, (Debénath and Duport, 1971), La Quina (Martin, 1910; Marshack, 1991), Cotencher (Dubois and Stehlin, 1933), La Ferrassie (Capitán and Peyrony, 1912; Bordes, 1969), L'Ermitage (Pradel and Pradel, 1954), Tagliente (Leonardi, 1988), Turské Mastale (Neustupny, 1948), Temnata (Crémades et al., 1995), Prolom II (Stepanchuk, 1993), Axlor (Barandiarán and García-Diez, 2007) and Vergisson IV (d'Errico et al., 2003; Soressi and d'Errico, 2007; Vandermeersch et al., 2008) are noteworthy. The only known examples from the Near East comprise a cortex of a flint flake engraved with a set of concentric lines from Quneitra (Goren-Inbar, 1990; Marshack, 1996; d'Errico et al., 2003) in a level dated to ca. 60 ka, and another cortex from Qafzeh Cave which has a set of parallel incisions and which derives from the same levels as the human burials (Hovers et al., 1997).

1.2. Archaeological context

The Klasies River archaeological site is located on the Tsitsikama coast in the Eastern Cape Province, South Africa (Fig. 1). The locality comprises five caves (labelled 1–5) forming three archaeological

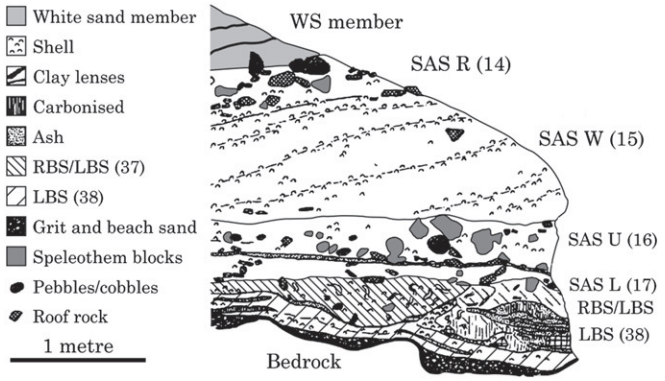


Fig. 2. The stratigraphy of Klasies River Cave 1 in the east face entrance area (redrawn from Rightmire and Deacon, 2001: Fig. 2).

sites along five kilometres of the coastline. The 'main site' is represented by Caves 1 and 2 and consists of a single depository bounded by a 40 m high cliff face. In addition to Caves 1 and 2 the cliff also holds two shelters, Cave 1 and 2 and three overhangs, numbered 1A, 1B and 2. A 20 m deep sequence of well-stratified archaeological deposits accumulated within and against these caves and overhangs. These accrued as a large cone which eventually blocked the opening of even the uppermost Cave 2. Overlying the cliffs is a Plio-Pleistocene calcareous sand dune which has provided one of the sources of sediments to the main site. Water containing calcium carbonates from the overlying dune have percolated through fissures, buffering acid ground water and allowing the development of speleothems and the preservation of shell and bone.

Following comprehensive excavations by Singer and Wymer (1982) in 1967 and 1968, the site was investigated by Deacon after 1984 (Deacon, 1995; see Wurz, 1999 for a history for research). Finds were not routinely plotted and systematically recorded during the Singer and Wymer excavation, nor were features such as hearths documented. The strata were excavated in layers, following the depositional stratigraphy and were defined either on lithology or by arbitrary convenience. Deacon's research intended to clarify the site formation processes, establish a more precise stratigraphic and cultural succession, and promote collaboration with other scholars to better characterise key finds and refine the chronology

Table 1
The chronology of Klasies River Cave 1 sequence.

Layer (Singer & Wymer)	Layer (Deacon)	Cultural Attribution	Date (ka)	Method	Reference
13	WS	MSA IV	65	AAR	Bada and Deems, 1975
13	WS	MSA IV	70.7 ± 7.4	TL-OSL	Feathers, 2002
14	SASR	MSA II	85.2 ± 2.1	U/Th	Vogel, 2001
14	SASR	MSA II	94.6 ± 3.2	U/Th	Vogel, 2001
14	SASR	MSA II	100.8 ± 7.5	U/Th	Vogel, 2001
15	SASW	MSA II	70.9 ± 5.1	TL-OSL	Feathers, 2002
15	SAS	MSA II	OIS 5c/5a	OIS	Shackleton, 1982
15	SAS	MSA II	OIS 5c	OIS	Deacon et al., 1988
16	SASU	MSA II	89	AAR	Bada and Deems, 1975
17	SASL	MSA II	88–93 ka	ESR	Grün et al., 1990
37	RBS	MSA I	90	AAR	Bada and Deems, 1975
38	LBS	MSA I	106.8 ± 12.6	TL-OSL	Feathers, 2002
38	LBS	MSA I	110	AAR	Bada and Deems, 1975
40	LBS	MSA I	108.6 ± 3.4	U/Th	Vogel, 2001

Table 2
Ochre pieces ochre recovered from the MSA levels of Klasies River Cave 1 (data from Wurz, 2000).

Context	Singer and Wymer (1982)	Deacon (1995)	Total
MSA IV	3	0	3
MSA III	25	33	58
HP	144	47	191
MSA II	36	10	46
MSA I	14	2	16
Total	222	92	314

of the stratigraphic sequence (Deacon and Geleijnse, 1988; Deacon, 1989, 1992, 1995, 2001; Grün et al., 1990; Wurz, 1997, 1999, 2000, 2002; Grine et al., 1998; Klein, 2000, 2001; Rightmire and Deacon, 2001; Feathers, 2002; Tribolo et al., 2005; Valladas et al., 2005; Jacobs et al., 2008).

The cultural stratigraphy defined by Singer and Wymer (1982) comprise four MSA (I, II, III and IV) divisions and a Howieson's Poort phase, sandwiched between the MSA II and the MSA III (Fig. 2). The objects described in this study derive from Layer 14 in Cave 1. According to Singer and Wymer, the stratigraphic sequence of this cave contains, from bottom to top, MSA I Layers 40, 38 and 37, MSA II Layers 17–14 and, following a stratigraphic hiatus, MSA IV Layer 13. Another hiatus, marked by a speleothem, is identified between Layer 13 and the uppermost LSA Layers 1–12. Stratigraphic correlation with the Cave 1A sequence indicates that the MSA I layers of Cave 1 represent the lowermost MSA I cultural horizons of the 'main site' stratigraphic sequence. The Singer and Wymer Layers 17–14 were renamed SASL, SASU, SASW and SASR by Deacon (Deacon and Geleijnse, 1988: 9).

The MSA levels of Klasies River Cave 1 have been dated using several methods (Bada and Deems, 1975; Shackleton, 1982; Vogel, 2001; Feathers, 2002). Table 1 summarises available radiometric ages for the Cave 1 sequence. Given their large standard deviations, the ages for the MSA II strata do not vary significantly and range between 100 ka and 70.9 ± 5.1 ka (see Wurz, 2002: 1003). Dates obtained for Level 14, from which the materials described in this paper derive, range from 100.8 ± 7.5 ka to 85.2 ± 2.1 ka (Vogel, 2001).

There are some problems with the interpretation of the archaeological stratigraphy of Cave 1 (see Wurz, 2002). From an examination of the published section drawings by Singer and Wymer (1982: Fig. 3.2), it appears that Layer 14 is not a coherent stratigraphic unit. The drawing shows Layer 14 as both overlying and underlying Layer 15, and also as a lateral equivalent of Layer 17 in some areas (Wurz, 2000: 9; Deacon, 2008: 145). Layers 16 and 17 are the primary human occupation horizons, and from Layer 15 upwards the deposits are clearly slanted in profile. The precise stratigraphic provenance of materials assigned to these layers may therefore be uncertain. This also relates to the human remains recovered from Cave 1. Layers 14–15 yielded numerous fragmentary human remains representing more than 10 individuals bearing both modern and archaic morphological features (Grün et al., 1990; Rightmire and Deacon, 1991; Deacon, 1992; Lam et al., 1996; Klein, 2001). Some remains also represent individuals that appear to have been dismembered, either as a result of cannibalism (Deacon, 1993, 2008; Deacon and Wurz, 2001) or the post-mortem 'ritualised' treatment of the dead (see White, 1986; Clark et al., 2003; White et al., 2003).

Pieces of red pigmentatious material, generally termed 'ochre', are present throughout the Cave 1 sequence and occur as ochre

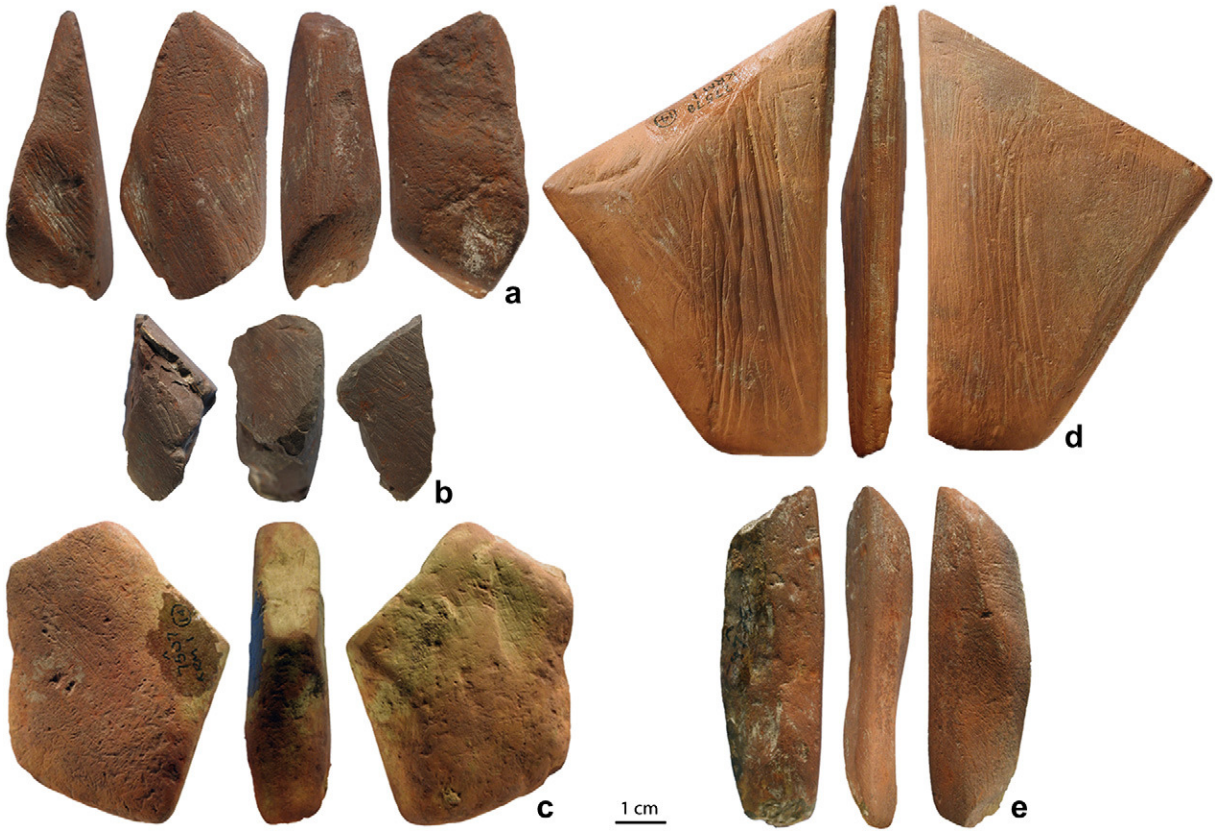


Fig. 3. Ochre pieces from Klasies River Cave 1, Layer 14, bearing traces of modification resulting from grinding and scraping: a) KRM 2; b) KRM 3; c) KRM 12; d) KRM 10; e) KRM 11.

'crayons', amorphous pieces larger than 4 cm^2, and very small fragments (Wurz, 2000: 110). Table 2 provides an indication of the quantities of ochre recovered from Cave 1. Twenty-three of the 92 pieces excavated by Deacon exhibit traces of modification, and several of these are shaped like 'crayons'. The nature of the pigmentatious materials, their geological origin and the techniques by which they were processed have not been attended to in detail.

2. Material and methods

The material analysed in this study is curated at the Iziko-South African Museum in Cape Town. Singer and Wymer mention the discovery of 36 ochre pieces in the MSA II layers. Only 13 of these were available for analyses (Fig. 3). Each piece was examined with a Leica S8 APO stereomicroscope to identify anthropogenic traces and natural features. The specimen bearing possible engravings, here labelled KRM 13, was photographed with a Nikon Coolpix 990 digital camera. The identification of grinding and scraping traces and of deliberately incised lines is based on criteria obtained from experimental research (d'Errico and Nowell, 2000; Soressi and d'Errico, 2007, d'Errico, 2008; Hodgskiss, 2010), examinations of engravings on stone and bone surfaces (d'Errico, 1995, 1996; Rifkin, in press), and by comparison with published engraved pieces from Blombos Cave (Henshilwood et al., 2002, 2009). Digitised images were imported into Adobe Illustrator and the modified areas traced. The chronology of the engravings and scraping marks, the type of engraving implement involved, the direction of the lines and the identification of lines produced in a single session by the same tool was established on the basis of experimental criteria (d'Errico, 1995).

Non-invasive analyses were performed on the Klasies River ochres recovered from Layer 14. We analysed the elemental composition of each fragment by X-ray fluorescence (XRF). Visible spectroscopy was used to obtain $L^*a^*b^*$ values. XRF analysis presents a qualitative approach to the identification of chemical elements (starting from Si) in analysed samples. Analyses with both techniques were completed only on the most even, uniform and cleanest surfaces of the objects to avoid conflicting and therefore

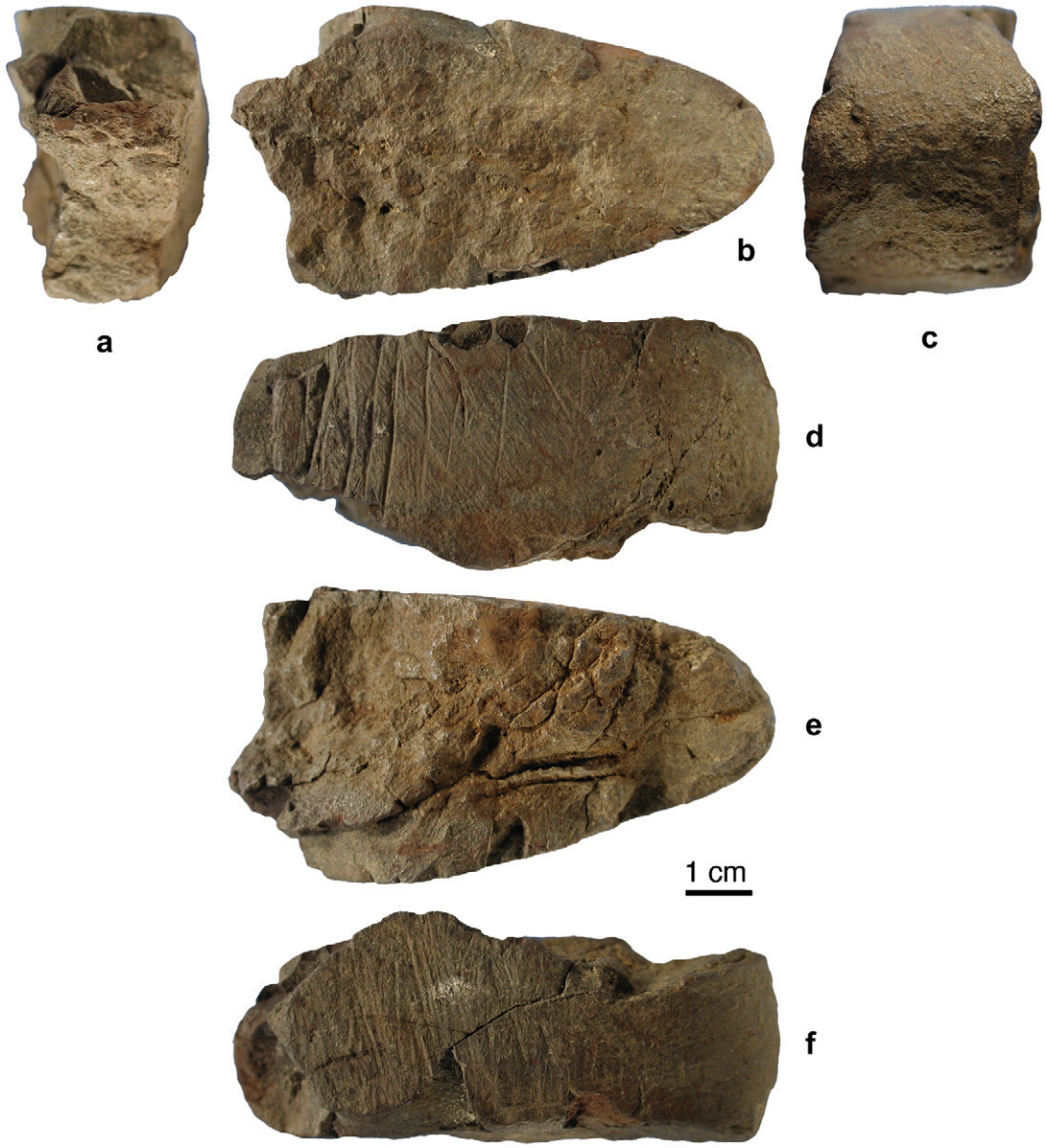


Fig. 4. The ground ochre fragment (KRM 13) which exhibits set of sub-parallel linear incisions on one face.

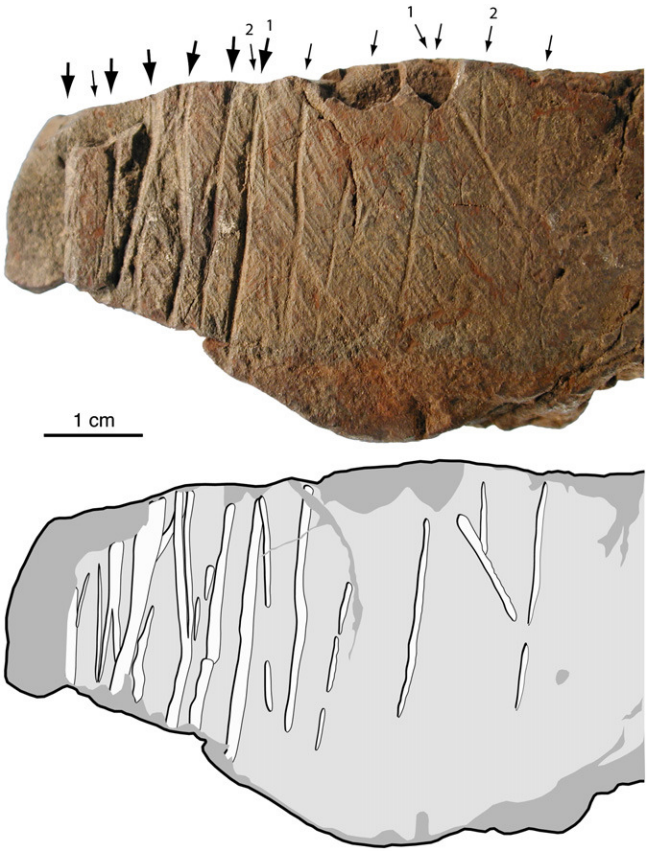


Fig. 5. Close-up view of the engraved area (top) and tracing of the engraved lines (bottom) on KRM 13. Incised lines are identified by black shadowed outlines filled with a white pattern, ground areas by a light grey pattern and breakages by a dark grey pattern. Small arrows indicate single stroke lines and thick arrows multiple stroke incisions. Figures indicate the chronology of the lines.

erroneous measurements. Although most of the specimens present a reasonably homogeneous surface, some do exhibit a stratified structure and a combination of shades. For this reason, measurements were taken from different zones of the sample to verify the repeatability and consistency of the results. The analysed surface areas typically covered approximately 0.8 cm in diameter for XRF and 0.5 cm for the visible spectroscopy analyses.

We used a mobile SPECTRO xSORT X-ray fluorescence spectrometer from Ametek, equipped with a silicon drift detector (SDD) and a low power W X-ray tube with 40 kV as an excitation source. The spectrometer is internally calibrated by way of the automated measurement of the contents of its metal shutter, and controlled with a PDA. Measurements were acquired by using a positioning device consisting of a lead receptacle to which the spectrometer is fixed. The analysed object is positioned and analysed from underneath. Spectra acquisition times were set to 60 s and the acquired data processed with PyMca software to fit the spectra.

Visible spectroscopy was practised with an Avantes AvaSpec-2048 fibre optic spectrometer equipped with a 2048 pixel CCD detector set to operate in the retrodiffusion mode. This instrument is equipped with an optical fibre probe which is set close (2 mm) to the sample surface at an angle of 2°. An AvaLight-HAL was used as an illumination source. The probe contains several illuminating fibres including one for the collection of diffused light. The equipment is calibrated with a Halon D65 white reference sample in the same lighting conditions as for the archaeological samples. Both the absorbance spectra and the colour parameters (L^*, a^*, b^*) are subsequently obtained by Avasoft 7.5 software. Principal component analysis of $L^*a^*b^*$ measurements and XRF results was obtained using PAST software.

3. Results

3.1. Description of the engraved piece

The engraving occurs on a parallelepipedal fragment of an originally large flat pebble (Fig. 4). The irregular morphology of the three breakage surfaces, revealing the presence of cracks and voids in the matrix, suggests that the anisotropic nature of the material may have favoured the enlargement of the cracks that ultimately resulted in the fracturing of the object. Accidental or deliberate heating could have played a role in the process. What remains of one of the original surfaces (Fig. 4f) is covered by parallel overlapping striations produced by scraping the surface with a lithic implement or by rubbing it against a hard and very coarse abrasive surface. On the edge of the pebble these traces are partially erased by finer striations produced by grinding, perpendicularly crossing those produced by scraping and rubbing.

The opposite aspect (see Fig. 4d and Fig. 5) exhibits numerous parallel elongated striations, which obliquely cross the preserved outer surface of the pebble. These most probably result from the rubbing of the object against a fine grained stone surface. The elevated ridges between the grooves appear to have been

Table 3
Selected results of the X-ray fluorescence analysis and colour measurements of pigment pieces from Klasier River Cave I, layer 14. Arbitrary units presented correspond to the obtained counts of each element normalized with Ar counts.

Sample				X-ray fluorescence (arbitrary units)														CIE $L^*a^*b^*$ values		
No.	Layer	Quad.	Inv. No.	P–K	K–K	Ca–K	V–K	Cr–K	Mn–K	Fe–K	Co–K	Ni–K	Cu–K	Zn–K	As–K	Sr–K	Ba–K	*L*	*a*	*b*
1	14	A		30	289	3332	21	179	1010	237,827	951	20	191	263	35	192	121	46.18	16.93	13.7
2	14 K–L	E9-1-1	1293	7	375	605	76	200	3927	309,595	947	20	182	474	106	185	105	45.41	19.38	16.82
3	14	E8-4-1	8297	17	106	929	48	169	9975	359,601	936	14	124	436	63	186	86	40.28	6.29	3.83
4	14 D	E8-4-3		8	1065	110	46	122	106	93,915	636	30	253	176	43	181	170	60.67	15.49	14.7
5	14 D	E8-4-3	8235	14	939	126	43	118	102	89,590	633	19	240	183	45	155	153	53.81	12.91	13.19
6	14 H	E8-7-4		10	1295	175	40	112	215	112,636	678	4	185	160	43	107	145	51.44	11.8	10.1
7	14		1619	24	1569	658	73	134	106	56,332	564	84	340	377	66	192	220	68.14	10.65	11.22
8	14 K–L	E9-1-1		5	278	628	32	119	299	111,025	674	32	213	473	517	187	112	50.59	15.77	13.64
9	14 A	C1		5	150	37	12	92	47	40,735	392	34	199	107	43	58	86	50.02	22.79	19.32
10	14		27578	15	770	1076	74	174	172	173,957	865	9	191	300	37	240	115	65.11	18.1	18.12
11	14	E8-5-2	4795	16	672	2276	45	208	240	273,911	1141	19	225	310	60	487	129	49.5	17.76	16.31
12	14 B	E8-3-5	7507	13	263	323	47	158	2020	215,102	938	19	200	749	86	775	137	57.58	22.53	26.32
13	14 A	C1		51	481	4871	190	60	90260	115,661	5537	506	767	7229	454	2663	1203	41.55	3.14	12.52

smoothed and substantial amounts of finely ground pigment powder remain visible at the bottom of the grooves. A robust rounded lithic point was used to incise a sequence of a dozen or so straight and curvilinear sub-parallel lines on the object. Whereas incised lines were produced by the repeated application of the lithic point on the left side of the engraved surface, lines were produced by single strokes on the right. Multiple stroke lines are deeper and comprise, in two instances, adjacent grooves that converge into a single linear feature. In another instance, a single deep groove 'splits' into two narrower and shallower incised lines, the latter resulting from different directions taken by the tip of the implement as it emerged from the original deeper groove. The former and existing outlines of and junctions between multiple stroke lines allow the identification of the direction followed by the tool during the engraving process. This is indicated by arrows in Fig. 5.

Due the lack of clear intersections between lines, the exact chronology of the incisions is difficult to establish. In only two instances is it possible to identify the order of incision. This concerns two short lines, slightly oblique to the others, which appear to have been engraved by a single implement at a later stage.

3.2. Elemental analysis

Most pigment pieces from Layer 14 share an analogous elemental composition (Table 3 and Fig. 6), with a major occurrence of Fe, minor proportions of K, Ca, Mn, Cr, Sr and traces of P, V and Ni. In general, Fe appears to be positively correlated with Cr and Co, and Cu with Ba. KRM 7 (Inv. 1619) and KRM 9 exhibits the lowest concentrations of Fe. The engraved piece (KRM 13) differs from the other specimens in terms of markedly higher concentrations in Mn, Co, Cu, Zn, Sr, Ba and As. KRM 3 (Inv. 8297) is the only specimen with a consistent, though much lower, concentration of Mn.

The difference in composition between the engraved object (KRM 13) and the remainder of the analysed pieces is emphasised by the principal component analysis (PCA) of the elemental 'raw counts' (Fig. 7a). PCA plots of *L*a*b* colour measurements (Fig. 7b) display a scattered pattern with three outlier specimens. Whereas the engraved KRM 13 and the dark patinated KRM 3 (Inv. 8297) are separated from the other specimens on the one axis, KRM 7 (Inv. 1619), which is covered with white concretions, appears as isolated on the other axis.

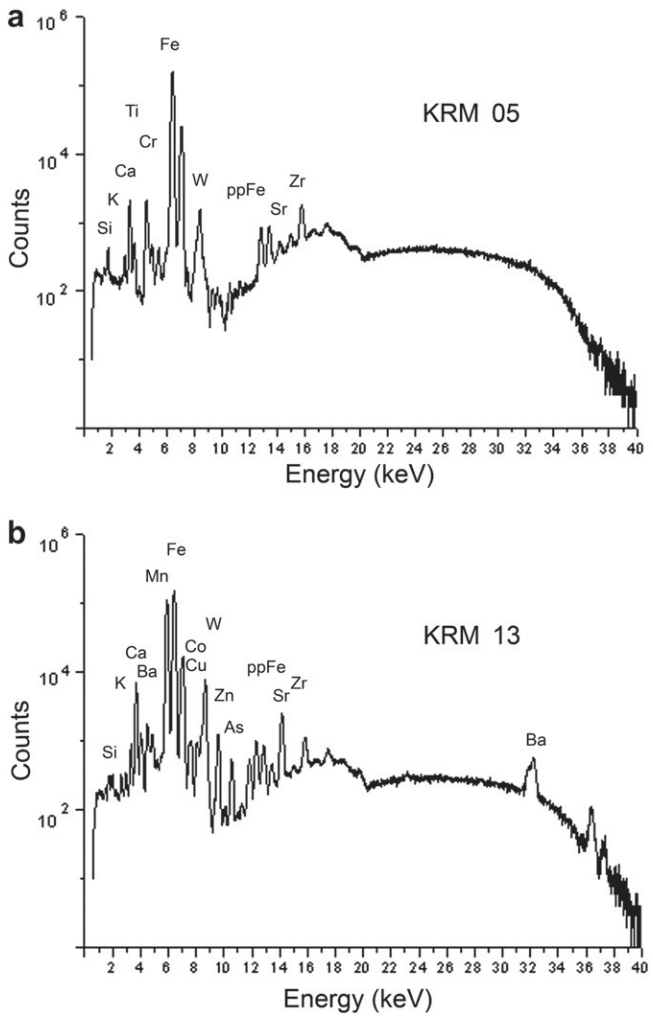


Fig. 6. X-ray fluorescence spectrum of the modified ochre piece KRM 5 from Klasies River Cave 1 Layer 14 (a), compared to that obtained from the engraved piece KRM 13 (b).

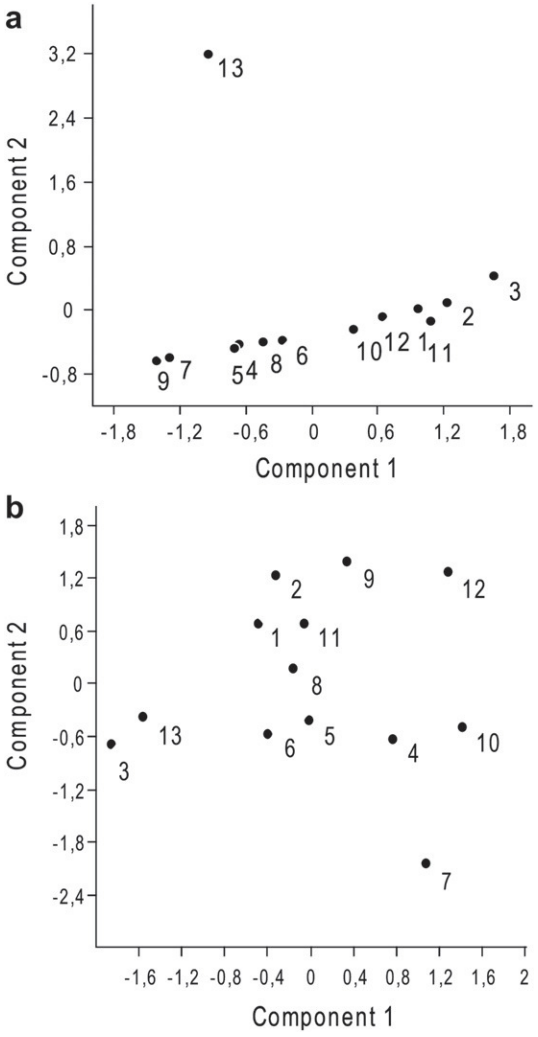


Fig. 7. Principal component analysis of the 22 elements identified by the XRF analysis (a) and *L*a*b* colour measurements (b) of the 13 analysed pigment pieces from Layer 14.

4. Discussion and conclusion

The engraved object analysed in this study represents only a fragment of an originally larger piece on which ground surfaces and engravings occurred. Prior to breakage the engraved 'design' probably occupied a much larger surface area and may have featured a greater degree of complexity that we are now unable to grasp. Although fragmentation inevitably diminishes any chances of inferring scope from actions, a number of clues may facilitate discussion concerning both the possible utilitarian and symbolic purposes of these markings and, more in general, the significance of these incised lines for the Klasies River people.

Explanations proposed to support either symbolic or functional interpretations of early markings are variable in nature and heuristic power (see Bednarik, 1995, 2006; Lorblanchet, 1999; d'Errico et al., 2001; Henshilwood and d'Errico, 2005; Zilhão, 2007; d'Errico, 2009; Henshilwood et al., 2009; Henshilwood and d'Errico, 2011; d'Errico and Vanhaeren, 2008). Most authors allude to: 1) consistencies in the media on which engravings are made; 2) the preparation of surfaces prior to engraving; 3) the degree of neuro-motor control inferred from the analysis of markings; 4) the type of implement used; 5) the use of the same tool for the production of the entire pattern; 6) changes of tools indicating a possible accumulation in time and a 'notational' purpose; 7) the absence of obvious functional reasons behind the production of engravings; 8) the consistent organisation of the sequence of motions articulating the marking action; 9) the perceived regularity or symmetry of the resulting pattern; 10) the presence of engravings on several objects and types of materials rather than on a single object or material; 11)repetition of the same motif on more than one object; 12) variations within what is perceived as the same basic motif; 13) the production of various different motifs; 14) temporal continuity in the production of engravings on the same media; 15) persistence or change in the production of motifs over time; 16) the production of similar engravings on the same media at sites and 17) similarities in the media used for engravings across archaeological and historically known human cultures.

KRM 13 is the only piece, among 13 ochre pieces recovered from the MSA II layers of Klasies River Cave 1, to exhibit deliberately engraved individual lines. The only other piece, KRM 10 (Fig. 3d), that bears a slight degree of similarity with KRM 13, displays several deep sub-parallel intersecting grooves on both aspects. These grooves were however produced by scraping the surface with a robust point that repeatedly 'skipped' out of the primary groove during the scraping process. Considering the motion, the depth of the grooves and their degree of random intersection, they appear instead to be the consequence of an action intended to extract pigment powder rather than the deliberate marking of the surface. Another piece (Dayet pers. com.) that we were not able to examine apparently exhibits a single deep groove. The other fragments that we have examined are unmodified, rubbed or scraped with the apparent aim of extracting pigment powder, or they are shaped by rubbing against a coarse grindstone to produce pointed crayon-like specimens (Fig. 3d and e). These may have been used to create either red lines or 'spots' on soft pliable material such as human skin or tanned animal hide. KRM 13 clearly does not fit any of these categories. The raw material is much darker, heavier and has a dissimilar elemental composition compared to the remainder of the analysed assemblage. This indicates that the piece either derives from a different geological source or, considering the degree of consistency in the elemental composition of the other specimens, represents the deliberate selection of a geochemically distinct type of object intended for a similarly 'exceptional' purpose. In this respect, it is worth noting that most of the unambiguous examples of abstract engraved ochres from Blombos Cave (Henshilwood et al., 2009) are produced on comparatively darker and harder pieces of ochre. An essential question is how MSA people would have perceived such differences in colour. We know that genes, education, cultural affiliation and language affect colour categorisation in modern humans (Davidoff et al., 1999; Roberson et al., 2005; Lumsden, 1985). Bleek and Lloyd (1911: 359) recorded that the /Xam San used different terms for different varieties of iron oxide rich pigments and possessed the visual ability of easily discriminating them.

The results presented here suggest that spectral colour characterisation and non-invasive elemental analysis of archaeological ochre, with and without engravings, represent a viable research strategy to establish whether 'special' categories of ochre were selected for engraving purposes during the MSA. When applied to numerous MSA pigment collections, spectral colour measurements may identify patterns that could reveal colour discrimination preferences during the MSA.

In spite of the observed changes in engraving techniques present on ochre specimens from Blombos Cave, analyses suggest a remarkable continuity in engraving practices over a period of 25 ka (Henshilwood et al., 2009). This 'engraving tradition' is not limited to Blombos Cave and, in addition to the Klasies River specimen described here, also include engraved ochres from Klein Kliphuis (Mackay and Welz, 2008) and Pinnacle Point (Watts, 2010). Sufficient amounts of red ochre powder must have been produced prior to engraving the object when it was rubbed onto an abrasive grindstone surface. Even if we acknowledge that engravings were, before the breakage of the pebble, present on a much more extensive surface area, the shallow nature of the engraved lines contradicts the idea that a serviceable amount of pigment could have been acquired from the act of engraving the surface. Although the various lines of evidence mentioned above point toward a deliberate selection of the blank on which the engraving was made, the way in which the lines are juxtaposed and superimposed do not suggest much organisational consistency such as the presence of equispacing and symmetry. This implies that the incisions may not in fact have been produced to create and convey a distinct design or 'message' to an audience that could visually distinguish it. By the same token, the preserved lines do not fit the interpretation of a notational system. Individual marks cannot be visually identified as discrete signs, which preclude the use of a single mark to store and recover information (d'Errico, 1995, 2001). There is also no evidence of changes in tool type, which may have suggested the production of a notation based on the accumulation of information over time.

The ambiguities identified here are predictable as the implications of many archaeological discoveries for major debates concerning the emergence of 'modernity' are often unclear. Engravings are afforded an important role in these debates. Yet, not all engraved patterns are likely to have operated in the same way. Some may reflect conventional designs with broad meanings; others might not. The sub-parallel lines on KRM 13 or the incised flat slab from Klein Kliphuis might, for instance, be seen to convey limited or 'localized' symbolic information, while the more elaborate cross-hatched pieces from Blombos or Diepkloof may have had more conventionalized meanings. Although the purpose of marking this object remains uncertain, its detailed analysis adds relevant information to previously published occurrences of MSA engraved objects and contributes to clarify their distribution through time and space.

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CHAPTER 5

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ASSESSING THE EFFICACY OF RED OCHRE AS A PREHISTORIC HIDE TANNING INGREDIENT

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Assessing the Efficacy of Red Ochre as a Prehistoric Hide Tanning Ingredient

Riaan F. Rifkin



Abstract

Over the past four decades, several functional hypotheses have been proposed for archaeological ochre. Ochre has been shown to have antiseptic properties and to inhibit the bacterial production of collagenase. These qualities are repeatedly cited to support the hypothesis that red ochre was used to preserve or 'tan' animal hides in prehistory. If clothing made from hides was worn by Homo sapiens *in Africa, then hide tanning could have formed a part of the trend towards increasingly modern technological and social advances during the Middle to Late Pleistocene. This paper presents the results of an experimental study exploring the efficacy of ochre as a treatment for making unprocessed animal hide resistant to putrification and desiccation. This study shows that certain types of ochre do preserve animal hide. The implications of this technological advance for the emergence of human behavioural modernity in Africa are discussed.*

Résumé

Au cours des quatre dernières décennies, plusieurs hypothèses ont été proposées pour expliquer la fonction des ocres archéologiques. L'ocre a des propriétés antiseptiques et permet d'inhiber la production de la collagénase bactérienne. Ces propriétés ont été citées à plusieurs reprises pour soutenir l'hypothèse que l'ocre rouge a été utilisée, tout le long de la préhistoire, pour préserver ou tanner les peaux d'animaux. Si des vêtements en peau ont été inventés en Afrique par les Hommes modernes cette innovation a pu faire partie du bagage de comportements modernes créés sur ce continent. Cet article présente les résultats d'une étude expérimentale ayant l'objectif de vérifier l'efficacité de l'ocre pour rendre résistante à la putréfaction et la dessiccation des peaux d'animaux. Nous résultats indiquent que certains types d'ocre possèdent la capacité de préserver les peaux. Les implications de ces résultats pour l'émergence des comportements modernes sont discutées.

Keywords: red ochre, experimental archaeology, hide tanning, Middle Stone Age, modern human behaviour

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Introduction

The ability to transform animal hide into leather is one of the most important technological skills mastered by humans (Deacon 1995; Groenman van Waateringe 2001; van Driel-Murray 2001; Gilligan 2010; Pinhasi *et al.* 2010; Schlumbaum *et al.* 2010). Most studies emphasise the significance of cold-protective clothing for the spread of human populations into temperate Eurasian latitudes (Roebroeks *et al.* 1992: 552; Hofecker 2005: 188). In southern Africa, cold conditions, brought on by the advent of the Last Glacial Cycle during MIS 5d 110,000 years ago (ka), resulted in the expansion of a temperate zone similar to that experienced in Europe during the last glacial (Brauer *et al.* 2006: 453; Fisher *et al.* 2010: 1384). It is conceivable that the innovation of 'weather-resistant' forms of clothing formed an integral part of the adaptive strategies of humans that inhabited this southern temperate region during the Middle Stone Age (MSA) (Gilligan 2007: 501; Toups *et al.* 2010: 29).

This setting is also where the earliest indications of 'modern' human behaviour emerge, defined here as "… socially constructed patterns of symbolic thinking, actions, and communication that allow for material and information exchange and cultural continuity between and across generations and contemporaneous communities" (Henshilwood & Marean 2006: 9). At Blombos Cave, the Still Bay levels with an age of 78 ± 6 to 72.7 ± 3.1 ka (Henshilwood *et al.* 2002) and lower MSA levels, dated to 98.9 ± 5.5 ka (Jacobs *et al.* 2006), contain artefacts indicative of complex social and symbolic behaviours. These include shell beads (Henshilwood *et al.* 2004), bone implements (d'Errico & Henshilwood 2007), innovative lithic manufacturing technologies (Mourre *et al.* 2010) and engraved lines on ochre (Henshilwood *et al.* 2002, 2009). The MSA is also marked by a significant increase in the incidence of red ochre at archaeological sites (Knight *et al.* 1995; Henshilwood *et al.* 2009; Watts 2010).

It is not surprising then, that processes related to the manufacture of clothing appear to correspond with the advent of complex social and symbolic behaviours during the MSA. The DNA sequencing of a global sample of human body lice supports this notion. The conspecific human body louse (*Pediculus h. humanus*) emerged because of humans wearing composite forms of clothing. The human body is an inhospitable place for body lice to breed, but the space between human skin and clothing provides a suitable environment. Body lice originated in Africa between 107 and 72 ka (Kittler *et al.* 2004: 2309; Reed *et al.* 2004: 1973), and perhaps as early as 170 ka (Toups *et al.* 2010: 29), hence the inference that the origin of *P. humanus* coincides with the origin of clothing.

There is sufficient archaeological evidence for the production of leather garments during the southern African Later Stone Age (LSA) (Parkington & Poggenpoel 1971; Deacon 1976; Deacon & Deacon 1980; Manhire 1993; Sealy *et al.* 2000). It is however probable that 'tanning' technologies were already in existence during the MSA and that ochre formed part of hide-processing techniques. Besides exclusively symbolic interpretations (Knight *et al.* 1995; Power & Watts 1997; Watts 2002, 2009), ochre was also used as a form of skin protection against the sun or from insects (Roper 1991; Wadley 2001), as a medicine or geophagic substance (Velo 1984, 1986; Mahaney *et al.* 1993), as a constituent in paint (Prinsloo *et al.* 2008), for knapping bifacial foliate points (Soriano *et al.* 2009) and as an ingredient in lithic hafting mastics (Wadley *et al.* 2004, 2009; Wadley 2005, 2006; Lombard 2007, 2008). A further functional hypothesis for ochre from LSA and MSA archaeological sites is that it was used to process and preserve animal hides (Keeley 1980; Audouin & Plisson 1982; Velo 1984; Couraud 1991; Wadley 2006).

The aim of this study is to investigate whether mineral pigments or ochres are suitable for the preservation or 'tanning' of animal hide. The methodology involved conducting actualistic experiments (Outram 2008: 2) to determine the processes, methods and materials that might have been applied in the past. An untreated animal hide, lithic scrapers and tanning ingredients were obtained from non-archaeological sources. Experimental ochres were collected from four geological formations (***Fig. 1***). As the red ochres at Blombos Cave are derived from Bokkeveld Group shales, the ochre used here was also collected from these sources (Henshilwood *et al.* 2009: 3; Watts 2009: 83).

Ochre and tanning

Besides utilising plant fibres to produce clothing and footwear (Deacon & Deacon 1980; Soffer *et al.* 2000; Kvavadze *et al.* 2009), animal skins present a suitable alternative. Tanned hides are a portable form of thermal protection that provides insulation against cold temperatures, moisture and wind chill, without impeding mobility. Unprocessed hides rapidly putrefy and desiccate, making them unsuitable for clothing or other applications. These effects can be eliminated by tanning, during which putrescible biological matter in a hide is converted into a stable material resistant to microbial attack and that has enhanced resistance to humidity and desiccation (Péquignot *et al.* 2006: 139). The term 'tanning' is widely used to refer to mineral (Al or Fe salts) and aldehyde (animal oils and fats) tanning procedures, although strictly these should be

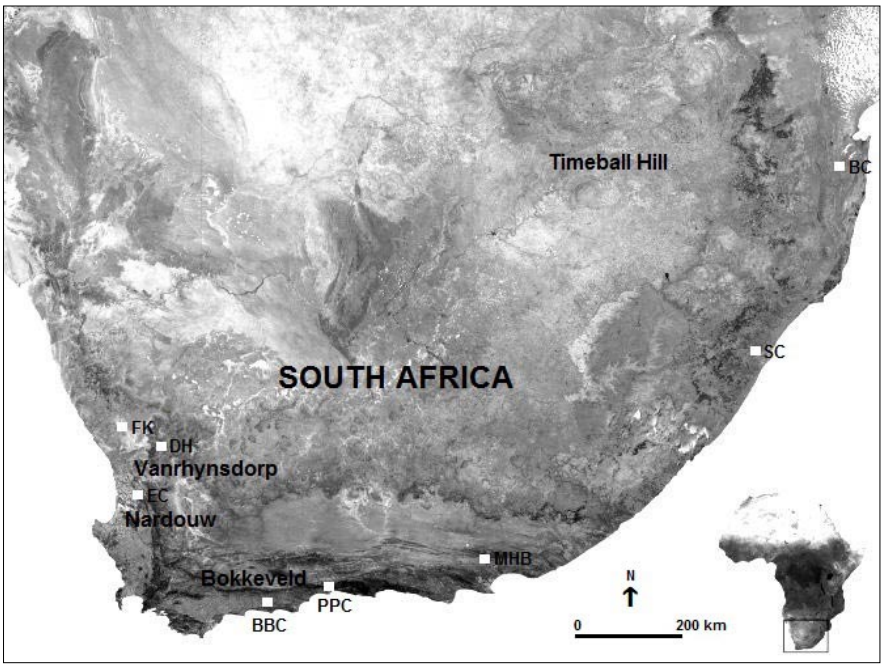


Fig. 1. Map of South Africa indicating the geological sources from which experimental mineral ingredients derive. Sites referred to in the text are indicated as: BBC - Blombos Cave, BC - Border Cave, DH - De Hangen, EC - Eland Cave, FK - Faraoskop, MHB - Melkhoutboom, PPC - Pinnacle Point Cave and SC - Sibudu Cave.

termed 'tawing' and 'chamoising'. Mineral tanning or 'tawing' does not actually produce leather that is resistant to moisture and does not therefore result in 'tanned' leather (Reed 1972).

Tanning is best defined as the structural modification of proteins (Brown & Taylor 2003: 409), but cross-linking or binding to collagen is accepted as the primary role of a tanning agent. In the case of chromium (Cr III) sulphate ($Cr_2(SO_4)_3$) tanning, the process involves the formation of a complex between Cr and the side-chain carboxylate groups of glutamic and aspartic acids of collagen (Covington *et al.* 2001: 461). The first known tanning methods employed plant tannins, animal fat, wood ash, powdered minerals, smoke, and combinations of these substances (Binford 1967; Sykes 1991; White 2006; Püntener & Moss 2010; Spangenberg *et al.* 2010). Variations of these methods survive in the modern industry, but tanning with chromium sulphate ($Cr_2(SO_4)_3$) prevails. The chemistries of Cr and collagen are well studied and much is known about the processes responsible for effective tanning (Covington 1997). However, the efficacy of prehistoric and ethnographically known tanning techniques, particularly those involving the use of ochre, has not been extensively explored.

The term 'ochre' designates any mineral substance containing iron oxide such as red haematite (Fe_2O_3), or iron hydroxide such as brown goethite (FeO(OH)) or yellow limonite ($Fe_2O_3(OH)\ nH_2O$) (Cornell & Schwertmann 2003: tab. 1.1; Easthaugh *et al.* 2008: 285). Southern African MSA sites, spanning 285 to 22 ka (McBrearty & Tryon 2005: 257; Wurz 2002: 1013), generally contain red ochre and red haematite, but yellow limonite, specular haematite, green and grey shales, black manganese, white kaolinite and brown goethite are also reported (Barham 2002; Henshilwood *et al.* 2009; Wadley 2009). Wear patterns on recovered ochre pieces are indicative of abrasive processing methods and indicate that the extraction of ochre powder was a key objective (Henshilwood *et al.* 2009: 4). However, because ochre powder could have been put to diverse uses, processed ochres do not necessarily represent the direct outcome of specific functional or symbolic behaviours.

The 'ochre as a hide-preservative' theory draws largely on Mandl's (1961) work on the preservative effects of iron oxides. Ochre has antibacterial properties (Mandl 1961; Velo 1984, 1986; Ellis *et al.* 1997) and inhibits collagenase, supporting the theory that red ochre was used to tan hides in prehistory. Many reports about hide-tanning experiments (Kleban & Bayer 2004; Püntener & Moss 2010) and analyses of wear traces on scrapers used in tanning activities have been published (Semenov 1964; Broadbent & Knutsson 1975; Deacon & Deacon 1980; Beyries & Rots 2008; Rots 2009), but most do not provide clear assessments of the efficacy of red ochre as a tanning ingredient.

In light of the current interest in the symbolic and utilitarian functions of ochre, and as there is scant published information on the topic, the research presented in this paper was carried out to independently assess the efficacy of red ochre as an ingredient used for hide tanning.

Ethnographic and archaeological leather

The functional value of animal hides to southern African hunter-gatherers is mentioned in many ethnographic reports (Sparrman 1785; Bleek & Lloyd 1911; Schapera 1930; Marshall 1961; Steyn 1984), as are references to hide-processing techniques (see Badenhorst 2009 for a review). In the 1920s San hunter-gatherers of the Karoo processed hides by scraping and rubbing them, after which they were folded, danced upon and buried in sand for some hours. A mixture of fat and 'red clay' was then rubbed into the hide (Bleek 1928: 9). Schapera and Goodwin (1953: 147) noted that the application of ochre and fat to leather produced by Bantu speaking agro-pastoralists gave the impression of a 'heavy-loaded' leather (Fehr 1968: 30). There are, however, many ways of tanning and dyeing leather and ochre is not an essential component of either process (see Burchell 1822; Schapera 1930; Latrobe 1969; Steyn 1984; van Wyk and Gericke 2000; Kimura *et al.* 2001; Badenhorst 2009; Mannering *et al.* 2010; Pinhasi *et al.* 2010; Püntener & Moss 2010; Schlumbaum *et al.* 2010). The Ju/'hoan of the Central Kalahari produced karosses by applying tannin extracts from wild teak (*Pterocarpus angolensis*) bark to the hide following hours of manual softening. Karosses were also maintained by bimonthly treatments with the teak bark extracts (Lee 1979: 276).

Archaeologically, leather conservation is the exception and occurs largely in conditions of extreme aridity and cold, excessive salinity or in peat bogs where secondary tanning may occur (van Driel-Murray 2001: 185; Harris 2006: 69). Leather items such as the shoe from Areni 1 in Armenia dated to 5.6 ka (Pinhasi *et al.* 2010), the garments worn by Ötzi from Hauslabjoch 5.3 ka (Püntener & Moss 2010), a tailored legging from the Schnidejoch pass in Switzerland dated to 4.2 ka (Schlumbaum *et al.* 2010) and the garments from Danish bog sites dated to 2.7 ka (Mannering *et al.* 2010: 263) are rarely recovered (***Fig. 2***).

Several leather fragments have been recovered from South African LSA contexts (Deacon 1976) (***Fig. 3***). One instance involves a human burial at Eland Cave in the Western Cape Province dated to 2.1 ka (Sealy *et al.* 2000: 36). The grave contained five leather fragments with indications of stitching and decorative cross-hatched incisions on the external and inner sides of the hides. Perforated and cross-hatched leather fragments, dated to between 1.2 ka to 2 ka, have also been recovered from Faraoskop (Manhire 1993), Melkhoutboom (Deacon & Deacon 1999), De Hangen (Parkington & Poggenpoel 1971) and Scott's Cave (Deacon 1967) in the Western and Eastern Cape Provinces. It is not presently known whether any of these specimens do in fact exhibit evidence for the use of ochre in their preparation. Only microscopic and chemical analyses (*e.g.* Leach 1995; Melniciuc Puică *et al.* 2006) would reveal the exact nature of the ingredients used to process these finds.

Leather has not been recovered from Pleistocene archaeological sites, but there is evidence for the processing of animal hides (Soffer *et al.* 2000; Gilligan 2010). At Tabun Cave in Israel, residual traces of hair, collagen and blood have been detected on lithic scrapers dated to 90 ka (Loy & Hardy 1992), and at Ksar Akil in Lebanon, wear analyses of lithic end scrapers and a *Glycymeris bimaculata* shell scraper suggest that the site was a locus for processing hides some 40 ka (Marks 1990: 70; Douka 2010: 2). At Umm el Tlel in Syria, the discovery of a

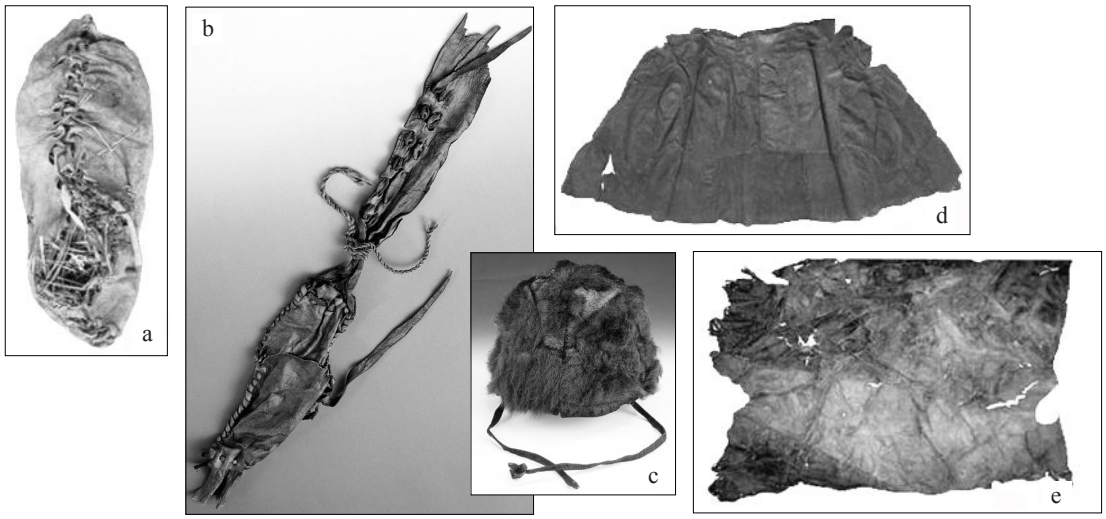


Fig. 2. Leather items recovered from archaeological contexts: a) the leather shoe from Areni I (Pinhasi *et al.* 2010: fig. 1); b) a bear skin cap and c) a leather belt associated with the remains of Ötzi (Copyright South Tyrol Museum of Archaeology, www.iceman.it); d) a leather cape from a peat bog in Denmark (Mannering *et al.* 2010: fig. 6, Copyright National Museum of Denmark); e) the tailored legging from the Schnidejoch pass (Grosjean *et al.* 2007: fig. 3) (Images not to scale).

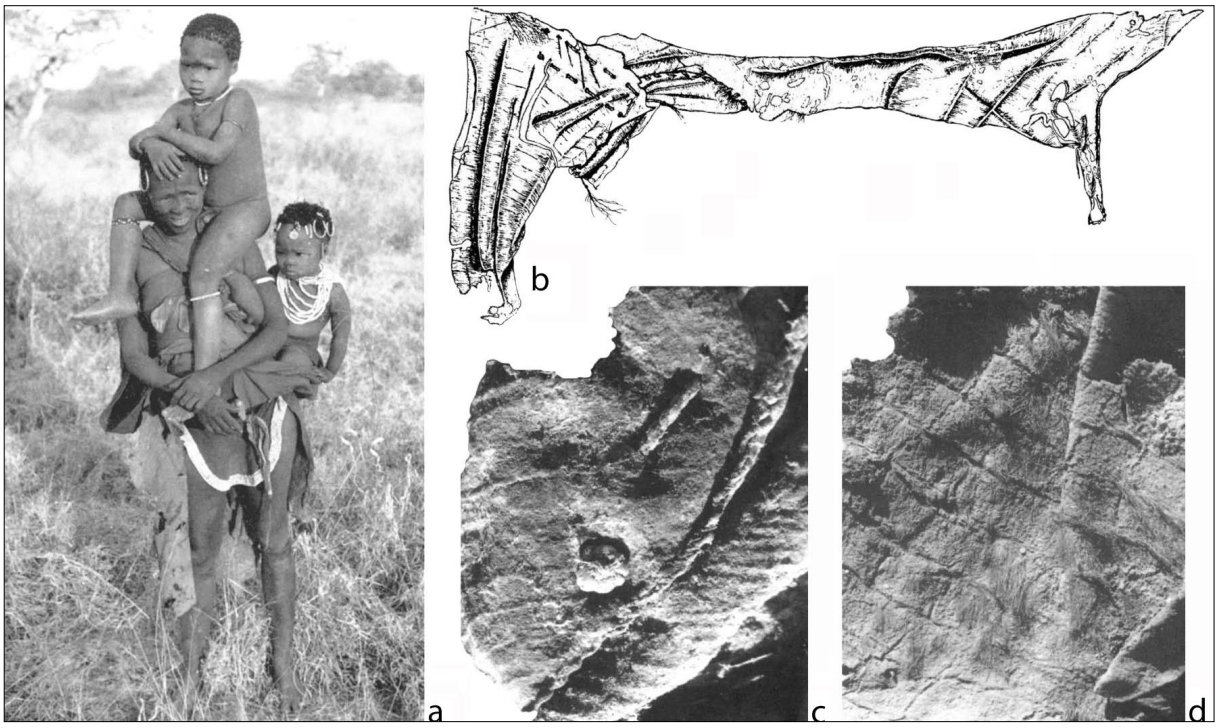


Fig. 3. Ethnographic leather attire and fragments from archaeological contexts: a) a !Kung San woman and children from the Central Kalahari Desert wearing rudimentary and composite leather garments (Marshall 1960: fig. 3); b) a sewn fragment possibly representing a male loin-cloth from Melkhoutboom (Deacon & Deacon 1980: fig. 7.2); c) a composite sewn fragment from Eland Cave (Sealy *et al.* 2000: fig. 7); d) another leather fragment from Eland Cave with rectangular patterns incised on the exterior side (Sealy *et al.* 2000: fig. 6).

convergent side-scraper with traces of bitumen mastic suggests that scrapers were hafted and used to process hides 40 ka (Boëda *et al.* 1996: 337).

At Blombos Cave, end and circular scrapers form a large part of the formal MSA lithic assemblage. The working edges of end scrapers are comparable to LSA examples, and although this still needs to be demonstrated conclusively, may have been used to prepare hides for tanning (Henshilwood *et al.* 2001a: 429). As is the case for bifacial foliate Still Bay points (Villa *et al.* 2009), lithic scrapers may also have been hafted. While each case needs to be demonstrated independently, hafted and also handheld scrapers are likely to have been used to process animal hide (Beyries & Rots 2008; Rots 2009), and to remove fat rather than hair, as is shown by archaeological examples (Sealy *et al.* 2000: 35; Hoffecker 2005: 190; Schlumbaum *et al.* 2010: 2).

Several polished and ochre-stained bone awls and points have been recovered from levels at Blombos Cave dated to between 82 and 75 ka (d'Errico & Henshilwood 2007: 143) (***Fig. 4***). These were likely used to "perforate fairly soft material such as well-worked hides, possibly during the manufacture of clothing and / or carrying bags, and were probably used in an 'awl-like' action" (Henshilwood *et al.* 2001b: 662). Although eyed needles are typically associated with tailored clothing in Europe from 40 ka (Rogachev & Sinitsyn 1982; Vasil'ev *et al.* 1987), the piercing of hides for sewing can also be accomplished with basic pointed implements (Gilligan 2010: 50). It has been proposed that many Upper Palaeolithic eyed needles are too delicate to have been used to perforate leather (Soffer 2004: 411). Replication studies and the analysis of Châtelperronian and Aurignacian awls confirm that these more robust implements were used for that purpose (d'Errico *et al.* 2003: 266).

To evaluate the hypothesis that ochre was used to process and preserve animal hides during the MSA, an untreated antelope hide was acquired and subjected to various tanning procedures that were possibly used by MSA hunter-gatherers in southern Africa. Wadley *et al.* (2009) have shown that complex technologies existed during the MSA and that people were competent alchemists. This could be extended to suggest that they were also acquainted with tanning practices. I now describe the materials and methods employed during the tanning experiments, including the acquisition and scraping of hide samples, the various tanning, tawing and chamoising procedures I employed and the ingredients applied. I also clarify the protocol devised to monitor the experimental samples and to evaluate the efficacy of the applied tanning techniques.

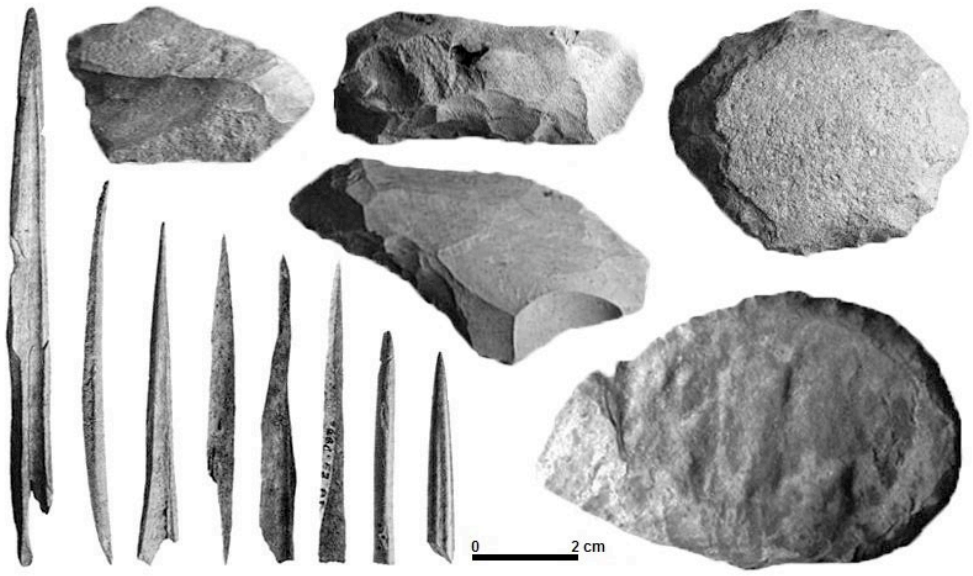


Fig. 4. Bone tools and lithic scrapers recovered from MSA levels at Blombos Cave. The first six bone implements are awls and the two on the right are bone points (Henshilwood *et al.* 2001a: fig. 11).

Materials and methods

Hide acquisition and preparation

The hide of a freshly killed adult female kudu antelope (*Tragelaphus strepsiceros*) was obtained from the Vaalkop Private Game Reserve in the Northern Province of South Africa. This species was selected because of its wide distribution across southern Africa. Medium to large-sized bovids also form a large part of faunal assemblages from South African MSA contexts (Klein 1976; Henshilwood *et al.* 2001a; Clark & Plug 2008). A more extensive study engaging a variety of different hides is necessary to ascertain whether there are any dissimilarities in how the skins from diverse species react with or absorb tanning ingredients.

The hide was removed from the carcass by skinning with a steel knife 10 minutes after death. The body temperature of the animal was 36.3 °C and the pH between the skin and the ribs 7.7. After skinning and washing with aquifer-derived water, I selected two large sections of hide from along the ribs, excluding the top of the back and the stomach. This hide was cut into 28 portions measuring 10 by 15 centimetres. This was done so that the specimens were not affected by: 1) tanning ingredients other than those I used, and 2) variations in the reactions that could be attributed to dissimilar hair follicle densities and / or hide thicknesses (***Fig. 5***).

The next step entailed removing excess flesh and fat from the inner side of the hide. The dermis or corium contains two sub-layers that can be transformed into leather. These are the grain layer, in which the hair shafts are embedded, and the fibre layer, which comprises a mass of interlacing bundles of collagen fibres (Hardwick 1996: 3). The corium measured 2.3 mm in width, to which a further 0.5 to 2.5 mm of fat and membranous matter was attached. Ethnographic accounts (Campbell 1815: 521; Schapera 1930: 11) and archaeological evidence (Sealy *et al.* 2000: 35; Harris 2006: 71; White 2006: 6; Schlumbaum *et al.* 2010: 2) indicate that hides were not always dehaired. I therefore decided not to remove the hair from the specimens. I used 56 silcrete scrapers to process the hide samples during the experiments. The addition of mineral tanning ingredients at the beginning of hide processing may desiccate specimens to such an extent that defleshing becomes extremely difficult (Moss, 1983: 228). The specimens were therefore scraped when wet to remove excess membranous matter and fat, and when dry (five days after experimental treatment commenced) to remove excess ochre and skin residue (***Fig. 6***).

The experimental scrapers are reproductions of end, side and circular scrapers from MSA contexts at Blombos Cave. These are made by retouching unifacial silcrete flakes along their distal and mesial edges (***Tab. 1***). I tied the scrapers into terminally split wooden shafts (indicated as ST) or onto L-shaped wooden hafts (LST) with 40 mm to 80 mm of bovine leather and raw hide strips, or I used them in unhafted form (Broadbent & Knutsson 1975; Weedman 2006; Beyries & Rots 2008; Rots 2008, 2009). Some of the handheld scrapers were wrapped in gemsbok (*Oryx gazella*) and springbok (*Antidorcas marsupialis*) hide strips to provide protection from sharp edges.

Tanning procedures

I based the types of tanning materials and processing methods employed on a review of processes described ethnographically (Webley 1990; Weedman 2006; Badenhorst 2009) and those in current use (Lampard 2002;



Fig. 5. The removal of the hide from the carcass: a) the animal was suspended from a tree to facilitate the removal of the hide; b) the hide was removed by pressing the skin from the ribs and by severing the internal membranes with a knife.

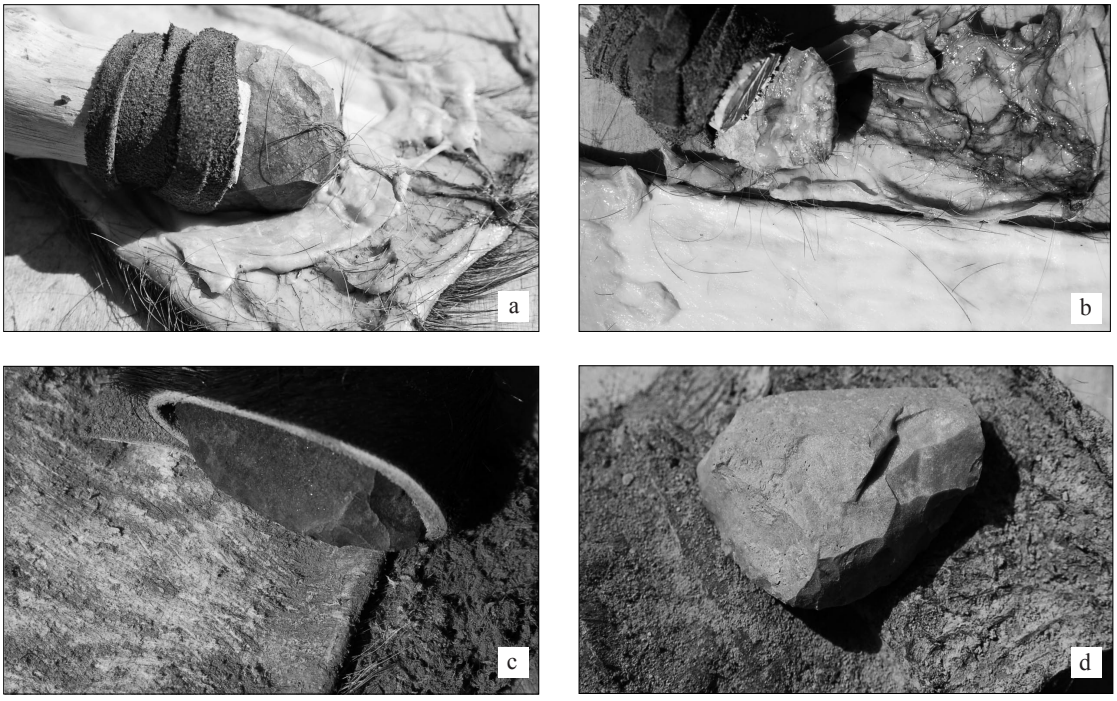


Fig. 6. The preparation of hide samples by scraping: a) a convex circular scraper tied onto an L-shaped haft with tanned bovine leather strips (scraper 15); b) a convex side scraper tied into a terminally split haft with tanned bovine leather strips (scraper 6); c); a convex convergent scraper wrapped in *Oryx gazella* hide (scraper 40); d) a convex convergent scraper used without leather wrapping (scraper 52).

Experiment	Scraper	Scraper type	Length	Width	Thickness	Edge angle	Hafted	Arrangement	Wrapped	Scraping motion	Duration (m)
1	1	Concave convergent	28.20	21.55	5.85	65 – 75°	√	ST	x	Unidirectional	37
	29	Convex convergent	50.51	45.63	16.10	55 – 65°	x		√	Unidirectional	10
2	2	Concave side	35.11	21.09	10.16	55 – 65°	√	ST	x	Unidirectional	44
	30	Convex circular	45.66	38.78	15.02	65 – 75°	x		x	Unidirectional	10
3	3	Convex side	33.95	26.65	13.72	65 – 75°	√	ST	x	Unidirectional	41
	31	Concave side	27.65	17.85	12.00	65 – 75°	x		x	Unidirectional	10
4	4	Convex side	42.35	40.66	11.80	55 – 65°	√	ST	x	Unidirectional	25
	32	Convex circular	23.97	29.90	11.79	55 – 65°	x		√	Unidirectional	10
5	5	Concave end	33.12	26.84	8.52	55 – 65°	√	ST	x	Unidirectional	15
	33	Convex side end	32.51	22.54	13.51	55 – 65°	x		x	Unidirectional	10
6	6	Convex side	34.41	30.58	11.85	55 – 65°	√	ST	x	Unidirectional	11
	34	Convex end	57.68	51.62	14.89	55 – 65°	x		x	Unidirectional	10
7	7	Concave convergent	35.77	24.57	9.35	55 – 65°	√	ST	x	Unidirectional	12
	35	Convex side	39.94	24.78	12.81	65 – 75°	x		√	Unidirectional	10
8	8	Concave side	29.92	36.04	12.30	55 – 65°	√	ST	x	Unidirectional	14
	36	Concave circular	31.26	29.33	12.88	55 – 75°	x	-	-	-	-
9	9	Concave circular	29.09	31.60	8.36	65 – 75°	√	LST	x	Unidirectional	19
	37	Concave end	52.71	31.77	13.35	65°	x		x	Unidirectional	10
10	10	Concave side	47.86	24.78	6.54	65°	√	ST	x	Unidirectional	22
	38	Convex end	55.58	29.79	13.42	65°	x		√	Unidirectional	10
11	11	Concave side	18.93	24.12	6.89	65 – 75°	√	LST	x	Unidirectional	34
	39	Concave circular	34.15	30.42	12.48	65 – 85°	x		x	Unidirectional	10
12	12	Concave end	26.80	26.35	7.42	75 – 85°	√	LST	x	Unidirectional	23
	40	Concave side	54.67	36.34	13.74	65 – 75°	x		√	Unidirectional	10
13	13	Convex side	44.55	29.17	11.18	45 – 55°	√	ST	x	Unidirectional	14
	41	Concave convergent	46.29	42.34	15.75	75 – 85°	x		x	Unidirectional	10
14	14	Concave side	40.88	19.69	8.26	55°	√	ST	x	Unidirectional	18
	42	Convex side	44.79	22.42	17.31	55 – 65°	x		√	Unidirectional	10
15	15	Convex circular	29.58	30.03	10.23	65 – 75°	√	LST	x	Unidirectional	26
	43	Concave circular	38.80	31.58	16.31	75 – 85°	x		x	Unidirectional	10
16	16	Concave circular	32.43	27.60	9.46	65°	√	ST	x	Unidirectional	23
	44	Concave circular	33.51	34.52	12.46	65 – 75°	x		x	Unidirectional	10
17	17	Concave end	35.57	34.60	11.91	65 – 75°	√	ST	x	Unidirectional	12
	45	Convex side	46.51	28.45	14.90	55 – 65°	x		x	Unidirectional	10
18	18	Concave end	28.33	25.73	7.10	55 – 65°	√	ST	x	Unidirectional	16
	46	Concave side	48.83	29.48	11.37	65 – 75°	x		√	Unidirectional	10
19	19	Concave side	31.35	19.19	6.31	55 – 65°	√	LST	x	Unidirectional	21
	47	Convex end	19.74	26.00	9.04	55 – 65°	x		x	Unidirectional	10
20	20	Convex side	35.56	22.80	10.80	55 – 65°	√	ST	x	Unidirectional	18
	48	Convex circular	41.77	32.24	19.93	75 – 85°	x		√	Unidirectional	10
21	21	Convex end	27.93	21.61	12.96	65 – 75°	√	ST	x	Unidirectional	13
	49	Concave side	38.78	27.43	13.36	65 – 75°	x		x	Unidirectional	10
22	22	Concave end	35.20	27.13	10.42	45 – 55°	√	LST	x	Unidirectional	9
	50	Concave side	40.65	29.92	14.80	55 – 65°	x		√	Unidirectional	10
23	23	Concave circular	20.97	24.01	9.04	65 – 75°	√	ST	x	Unidirectional	12
	51	Convex side	39.12	24.47	12.03	55°	x		x	Unidirectional	10
24	24	Convex side	48.48	29.49	11.16	65 – 75°	√	ST	x	Unidirectional	13
	52	Concave side	43.17	29.95	11.97	65 – 75°	x		x	Unidirectional	10
25	25	Convex circular	29.46	28.44	12.64	65 – 75°	√	ST	x	Unidirectional	14
	53	Convex side	43.85	28.08	15.68	45 – 65°	x		x	Unidirectional	10
26	26	Concave circular	48.10	33.16	9.89	55 – 65°	√	ST	x	Unidirectional	11
	54	Convex circular	31.12	39.81	11.51	65°	x		√	Unidirectional	10
27	27	Concave circular	35.36	34.80	11.94	55°	√	ST	x	Unidirectional	9
	55	Concave circular	18.27	26.84	8.41	55°	x		x	Unidirectional	10
28	28	Concave side	42.15	29.02	10.02	65 – 75°	√	ST	x	Unidirectional	14
	56	Concave side	44.55	32.85	16.06	55 – 65°	x		x	Unidirectional	10

Tab. 1. Morphological information of scrapers used to process hide samples before and after the application of ingredients. Length, width and thickness are indicated in mm and the total duration of the scraping action in minutes.

Covington 2008; Kleban & Bayer 2004). The literature indicates there are at least five ways in which raw hides can be converted into leather, namely:

1. Tanning, *i.e.* treatment with tannins and tannic acid such as that derived from *Acacia karroo* and other tannin-rich pods and barks (Covington 1997: 114; van Wyk *et al.* 1997: 20);
2. Tawing, *i.e.* treatment with mineral powders such as Al or Fe salts (Mandl 1961: 196; Covington 1997: 119);
3. Chamoising, *i.e.* treating hides with aldehyde-rich animal oils and fats derived from brains and from around the kidneys (Covington 1997: 121; van Driel-Murray 2002: 20);
4. Smoke tanning, *i.e.* treating hides by way of prolonged exposure to hydrocarbon-rich smoke (Binford 1967, 1972; Groenman van Waateringe *et al.* 1999);
5. Various combinations of the above processes (Lampard 2002; Covington 2003).

Modern tanning procedures comprise no less than eight individual steps, each of which entails a series of specific actions and chemical additions (Thanikaivelan *et al.* 2004: 182). I now describe the procedures followed and the ingredients used during the experiments.

Tanning ingredients

Ethnographically, hides were immersed in tanning solutions or ingredients were applied in the form of a paste or watery solution to the inner surface of the hide. The latter technique was employed during these experiments. I determined a ratio of the surface area relative to the tanning ingredient used by testing the surface covering capacity of powdered materials on a commercially tanned oryx hide. The experiment showed that 100 grams of vegetable, mineral or aldehyde ingredients was sufficient to cover each sample to a depth of 2 to 6 millimetres. When different tannages were combined, I divided this figure to apply equal amounts of ingredients to hide samples.

Control samples (specimens 1–5)

These functioned as specimens against which the efficacy of ingredients and methods could be evaluated. I subjected sample 1 to all the activities and environments to which the treated samples were exposed, but it was not treated with oils, tannins or minerals. Sample 2 was treated with coarse salt (NaCl) and Deer Hunter's and Trapper's Hide Tanning Formula™. Sample 3 was treated with a red lateric soil classified as the Hutton, and sample 4 with a brown loamy soil resembling the Jonkersberg form (Soil Classification Working Group 1991). Soil samples were sourced from non-agricultural indigenous savannah regions. Sample 5 was treated with commercially available unrefined salt.

Table 2 provides details about the experiments and the sources and amounts of ingredients applied to specimens.

Smoke 'tanning' (6)

Wood smoke releases polycyclic aromatic hydrocarbons, which diminish microbial growth, enzyme activity, oxidation and insect infestation (Hobbs *et al.* 2003: 2; Sérot *et al.* 2004: 1). I used sickle bush (*Dichrostachys cinerea*) wood, impala antelope (*Aepyceros melampus*) and zebra (*Equus burchelli*) dung and green leaves and twigs from the Lavender fever-berry (*Croton gratissimus*) to produce a smoke-rich fire. Green Raisin-bush (*Grewia flavescens*) branches were used to construct a frame on which the hide specimen was suspended over the fire. The hide was smoked for 2 hours, 15 to 20 centimetres above the smouldering fire, during which the temperature was controlled to optimise smoking and avoid charring.

Vegetable tanning (7)

Many plant species contain condensed or hydrolysable gallotannins and ellagitannins in their bark, fruits and leaves (Covington 1997: 114). I selected sweet thorn (*Acacia karroo*) as a tanning ingredient because of its wide distribution across southern Africa (Barnes *et al.* 1996), the frequent references to its use in ethnographic accounts and because the utility of *A. karroo* resin during the MSA has been established (Wadley *et al.* 2009). I collected samples by harvesting bark from five individual specimens. The trees sampled occurred in vegetation zones not altered by recent human activity. Samples were air-dried and reduced to fine particles with a sharp knife. The tannin content of *A. karroo* may be up to 80.7 grams per kilogram (Mokoboki *et al.* 2005: 221), and I obtained a tannin extract by soaking 250 grams of ground bark in 1 litre of clean water for 12 hours.

Aldehyde chamoising (8)

The term 'aldehyde' refers to organic compounds that contain a carbonyl group (CHO) in which the carbon atom is bonded to at least one hydrogen atom. Through auto-oxidation, carboxylic and fatty acids are reduced to aldehydes. The archetypal aldehyde tannage is with formaldehyde, which is also used to preserve biological specimens (Covington 1997: 121). In the

#	Experiment	Tanning ingredients	Sample weight	Active compounds	Amount
1	Control	Untreated	62.5 g	None	100 g
2	Control	Modern	63.4 g	Not disclosed	100 g
3	Control	Red Hutton	47.2 g	Organic C / Fe / N / SiO / K	100 g
4	Control	Brown Jonkersberg	47.0 g	Organic C / Mg / N / SiO / K	100 g
5	Mineral	Coarse salt	54.7 g	NaCl	100 g
6	Smoke	*Dichrostachys cinerea*	73.1 g	Inorganic halogens	2 hours
		Herbivore dung		CL / Br / I	
				Chloride / nitrate / sulfate SO4 / Cl / NO3	
		Croton gratissimus		Terpenoids, volatile oils, proanthocyanidins, flavonoids, esters	
7	Vegetable	*Acacia karroo*	49.6 g	Hydrolysable tannins	100 g
				OH(HO)COOH(OH) Trihydroxybenzoic acid	
8	Animal	Fat and brain	72.5 g	$HOCH_2(CHOH)_nCHO$ Para-formaldehyde	100 g
				$Ch_2OC(CH_2)_{16}CH_3$ Tristearin	
				$CH_3(CH_2)_{16}COOH$ Staeric acid	
9	Sulfate	Aluminium	57.7 g	$AlK(SO_4)_212H_2O$ Aluminium potassium silicate hydroxide	100 g
10	Sulfate	Ferrous	73.7 g	$Fe_2O(SO_4)_2$ Iron (III) sulfate	100 g
11	Mineral	Red ochre	51.5 g	FeO Iron (II) oxide	100 g
12	Mineral	Red ochre	57.4 g	FeO / SO_4 Iron (II) oxide / surface salts	100 g
13	Mineral	Red haematite	74.5 g	Fe_2O_3 Iron (III) oxide	100 g
14	Mineral	Yellow limonite	60.6 g	$Fe_2O_3(OH)\ nH_2O$	100 g
				Hydrated iron (II) / crypto-crystalline lepidocrocite	
15	Mineral	Brown goethite	53.7 g	FeO(OH) Iron (II) oxide hydroxide	100 g
16	Mineral	White kaolinite	57.1 g	$Al_4[Si_4O_{10}](OH)_8$ Aluminium silicate hydroxide	100 g
17	Mineral	Black magnetite	50.5 g	Ferrous-ferric oxide	100 g
				Fe_3O_4 Iron (II / III) oxide hydroxide	
				Mg / Al / Ti / Mn / Ca	
18	Mineral	Black shale	68.2 g	Magnesium di- / oxide	100 g
				Mno / MnO_2 Manganite	
				MnOOH	
19	Combination	Red ochre	71.7 g	FeO	50 g
		Animal fat		$HOCH_2(CHOH)_nCHO$	50 g
20	Combination	Red haematite	60.7 g	Fe_2O_3	50 g
		Animal fat		$HOCH_2(CHOH)_nCHO$	50 g
21	Combination	Yellow limonite	60.4 g	$Fe_2O_3(OH)\ nH_2O$	50 g
		Animal fat		$HOCH_2(CHOH)_nCHO$	50 g
22	Combination	*Acacia karroo*	58.7 g	OH(HO)COOH(OH)	50 g
		Animal fat		$HOCH_2(CHOH)_nCHO$	50 g
23	Combination	*Acacia karroo*	56.3 g	OH(HO)COOH(OH)	50 g
		Red ochre		FeO	50 g
24	Combination	*Acacia karroo*	54.5 g	OH(HO)COOH(OH)	50 g
		Yellow limonite		$Fe_2O_3(OH)\ nH_2O$	50 g
25	Combination	Wood ash	51.2 g	K / Mg / Ca / Al / Cu / B / As	50 g
		Animal fat		$HOCH_2(CHOH)_nCHO$	50 g
26	Combination	*Acacia karroo*	46.5 g	OH(HO)COOH(OH)	33 g
		Animal fat		$HOCH_2(CHOH)_nCHO$	33 g
		Red ochre		FeO	33 g
27	Combination	*Acacia karroo*	63.9 g	OH(HO)COOH(OH)	33 g
		Animal fat		$HOCH_2(CHOH)_nCHO$	33 g
		Red haematite		Fe_2O_3	33 g
28	Combination	*Acacia karroo*	67.5 g	OH(HO)COOH(OH)	33 g
		Animal fat		$HOCH_2(CHOH)_nCHO$	33 g
		White kaolinite		$Al_4[Si_4O_{10}](OH)_8$	33 g

Tab. 2. Details of hide-tanning experiments. Ingredients, primary active compounds and the amounts of ingredients utilised are indicated. The compositions of active chemical compounds are approximate as additional elements may be present in various degrees.

experiments, I used fat derived from the brain and fatty deposits from around the kidneys and below the skin of the kudu antelope. The ingredients were exposed to direct sunlight for 2 hours prior to application to 'soften' the fat and to facilitate penetration into the hide sample.

Mineral tawing (9–18)

Aluminium sulphate ($AlK(SO_4)_2 12H_2O$ and $Al_2(SO_4)_3$) has been identified as a viable alternative for chromium (III) sulphate ($C_rOH(H_2O)_5SO_4$) and has been used for centuries (Haroun *et al.* 2009: 21). Hides have also been tanned with iron salts (chlorides, sulfates and nitrates *e.g.*, $Fe_2O(SO_4)_2$). First patented in 1770 in Great Britain and employed during the 1930s in Germany, iron (Fe III) is the active ingredient (Kleban & Bayer 2004: 6). Sample 9 was treated with aluminium sulphate and sample 10 with iron III sulphate. Red and yellow ochre and white kaolinite and grey shales were collected from outcrops of the Bokkeveld Group deposits of the Cape Supergroup (Vorster 2002) at several locations in the Western Cape Province. Red ochre containing precipitated crystalline salt deposits was sourced from the Timeball Hill Formation of the Transvaal Supergroup (Catuneanu & Eriksson 2002). Weathered nodules of red haematite were sourced from the same geological formation. I ground the mineral specimens into powder on coarse quartzitic sandstone grindstones (***Color plate 1***). Manganite was purchased from a commercial supplier.

To determine the elemental composition of mineral tanning ingredients, I used a mobile Ametek SPECTRO xSORT X-ray fluorescence spectrometer equipped with a silicon drift detector (SDD) and a low power X-ray tube with 40 kV as excitation source. The device is internally calibrated by the automated measurement of the contents of its own metal shutter and controlled with a PDA. The acquisition of elemental spectra was set for a length of 60 seconds. The results are presented in ***Table 9*** and further illustrated in ***Figures 8*** and ***9***.

Combination tannages (19–28)

Tanning methods are frequently combined into a single process. Combination tanning methods are viewed as the most effective means of tanning hide, especially when combining animal oils, vegetable tannins and iron rich mineral ingredients (Lampard 2002; Covington 2008). Samples 19 to 28 were tanned using two or three combinations of ochre, vegetable tannins, wood ash and animal fat. These ingredients derive from the same sources as those used during the single-element experiments.

Application of ingredients

Ingredients were applied to hide samples after they had been washed with mineral water, scraped clean and while they were still damp. The ingredients were rubbed into the hides by hand for 2 minutes and the samples were stretched and rolled between the hands for 10 minutes. They were then rolled up with the hair on the outside, secured with an elastic band and stored for 24 hours. In the case of combination tannages, samples were unrolled and the next treatment applied. To facilitate the saturation of ingredients, samples were hydrated with 40 millilitres of water. The samples were rolled up, secured with an elastic band and left for 12 hours. In three instances a third application of tanning ingredients was necessary. The process followed the same steps as those outlined above.

Five days after the final application of ingredients, specimens were unfolded and left to dry for 24 hours. To soften the samples, I used six quartzite cobbles to 'scrape' the specimens. Scraping stones were widely used in North America (Schlanger 1991), and a similar strategy was used by the Nama hunter-pastoralists of the Northern Cape. These stones are termed scrapers but they do not comprise retouched flakes of any form. Instead, coarse amorphous sandstone cobbles were used to soften hides (Webley 1990: 28).

Routine monitoring

Following the experiments, hide samples were stored outspread on clean polystyrene trays. The storage space was aerated daily and samples were not exposed to sunlight. After an initial 24-hour evaluation, I assessed the specimens at 5, 15 and 30-day intervals. The evaluation entailed recording changes in eight measurable categories. These form part of standard leather assessment scales (Covington *et al.* 2001; Bernath, Miu & Guttmann[1]) and include noting changes in pH values, weight, thickness, colour and differential pliability, fungal development, saprophagic activity and odour.

Changes in pH values

Highly alkaline and acidic environments are generally not conducive to bacterial growth and fungal infestation (Baath *et al.* 1992: 4026). The solubility of mineral elements and the incidence of chemical reactions are also dependent on changes in pH levels (Matinéz & McBride 1988: 537), and there is substantial modification of collagen in both alkaline and acidic contexts. Alkalinity causes collagen fibrils to separate from one another, the extension of the helix structures and the overall

expansion of the dermal structure (Covington 1997: 111). The expansion of collagen fibres facilitates the penetration of tanning ingredients (Lischuk *et al.* 2006: 194). This also occurs under acidic conditions, which facilitates the infiltration of ingredients and which acts as a buffer against deterioration after tanning.

Ordinal evaluation scales

Ordinal scales (Stevens 1946) assign values to characteristics to represent the rank order of assessed entities in relation to each other, but differences between allocated values are not quantifiable. I devised four ordinal scales (Rots & Williamson 2004: 1290) to assess hide pliability, susceptibility to fungal and saprophagic infestation and changes in odour. Results for ordinal scale assessments cannot usually be compared across different studies. The concept of order is nevertheless significant and can provide an accurate evaluation of variation over time within a single study.

Hide pliability

The thermal insulating properties of clothing are documented in many studies of clothing physiology (Gilligan 2010: 22). It is not the type of material that diminishes heat loss, but the incidence of pockets of air trapped next to the skin. Heat loss is minimised by developing tailored garments that are properly fitted to the human body. Any movement of air within or between different layers of clothing and the skin reduces thermal effectiveness. Supple fitted garments enclose the body more extensively, creating a uniformly warm environment which minimises heat loss and which enhances the protective capacity of garments against cold temperatures. Hide pliability therefore relates directly to the flexibility and functionality of the end product.

In the modern leather industry, complex machinery is used to assess the pliability of tanned leathers, the property of being fully flexible without cracking or tearing. The ordinal scale developed to assess the pliability of samples is based on an appraisal of the incidence of cracking and splitting at folding zones (Liu *et al.* 2002: fig. 1). The score range progresses from zero, which signifies a positive result, to five, which corresponds to a negative valuation. The scales developed to evaluate the presence of fungal hyphae, saprophagic organisms and the odour of experimental specimens are based on the same scoring system. ***Table 3*** illustrates the scale developed to assess the pliability of hide samples.

	Allocated value						
+	0	1	2	3	4	5	-
0	Sample is fully pliable without cracking or splitting						
1	Incidence of slight cracking without splitting						
2	Only partial cracking and slight splitting						
3	Substantial cracking and notable splitting						
4	Incidence of severe cracking and splitting						
5	The sample is not pliable and readily splits open						

Tab. 3. The ordinal assessment scale developed to evaluate the pliability of experimental hide samples.

Fungal infestation

Eukaryotic microorganisms such as fungi can cause serious structural and aesthetic damage to leather (Bilgi *et al.* 2009: 1602). At least 23 different fungal genuses are identified as being detrimental to chrome-tanned leather (Birbir *et al.* 1994). The detection of fungal activity was based on the microscopic incidence of hyphae and mycelium, the main mode of fungal vegetative growth (Polacheck *et al.* 1989).

Saprophagic activity

An ordinal scale was developed to assess the prevalence of saprophagic organisms (mostly maggots) on hide samples. Many fly species target the hides of live animals (*e.g.*, *Lucilia sericata*), but most species breed in carrion and faeces (Villet *et al.* 2006). Blowfly larvae have been known to appear within three days of adults visiting a carcass (Braack 1984: 9). Besides causing severe damage to animal hide, many fly species are vectors of enteric diseases (Richards *et al.* 2009). It is therefore important to monitor the presence of flies and fly larvae during the tanning process.

Odour and bacterial activity

Detecting bacterial activity on tanned leathers is a complicated matter (Birbir & Ilgaz 1996); however, like changes in colour (Couturier *et al.* 1988), changes in odour intensity frequently result from lipid oxidation and the microbial metabolism of proteins (Stohr *et al.* 2007). Hedonic tone assessment entails rating odours on a scale ranging from pleasant (*i.e.* zero) to very unpleasant (*i.e.* five).

1 Bernath, A., Miu, L. & Guttmann, M. "Identification, Micro-analysis, Evaluation and Diagnosis of an Ethnographic Leather Object". Paper presented at the 9th International Conference on NDT of Art, Jerusalem, Israel, 25th to 30th May 2008.

Results and discussion

Twenty-four hours after the final application of ingredients, I evaluated the efficiency of experimental tanning techniques by documenting changes in pH values, weight, hide thickness, colour and pliability, fungal presence, saprophagic activity and odour. ***Table 4*** presents the values allocated to individual samples.

Due to irreversible damage caused by saprophagic (fly larvae) activity, I decided to eliminate sample 8 from the study. The remaining samples did not display marked signs of deterioration, although some (3, 4, 18, 20 and 21) did show indications of microbial activity and changes in odour. Five days after the initial 24-hour assessment, I again evaluated hide samples according to the eight measurable categories (***Tab. 5***).

Samples 20 and 21 were salvaged before saprophagic activity caused irreversible damage. In both instances, maggots were most active at the central part of the rolled-up samples. This area remained moist during storage and provided a suitable environment for the larvae to feed. Maggots were removed from the specimens with a dental pick, which were left to dry in the sun for 2 hours before softening. Samples 3, 4 and 18 did not deteriorate beyond the changes noted in ***Table 4***. Specimen 19, which was treated with red ochre and animal fat, also exhibited saprophagic activity. The sample experienced no structural damage and remained fully 'functional'. None of the remaining experimental samples displayed marked changes in odour or any form of saprophagic activity, although the pliability of most specimens declined markedly. I softened the hide samples by manual manipulation, by rubbing them with quartzite cobbles and by scraping with hand-held silcrete scrapers. ***Table 6*** indicates the pliability values allocated to samples after softening by hand for 15 minutes, rubbing with quartzite cobbles for 10 minutes and scraping with silcrete scrapers for 10 minutes.

I allocated pliability ratings of 4 and 5 to the most rigid specimens (1, 3, 14, 16 and 21). These samples exhibited severe inflexibility and surface splitting, and it is unlikely that these could be of much use in terms of producing functional leather garments. Samples that were rated 3 (4, 17 and 23) may become completely functional with supplemen-

#	Experiment	Weight	Width	Colour	NCS Code	Pliability	Odour	Fungal	Animal	pH
1	Untreated	28.5 g	3.45 mm	Brown	3560-Y20R	2	1	0	0	8.3
2	Modern	54.8 g	3.66 mm	Mustard	2070-Y10R	0	1	0	0	6.1
3	Red soil	34.4 g	3.66 mm	Brown	3060-Y30R	1	5	0	0	7.4
4	Brown soil	38.1 g	3.29 mm	Brown	3050-Y40R	1	5	0	0	7.2
5	Coarse salt	60.4 g	2.75 mm	Beige	0907-Y70R	0	2	0	0	6.4
6	Smoke	55.1 g	2.26 mm	Mustard	2060-Y10R	1	2	0	0	6.6
7	Vegetable	59.1 g	2.28 mm	Pink	2030-R	0	1	1	0	6.4
8	Animal	68.4 g	2.98 mm	Yellow	1080-Y	0	5	0	5	5.7
9	Aluminium	73.8 g	3.97 mm	Beige	0907-Y50R	0	2	0	0	5.1
10	Ferrous	44.2 g	2.65 mm	Mustard	1080-Y10R	1	4	0	0	5.7
11	Red ochre	47.1 g	3.17 mm	Red	2075-Y60R	0	4	0	0	7.1
12	Red ochre	48.5 g	3.32 mm	Pink	2040-Y70R	0	4	0	0	5.9
13	Haematite	66.5 g	3.19 mm	Maroon	5540-Y90R	0	0	0	0	6.6
14	Limonite	56.6 g	3.85 mm	Yellow	0570-Y20R	0	0	0	0	7.1
15	Goethite	37.7 g	4.13 mm	Brown	4050-Y10R	0	0	0	0	7.4
16	Kaolinite	57.6 g	3.15 mm	Mustard	1080-Y	0	1	0	0	8.4
17	Manganite	40.7 g	3.86 mm	Black	8005-R50B	0	3	0	0	6.6
18	Black shale	54.8 g	2.86 mm	Brown	5040-Y10R	0	5	0	0	7.1
19	Combined	62.1 g	2.74 mm	Red	2075-Y60R	0	2	0	1	6.1
20	Combined	52.9 g	2.41 mm	Maroon	5540-Y90R	0	3	0	4	7.1
21	Combined	52.6 g	2.49 mm	Yellow	0570-Y20R	0	2	0	3	7.1
22	Combined	68.1 g	2.44 mm	Pink	2030-Y90R	0	1	1	0	7.1
23	Combined	68.5 g	2.02 mm	Pink	2030-R10B	0	2	1	0	7.4
24	Combined	70.3 g	2.08 mm	Pink	2040-Y80R	0	0	1	0	7.2
25	Combined	47.2 g	2.51 mm	Grey	5005-R50B	0	3	0	0	8.1
26	Combined	41.6 g	2.08 mm	Pink	2030-R	0	1	1	0	6.5
27	Combined	64.7 g	3.77 mm	Pink	2030-R20B	0	1	1	0	6.2
28	Combined	63.4 g	3.26 mm	Pink	2040-Y90R	0	1	1	0	6.6

Tab. 4. Results for the evaluation of eight measurable characteristics (pH, weight, width, colour, pliability, fungal growth, saprophagic microbes and odour) of experimentally tanned hide samples 24 hours after combination tanning treatments were completed. During storage, the temperature ranged from 18.3°C to 29.8°C and the humidity from 29.5 % to 78.6 %.

#	Experiment	Weight	Width	Colour	NCS Code	Pliability	Odour	Fungal	Animal	pH
1	Untreated	28.1 g	2.99 mm	Brown	8010-G90Y	4	1	0	0	6.8
2	Modern	35.5.g	2.98 mm	Yellow	0520-Y	2	2	0	0	4.2
3	Red soil	18.8 g	3.05 mm	Brown	6030-Y70R	4	1	2	0	6.1
4	Brown soil	21.3 g	3.32 mm	Brown	7020-Y40R	4	2	1	0	5.8
5	Coarse salt	36.8 g	3.04 mm	Beige	0570-G80Y	1	2	0	0	5.2
6	Smoke	23.6 g	2.38 mm	Brown	8010-G90Y	2	2	4	0	5.8
7	Vegetable	17.4 g	1.81 mm	Brown	8010-Y70R	3	1	1	0	5.1
8	Animal									
9	Aluminium	38.0 g	4.91 mm	Beige	0502-R	2	1	0	0	3.8
10	Ferrous	36.7 g	2.70 mm	Yellow	3060-Y10R	3	1	0	0	3.4
11	Red ochre	34.5 g	3.51 mm	Red	3560-Y80R	3	1	0	0	3.0
12	Red ochre	28.1 g	2.45 mm	Pink	3020-Y90R	2	3	0	0	5.1
13	Haematite	30.1 g	3.23 mm	Maroon	7020-R10B	3	1	1	0	6.1
14	Limonite	35.9 g	4.62 mm	Brown	5010-Y70R	3	1	0	0	6.1
15	Goethite	25.6 g	3.49 mm	Brown	4010-Y90R	3	1	2	0	5.9
16	Kaolinite	30.9 g	3.71 mm	Grey	1005-R50B	4	1	0	0	6.2
17	Manganite	26.7 g	2.79 mm	Black	8005-R50B	3	1	1	0	6.3
18	Black shale	33.3 g	3.56 mm	Grey	7000-N	3	1	1	0	6.2
19	Combined	24.3 g	2.97 mm	Brown	6030-Y80R	4	2	0	1	6.2
20	Combined	33.2 g	2.16 mm	Maroon	5540-Y90R	2	4	3	5	5.1
21	Combined	34.2 g	1.80 mm	Mustard	3560-Y20R	2	4	1	4	5.8
22	Combined	34.1 g	2.65 mm	Brown	8010-Y10R	2	3	0	0	5.4
23	Combined	27.0 g	1.74 mm	Red	3060-Y80R	2	1	0	0	5.3
24	Combined	31.2 g	2.64 mm	Mustard	1080-Y10R	1	2	0	0	5.4
25	Combined	24.3 g	1.62 mm	Grey	7005-R50B	3	2	0	0	5.9
26	Combined	19.1 g	1.46 mm	Brown	5040-Y80R	1	1	3	0	6.3
27	Combined	21.5 g	2.51 mm	Maroon	7020-R10B	3	1	1	0	6.1
28	Combined	34.6 g	2.29 mm	Grey	4005-R50B	1	1	3	0	6.1

Tab. 5. Results for the evaluation of measurable characteristics of tanned hide samples 5 days after the conclusion of treatment. The assessment was performed prior to the softening of the specimens by manual manipulation and scraping with quartzite cobbles and silcrete scrapers. The temperature in the storage area ranged from 16.8°C to 27.2°C and the humidity from 27.1 % to 80.6 %.

tary softening and the addition of vegetable oils or animal fats. Of the more pliable samples (2, 5, 6, 7, 9, 10, 11, 12, 13, 15, 18, 19, 20, 22, 24, 25, 26, 27 and 28) specimens 5 (coarse salt), 7 (vegetable tannins), 11 (red ochre), 13 (haematite), 25 (wood ash and animal fat), 24 (vegetable tannins and limonite), 27 (vegetable tannins, animal fat and haematite) and 28 (vegetable tannins and kaolinite) were allocated a rating of 1, indicating full pliability with negligible surface cracking. These samples are considered fully serviceable in terms of the production of tight-fitting composite leather garments. The most pliable specimens (2, 9 and 12) comprised those treated with the modern tanning solution (2), aluminium sulphate (9) and the 'saline' red ochre (12). I noted no changes in pliability values after the manual and lithic softening component was completed.

The evaluation of tanning methods also entailed assessing hide samples fifteen and thirty days after the initial appraisal (***Tabs. 7*** and ***8***). Apart from slight fungal growth on three specimens (1, 3 and 7), no marked changes in values were recorded 45, 60 and 90 days after the initial assessment.

Pliability and elemental composition

To determine which of the 28 tanning techniques were the most efficient, I compared the pliability values allocated to samples 6 to 28 with those of the control specimens (1 to 5) and to each other. Hide pliability relates directly to the functional potential of the end product, and the comparison of changes in pH with modern tanning methods provides insight into the chemistry of experimental tanning techniques. The XRF results obtained for the mineral ingredients illuminate the reactive capacity of experimental ochres.

Pliability values

Color plates 2 and ***3*** illustrate the physical nature of experimental samples 90 days after the experiments. Microphotographs were taken with a ColorView digital camera mounted on an Olympus SZX 16 stereo zoom microscope. The samples in ***Color plate 2*** received pliability ratings of 4 and 5 and exhibited severe inflexibility and surface cracking and splitting. These are deemed unsuitable for the manufacture of tight-fitting tailored leather garments.

#	Experiment	Manual softening	Cobble rubbing	Lithic scraping	Total processing time	Pliability value
1	Untreated	15	10	10	35	5
2	Modern	15	10	10	35	0
3	Red soil	15	10	10	35	4
4	Brown soil	15	10	10	35	3
5	Coarse salt	15	10	10	35	1
6	Smoke	15	10	10	35	2
7	Vegetable	15	10	10	35	1
8	Animal					
9	Aluminium	15	10	10	35	0
10	Ferrous	15	10	10	35	2
11	Red ochre	15	10	10	35	1
12	Red ochre	15	10	10	35	0
13	Haematite	15	10	10	35	1
14	Limonite	15	10	10	35	4
15	Goethite	15	10	10	35	2
16	Kaolinite	15	10	10	35	4
17	Manganite	15	10	10	35	3
18	Black shale	15	10	10	35	2
19	Combined	15	10	10	35	2
20	Combined	15	10	10	35	2
21	Combined	15	10	10	35	4
22	Combined	15	10	10	35	2
23	Combined	15	10	10	35	3
24	Combined	15	10	10	35	3
25	Combined	15	10	10	35	1
26	Combined	15	10	10	35	2
27	Combined	15	10	10	35	1
28	Combined	15	10	10	35	3

Tab. 6. The amounts of manual and lithic processing applied to render tanned samples pliable. Duration is indicated in minutes and pliability was allocated after the softening component was completed.

The samples in ***Color plate 3*** display the preferred degree of malleability and suppleness of leather garments. Control sample 2, which was treated with the modern tanning formula, provides an example of the transformation of tightly packed collagen fibres characteristic of raw hide into a matrix of loose, separated collagen bundles, an attribute of properly tanned hide. This type of open collagen structure reflects the best possible degree of pliability, softness and therefore suitability for tailoring and the production of tight-fitting leather clothing. This arrangement of collagen fibres is also displayed in samples 5, 7, 9, 11, 12, 13, 24, 26 and 28, and, to a lesser extent, samples 6, 10, 15, 18, 19, 20, 22, 25 and 27.

The pliability values allocated to different specimens (***Fig. 7***) therefore signifies the general capacity of different tanning methods and ingredients to produce leather that is best suited for the manufacture of composite and tight-fitting leather garments.

Elemental composition

Collagen fibre is capable of reacting with various metal ions, including Al (III), Zr (IV) and Fe (III) (Tang *et al.* 2005: 5882). Aluminium is common in clay formations (Young *et al.* 2010: 134), and since $Al_2(SO_4)_3$ is surpassed in tanning capacity only by chromium (III) sulphate ($C_rOH(H_2O)_5SO_4$), the incidence of aluminium sulphates in clays might be sufficient to facilitate tanning. The role of iron oxides as sulphate absorbers in clay deposits is also widely recognised (Alves & Lavorenti 2004), and the Bokkeveld shales are characterised by a particularly high degree of salinity (Greeff 1996: 69). Iron chlorides, sulfates and nitrates also occur in the form of melanterite ($FeSO_4$ $7H_2O$), jarosite ($KFe_3(SO_4)2(OH)_6$) and pyrite (FeS_2) (Easthaugh *et al.* 2008: 209). Through oxidation, pyrite readily transforms into substances categorised as 'ochre', such as limonite, haematite and goethite (Courtin-Nomade *et al.* 2009: 716). Substantial amounts of chlorides, sulfates and nitrates may therefore be present in what is generally referred to as ochre, and this may explain the efficiency of the saline red ochre (sample 12) as a tanning ingredient. To verify this notion, I ascertained the elemental compositions of the mineral ingredients by way of XRF analysis (***Tab. 9***). The implications of these results are discussed in detail below.

Tanning with mineral powders such as red ochres can be even more effective when combined with other ingredients. This is illustrated by specimens 24, 25, 27 and 28, which received pliability ratings of 1, and implies that ochre must become at least partially soluble in order to react with other elements. The insolubility of iron oxides has been cited as a primary cause of the inefficacy of ochres to tan animal hide. This notion is based on a misunderstanding of the basic chemistry of ochre, where the properties of soluble iron salts ($FeSO_4$, $FeCl_2$, $Fe(SO_4)_3$, and $FeCl_3$) have been assumed to be shared by insoluble iron oxides (Fe_2O_3 and FeO) (Watts 2009: 72). Iron most generally occurs in a ferrous (Fe II) form, and, through oxidation, ferrous iron is converted to the ferric form (Fe III *e.g.*, Fe_2O_3) (Hrardil *et al.* 2003). Ferric Fe (III) compounds are only water soluble in strongly acidic solutions, but solubility increases when these are reduced to Fe II under certain conditions. Iron and goethite becomes mobile and increasingly soluble when combined chemically with acidic gallotannins and ellagitannins present in *Acacia karroo* bark (Okibe *et al.* 2003). It is therefore unlikely that the perceived insolubility of iron oxides is a limiting

#	Experiment	Weight	Width	Colour	NCS Code	Pliability	Odour	Fungal	Animal	pH
1	Untreated	25.2 g	2.83 mm	Beige	2010-Y30R	3	1	0	0	5.9
2	Modern	35.1.g	2.89 mm	Beige	1010-Y10R	0	1	0	0	4.4
3	Red soil	18.2 g	3.01 mm	Beige	2020-Y40R	2	0	0	0	5.9
4	Brown soil	20.6 g	3.27 mm	Beige	1020-Y10R	2	0	0	0	5.8
5	Coarse salt	35.2 g	2.96 mm	Beige	0502-Y	1	0	0	0	5.3
6	Smoke	22.9 g	2.15 mm	Beige	0907-Y10R	2	0	0	0	5.1
7	Vegetable	18.8 g	1.76 mm	Beige	1015-Y20R	2	1	0	0	5.6
8	Animal									
9	Aluminium	37.3 g	4.83 mm	Beige	0603-G80Y	2	1	0	0	3.9
10	Ferrous	36.1 g	2.62 mm	Beige	0520-G20Y	2	1	0	0	3.6
11	Red ochre	33.8 g	3.47 mm	Beige	0510-Y40R	1	0	0	0	4.4
12	Red ochre	27.6 g	2.37 mm	Beige	0507-Y20R	0	0	0	0	5.2
13	Haematite	29.2 g	3.16 mm	Beige	0510-Y40R	1	0	0	0	6.2
14	Limonite	34.8 g	4.58 mm	Beige	0515-G90Y	2	1	0	0	6.3
15	Goethite	24.3 g	3.36 mm	Beige	1510-Y10R	2	1	0	0	6.1
16	Kaolinite	29.4 g	3.63 mm	Beige	0502-Y	3	1	0	0	6.4
17	Manganite	25.6 g	2.66 mm	Beige	0505-G50Y	3	1	0	0	6.5
18	Black shale	32.4 g	3.48 mm	Beige	1005-G80Y	2	1	0	0	6.4
19	Combined	23.7 g	2.82 mm	Beige	0505-Y10R	1	1	0	0	6.4
20	Combined	32.4 g	2.04 mm	Beige	0507-G80Y	1	2	0	0	5.3
21	Combined	33.1 g	1.62 mm	Beige	0603-Y40R	2	2	0	0	5.9
22	Combined	32.8 g	2.49 mm	Beige	0804-Y30R	2	2	0	0	5.6
23	Combined	26.2 g	1.68 mm	Beige	0505-Y10R	1	1	0	0	5.8
24	Combined	30.1 g	2.55 mm	Beige	1010-Y10R	1	1	0	0	5.9
25	Combined	23.4 g	1.57 mm	Beige	0505-Y	2	1	0	0	6.3
26	Combined	18.3 g	1.31 mm	Beige	0510-G80Y	1	1	0	0	6.2
27	Combined	20.1 g	2.43 mm	Beige	0505-Y10R	1	1	0	0	6.3
28	Combined	33.2 g	2.18 mm	Beige	0505-Y30R	1	1	0	0	6.4

Tab. 7. Results of the evaluation of the eight measurable characteristics 15 days after treatment. The storage temperature ranged from 15.8°C to 26.6°C and the humidity from 49.3 % to 79.0 %.

#	Experiment	Weight	Width	Colour	NCS Code	Pliability	Odour	Fungal	Animal	pH
1	Untreated	25.2 g	2.81 mm	Beige	2010-Y30R	3	1	1	0	5.7
2	Modern	35.1.g	2.85 mm	Beige	1010-Y10R	0	1	0	0	4.7
3	Red soil	18.2 g	2.91 mm	Beige	2020-Y40R	2	0	2	0	5.9
4	Brown soil	20.6 g	3.17 mm	Beige	1020-Y10R	2	0	0	0	5.9
5	Coarse salt	35.2 g	2.83 mm	Beige	0502-Y	1	0	0	0	5.4
6	Smoke	22.9 g	2.04 mm	Beige	0907-Y10R	2	0	0	0	5.3
7	Vegetable	18.8 g	1.63 mm	Beige	1015-Y20R	2	1	3	0	5.6
8	Animal									
9	Aluminium	37.3 g	4.72 mm	Beige	0603-G80Y	2	1	0	0	4.2
10	Ferrous	36.1 g	2.55 mm	Beige	0520-G20Y	2	1	0	0	3.8
11	Red ochre	33.8 g	3.41 mm	Beige	0510-Y40R	1	0	0	0	4.7
12	Red ochre	27.6 g	2.32 mm	Beige	0507-Y20R	0	0	0	0	5.1
13	Haematite	29.2 g	3.12 mm	Beige	0510-Y40R	1	0	0	0	6.2
14	Limonite	34.8 g	4.56 mm	Beige	0515-G90Y	2	1	0	0	6.4
15	Goethite	24.3 g	3.31 mm	Beige	1510-Y10R	2	1	0	0	6.3
16	Kaolinite	29.4 g	3.62 mm	Beige	0502-Y	3	1	0	0	6.5
17	Manganite	25.6 g	2.63 mm	Beige	0505-G50Y	3	1	0	0	6.5
18	Black shale	32.4 g	3.42 mm	Beige	1005-G80Y	2	1	0	0	6.6
19	Combined	23.7 g	2.80 mm	Beige	0505-Y10R	1	1	0	0	6.6
20	Combined	32.4 g	2.00 mm	Beige	0507-G80Y	1	1	0	0	5.4
21	Combined	33.1 g	1.57 mm	Beige	0603-Y40R	2	1	0	0	5.9
22	Combined	32.8 g	2.41 mm	Beige	0804-Y30R	2	1	0	0	5.7
23	Combined	26.2 g	1.62 mm	Beige	0505-Y10R	1	1	0	0	5.9
24	Combined	30.1 g	2.48 mm	Beige	1010-Y10R	1	1	0	0	6.2
25	Combined	23.4 g	1.51 mm	Beige	0505-Y	2	1	0	0	6.4
26	Combined	18.3 g	1.26 mm	Beige	0510-G80Y	1	1	0	0	6.2
27	Combined	20.1 g	2.37 mm	Beige	0505-Y10R	1	1	0	0	6.3
28	Combined	33.2 g	2.11 mm	Beige	0505-Y30R	1	1	0	0	6.4

Tab. 8. Results of the evaluation of the eight measurable characteristics 30 days after treatment. During storage, the temperature ranged from 13.6°C to 23.2°C and the humidity from 36.7 % to 61.5 %.

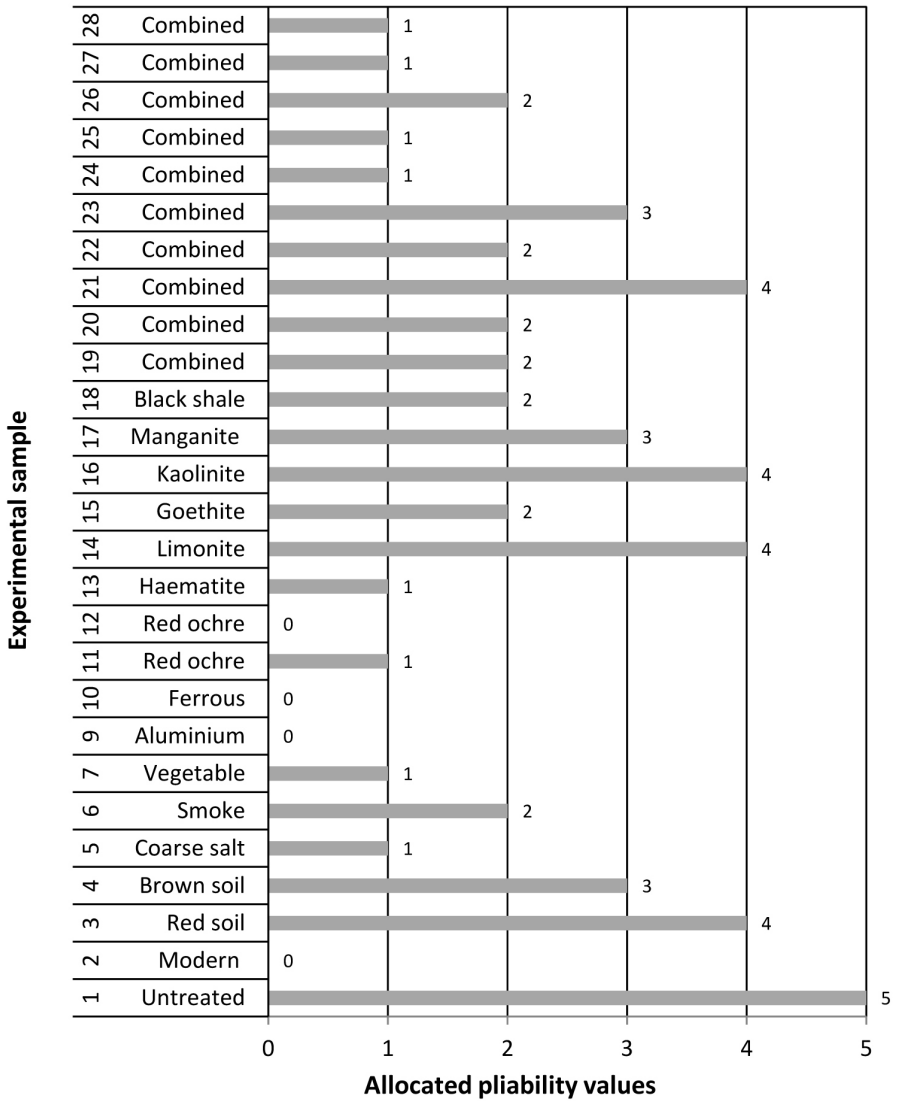


Fig. 7. Comparison of pliability values allocated to experimental samples.

factor in terms of the capacity of red ochre to tan hides, especially when used in combination with other reactive ingredients.

Conclusion

The objective of my experiments was not to challenge the hypothesis that ochre was used as a pigment in symbolic contexts during the LSA and MSA, but rather to evaluate the efficacy of ochre, and of combinations of ochre with animal fats and vegetable tannins, in treating raw animal hide so that it could be used to make clothing or other artefacts. From the results I conclude that the most effective tanning strategy is that comprising the modern Deer Hunter's and Trapper's Hide Tanning Formula™ (sample 2), followed by specimens 5 (coarse salt), 7 (vegetable tannins), 9 (aluminium sulphate) and 10 (ferrous sulphate). I did anticipate these results as these ingredients form part of contemporary tanning procedures. This study is a preliminary exploration of the efficacy of ochre as a tanning ingredient. Comprehensive research comprising a wider range of animal species and geological and colourimetric types of ochre is required.

Of the mineral (ochre) tannages, the most successful technique was that comprising the saline red ochre sample (12), followed by specimens 11 (red ochre) and 13 (haematite). The red ochre used in experiment 12 was highly effective in generating a fully pliable leather exhibiting resistance to desiccation and putrification. It was allocated the same pliability rating (0) as the specimens treated with aluminium sulphate (sample 9) and ferrous sulphate (sample 10). ***Figures 8*** and ***9*** provide an indication of the elemental composition of the ingredients applied to samples 10, 11, 12 and 13.

	Black shale	Aluminium	Coarse salt	Hutton soil	Iron salts	Jonkersberg	Kaolinite	Limonite	Magnetite	Red ochre (11)	Haematite	Red ochre (12)	Wood ash
SiO2	6685	607		7864	484	10418	5823	7610		7149		4653	2004
P2O5	0			0	0	0	0	0		0		0	10276
SO3	0			22	38043	49	0	117		377		6792	3757
Cl	827	5831	200041	376	338	371	372	1842		374		3597	2512
K2O	85495	96301	698	7581	0	3756	21763	34878		20621		25107	84672
CaO	934	465	6163	15140	0	4251	892	115		1108		7006	1202052
TiO2	37094	0	50	34779	0	29998	21274	39641	51496	35771	3846	25716	11970
V2O5	2687	0	0	1272	0	0	0	2067	0	1726	0	1719	535
Cr2O3	2548	756	742	6800	255	4457	112	2207	10427	3412	4013	2984	1495
MnO2	1066	238	254	15802	0	7225	1521	1332	151715	0	24715	29716	5817
Fe2O3	556432	4818	3827	1460660	5513763	1217790	96460	1802393	9250508	3593885	9303704	1936241	287357
CoO	0	137	0	0	0	0	1734	0	45877	0	83431	0	0
NiO	3808	3413	3270	8206	3090	4812	4717	5177	4647	4000	466	5611	3935
CuO	0	1103	714	7552	0	3209	3958	892	9260	3315	2659	3434	6128
ZnO	6935	5116	0	6261	1760	5003	8824	7419	13098	6680	3802	8202	8430
Ga	2251			713	722	156		643		1683		1117	635
As2O3	0	0	0	191	0	784	0	2921		5780		3099	0
Se	0	1049	7	0	0	0	81	0		943		24	1679
Br	132	0	15625	128	0	643	92	1867	0	751	0	642	2748
Rb2O	71315	3291	848	9588	0	6140	33449	29977		14253		27353	9203
SrO	26800	646	1488	5428	0	3654	137939	11987		12238		24052	172911
Y	9404	0	0	3966	0	2677	15334	10933		4271		9382	5947
ZrO2	53424	1	1	48896	1	80972	42545	46914	3636	29249	5295	19635	20159
Nb2O5	4733	0	0	3000	0	5870	2726	2328	843	0	0	2310	0
Mo	4692	0	0	6396	5781	7567	12935	5715	10445	5336	7406	5332	3755
Ag	0	1124	870	0	1119	1469	2127	91	484	0	360	0	0
Cd	0	2154	1069	0	292	974	1061	235	0	0	374	0	0
SnO2	0	913	2057	0	240	0	0	0	1790	0	598	0	0
Sb2O5	0	863	0	0	520	0	0	250	376	0	0	0	0
I	0	1100	1069	0	0	0	0	1861		0		0	0
Ba	1414	0	0	0	0	0	2343	757		15		985	0
Hf					33		1081			731			
Ta2O5	1614			1451	908	2441	2885	1634		496		1369	353
WO3	0	1045	447	0	0	0	0	0	0	0	0	0	0
Hg	0	716	773	0	0	0		0	0	355	0	0	571
Tl	0			0	0	0		0		4		0	243
PbO	1702	549	955	1635	0	5219	3951	4559	232	0	242	1231	3145
Bi	0	0	0	0	0	0	0	0	20	542	0	0	573
Th	2116	557	1011	1410	0	869	4996	2580		3621		3332	3502
U	1410	151	0	0	0	346	4112	1844		1760		1680	3852

Tab. 9. XRF values recorded for mineral ingredients employed during the experiments. Elemental compositions are presented at 'net counts' of elements during the 60 second spectra acquisition period.

The general perception that the iron (Fe) present in red ochres neutralises the action of collagenase and prevents the breakdown of collagen appears to be largely accurate (***Fig. 8***). But in addition to iron oxides, chlorides, sulfates and nitrates (*e.g.*, FeO, Fe_2O_3 and $Fe_2O(SO_4)_2$), red ochres such as samples 11, 12 and 13 also contain variable amounts of SO_3 (sulphur trioxide), Cl (chlorine), TiO_2 (titanium dioxide), Cr_2O_3 (chromium oxide), MnO_2 (manganese dioxide), NiO (nickel oxide), CuO (copper oxide), ZnO (zinc oxide), As_2O_3 (arsenic trioxide), Br (bromine), Rb_2O (rubidium oxide), ZrO_2 (zirconium oxide), Mo (molybdenum), Ba (barium), PbO (lead oxide), Th (thorium) and U (uranium) (***Fig. 9***). Of these elements, SO_3, TiO_2, Cr_2O_3, MnO_2, Cl, ZnO, As_2O_3, ZrO_2 and aluminium sulphates and chlorides (*e.g.*, $Al_2(SO_4)_3(H_2O)_{18}$ and $AlCl_3$) are known to react with hide collagen to produce 'mineral-tanned' leathers (see Covington 1997 for a discussion).

Evidently, at least some geological and elemental varieties of ochres do possess antibacterial and antifungal properties and the capacity to inhibit collagenase. The results obtained from my experiments largely correspond with the conclusions reached by Audouin & Plisson (1982), who noted that the treatment of hides with red ochre is advantageous, especially in terms of preventing and reversing the process of decay. Unsatisfactory results were obtained for a specimen treated with yellow ochre; it remained stiff, thick and rough in contrast to a specimen treated with red ochre, which dried rapidly and became thin and soft. Although a more diverse mineral sample is required to substantiate this notion, it certainly appears that, when used as a single tanning element, iron-rich red ochre may produce a better quality hide than yellow ochre and white kaolinite with lower iron contents.

Archaeologically, the red and principally shale-derived ochres recovered from MSA contexts such as Blombos Cave (d'Errico *et al.* in prep.), Klasies River (d'Errico *et al.* in prep.) and Nelson Bay Cave (Bernatchez 2008) also comprise elements that are either known to react with hide collagen, or which have recognised preservative qualities. The presence of large quantities of ochre at MSA sites (Henshilwood *et al.* 2002; Wadley 2010; Watts 2010) may therefore indicate that, apart from established and hypothesised symbolic and functional uses of ochre, the application of red ochre to raw hides and leather garments must have offered some functional and adaptive advantages. This view is supported by the recent use of a rudimentary but very effective ochre and fat maintenance strategy by Bantu-speaking agro-pastoralists (Schapera & Goodwin 1953: 147; Fehr 1968: 30).

The use of reactive dyes such as iron oxides (Fe_2O_3) constitutes a form of re-tanning because they bind to collagen side-chains via covalent links (Kleban & Bayer 2004; Covington 2008). The Ovashimba (Himba) of the Kunene region in northern Namibia are renowned for their use of red ochre as a body cosmetic. It is locally known as *otjise* and is comprised of a mixture of dairy-derived 'butterfat' and finely ground red ochre powder (see Blauer 1999: 7, 162). Ovashimba woman apply *otjise* to their skin every two to three days, during which all their leather garments are also treated with the same fatty substance (***Fig. 10***). Leather garments are also maintained by the application of the *otjise* mixture every two to three days, which is said to both 'look nice' and increase the longevity of leather objects, many of which remain fully functional for up to four years.

Activities that engage a considerable degree of technical skill, such as that required by the reduction sequences involved in lithic manufacture (Mourre *et al.* 2010), the use of pyrotechnology to enhance lithic

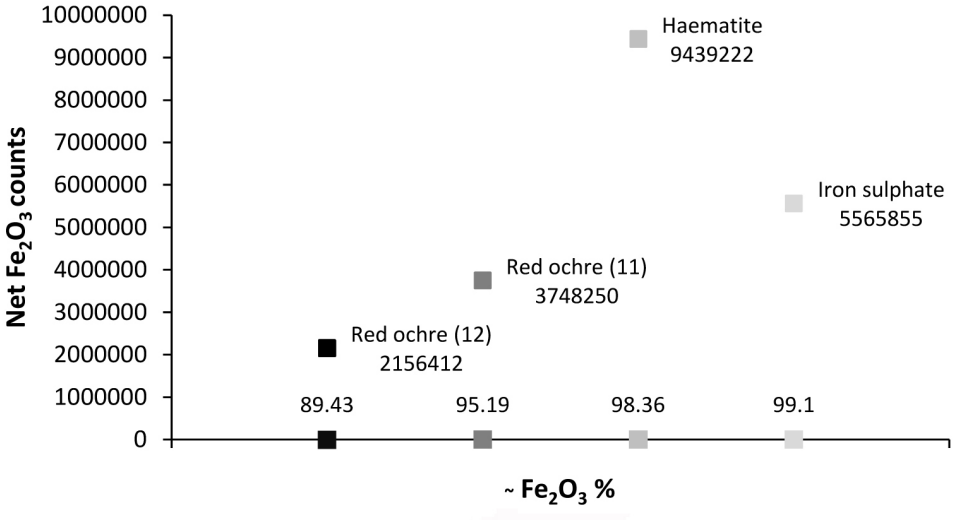


Fig. 8. Comparison of approximate Fe_2O_3 concentrations recorded for the commercial sample 10 (iron sulphate) and the natural mineral samples 11 (red ochre), 12 (red ochre) and 13 (haematite).

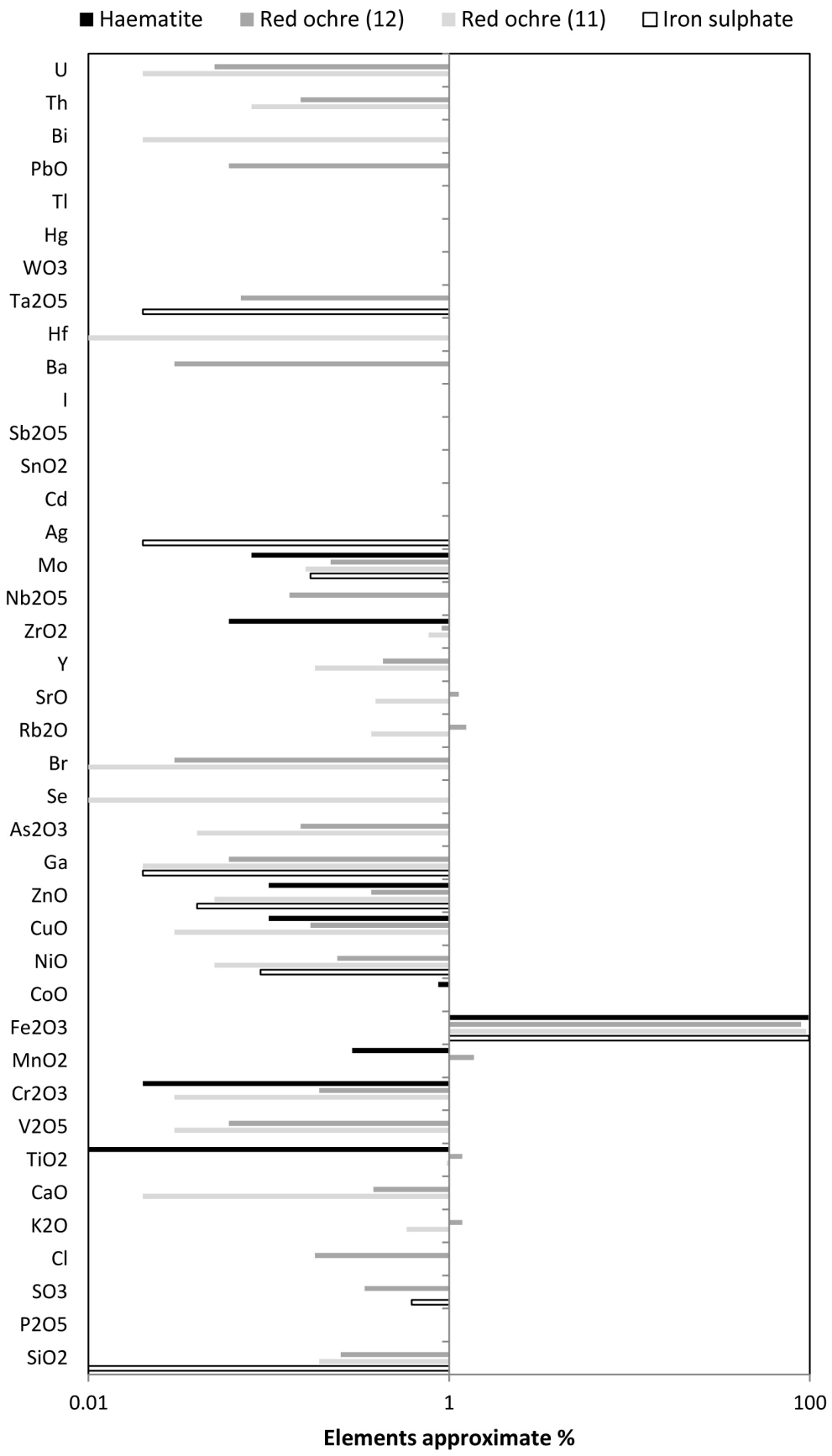


Fig. 9. Comparison of elemental values besides Fe_2O_3 recorded by XRF analysis for sample 10 (iron sulphate) and the mineral samples 11 (red ochre), 12 (red ochre) and 13 (haematite).

flaking efficiency (Brown *et al.* 2009), the production of hafting mastics (Wadley *et al.* 2009) and the heating of ochre to obtain the deepest red hues (Hovers *et al.* 2003) present credible evidence for 'behavioural modernity'. I argue here that the same is true for the manufacture of leather clothing. The ability to produce leather garments necessitates specialised scraping, cutting and piercing implements and a thorough understanding of the complex sequential procedures and ingredients implicated in hide processing and preservation (Wynn 2009). In Pleistocene contexts such as Blombos Cave, humans who possessed such knowledge must have been better equipped to withstand shifting environmental conditions, while those groups lacking such technologies were probably much more restricted in terms of ecological niche expansion.

Disentangling the functional worth from the symbolic significance of ochre is challenging, particularly so in terms of the exploitation of red ochre during the MSA. Ground and scraped ochres from MSA contexts are generally the by-products of a sequence of processing actions and subsequent usages that is difficult to reconstruct. It is for this reason that the interpretation of archaeological ochre is inherently controversial in nature (Wadley *et al.* 2009; Watts 2009; Wynn & Coolidge 2010). Thus, and although the association of ochre with hide working is widely viewed as a mere 'decorative inclusion', a generalisation supported by ethnographic data (Marshall 1959; Rudner 1982), it certainly could also have fulfilled a functional and largely preservative function in the LSA and the MSA.

Simultaneously, it is to be expected that the application of red ochre to leather garments, either to preserve or to colour these items, may also have served a profoundly symbolic purpose in prehistory. It is imprudent to presuppose that the presence of ochre in archaeological contexts always connotes 'ritual' and 'symbolism' (Riel-Salvatore & Clark 2001: 459; Wadley 2001: 204). Ethnographic records do reveal that people attach considerable symbolic value to red ochre in particular, but it is essential to demonstrate, and not simply to assume, the symbolic nature of ochre in the 'deep past' (Wadley 2005: 3; d'Errico 2008: 5). And even if ochre did have numerous secular and functional uses during the LSA and MSA, it does not inexorably detract from its symbolic significance, and it does not deny that seemingly secular activities may very well have been imbued with symbolism (Lombard 2007: 415).

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Fig. 10. Examples of combination and semi-tanned leather garments produced by the Ovashimba of northern Namibia: a) a leather back-garment embroided with cowrie (*Cypraea* species) shells and beads; b) a composite sewn leather garment worn by women across the region.

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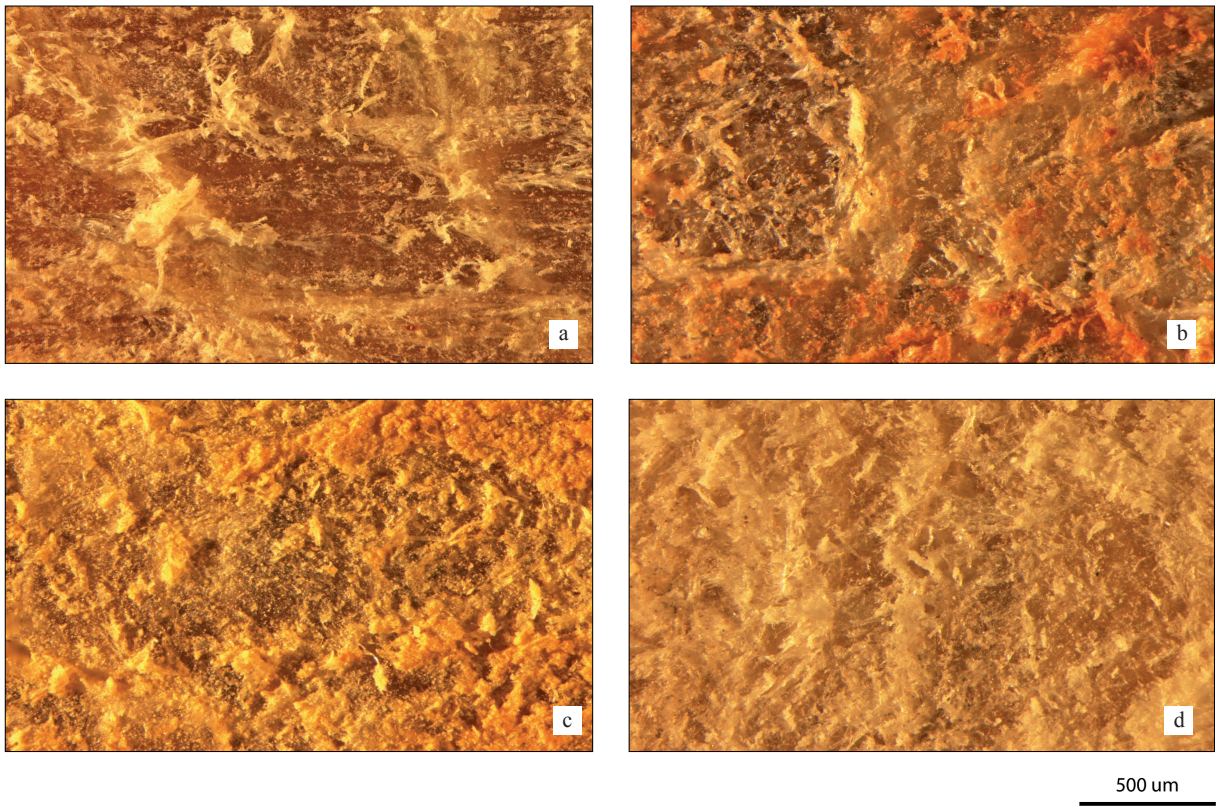
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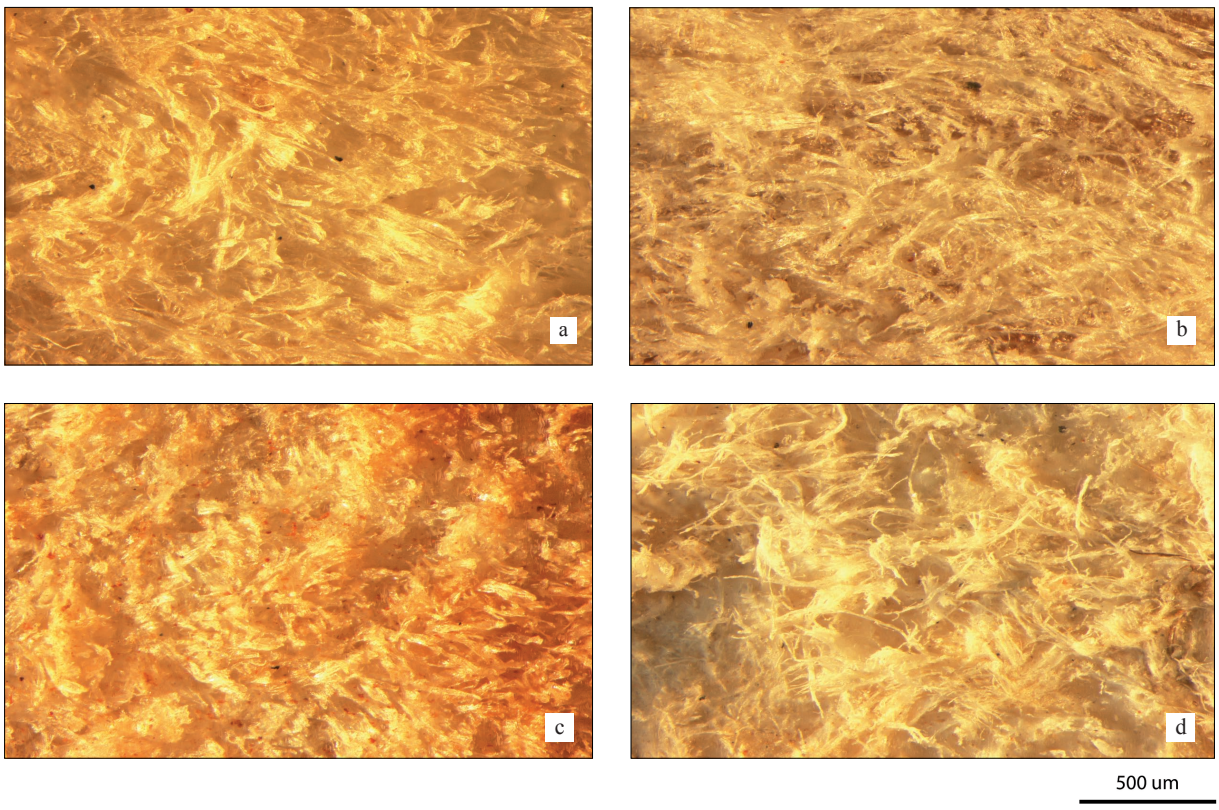
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Color plate 1. The extraction of powder from mineral sources: a) grinding a hard haematite nodule into a fine powder; b) grinding a soft yellow limonite fragment; c) grinding a soft water-worn grey shale chunk; d) extracting powder from a hard red ochre fragment by grinding onto a coarse quartzitic sandstone grindstone.



Color plate 2. Desiccated and inflexible hide samples (at 50 x magnification): a) sample 1 (untreated control); b) sample 3 (red Hutton soil); c) sample 14 (yellow limonite) and d) sample 16 (white kaolinite).



Color plate 3. Fully pliable hide samples (at 50 x magnification): a) sample 2 (modern control); b) sample 5 (coarse salt); c) sample 11 (red ochre); d) sample 12 (red ochre).

CHAPTER 6

RESEARCH IN PROGRESS

In this chapter I introduce three on-going experimental and analytical research projects and explore the feasibility of drawing on the Ovashimba as an ethnographic analogue for the interpretation of archaeological ochre. I show that ethnographic analogies present a basis for the formulation of research questions about the use of ochre in the MSA. I also evaluate the causative factors that might explain the preference for red ochre and how MSA humans may have perceived different colours.

6.1. Introduction

In the absence of explicit evidence for past behaviour, archaeologists may rely on ethnographic analogies to both formulate and evaluate hypotheses concerning human behaviour in the past. The same is true for the interpretation of ochre from MSA contexts. In this chapter I consider how ethnoarchaeological data collected among the Ovashimba of the Kunene Region in northern Namibia can enhance our understanding of ochre use during the MSA. Although ethnoarchaeology itself has not been defined or systematised as an academic discipline, the concept has been defined as '… the study of material culture in systemic context for the purpose of acquiring information, both specific and general, which will be useful in archaeological investigation. Ethnoarchaeology … involves pursuit and study of an actual situation in which specified behaviours can be observed, rather than fabrication of situations in which such behaviours can be simulated' (Schiffer 1978:230).

Ethnoarchaeology is recognised to provide '… material for building stronger archaeological inferences than do common sense explanations of material culture patterning …' (Stark 2003:195). While this may be true, the lack of methodological consensus relating to the 'regularities' that should be the goal of ethnoarchaeological research have resulted in very different kinds of studies (see David 1992; David & Kramer 2001). Lack of methodological consensus explains why under the label 'ethnoarchaeology', one finds very different kinds of studies, ranging from those that report mere ethnographic observations, to those aimed at constructing cross-cultural correlates transferable to archaeological facts (Roux 2007). One consequence is that ethnoarchaeology appears as a poorly formulated field, often criticised by archaeologists (Wobst 1978; Stahl 1993) who believe that they could do without it. Key concerns include the feasibility of interpreting archaeological facts without a modern reference base, and whether ethnoarchaeological studies can provide a solid reference for the interpretation of archaeological patterns. Questions such as whether it is possible to reconstruct the particular skills developed by different cultural groups when there are no modern societies that are analogous to ancient societies and if it is possible to reveal universals on the basis of modern local observations are also recurring. I demonstrate here that ethnoarchaeology can indeed provide such reference data and that its transfer to archaeological facts does facilitate the formulation of interpretations about the past.

But ethnoarchaeological data is of limited relevance if the validity of inferred hypotheses is not tested against independent empirical data (see Gee 1995; Sivertsen 2005; Outram 2008 for discussions). Theoretical work in science employs the hypothetico-deductive or 'scientific' principle. A hypothesis is formulated and then tested to see if it can be 'falsified'. Scientific

testing is regarded as the testing of the general validity of a hypothesis. If a hypothesis resists falsification and is supported by experimentation, it can be regarded as 'valid'. Valid does not necessarily mean 'true', but merely that the principles behind the hypothesis can continue to be used until falsified and replaced by a better set of principles (Outram 2008:1).

In archaeology this can achieved by actualistic experiments, the strength of which lies in the fact that observations are made over short durations and in actualistic and controlled contexts (Roux 2007:170). If a prediction is found to be in disagreement with new experimental results, the theory may either be discarded or it may continue to be applicable within a limited range of measurable parameters. It therefore stands to reason that, if a particular experiment involving ochre produces a specific result today and is reproducible, it will have produced the same result at 100 ka. And even if certain applications might not have been in use at 100 ka, the possibility that such uses existed cannot be excluded because these are among the potential uses to which ochre can be put.

6.2. Ovashimba ochre exploitation

A foremost example of the use of red ochre as a body cosmetic is that of the extant Ovashimba, an agro-pastoralist people living in two adjoining provinces of southern Angola and northern Namibia. Historical reports for ochre use amongst the Ovashimba derive from Galton (1853) and Tönjes (1911) and recently from Becker (2006) and Petru (2010). The Ovashimba are one of several Herero-speaking groups in south-western Africa, including the Zemba, Hakavona, Kuvale and Kwanyoka. Precise dates for the appearance of the Ovashimba in Namibia are unknown. They are either Herero who remained in the Kunene Region on a southward migration from the Central Lakes region into central Namibia, or they became the final settlers in the terminal destination on a westward Herero migration into the area (Vedder 1928). Recent archaeological explorations indicate that the region has been inhabited by humans since 220 ka (Nicoll 2010).

6.2.1. Ethnoarchaeological research

Fifteen Ovashimba women and men were interviewed over a period of 5 days in June 2011 at Ovinjange, Otjongoro and Okamanga villages in the northern Kunene Region of Namibia (Figure 1). A representative from the National Museum of Namibia and an interpreter and a guide from the Namibian National Heritage Council accompanied the research team, namely Francesco d'Errico, Loic Quentin and me. The objective was to document and describe the *chaîne opératoire* of ochre exploitation amongst a 'traditional' although contemporary

society. While this will be addressed in detail in a forthcoming paper, some observations warrant mentioning here. Ovashimba women are renowned for covering their bodies and hair with a deep red ochre-based substance. It is locally known as *otjise* and consists of roughly equal amounts of milk-derived clarified butter and red ochre powder. Strategies involved in obtaining red (*otji-serundu*) ochre include purchasing ochre from Zemba agro-pastoralist merchants in Opuwo, excavating ochre from ochre-rich cliff-faces (such as the Okanguduba ochre mine) or selecting ochre from deep pits which are both owned and excavated by Zemba agro-pastoralists (the Ombuumbuu ochre mine). Ochre is also exchanged with travelling merchants for goats and fresh produce and is widely shared amongst women within villages. Ovashimba women use around 60 g of powder to cover their bodies (every 2 to 3 days) and 320 g to treat their hair (every 3 to 4 weeks). Ochre powder is produced by first crushing and then grinding red ochre chunks between round upper and flat lower grinding stones. Round cobble-like upper grinding stones are sourced from the banks of the Kunene River some 100 km to the northeast and flat slab-like lower grinding stones from mountain ranges 50 km north of the villages.

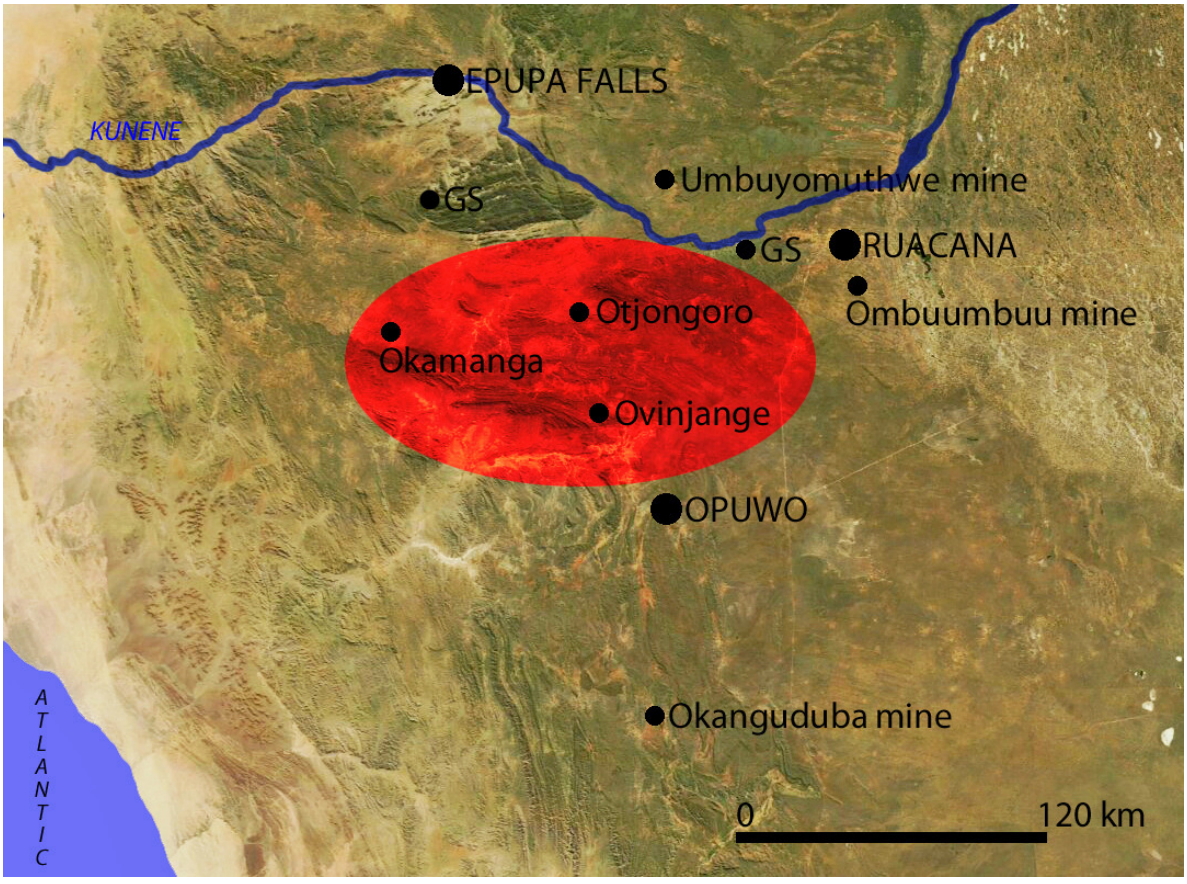


Figure 1. The location of the Ovinjange, Otjongoro and Okamanga villages in the Kunene Region of northern Namibia.

Grindstones are owned by individuals but widely shared, inherited and remain in use for up to 40 years. Many display conspicuous wear traces and faceting not observed on MSA or LSA grinding implements. These are used solely for the extraction of ochre powder, with other grinding sets used to process maize and aromatic plants. Clarified butter is produced by skimming the cream off the surface of milk that is poured into a large container, then by shaking 2 to 3 litres of the cream-rich concentrate in a *Lagenaria* species calabash gourd to separate the fatty substances from the watery solution and by slowly boiling the fatty mass in an iron pot above an open fire. This remaining greasy substance is stored and mixed with ochre powder when desired. Each woman also stores her own supply of ochre powder in containers traditionally made from cattle horns and leather. Whereas ochre processing occurs arbitrarily and forms part of the general sociable settings of daily life, the application of *otjise* occurs within the confines of the woman's huts.

6.2.2. The uses of red ochre

When Ovashimba woman apply *otjise* to their skin every two to three days, personal belongings such as gourds, leather aprons, headdresses and dresses, wooden containers and jewellery are also coated with the mixture (Galton 1853:191). In the 1830s Alexander (1838:144) observed that both women and men are 'fond of greasing the skin' with *otjise*, and our ethnographic interviews confirm this statement. The Ovashimba analogue (Botha & Knight 2009:398) does not therefore correspond with interpretations concerning the use of red ochre exclusively in terms of the Female Cosmetic Coalitions model (Knight et al. 1995; Power & Aiello 1997; Watts 2009) which prioritises the role of female reproductive strategies in driving early ochre use. Red ochre features prominently in initiation ceremonies (Tönjes 1911:136), is applied by men when they are to be wed or when they undertake extensive journeys (Galton 1853:190) and is applied to human corpses prior to interment (Tönjes 1911:142) (Figure 2). Similar practices have been reported further south for San hunter-gatherers and Khoe hunter-pastoralists (Thunberg 1775:303) and for Tswana (Campbell 1815:175) and Xhosa pastoralists (Gordon 1786:139).

In addition to the argument by Mithen (1999:154) that the use of ochre as a body cosmetic is not necessarily 'symbolic' as there is no displacement between the signifier and the signified, there are a number of alternative reasons why early humans may have covered their bodies with red ochre. For the Ovashimba, the efficacy of *otjise* as a sunscreen and as a mosquito repellent comprises two such reasons. A third functional use involves the ingestion of red ochre powder, especially by pregnant women and by young children.



Figure 2. Ovashimba women process red ochre chunks into a fine powder (a) by grinding between round upper and flat lower grindstones (b) after which it is casually mixed with clarified butter (c) and generously applied to all parts of the body (d), occasionally also by Ovashimba men (e) (photograph courtesy of Luca Gargano) (Otjongoro Village and Ombuumbuu ochre mine, Kunene and Umusati Regions, Namibia).

For the hypotheses that red ochre functioned as a source of mineral nutrients and a detoxification agent, a sunscreen and an insect repellent in the LSA and the MSA, it is necessary to demonstrate that other types of ocherous clays do not possess similar characteristics or provide comparable degrees of supplementation or protection. In archaeological terms, current evidence (Barham 2002; Watts 2002, 2009; Hovers et al. 2003; Marean et al. 2007; Henshilwood et al. 2009) indicate that a preference for red ochre emerges after 200 ka. But two key questions about the exploitation of ochre in prehistory must be answered before substantiated claims for the evolutionary significance of red ochre can be made. First, are there any particular causative factors that might explain the preference for red ochre after 200 ka? Second, is it possible to determine how MSA humans perceived different colours in general and red in particular? Although there is currently no consensus on the causes of this shift towards red ochre in particular, the fields of linguistics, cognitive psychology and evolutionary genetics do provide causative explanations.

6.2.3. The significance of 'red' ochre

Because the systematic use of ochre is considered a non-linguistic 'phenotype' related to the emergence of language (d'Errico et al. 2009:14), the explicit focus on red ochre renders the Ovashimba of interest in terms of the seemingly similar emphasis on the 'red' during the LSA and MSA. According to the criteria of Kay et al. (1991) the Otjihimba language has five basic colour terms, namely *oshi- or otji-serandu* (red including orange, pink and purple), *otjidumbu* (beige, yellow and some light green), *otjizoozu* (dark colours and black), *otjivapa* (all light colours including white) and *otjiburou* (green with blue and purple) (Franklin et al. 2004, 2006; Roberson et al. 2005). There are also secondary terms and a few borrowed terms such as *otjingirine* (green) and *otjipinke* (pink) (Danoutis et al. 2006). A similar range of colour terms have been documented amongst the Berinmo-speakers of Papua New Guinea (Roberson et al. 2000, 2005) (Figure 3). Although linguistic studies provide evidence of differences in cognitive colour perception across language groups (Roberson et al. 2005), concerns remain as to how representative data derived from remote communities may be in terms of explaining the significance of colour perception in prehistory. Whether language and cognition are linked or separate also remains contested (Enard et al. 2002; d'Errico et al. 2003, 2009a; Roberson et al. 2000, 2005; Knight 2008, 2009; Henshilwood & Dubreuil 2009; Watts 2009; Wynn & Coolidge 2010). But if a regular pattern of evolution in colour terminologies does exist, as suggested by Kay et al. (1991), then languages at the same evolutionary 'stage', such as those with only five basic colour terms representing the universal character of colour categories (Belpaeme & Bleys 2005:294), might be expected to have comparable cognitive representations of colour.

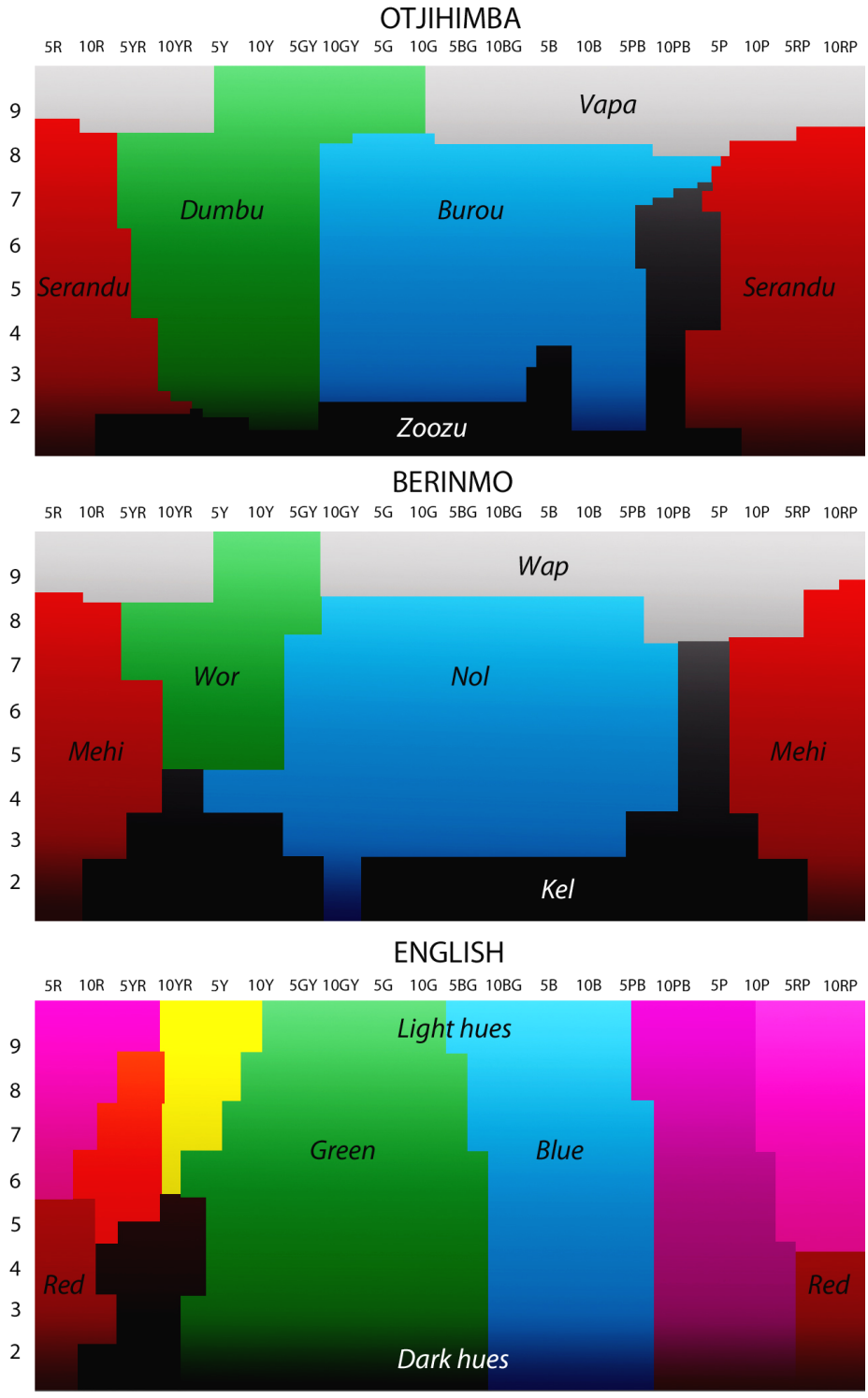


Figure 3. The results for Otjihimba colour classification tests compared with that of Berinmo and English for 160 light-saturated Munsell colour chips. Twenty Munsell hues (R, YR, Y, YG, G, BG, B, PB, P and RP) are represented on the x axis at eight Munsell lightness levels (9, 8, 7, 6, 5, 4, 3 and 2) on the y axis (image modified from Roberson et al. 2005: Figure 1). Colours do not represent actual Munsell hues and may vary according to printing technology and screen resolution.

The results for colour naming tests provided by Roberson et al. (2000, 2005) indicate that the five basic colour terms used by Otjihimba- and Berinmo-speakers are used to categorise 86% and 89% of the presented colour stimuli respectively. All the participants were tested for normal colour vision, so it is not colour perception as such but rather colour categorisation that differs markedly from the Western system of colour classification. Regardless of the seemingly high degree of colour constancy, the tendency to perceive and subsequently classify the colors of objects as unchanging regardless of varying lighting conditions (Foster 2003; MacLeod 2003), Ovashimba women have very specific criteria for the types of red ochre they prefer. Although hue and saturation are the most important, the quality of ochres is also measured according to grain size, with fine-grained pieces with no hard inclusions being the most desired (Figure 4).

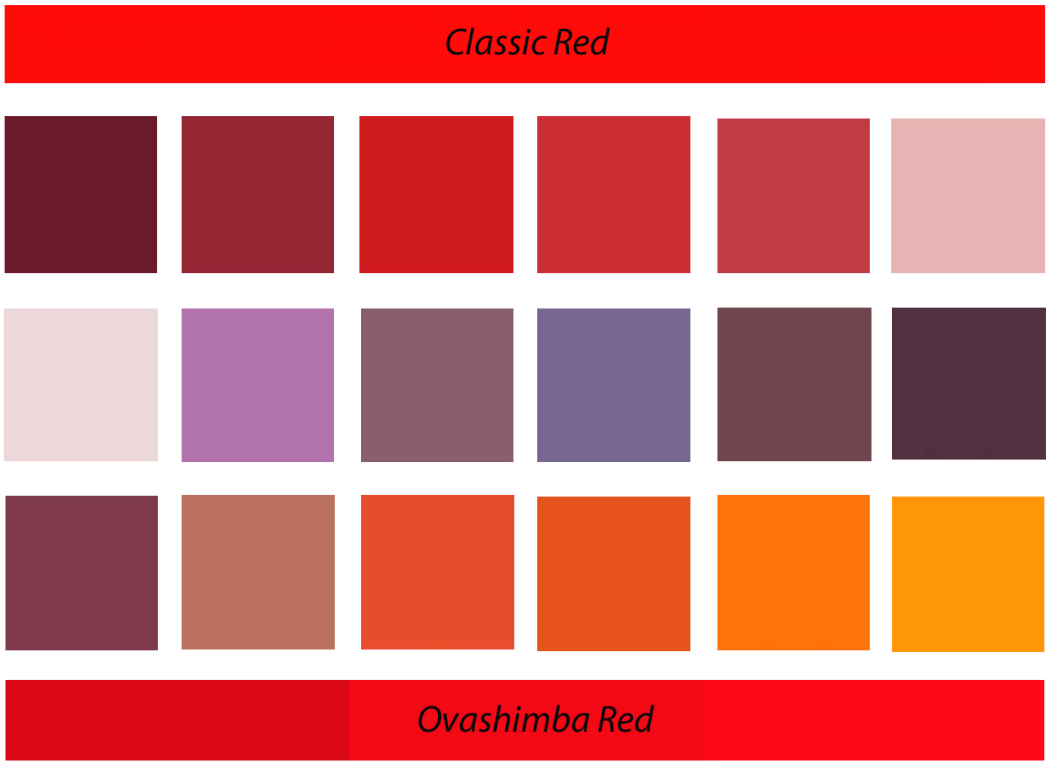


Figure 4. A more detailed indication of the wide range of colours classed as 'red' by the Ovashimba. Colours are based on the Munsell data provided by Roberson et al. (2005) with *Classic Red* indicated as Munsell 5R. Measurements for the red hues preferred by Ovashimba women (*Ovashimba Red*) are indicated as Munsell 7.5R 4/12, 7.5R 4/14 and 7.5R 4/16 and are based on visual comparison with 3 Ovashimba ochre samples (digital colour representations derived from http://munsell.com/). Colour rendering is approximate.

An essential question is how MSA humans perceived different colours in general and red in particular. Historically, /Xam San hunter-gatherers clearly distinguished dark red-maroon

hematite or '//ka' from brighter red ochre or 'ttò' (Bleek & Lloyd 1911:359). Bright specularite or '//hara' was valued as a black, sparkly powder applied to the hair and was differentiated from all other forms of red ochre (Bleek & Lloyd 1911:356). In the MSA, red ochre is not ubiquitous prior to 200 ka to 150 ka (van Peer et al. 2003, 2004; Watts 2009) and there is a gradual trend towards the selection of ochre with the strongest red hues from 164 ka (Marean et al. 2007) to 143 ka (Watts 2009) and 100 ka (Hovers et al. 2003; Henshilwood 2004; Henshilwood et al. 2009, 2011). This increasing focus on red ochre occurred during a time of rapid population expansion between ~200 ka to 50 ka (Verrelli & Tishkoff 2004:367) and may relate to the emergence of fully modern human behaviour during the MSA.

In psychological terms, the colour red is generally associated with dominance in primates and is linked explicitly to sexual selection (Little & Hill 2007; Elliot & Niesta 2008). Red influences human emotion and expressed aggression and is a recognised element of signalling in many social interactions. Colour has been shown to affect the outcome of contests in humans, with red offering a significant advantage in terms of the achievement of victory (Hill & Barton 2005:293). In evolutionary terms, trichromatic vision is characteristic of all apes and of humans. Primate trichromacy has been interpreted as an adaptation to detect ripening fruit against a background of mature foliage, linking the evolution of colour vision to diet (Dominy et al. 2003). Trichromacy is also viewed as an adaptation to distinguish colour modulations in skin based on blood flow and which serves to assess the temperament of other individuals. Primates with trichromatic vision are mostly bare-faced and, as in humans, facial reddening signals aggression, confrontation and excitement (Little & Hill 2007:162).

A large percentage of human females possess more than the standard three classes of retinal photopigments (Jameson et al. 2001:244). Women with four and up to five photo-pigment genotypes are therefore able to perceive much more chromatic appearances in comparison with male or female trichromats. Could this relate to the trend towards the preference for ochre with the strongest red hues after 200 ka? Compared with the presence of the long-wave 'red' opsin gene (OPN1LW) in chimpanzees, humans in general and sub Saharan Africans in particular (specifically the Hadza, Sandawe and Pygmies) have an excess of genetic substitutes at this locus. These are also significantly skewed towards the 'red-orange' visual spectrum. This indicates that subtle changes in trichromatic colour vision amongst *Homo sapiens* occurred relatively recently in human evolution, possibly well after 200 ka (Verrelli & Tishkoff 2004:369).

The following three case studies represent research papers currently in progress. These projects aim to illustrate that the employment of ethnographic analogies in conjunction with

actualistic experimentation present viable research avenues in terms of furthering current understandings of ochre use during the LSA and the MSA. These projects are not informed by ethnographic accounts alone, but also by archaeological evidence for the use of ochre as a geophagic substance (Johns & Duquette 1991; Mahaney et al. 2000; Clark 2001; Wadley 2001) and as a body cosmetic during the MSA (Henshilwood et al. 2004; d'Errico et al. 2005, 2008, 2009; Bouzouggar et al. 2007; d'Errico & Vanhaeren 2008).

6.3. Case study 1: Ochre and geophagy

Geophagy in prehistory: Implications for the interpretation of archaeological ochre

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The deliberate ingestion of soil and clay has been reported for African elephants (Ruggiero & Fay 1994) and buffalo (Mahaney & Hancock 1990), grizzly bears (Mattson et al. 1999), deer (Arthur & Alldredge 1979), tapirs (Izawa 1993) and numerous species of bats (Voigt et al. 2008), birds (Diamond et al. 1999) and reptiles (Hellgren et al. 2000). Primates have also been known to habitually ingest soil and clay. Of the 185 extant primate species that have been observed to habitually practice geophagy (Krishnamani & Mahaney 2000), three of the 12 apes, seven of the 36 prosimians, ten of the 64 New World monkeys and 19 of the 73 Old World monkeys have been observed to practice geophagy on a regular basis. Mineral supplementation has been proposed as a prime motivational factor for geophagy in primates (Inoue 1987; Davies & Baillie 1988; Heymann & Hartmann 1991), but primate ecologists have also proposed a detoxification function (Lozano 1998; Reynolds et al. 1998; Krief et al. 2006) for the ingestion of various clays. Whereas geophagy is viewed as an adaptive behavioural strategy in primates (Klaus et al. 1998; Krishnamani & Mahaney 2000; Dominy et al. 2004), it is seen as an anthropological idiosyncrasy and a symptom of metabolic dysfunction in humans (Engberg 1995).

In Africa, geophagy has been recorded amongst more than 150 traditional societies (Laufer 1930; Gelfand 1945; Cooper 1957; Vermeer 1971; Abrahams & Parsons 1996; Abrahams 2002; Kikouama & Balde 2010; Yamashina 2010). A literature review also illustrates the antiquity of the practice. Geophagy was first mentioned by Aristotle some 2 000 years ago (Mahaney et al. 2000), but likely extends much further back into prehistory. Evidence for the habitual consumption of clays by humans derives from Kalambo Falls in Zambia (Clark 2001). At sites A, B and C, *Homo sapiens* associated with Upper Acheulean (Moola) and later Sangoan (MSA) artefacts appear to have addressed mineral deficiencies by collecting and ingesting clays from the nearby river. It is posited that the brown and black lumps of 'peaty' clays may have been consumed in conjunction with aquatic sedges. Uranium series dating indicate that this occurred between 190 ka and 175 ka (McKinney 2001).

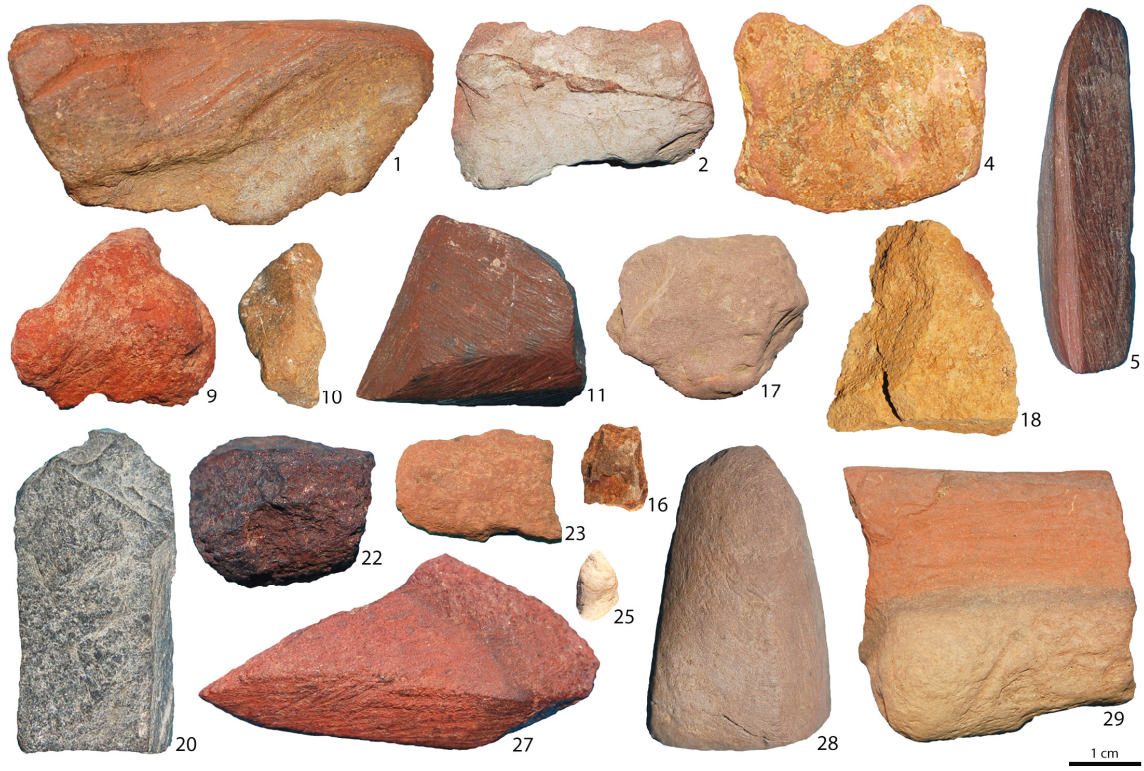


Figure 5. Examples of ochre specimens recovered from Still Bay contexts at Blombos Cave between 1997 and 2009 currently subjected to SEM, EDXR and colourimetric analyses.

Of the functions of geophagy proposed for primates, two are most plausible for humans, namely mineral supplementation, particularly with respect to 'brain selective nutrients' such as Cu, Mg, Se, Zn, I and Fe (Cunnane 2010), and the absorption of dietary toxins such as vegetal metabolites, enterotoxins and tannins. Geophagic behaviour would also increase the ability of humans to contend with diseases derived from viral, bacterial and fungal infections by competing with enzyme cofactors, binding biological molecules to inhibit bacterial function

or by replacing ions essential to membrane stabilisation (Carretero & Pozo 2010). To evaluate the theory that ochre may have functioned as a viable source of mineral nutrition and as a detoxification agent in the MSA, the analysis of 30 ochre specimens recovered from the Still Bay levels (CAE to CFB) of Blombos Cave is currently in progress (Figure 5).



Figure 6. Chromatic representations of Natural Colour System (NCS) colourimetric values of analysed ochre samples. The figure provides an easily discernible and qualitative indication of colour variation of processed ochre during the Still Bay at Blombos Cave. How these colours are perceived depends on personal physiology and cultural affiliation. Colour rendering may also vary according to printing technology and screen resolution.

The Blombos sample comprises soft red, purple, yellow, green, white and grey clays, and harder ferruginous specimens. These range from less than 1 g to more than 80 g in weight, and all bear traces of processing by applied scraping or direct grinding. The sample was

selected to represent the most prevalent geological and colourimetric forms recovered. Between 55% and 75% of the ochre from levels CAE to CFB do not possess the deep red hues typically associated with 'symbolic' activities. Colourimetric values were obtained by chromatic comparison with the Natural Colour System (NCS) Digital Colour Index (Figure 6).

To confirm the clay mineralogy of the samples, imagery obtained through SEM observation will be compared with existing records of known clay mineral morphology. The results will be verified by the Macaulay Land Use Research Institute (Figure 5). To determine the mineralogical composition of the samples, an Oxford X-ray microanalyser with an X-max sensitivity detector attached to a Zeiss EVO 10LS Variable Pressure Scanning Electron Microscope (VPSEM) is being employed. The curative effects of clays have been attributed to diverse mineral content and physical properties (Veniale et al. 2004). Through adsorption, clays can provide up to 55% of the recommended daily allowance (RDA) of Ca, Fe, Mg, I, Zn, Co, Cu, Se, Zn, Ni and K (Abrahams et al. 2006; Brand et al. 2009). The structure and charged surfaces of clay minerals also generate reactive areas which facilitate the absorption of toxic compounds from the digestive tract (Carretero & Ponzo 2010; Cunningham et al. 2010). This high cation exchange capacity (CEC) of kaolinite and smectite clays in particular forms the basis for creating inorganic bacteriostatic materials by replacing native ions with antibacterial ions such as Cu, Zn and Ag (Williams et al. 2009; Carretero & Ponzo 2010) (Figure 7).

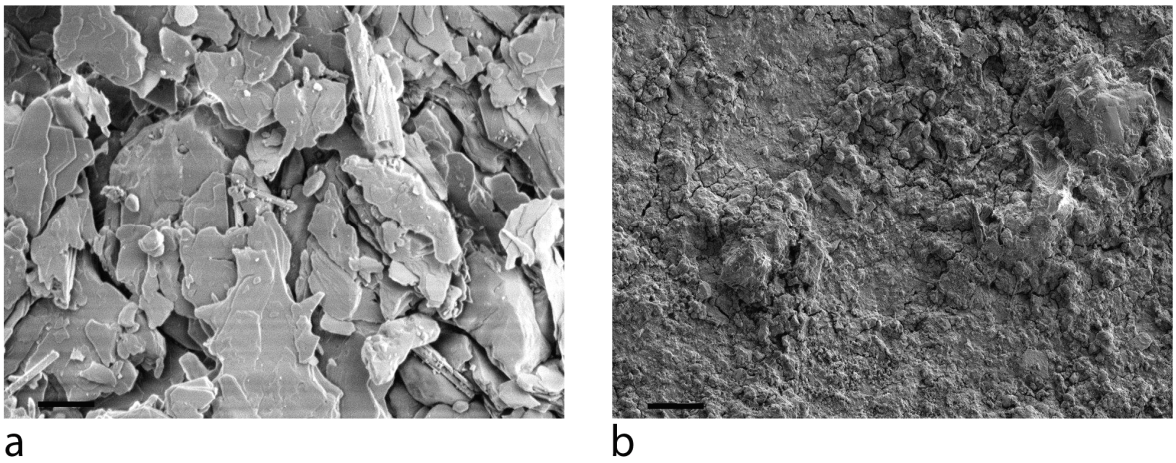


Figure 7. SEM photographs illustrating the clay mineralogy of two ochre samples from the Still Bay levels of Blombos Cave. A soft fine-grained light grey shale specimen (sample 3) exhibits prominent plate-like structures typical of kaolinite clays (a) and a hard fine-grained dark purple specimen (5) exhibits structural characteristics typical of haematite with some interspersed dioctahedral smectite and platy illite minerals (b). Scales represent 2 µm.

It is improbable that early *Homo sapiens* sampled geophagic materials on a 'trial and error' basis. Klein et al. (2008) recently compared the composition of soils eaten by chimpanzees in Kibale National Park, Uganda, with those used by traditional healers to treat ailments in human patients. The materials ingested by chimpanzees and humans are collected from similar sources, display the same external aspects and exhibit a similar physical and chemical profile, indicating equivalent mineralogical content. All the samples are rich in kaolinite, the principal component of modern anti-diarrheal medicines. The exploitation of similar geophagic sources by humans and chimpanzees is remarkable, especially in terms of the prevalence of ochre derived from clay rich shales and siltstones in MSA archaeological contexts. It stands to reason that geophagy has always formed part of the human diet, and it is therefore expected that this study will expand our current understanding of the versatility of ochre-use in prehistory to also include geophagy as an alternative justification for ochre exploitation. It is also posited that the preventive and therapeutic consumption of ochre derived from smectite, illite and kaolinite clays played an essential role in permitting *Homo sapiens* to expand their dietary repertoire by facilitating the ingestion of formerly 'inedible' plant species, especially geophytes. Habitual geophagy also had progressive effects, through mineral adsorption, on the physical and cognitive development of *Homo sapiens*. This in turn facilitated the intensification and preservation of durable social networks, a distinctive trait of fully 'modern' human behaviour (Henshilwood & Marean 2006). The adaptive functions of geophagy were presumably multifactorial, with none of the proposed functional mechanisms being mutually exclusive.

Unlike the occurrence of human teeth marks on Palaeolithic resins (Aveling & Heron 1999; Johns et al. 2000), there is presently no definitive archaeological evidence for the existence of geophagy during the MSA. It does however seem realistic to accept that early hominins may have displayed at least the range of extant human and ape geophagic behaviours (Johns & Duquette 1991; Clark 2001; Hockett & Hawes 2003; Sponheimer & Lee-Thorp 2003; Hernandez-Aguilar et al. 2007). Recent advances in archaeometric analytical methods and procedures also present novel prospects for exploring the contexts in which ochre may have functioned during the MSA. The explanatory worth of geophagy as an additional, but not necessarily alternative functional hypotheses for the use of ochre during the MSA, does not detract from the likely symbolic significance of ochre, and it does not deny that seemingly secular activities may also have been imbued with symbolism.

6.4. Case study 2: Ochre as a sunscreen

Evaluating the protective effects of red ochre on human skin subjected to UV radiation

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(To be submitted to the *Journal of Anthropological Archaeology*)

The employment of ochre as a sunscreen is a frequently-cited alternative functional use for ochre during the LSA and MSA (Bahn & Vertut 1988; Wadley 1993, 2001). Contemporary sunscreens are ultraviolet radiation (UVR) absorbing chemicals that attenuate the amount and nature of UVR reaching viable cells in the skin. They are selected and tested for their ability to prevent erythema or 'sunburn'.

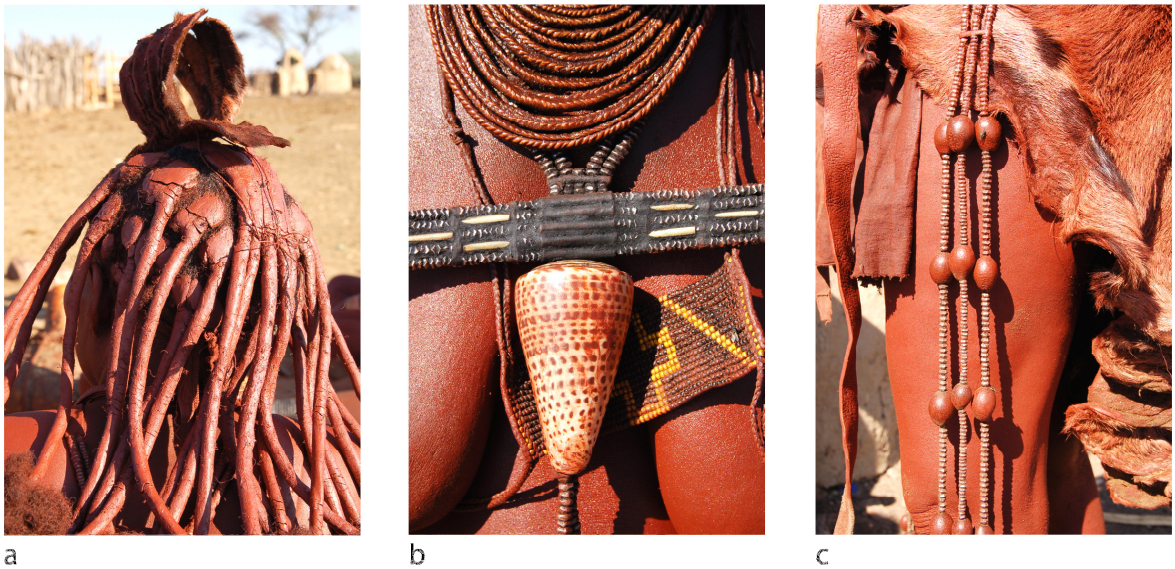


Figure 8. Ovashimba women generously apply *otjise* to their hair (a), upper bodies (b) and legs (c) on a regular basis (Okamanga Village, Kunene Region, Namibia).

Although the spectrum of UVR reaching viable cells is altered by topically applied sunscreens (Gasparro 1999:71), no sunscreen fully prevents photodamage. Suberythemal doses of UVR are known to cause a variety of molecular changes including DNA damage. Sunscreens typically contain chemical filters that absorb UV (most often UVB) sunlight and physical filters that block UVB and UVA sunlight through reflection and scattering. The two most commonly used inorganic sunscreens are titanium dioxide (TiO_2) and zinc oxide (ZnO). For the hypothesis that ochre may have been used as a 'sunscreen' in the LSA and the MSA, it is necessary to demonstrate that other types of ground clays, with or without animal fat, does not provide a similar degree of protection.

This is possible with the aid of a full-thickness skin model by which minimum sun protection factors (SPF) of various sunscreens can be determined. Early attempts to define sunscreen protection by *in vitro* methods involved measuring the transmission of UV light through a dilute solution of sunscreen or measuring the UV transmission through a film of sunscreen applied to a quartz glass. Groves et al. (1979) has shown that these methods cannot be used reliably due to their overestimation of SPF values. We have selected the method for the determination of SPF described by Diffey and Robson (1989).

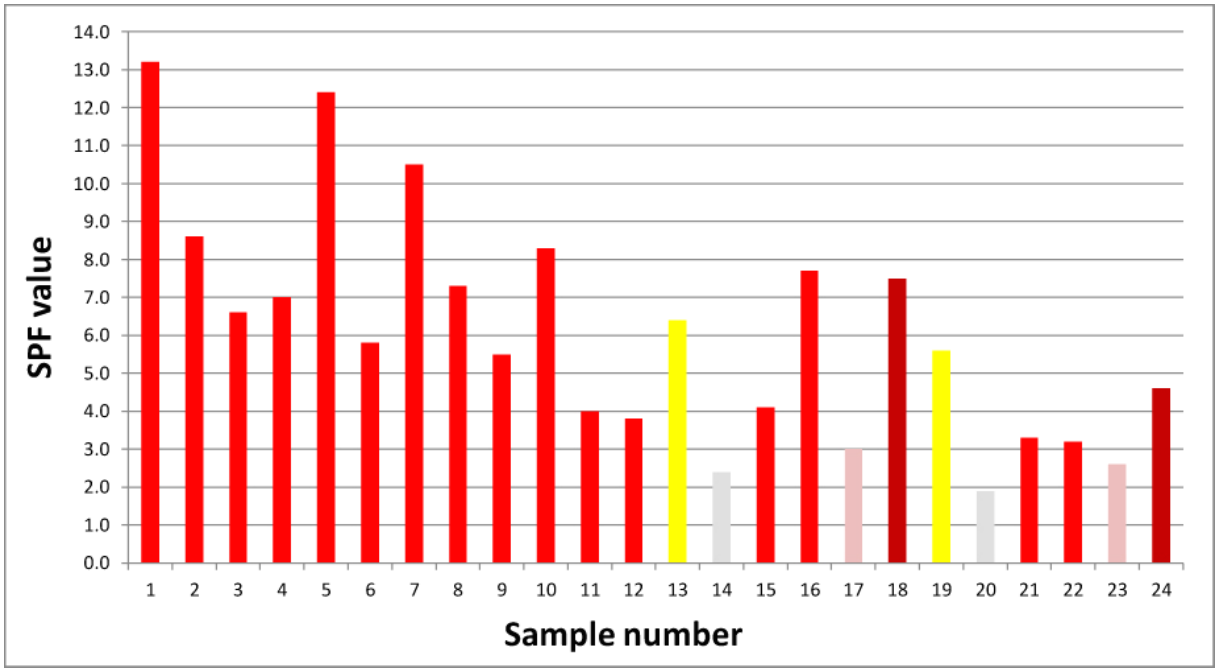


Figure 9. Results indicating SPF values obtained for dry ochre powder used by the Ovashimba (samples 1 to 12) and ochre powder derived from geological contexts in the vicinity of Blombos Cave (samples 13 to 24). Colour bars indicate the approximate colours of analysed ochre samples.

This entails measuring the amount of ultraviolet light transmitted through Transpore ™ tape with and without sunscreen applied. Close links between *in vitro* and *in vivo* data have been observed. Preliminary results indicate that the red ochre applied by Ovashimba women confers a significant degree of protection against UV rays (Figure 9). This is possibly due to the conventional grinding processing method (between upper and lower grinding surfaces) which results in smaller particle sizes, larger surface covering capacities and increasing reflective indices. Evaluating the efficacy of ochre as a sunscreen exposes another previously unexplored alternative functional application of red ochre during the MSA. From a purely functional perspective, genetic and ecological models have demonstrated that niche construction can affect evolutionary outcomes (Laland et al. 2010). The use of ochre as a form of protection from the sun may therefore have enabled early *Homo sapiens* to negate the deleterious effects of constant exposure to UV rays.

6.5. Case study 3: Ochre as an insect repellent

Red ochre, mosquitos and the emergence of modern human behaviour in Africa

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(To be submitted to the *Journal of Archaeological Science*)

Strategies for coping with disease pathogens must have been essential during human evolution, and may have comprised biological and behavioural mechanisms. Biological examples include the selection for genes that confer resistance to *Plasmodium* strains (Ferwerda et al. 2007; Piel et al. 2010; Silva et al. 2011). In behavioural terms, the first methods employed to repel insects may have entailed covering the skin with mud or with aromatic plant extracts (Karunamoorthi et al. 2008). In most circumstances, applying repellents to the skin may have been the only feasible way to protect against insect bites. Such strategies are common amongst various species of birds (Mennerat et al. 2009), rhinoceros, elephants, bovids, suids (Bracke 2011) and primates (Laska et al. 2007).

Modern insect repellents comprise synthetic or plant derivative chemicals. The most widely marketed chemical-based insect repellent is Deet (N-diethyl-3-methylbenzamide), a broad-spectrum repellent that is effective against many species of mosquitoes, fleas and ticks (Fradin & Day 2002: 16). Mechanical repellency mechanisms are known to also provide efficient protection from arthropod bites. Inert dusts such as diatomaceous earth and kaolin clay have been used with success to control various species of insects (Sisterson et al. 2003; Arnaud et al. 2005; Glen & Puterka 2005; Svendsen et al. 2005). Given the capacity of kaolin clay particles and diatomaceous earth to prevent insects from piercing the human epidermis (Williams et al. 2009; Cunningham et al. 2010) it may be expected that clay derived ochre powder could possess equivalent repellency capabilities.

The aim of our experiments is to determine the responses of female *Anopheles arabiensis* mosquitos to sources of nourishment covered in six different types of ochre powder. The experimental protocol was devised according to the criteria and procedures for efficacy evaluation of mosquito repellents on human skin prescribed by the World Health Organisation (WHO 2009). Pathogen-free laboratory-raised female *Anopheles arabiensis* mosquitos of 5 to 10 days old will be utilised. Experimental ochre was sourced from the Otjongoro Village in Namibia and from the Palaeozoic Bokkeveld Group deposits of the Cape Supergroup (Vorster 2002), a principle source of commercially quarried red and yellow ochre in South Africa (Figure 10).

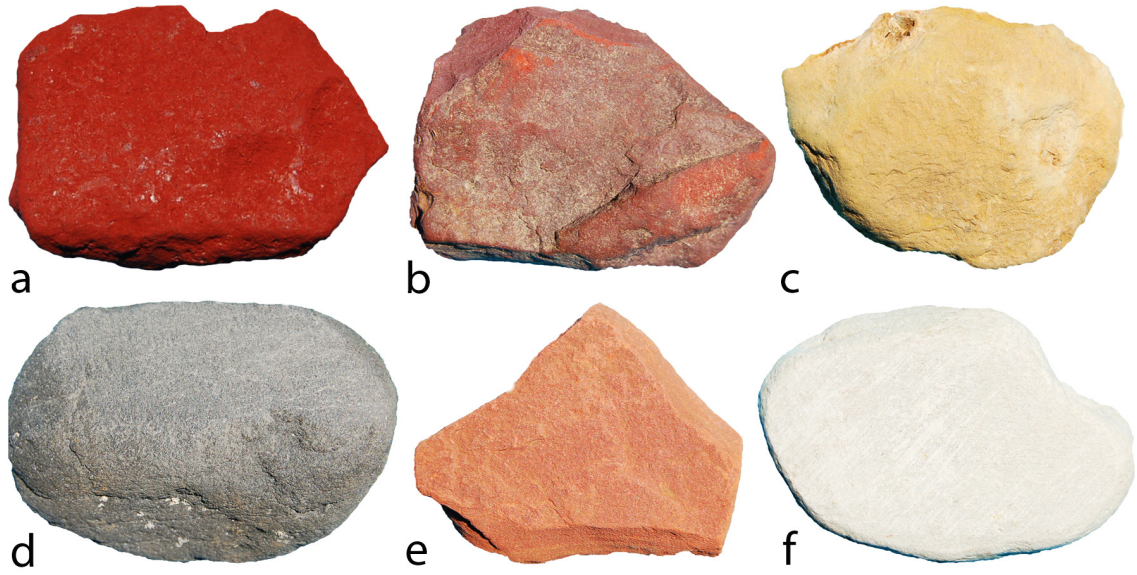


Figure 10. Ochre samples to be applied to skin test surfaces. The first sample (a) was collected from the Kunene Region in Namibia and the remaining specimens (b, c, d, e and f) derive from the Bokkeveld shale deposits in the Western Cape Province of South Africa. Images not to scale.

The means by which ochre may operate as a mosquito repellent is likely to be two-fold. It is expected to limit chemical detection of human skin surfaces by inhibiting microbial activity on the skin surface (Braks et al. 1999; Williams et al. 2009) and prevent the mosquito fascicle from penetrating the human skin by forming a physical barrier (Madison 2003; Cunningham et al. 2010).

Mosquitos feed through a tubular structure, the proboscis, which houses an outer protective sheath (the labium) and a group of feeding stylets (the fascicle). The fascicle consists of a labrum tube which is the primary path for blood flow, several mandibular tubes, maxillae with saw-toothed tips and a central salivary duct (Kong & Wu 2009:144). The fascicle is used to perforate the stratum corneum (which is 5 - 20 µm thick) and the epidermis (50 - 150 µm) before access to blood capillaries is reached in the reticular dermis (1 - 4 mm) (Lee et al. 2009; Cevc & Vierl 2010). Natural pore widths on human skin range from 1.4 - 3.4 µm in diameter and the effective openings of most hydrophilic conduits generally range from >5 µm to < 10 nm (Cevc & Vierl 2010:281). Mosquito fascicle diameters range from 0.1 to 1 µm at the tip to 25 - 30 µm at its maximum width and are therefore too large to be inserted into natural skin pores to access blood. Clay particles vary in size and range from 62.5 µm to < 2 µm (0.002 mm) in diameter (Williams et al. 2009). Whereas larger clay particles (<62.5 and > 30 µm) are likely to prevent the insertion of the fascicle into the stratum corneum and the epidermis by forming a structural barrier, smaller clay particles (<30 to 2 µm) may inhibit the ability of mosquitos to feed again by preventing the labium from enfolding the fascicle or by obstructing the central salivary duct and the labrum tube. Mosquito nets treated with diatomaceous earth have been highly effective against mosquitoes that are resistant to chemical insecticides (Collins 2008:47). Besides presenting a physical barrier, the mechanism responsible for killing mosquitos involves desiccation, amputation of antennae and legs and the obstruction of the mouthparts necessary for successful feeding (Collins 2008:46). Similar mechanisms have been reported for kaolin particle films (Glen & Puterka 2005; Svendsen et al. 2005).

In addition to restricting the rate of infection by mosquito-borne diseases, ochre may also have significantly reduced infection from various hematophagous organisms such as ticks (Estrada-Pena & Jongejan 1999) fleas (Azad & Beard 1998) and body and head lice (Raoult & Roux 1999; Fournier et al. 2002). An ochre-covered human body may therefore have offered significant advantages during the evolution of *Homo sapiens* in Africa, especially in terms of reducing the susceptibility of humans to mosquito-borne diseases inhabiting areas where mosquito-borne diseases are prevalent.

6.6. Summary

Recent ethnographic interviews conducted amongst the Ovashimba of northern Namibia have proven informative in terms of revealing an extensive range of functional uses for red ochre. Whether a similarly broad range of applications existed during the LSA and MSA remains uncertain. The Ovashimba analogy cannot be extended directly into the MSA, but the data derived from ethnographic interviews and participant observation certainly facilitated the formulation of expectations concerning the possible applications of ochre in the MSA. The challenge is to transform these expectations and ideas into reliable middle-range arguments that can link what has been observed ethnographically, with what has been established experimentally and with currently available archaeological evidence.

For example, there exists ample archaeological evidence for the use of red ochre as a body cosmetic during the MSA, most generally in the form of ochre residues adhering to personal ornaments such as shell beads (Henshilwood et al. 2004; d'Errico et al. 2005, 2008, 2009b; Bouzouggar et al. 2007; d'Errico & Vanhaeren 2008). The question of whether the ochre served symbolic or functional purposes, or both, is unclear. Archaeological evidence confirms that MSA humans possessed the ability to process ochre by crushing and grinding and by adding greasy substances, which also required a degree of processing, to produce ochre-rich 'pigment' mixtures at least 100 ka (Henshilwood et al. 2011). The exact uses of these compounds are not self-evident, but possible usages may include 'painting' a surface for either decorative or protective purposes (Henshilwood et al. 2011:222). In the context of the Ovashimba, and besides the palpable symbolic connotations of red ochre, *otjise* also serves as a sun protection agent, a mosquito repellent and as a hide preservative. It is conceivable that similar applications may have applied to the use of red ochre compounds at 100 ka.

The use of ochre as a sunscreen, a mosquito repellent and possibly also as a form of mineral supplementation and a detoxification agent may therefore have played a role in enabling *Homo sapiens* to adapt to changing environmental and social circumstances during the MSA. In Chapter 7 I review the results and hypotheses present in Chapter 3 to 6 in terms of their interpretative contributions to interpretations of ochre use in prehistory. I also explore the ways in which future research may improve on what has been gained from my research.

CHAPTER 7

DISCUSSION

In this chapter I provide a summary and discussion of the principal conclusions reached in Chapters 3 to 6. The results are reviewed in terms of the interpretative contributions of the published papers to current interpretations of ochre use in prehistory, and the ways in which future research may improve on what has been gained from my research.

7.1. Introduction

Since the debate concerning 'red ochre and human evolution' commenced more than three decades ago (Wreschner 1980), archaeologists have shown increasing awareness of the significance of ochre in terms of the emergence of fully modern or 'fully symbolic *sapiens*' behaviour (Henshilwood & Marean 2006:9). Most interpretations of ochre are based largely on the perceived significance of a specific colour - red (Knight et al. 1995; Power & Aiello 1997; Power & watts 1997; Watts 1999, 2002, 2009), and on the recently established association between engraved red ochre and the symbolic contexts in which these occur (Henshilwood et al. 2002, 2009; Mackay & Welz 2008; Watts 2010).

Blombos Cave is perhaps the most pertinent example of the occurrence of unrefined red ochre, ground and scraped red ochre, red ochre crayons and engraved red ochre within a context in which several other types of artefacts that represent examples of symbolic and technological modernity occur (d'Errico et al. 2001, 2005; Henshilwood et al. 2002, 2004, 2009; Mourre et al. 2010). For instance, the inference that faceted ochres were used as 'crayons' indirectly links ochre crayons to 'art' and, by implication, symbolic behaviour. This is likely to be one of the reasons why crayons, and, simply by association, even unmodified red ochre is considered to exemplify symbolic behaviour (Wadley 2005a:2). Unless ochre is deliberately engraved, display clear signs of secondary use as crayons or is unequivocally implicated in the production of complex paint-like mixtures (Henshilwood et al. 2011), the mere presence of ochre in the archaeological record cannot be viewed as indicative of symbolic behaviour. But then again, even engraved ochres may not necessarily have functioned as 'symbols' (d'Errico et al. 2011), and the production and use of ocherous red 'paint' may or may not always have been implicated in symbolic activities (d'Errico et al. 2005:16; Henshilwood et al. 2011:219).

The exploitation of red and various other colourimetric categories of ochre is not limited to modern *Homo sapiens* (Barham 2002; Beaumont & Vogel 2006; Soressi & d'Errico 2007; Zilhão et al. 2010; Roebroeks et al. 2012). The habitual exploitation of red ochre has nevertheless been stated to represent a species-specific behavioural trait for *Homo sapiens* (Henshilwood et al. 2009; Watts 2010). That the term 'ochre' equates with the colour 'red' can almost be assumed, even if no colour prefix is provided (Watts 2010). But besides red ochre, large amounts of yellow limonite, specular haematite, black manganese, green, yellow, pink, grey and purple shales, white kaolinite and brown goethite frequently occur in MSA sites (Barham 2002; d'Errico 2008; Henshilwood et al. 2001, 2009; Wadley 2009; Watts 2009, 2010).

Resembling red, all colour stimuli are context specific. Different colours are therefore likely to have conveyed diverse meanings and served dissimilar functions in different contexts. The same is true in terms of chemical composition and mineral content. The colour of ochre has been known to be indicative of mineral content (Elias et al. 2006; Rapp 2009; Young et al. 2010) and may have acted as a stimulus for selection (Bolton et al. 1998; Wilson 2003), depending on the intended purpose or application in mind. The choice of non-red types of ochre most probably relate to functional applications and not to purely colour-related and symbolic motivations.

7.2. Inferring symbolism and functionality

It appears that the general assumption that the exploitation of ochre necessarily equates with 'symbolic' behaviour encouraged researchers to explore at least some of the proposed utilitarian hypotheses for archaeological ochre. This is certainly the case with my research. Recent work by Wadley (2005a, b; 2009), Wadley et al. (2004, 2009), d'Errico et al. (2005, 2010), Lombard (2006, 2007a) and Henshilwood et al. (2009, 2011) exemplifies the value of actualistic experiments and the application of novel analytical techniques to elucidate the uses to which ochre may have been put. I now present the core research questions posed in Chapter 1 and discuss each of these in terms of their conclusions, their contribution to MSA research and the prospects that these studies may hold for future research.

7.2.1. Experimentation and wear analyses

The core questions that I addressed in Chapters 1 and 3 are: *1) how was ochre processed and what the uses of the resultant ochre powder and the remainder of the modified pieces may have been?; 2) are so-called ochre crayons to be interpreted as such, or are these pieces simply the result of abrasive processing methods intended to extract pigment powder?; 3) what criteria can be used to discern between primary or processing and secondary or use wear traces on archaeological ochre?; 4) whether the experimental processing of ochre to extract pigment powder could enhance our understanding of the mechanisms implicated in the processing and the possible subsequent applications of ochre during the MSA.*

The objective was to expand existing comparative references for the analysis of wear traces on archaeological ochre by exploring the mechanisms and implements involved in ochre processing, by investigating the formation of primary processing wear features and by observing the formation of wear traces resulting from the secondary use of processed ochre

(Rifkin 2011a). This necessitated devising an experimental protocol according to which experiments that generated wear traces similar to those observed on archaeological ochre could be performed in an actualistic, systematic and replicable manner.

The formation of what is widely referred to as ochre 'crayons' formed a central part of this study. Crayons frequently stem from grinding ochre directly onto hard abrasive surfaces to extract pigment powder, with convergent facets resulting from the rotation of a piece to either target specific pigment-rich areas or simply to avoid scraping ones fingers onto the grinding surface. Wear traces suggestive of creating linear designs by 'drawing' generally manifest as small superimposed processed planes that exhibit grooves and striations either transversely or perpendicular to those derived from the original processing action. Convergent and superimposed faceting is not however an inevitable consequence of ochre processing. But what is the evolutionary significance of ochre crayons? And what would the implications for the presence or absence of crayons be in MSA contexts? The manganese chunks from the Mousterian sites of Pech de l'Azé I and IV indicate that Neanderthals did use crayons to 'draw' with, presenting a strong argument in favour of the capacity of Neanderthals to have independently developed complex symbolic cultural practices (Soressi & d'Errico 2007). The European Upper Palaeolithic evidence for the use of crayons to produce parietal art also provides insight into what crayons may have been used for in the African MSA, although no such traces have yet been confirmed. Depicting animals by drawing with charcoal was a common practice at Chauvet Cave (Fritz & Tosello 2007). At Lascaux several images including the 'Great Bulls' were drawn in charcoal and in red ochre (Chalmin et al. 2007). At Ardales (Málaga) aurochs were drawn in outline with red ochre (Bicho et al. 2007), and at Rouffignac a mammoth was drawn with a manganese dioxide crayon and with a finger (van Gelder 2010).

Ochre crayons are rare in the African archaeological record, although some do occur from the time of the earliest records of ochre use (Clark & Brown 2001; Barham 2002; Watts 2002; Wadley 2005a). The preliminary analysis of some ochre 'crayons' from the Still Bay levels of Blombos Cave confirm that the defining descriptive measure for these crayons , namely specimens that exhibit three or more facets and that converge to a point, is problematic. Numerous morphological crayons actually exhibit no wear traces suggestive of use as a crayon, and many seemingly amorphous specimens may have been used to create coloured designs. Several archaeological specimens do however exhibit superimposed smaller facets bearing striations aligned transversely to the initial processing wear traces. The morphology and faceting of several crayons from Blombos Cave suggest that they may have been applied directly to abrasive surfaces to produce defined areas of colour, perhaps

consistent with a design. The results obtained from this study present a reliable empirical basis for developing expectations about the origin and morphology of wear traces on archaeological ochre. It is anticipated that these will in turn facilitate the inference of the methods used to process ochre derived from MSA contexts. Much additional analytical and experimental work is however necessary to define the criteria used to identify archaeological crayons. In addition to scheduled research involving the analysis of ochre crayons from Blombos Cave, the XRF, XRD, colourimetric and microscopic analysis of ochre from other MSA sites is essential.

One LSA context in which both representational depictions and ochre crayons occur is that of Apollo 11 in southern Namibia (Wendt 1976; Vogelsang et al. 2010). Seven stone slabs bear a number of possibly 'drawn' depictions in black, brown and red as yet unidentified pigments representing animals and a quasi-feline creature with human legs. The *art mobilier* derive from an LSA horizon initially dated to between 25.5 ka to 27.5 ka (Wendt 1976:7) and more recently to between 32.7 ka and 39.8 ka (Vogelsang et al. 2010:192). Ochre crayons occur in MSA levels throughout the sequence. The analysis of the *art mobilier* and the ochre from Apollo 11 has been initiated and the relevant research permits have been obtained from the National Heritage Council of Namibia (Rifkin et al. in prep.). The co-occurrence of 'drawn' *art mobilier* and ochre crayons may present the perfect opportunity to explore the uses and associated morphological characteristics of MSA crayons from a securely dated context.

7.2.2. Engraved ochre as symbolic behaviour

The second set of questions that I ask in Chapters 1 and 4 are: *1) is it possible to ascertain whether all engraved ochres operated in the same social or symbolic contexts?; 2) could some engraved pieces simply have functioned as portable source of ochre powder, or were engravings on ochre intended to reflect conventional designs with broad meanings, or more localised sets of symbolic information?; 3 whether all categories of engraved ochre necessarily functioned in 'symbolic' contexts.*

The objective was to analyse and describe an engraved ochre fragment recovered from Klasies River Cave 1 during the Singer and Wymer (1982) excavations (d'Errico et al. 2011). The archaeological context from which the piece derive includes several additional processed pieces and crayons and also human remains that appear to have been dismembered, either as a result of cannibalism (Deacon 1993) or the post-mortem 'ritualised' treatment of the dead (White et al. 2003).

The engraved specimen was subjected to non-invasive analytical methods including XRF and visible spectroscopy. Colourimetric results indicate that the brown-maroon colour and the manganese-rich composition of the engraved piece is distinctive from other processed pieces. This appears to imply that a specific type of raw material may have been deliberately selected for engraving purposes. Significantly, most of the engraved ochre from Blombos Cave (Henshilwood et al. 2009; Henshilwood & d'Errico 2011) also comprises comparatively dark and hard pieces of ochre. Engravings are perhaps the only category of potentially symbolic early material culture that still reflects the complete set of actions performed by the artist (Henshilwood & d'Errico 2011:77). Various explanations have been proposed to support the symbolic interpretation of early engravings, but none can verify that engravings carried a specific meaning for past humans and their social group. It is concluded that not all engraved patterns are likely to have operated in the same way. The manner of juxtaposition and superimposition of the engraved lines on the Klasies River piece do not display much organisational consistency in terms of symmetry and equispacing. This implies that the engraved 'pattern' may not have been produced to create a distinct design and convey a specific 'message' to an audience that could distinguish it. Whereas some engravings may have served to reflect conventional designs with broad meanings, others might not have functioned in the same way. The lines incised on the specimen from Klein Kliphuis (Mackay & Welz 2008) might also have conveyed only limited or more localised symbolic information. The more elaborately incised ochre from Blombos (Henshilwood et al. 2009) and the ostrich eggshell from Diepkloof (Texier et al. 2010) may have had more conventionalised meanings that were understood by a larger group of individuals.

It is evident that the method of communication and the use of symbols to mediate social behaviour in the MSA was complex and that a degree of regional variation may have existed (Henshilwood & d'Errico 2011:92). Our understanding of the symbolic behaviour of MSA *Homo sapiens* is still rudimentary and much research is required before substantiated claims can be made about the contextual significance of engraved ochre. The identification of another engraved piece nevertheless adds to our knowledge of potentially symbolic MSA artefacts. The results of this study also advocate that spectral colour characterisation and non-invasive elemental analysis of archaeological ochre present a viable research strategy to establish whether 'special' categories of ochre were indeed selected for engraving purposes. Spectral colour measurements should be applied to MSA ochre assemblages as this may facilitate the identification of patterns that could reveal colour preferences during the MSA.

7.2.3. Ochre as a hide tanning ingredient

The final set of questions I addressed in Chapters 1 and 5 are: *1) how effective is ochre in rendering unprocessed animal hide resistant to putrification and desiccation?; 2) does the use of ochre to process animal hide constitute a real 'tanning' process?; 3) should the capacity to preserve or tan animal hide be seen as forming part of the trend towards increasingly 'modern' technological and social advances during the Middle to Late Pleistocene?; 4)* whether ochre is suitable for the preservation or 'tanning' of animal hides.

This study (Rifkin 2011b) entailed subjecting unprocessed hide specimens to treatment with several geological and colourimetric types of ochre likely to have been available to people during the MSA in southern Africa. Hide pliability was selected as a principal evaluative category because it relates directly to the flexibility and functionality of processed hides or skins. Heat loss is minimised by tailored garments that are properly fitted to the human body since the movement of air within or between different layers of clothing and the skin reduces thermal effectiveness. Supple garments enclose the body extensively, creating a uniformly warm environment which minimises heat loss and which enhances the protective capacity of garments against cold temperatures. Hide pliability therefore relates directly to the flexibility and functionality of the end product. Manual softening and scraping with silcrete scrapers resembling those from the Still Bay levels of Blombos Cave was used to soften the samples.

Another technique for increasing the pliability of hide is to score it with closely spaced patterns or to rub it with coarse-grained rocks. Cross-hatched leather fragments dated to between 2.1 ka to 1.2 ka have been recovered from Eland Cave (Sealy et al. 2000), Faraoskop (Manhire 1993), Melkhoutboom (Deacon & Deacon 1999), De Hangen (Parkington & Poggenpoel 1971) and Scott's Cave (Deacon 1967) in the Western and Eastern Cape Provinces. Coarse 'scraping stones' were also widely used by the Nama hunter-pastoralists of the Northern Cape to soften leather (Webley 1990).

The pliability values allocated to specimens signify the general capacity of different 'tanning' methods and ingredients to produce leather that is best suited for the manufacture of tight-fitting garments. Remarkably, the hide samples treated with red ochre exhibited full pliability and no subsequent structural, fungal or bacterial deterioration. The mechanism by which red ochre appears to exert a 'tanning' effect appears to relate to both the mineral content and structural morphology of ochre. While the presence of extensive amounts of iron correlate with desirable pliability values, the high cation exchange capacity of clays is also known have bacteriostatic and antifungal properties (Williams et al. 2009:2). Mineral tanning does

not comprise true tanning since it does not involve the use of plant-derived tannins. Tanning in the real sense is only accomplished during the structural modification of proteins or when mineral elements cross-link onto or bind to collagen fibres. The mechanism by which ochre appears to exert a tanning effect on hide is therefore large preservative.

The question of when ochre-based tanning techniques were replaced with more efficient vegetable tanning methods remains uncertain. At Tell Mureybet in Syria ochre-based methods were substituted with vegetable-based techniques during the early Holocene. The widespread use of ochre for hide tanning during the Pre-Pottery Neolithic A, spanning 11.5 to 10.5 ka (Kuijt & Finlayson 2009:10966), suggest that more stable methods for preserving hides were not yet known. The 'discovery' of vegetable tanning methods occurred during the onset of the early Pre-Pottery Neolithic B some 10.7 to 8.9 ka (Ibánez et al. 2007:157). Archaeologically, the formerly abundant ochre stained blades and scrapers disappear, suggesting that more efficient vegetable based tanning methods were employed. Although it has not been established with certainty, the shoe from Areni 1 in Armenia dated to 5.6 ka (Pinhasi et al. 2010) is possibly vegetable tanned. There is also archaeological evidence for the use of various combination tanning methods. The garments worn by Ötzi 5.3 ka were tanned by way of combining animal aldehydes and wood ash (Püntener & Moss 2010), and the leather legging from the Schnidejoch pass dated to 4.2 ka (Schlumbaum et al. 2010) was tanned by employing aqueous extracts rich in tannin-phenolic compounds (Spangenberg et al. 2010:1863). The presence of fatty substances, lipids poor in unsaturated fatty acids, also suggests that animal fats may have been used for finishing off the tanned leather by oiling.

The ability to produce leather clothing requires specialised scraping, cutting and piercing implements and a detailed understanding of the sequential processes and ingredients implicated in hide processing and preservation. In MSA contexts, for example at Blombos Cave, humans who possessed such knowledge are likely to have been better equipped to endure changing environmental conditions, while those groups lacking such technologies were almost certainly more restricted in terms of ecological niche expansion. It would be of interest to subject ethnographic leather collections to non-destructive tests to determine the precise methods used to 'tan' hides by southern African hunter-gatherers. These methods are not however entirely non-invasive since they entail the application of ferrous sulphate ($FeSO_4$) to leather samples. A positive reaction for vegetable tanning results in the staining of the tested surface (van Driel-Murray 2002). Further ethnographic research amongst the Ovashimba and the !Kung San of the Kalahari Desert in Botswana may also provide useful information in terms of the variability of hide-tanning techniques that may have been used in prehistory.

7.2.4. Ethnographic analogy and archaeology

Ethnoarchaeology and experimental archaeology are two of the formal procedures of ethnographic analogy which may be used to derive analogues from the known record of human behaviour (Stanish 2008:1364). Ethnoarchaeology was originally conceived to provide more focused and complete analogies for archaeological application than could be gleaned from ethnographic and other sources (David 1992:330). Ethnoarchaeology is a research strategy which comprises ethnographic research performed to answer archaeological questions. It is defined as 'the ethnographic study of living cultures from archaeological perspectives' (David & Kramer 2001:2). Whereas ethnoarchaeology studies modern people to gain ethnographic analogues for a possible explanation of the material culture of past societies, experimental archaeology seeks to replicate the behaviours through which archaeological data are created. Both concepts rely on empiricist epistemological assumptions and have made valuable contribution to archaeological explanation. Historical and contemporary ethnographic analogies alone cannot however be used to fully reconstruct human behaviour in the MSA.

The information gained from studies of extant and historical people and their practices does present a stimulating basis for the formulation of research questions about, for example, the uses of ochre in the past. Historical ethnographic records indicate that people attached high symbolic value to red ochre, but they do not confirm that red ochre functioned exclusively in symbolic contexts and do not explain how the symbolic use of ochre arose (d'Errico et al. 2010:4). However, and if prehistoric human societies exhibited similar ranges of variation to contemporary and historical hunters and gatherers, the fundamental structure of modern hunter-gatherer adaptations are likely to have been in place for an extensive period of time (Kuhn & Stiner 2001:99). This notion is confirmed by genetic evidence affirming a shared ancestry of a number of populations who still practice a hunting and gathering lifestyle (Tishkoff et al. 2009). Certain social, symbolic and technological aspects of the hunter-gatherer way of life may therefore have remained largely unchanged, and the social and economic ways in which they conduct themselves may exemplify at least some of the characteristics of human life during the MSA.

Current research certainly appears to indicate that MSA humans were not a markedly 'different sort of hunting and gathering hominin' (Kuhn & Stiner 2001; Henshilwood et al. 2011) but instead that their social and economic conduct resembles at least some part of the manners and modes of contemporary and LSA hunter-gatherer behaviour. While this may indeed be true, disentangling the functional worth from the symbolic significance of ochre

remains a challenging research question, especially in terms of the exploitation of red ochre during the MSA.

7.3. Summary

As direct evidence on how and why ochre was utilised during the MSA has not been available, diverse interpretations for its use have been proposed. The interpretation that ochre was mainly used as a pigment prevails, and habitual pigment use is widely taken as evidence for colour symbolism. A result of this notion is that the exploitation of red ochre in particular is presumed by many to be inevitably symptomatic of symbolic and therefore modern human behaviour.

Granting that 'symbolically mediated behaviour' (Henshilwood & Marean 2003:635; Henshilwood & Dubreuil 2009:46) has emerged as one of the accepted indicators of human modernity (Chase & Dibble 1987; McBrearty & Brooks 2000; Klein & Edgar 2002, d'Errico 2003; d'Errico et al. 2003; Hovers et al. 2003; Henshilwood & Marean 2006; Henshilwood & Dubreuil 2011), I view the the interpretation of ochre in exclusively 'symbolic' terms as problematic. Admittedly, correlating material culture with behavioural complexity is difficult as direct evidence for behaviour is not easily extractable from the archaeological record (Henshilwood 2004:95). Tracing and interpreting the material products of the innovative cognitive advances during the MSA is just as complex, largely because unambiguous indications of material symbolism occurs only intermittently in the MSA (Henshilwood 2007:128).

These concerns also pertain to the explanation of processed and residual ochre from MSA contexts. Archaeological ochres are generally the result of largely unknown sequences of processing actions and subsequent usages that are difficult to reconstruct. These do not therefore represent the outcome of any specific functional or symbolic behaviour. This is one reason why the interpretation of ochre is inherently controversial in nature (Wadley et al. 2009; Watts 2009; Wynn & Coolidge 2010). Current interpretations regarding ochre use almost certainly represent only a glimpse of its actual use and application during the MSA. It is therefore essential to demonstrate, and not simply assume, the symbolic nature of ochre in prehistory. What could the roles of ochre have been in prehistoric technology and how might these have functioned to promote and maintain social relations within early *Homo sapiens* societies? In addition to providing a summary and discussion of the principal conclusions reached in this and the preceding chapters, this essential question is addressed in Chapter 8.

CHAPTER 8

CONCLUSION

In this chapter I consider the ways in which the results and hypotheses presented in Chapters 3 to 7 may advance current perceptions of ochre usage during the MSA. I also revisit the primary objective of my research, namely the question of how the symbolic and utilitarian applications of ochre may have functioned to enhance the lives of people in prehistory by promoting and maintaining social relations within MSA *Homo sapiens* societies.

8.1. Introduction

In this thesis I addressed three interconnected sets of questions relating to the exploitation of ochre during the African MSA. The first question (Chapter 3) dealt with the experimental establishment of the operational sequence of ochre processing and the viability of correlating particular use activities with the formation of specific wear patterning. I established that different processing techniques and secondary uses result in the formation of largely distinctive wear traces on experimental samples, and that similar processing and use traces occur on archaeological ochres (Rifkin 2011a). In Chapter 4 I assessed the legitimacy of inferring symbolic significance from engraved ochres, concluding that, because current explanations cannot verify that engravings unavoidably carried strictly symbolic meaning, not all engraved patterns may have functioned in the same way (d'Errico et al. 2011). In Chapter 5 I report on testing the efficacy of red ochre as a hide-tanning substance by actualistic experiments, the results of which proved to be largely affirmative (Rifkin 2011b). I believe that these three published papers and the on-going research projects presented in Chapter 6 will contribute to MSA research on several levels and help us to better understand the lives of these early *Homo sapiens* in southern Africa.

On one level, I have made several advances in terms of the conception of original methodological protocols and the employment of diverse archaeometric techniques to enhance current understandings of ochre use during the MSA. There are various non-invasive and non-destructive analytical methods to which archaeological ochre can be subjected (Creagh & Bradley 2006; Pollard et al. 2006; Goffer 2007; Stuart 2007). The employment of X-Ray Fluorescence (XRF) analysis is a widely used technique for the measurement of the elemental composition of archaeological ochre. Energy Dispersive X-Ray (EDXR) analysis and low vacuum Scanning Electron Microscopy (SEM) have also proven to be effective in terms of the identification of mineralogical and elemental composition. Resembling the use of Visible Spectroscopy to obtain L*a*b* colourimetric values, the continuing application of Micro Scale (μ)XRF and (μ)XRD, Ultraviolet (UV) Transmittance Spectrophotometry and Gravity Sedimentation techniques to determine the elemental compositions, UV reflectivity capacities and the particle sizes and colloidal characteristics of ochre are presenting exiting research prospects.

On another level, my generation of new experimentally-derived data sets have thus far proven valuable for answering questions about the relationship between the exploitation of ochre and the emergence of modern human behaviour. Examples include the confirmation of the existence of ochre crayons and prehensile and residual traces on ochre from the Still

Bay levels of Blombos Cave, the observation that distinctive types of raw materials were purposely selected on which to produce engraved 'designs' and the demonstration that red ochre exerts a preservative effect on animal hide. The validation of this latter enduring but unsubstantiated functional hypothesis for ochre also resulted in the development of expectations that might illuminate other utilitarian functions that may have been overlooked if such uses have simply been assumed. Newly formulated and fully 'testable' hypotheses in this thesis include exploring the ability of red ochre to minimise photodamage and the deleterious effects of exposure to harmful UV light, the capacity of red ochre to restrict infection by malaria-inducing *Plasmodium* parasites and of diseases transmitted by hematophagous disease vectors, and the potential of certain types of ochre to provide a source of mineral supplementation and to absorb dietary toxins.

The personal and experiential appreciation of the association between red ochre and the emergence of modern human behaviour may however be the most important advancement brought about by my research. Experiential archaeology describes an attempt to access the human past through the synthesis of past experiences by practical means (Ch'ng 2009:458). As opposed to experimental archaeology, which offers insight into past material facts via the creation of artefacts using archaeologically available technologies, experiential archaeology brings participants into the experience of living as a prehistoric human. I view the integration of experimental and experiential approaches as essential to archaeological interpretation. The experience I gained within the various experimental settings provides both practical confirmation and facilitates the conception of innovative research agendas and original hypotheses concerning the use of ochre in prehistory. These theories can now be addressed from a more informed position and with much improved theoretical, experimental and analytical competency.

8.2. Red ochre and technology

The study of technology has always played a central role in the practice of archaeology. Similarly, the research presented in this thesis is essentially a study of the technologies implicated in ochre exploitation during the MSA and the prospect of applying newly acquired knowledge to address a range of social questions about our ancestors. Dobres (2000:47-95) offers an inclusive summary of the philosophical and historical definitions of technology. Technology inevitably necessitates and incorporates human actions, experience and knowledge, hence the definition by Merrill (1977:vi) of technology as '… the culture surrounding the actions or activities involved in making or doing things …'. Definitions and perceptions of technology should not therefore be based solely on its 'technical' aspects

since it is, after all, an exclusively 'cultural' phenomenon. I define 'technology' and 'technological systems' as the acquired knowledge, technical processes and social practices implicated in and associated with the initial conception, ensuing production, subsequent consumption and ultimate discard of both tangible and intangible aspects of human culture (Miller 2007:5). Ochre appears to have permeated many aspects of human life during the MSA, but a key question is what symbolic and functional role did ochre actually play in the enhancement of prehistoric technology, and how may these have functioned to promote and maintain social relations in MSA *Homo sapiens* societies?

Red ochre is implicated in the very first unambiguous examples of the existence of fully modern human behaviour. There are three notable instances in which the 'technologies' or operational sequences of ochre exploitation in the MSA are unambiguous. The first example involves the use of red ochre in the manufacture of composite lithic hafting mastics at 70 ka (Wadley et al. 2009), the second the deliberate creation of abstract geometric and symbolic designs on red ochre between 72 ka and 100 ka (Henshilwood et al. 2009) and the third example entails the inclusion of ochre as a primary ingredient in compound pigment-rich mixtures at 100 ka (Henshilwood et al. 2011). Although the first securely dated instances of ochre exploitation by *Homo sapiens* involves the specimens from Sangoan (200 to 182 ka) contexts at Sai Island (van Peer et al. 2003, 2004), these later MSA occurrences represent the first unequivocal examples of the inclusion of ochre in human technological systems.

The archaeological evidence for the conceptual ability to produce abstract designs on red ochre and to conceive, manufacture and put to use ochre-based substances for various symbolic and utilitarian purposes, represent a benchmark in the evolution of complex human cognition. I now argue why these activities and substances can be viewed as demonstrative of technological improvements and reveal how these may have promoted and maintained social relations during the MSA.

8.3. Technology and social relations

Many historians (e.g. Hughes 1983; Ingold 1994; Landes 1998; Needham 2004; Nye 2006) suggest that technology was and remains to be the driving force in human evolution, to the point that the claim has become so prevalent that it is recognised as a doctrine termed 'technological determinism' (Aunger 2010:762). Whereas human technology is generally viewed as conceptually separated from similar activities in other species, others argue in favour of a 'continuity thesis for technology' which suggests that human technology is an evolutionary phenomenon with its roots in the technologies of related species. Many animals

manipulate their environments to produce objects and structures that resemble those made by humans. Spiders construct webs, birds build nests and chimpanzees fashion and use artefacts equal in complexity to the technology of the first hominids (Hernandez-Aguilar et al. 2007; Pruetz & Bertolani 2007; Carvalho et al. 2008; Schöning et al. 2008). Chimpanzees also develop and transmit cultural traditions, but they do not create symbolic systems and express these in their material culture (d'Errico et al. 2009a:20).

From 200 ka to 100 ka, anatomically and behaviourally modern humans expanded into new ecological niches, utilised increasingly larger foraging ranges, selected finer-grained raw materials from distant resources, developed and employed more sophisticated hunting techniques and significantly broadened their dietary base. The geographic patterning of artefact and artistic styles and evidence for symbolically mediated social behaviour also becomes prevalent during this period (McBrearty & Brooks 2000; Henshilwood & Marean 2003, 2006; Henshilwood et al. 2009, 2011; Texier et al. 2010). Resembling the positive effects of technological innovation in enhancing human subsistence strategies (Lombard 2006, 2011; McCall 2007; Brown et al. 2009; Mourre et al. 2010; Dusseldorp 2011; Faith 2011; Wurz 2011), technological advances relating to the symbolic and practical applications of ochre also functioned to mediate social relations in the MSA.

Granting that symbols are naturally functional and that functional features may be symbolic, I distinguish between 'symbolic' and 'functional' types of ochre-related technologies. The latter type is defined by its purpose pertaining to a specific function or utility, as opposed to being expressive, emblematic or representative of something.

8.3.1. Symbolic technology

The symbolic uses of ochre in the MSA in all probability functioned on two levels. I term the first 'individualistic' and the second 'collective'. The symbolic use of red ochre by individuals operated in a principally decorative sense and served to visually enhance the bodies, faces, hair and personal ornaments and attire of individuals. Different decorative 'styles' therefore fulfilled an important role in the processes of information exchange about individuals (Wobst 1977). This in turn served in the formation and confirmation of personal identities, much like personal ornaments such as shell beads may have served to convey information about the wearer (Henshilwood et al. 2004; d'Errico et al. 2005). In collective terms, the symbolic use of red ochre may have fulfilled certain functions within a specific social group, or it may have served to distinguish different social groups. In the first instance, ochre served to stimulate the formation of social and economic relationships, reinforce group solidarity and ensure

cooperation or to discern different statuses, achievements or affiliations amongst group members. On an intergroup level, the use of different ocherous shades, designs or patterns applied to different areas on the body or attire served as distinctive 'stylistic' features specific to members from a known but 'other' social or 'ethnic' group (Hodder 1982).

In terms of 'information exchange' theory offered by Wobst (1977), symbolic and stylistic differences are most effective for conveying messages to socially distant target groups or the 'extended social network' (Gamble 1999). The symbolic use of ochre in the MSA should then also be viewed in terms the 'social interaction' theory which rests on the assumptions that style is a learned cultural trait, that it reflects traditional norms about the appearance of an individual and that similarities in style reflect cooperating individuals who share norms (Wobst 1977). In both 'individualistic' and 'collective' contexts the symbolic implication of ochre is presumed to be based purely on the colourimetric properties and surface covering capacities of ochre.

8.3.2. Functional technology

Functional or utilitarian applications of ochre are assumed to have been based principally on knowledge concerning the efficacy of ochre in various applications as based on the variable structural and chemical properties of ochre (Konta 1995; Elias et al. 2006; Carretero & Pozo 2010; Hoang-Minh et al. 2010). The use of ochre in lithic hafting, lithic manufacturing and hide tanning technologies has been established. Further functional uses for red ochre may have entailed the topical application of ochre as a sun-protection element or as an insecticide, and its ingestion as a source of mineral supplementation and as a dietary detoxification agent.

Strategies for dealing with constant exposure to harmful UV radiation were essential during human evolution. Besides erythema and skin cancer, exposure to UV radiation results in a variety of molecular changes including DNA damage (Gasparro 1999) and immune system deficiencies (Mackintosh 2001). The implications of having knowledge about sun-protection technologies during the MSA are illustrated by a recent study by Valet and Valladas (2010) in which a link between the demise of Neanderthal populations in Europe and changes in the geomagnetic field of the earth is posited. Records indicate a reduction of ~10%, resulting in significantly less efficient shielding against UV radiation. The topical application of red ochre may therefore have served an important function in terms of limiting the negative effects of excessive exposure to UV sunlight by way of its light reflection and scattering properties (Hoang-Minh et al. 2010). Similarly, the topical application of ochre as an insect repellent

would also have conferred a significant adaptive advantage MSA *Homo sapiens*. There is archaeological evidence for the structural placement of aromatic plants with insecticidal properties in human habitation sites from 77 ka (Wadley et al. 2011), and chimpanzees have developed strategies to address *Plasmodium* infection (Masi et al. 2012).

Besides the advantages offered in terms of general mineral supplementation and the detoxification of plant foods, geophagy may have played a more critical role in the emergence of symbolically mediated culture than was previously realised. Substantial research relates mineral nutrients to brain development, cognitive function and diverse psychiatric symptoms. Several reviews (Kaplan et al. 2001, 2007; Popper 2001; Gesh et al. 2002) demonstrate that links between antisocial behaviour and psychological stability and mineral deficiencies are unequivocal. Lithium (in the ionic Li^+ phase) is a widely prescribed mineral-derived ingredient of psychoactive medications (Kovacsics et al. 2009). Due to its solubility as an ion, Li occurs in abundance in the ocean and is readily obtained from marine-derived smectite and illite clays (Howard 1981). Calcium deficiencies give rise to anxiety, depression and impaired cognitive function (Kaplan & Shannon 2007), magnesium improves the mental state of people suffering from manic depression, severe bipolar disorder and schizophrenia (Giannini et al. 2000), chromium supplements inhibit depression and anxiety (Kaplan et al. 2007) and iodine deficiency has been linked to neurological disorders, antisocial behaviour and mental retardation (Delange 2001). Iron (Fe), selenium (Se) and zinc (Zn) also fulfil critical roles in terms of ensuring and maintaining psychological and behavioural stability. Fe is essential for the functioning of neurotransmitters in the brain (Picchietti & Winkelman 2005; Konofal et al. 2008), low Fe levels are typical of individuals suffering from severe depression and Fe supplementation improves cognitive functioning (Bruner et al. 1996). Se supplementation improves mood scores and decreases anxiety and hostile antisocial conduct (Rayman 2000). Zn plays a role in synaptic transmission and DNA synthesis, and Zn deficiency is associated with impaired learning and memory, delayed motor development, increased immunodeficiency (Arnold et al. 2005) and an increase in aberrant forms of social behaviour (Tuormaa 1995).

The transition in archaeology from data to social interpretation is difficult (see d'Errico & Henshilwood 2011; Henshilwood & Dubreuil 2011), but the importance of ochre exploitation during the MSA can only be expressed in terms of complex multivariate explanations. This is so because the advantages offered by the habitual exploitation of ochre during the evolution of *Homo sapiens* were numerous. Although exclusively functional uses of ochre are rare, it can be argued that it was common in the past and that the use of ochre for symbolic purposes in ethnographic contexts does not imply similar use by MSA humans. Ochre could

also have functioned 'symbolically' before the emergence of anatomically modern *Homo sapiens* ~195 ka (Table 1), but it may in fact have had several functional uses 'early on' which subsequently evolved to comprise both symbolic significance and functional value. The use of red ochre as a sun-protection element and as an insecticide provides an apposite example of how 'red ochre as body cosmetic' may have simultaneously served both functional and a symbolic purposes. Habitual geophagy also had significant progressive effects on the physical and cognitive development of *Homo sapiens*. These advances in turn facilitated the intensification and preservation of durable social networks, a distinctive trait of fully 'modern' human behaviour (Henshilwood & Marean 2006).

8.4. Conclusion

The primary goal of the archaeology is to understand the general processes or underlying logic of human cultural evolution (Stanish 2008). Within current scientific archaeology, some interpretative approaches privilege ecology and others technology, demography or ideology. Most combine these factors into multivariate explanations for cultural evolution, and this is essential to better understand how ochre may have functioned to promote and maintain social relations during the MSA. Environmental change has often been posited as a causal factor in the evolution and dispersal of early hominins (McBrearty 1993; Carto et al. 2003; Maslin & Christensen 2007; Henshilwood 2008). In Africa, the visibility of human populations increases markedly during the early part of MIS 5 from 127 ka to 116 ka (MIS 5 e), when temperature, rainfall and vegetation patterns began to resemble those of today. These changes in climate and ecology were indeed stressful periods of rapid change for humans and placed a premium on socially mediated responses, including technological innovation (Barham & Mitchell 2008). The question is whether it is possible to reconstruct the origins of ochre-related technologies.

After 200 ka there is archaeological evidence for the advent of regional lithic technological styles (McBrearty & Brooks 2000). The Lupemban of central Africa is the earliest bifacial point technology in Africa (Marean & Assefa 2005). When rainforests expanded during MIS 5, hunters of grassland species moved north and south, taking bifacial technology to North Africa - the Aterian, and South Africa - the Still Bay (Wadley 2007). Still Bay bifacial points are similar to Sangoan bifaces and later Lupemban lanceolate points from Zambia (Clark & Brown 2001) and points from the Aterian of North Africa (Barton et al. 2009). This, and the fact that Sangoan and ensuing Lupemban affinities are recognised as far south as Namibia and as far north as the Sudan, suggests a single origin for bifacial technologies in central-east Africa during MIS 5. The Sangoan also provides the first evidence for the use of ochre

by *Homo sapiens* at 200 to 182 ka (van Peer et al. 2003, 2004). From then on, a preference for red ochre becomes increasingly evident in MSA contexts across southern and North Africa (Bouzouggar et al. 2007; Marean et al. 2007; d'Errico 2008; Wadley 2009, 2010; Watts 2009; d'Errico et al. 2009b, 2010, 2011; Henshilwood et al. 2011).

By the beginning of MIS 5 two behaviourally fully modern human populations were isolated at the opposite ends of Africa. One thrived on the southern coastal plain in South Africa after 145 ka (Henshilwood et al. 2002, 2004; 2009, 2011; Marean et al. 2007; Wadley 2007, 2010; Wadley et al. 2011) and the other prospered in the Maghreb, North Africa after 140 (Smith et al. 2007; Osborne et al. 2008; Barton et al. 2009; Castaneda et al. 2009; Garcea 2011). It is from these separated and isolated coastal plains of southern and northern Africa that the earliest archaeological indications of 'fully modern' and symbolic human behaviour derive. The regional distributions of projectile point styles may well indicate the existence of complex social networks, but the first cultural traditions emerge at 100 ka, as shown by the engraved ochres from Blombos (Henshilwood et al. 2009), Klein Kliphuis (Mackay & Welz 2008), Pinnacle Point (Watts 2010) and Klasies River (d'Errico et al. 2011). From 92 ka to 72 ka, evidence for personal ornamentation, in the form of perforated marine shell beads, appears during the Still Bay and the Aterian (d'Errico et al. 2005, 2008; Bouzouggar et al. 2007; Bar-Yosef Mayer et al. 2009; Zilhão et al. 2010). The transportation of shells over distances up to 200 km suggests the existence of interlacing exchange systems and possible long-distance social networks. These appear to have crossed cultural and ecological boundaries since at least three of the four sites where similar *Nassarius* species beads occur can be attributed to the Aterian at Taforalt and Oued Djebbana, the Still Bay for Blombos Cave, and the Levantine Mousterian for Skhul (d'Errico & Vanhaeren 2009). It is too early to conclude that there are three independent origins of bead-working, but the preference for a single genus supports the hypothesis of an interrelated phenomenon across a broad region covering a substantial time span (d'Errico et al. 2009). Red ochre occurs inside many of these shell beads (d'Errico et al. 2005, 2008, 2009b; Bouzouggar et al. 2007). These residues may not originate only from contact with human bodies as red ochre may also have been applied to the beads intentionally, perhaps as a preservative or colour-enhancing agent.

In its initial stages, symbolic and functional technological innovations, for instance those associated with lithic implements, abstract depictions, personal ornaments and red ochre, would tend to remain isolated within the region in which they were developed. It is probable that these innovations themselves may have facilitated their distribution across increasingly larger geographic regions. This process of technological diffusion may be described as a self-perpetuating cycle of innovation, dispersal, acceptance and ensuing adaptation to new

social and environmental circumstances unique to respective cultural or ethnic entities. Amongst modern humans, such 'cumulative cultural adaptations' or the progressive acquisition of socially learned traditions (Hill et al. 2009) exhibits an emphasis on actions rather than just goals. Theoretical modelling has also provided insights into why cumulative culture, the so called 'ratchet effect' (Tomasello 1999:202), is rare among non-humans, demonstrating that the selection force on social learning depends on the amount of previously existing useful culture to copy (Boyd & Richerson 2002). Cumulative cultural capacity is therefore indicated by traits that require multiple innovative steps and cannot simply be acquired through individual learning in a single generation. This characterises the exploitation of ochre by *Homo sapiens* during the MSA, from its intermittent usage before 200 ka to its pervasive application for various increasingly complex symbolic and functional purposes after 100 ka.

By this time, a 'shared' cognitive system appears to have been operational in Africa. While this notion remains largely hypothetical, the movement of ideas and innovations from south to north and vice-versa may certainly have coincided with the concurrent movement of human groups (Henshilwood 2008:104). From a purely functional perspective, genetic and ecological models have confirmed that cultural niche construction, such as that represented by the Still Bay and the Aterian, may also have influenced human evolutionary outcomes (Laland et al. 2010). The possibility exists that gene-culture co-evolution may have been a widespread phenomenon throughout the history of our species. This perspective also predicts that the genetic signatures of recent positive selection will more often have been generated by culture than signatures of selection from earlier periods in human evolution. Models of human evolution that do not consider the role of culture may therefore need to be replaced by models that do recognise gene-culture associations.

The employment of red ochre for symbolic purposes likely played an important role in mediating increasingly complex social relations that emerged during the MSA. As is the case in Europe between 40 ka and 30 ka (Strauss 2012), red ochre acts as a social signalling device and became essential for the functioning of new social relations by expressing identity in individual and intergroup terms. The use of ochre as a hide-tanning ingredient and as a sunscreen, a mosquito repellent and a form of mineral supplementation and detoxification agent by MSA *Homo sapiens* also played a significant role in enabling humans to modify natural selection within their eco-cultural environments. This effectively permitted early modern humans to act as co-directors of their own evolutionary processes (Odling-Smee et al. 2003; Nettle 2009). The hypothesised and confirmed functional applications of red ochre should not be viewed as replacement theories for the use of ochre in symbolic

contexts, but instead as indicative of the exploitation and extensive application of a raw material with remarkable colourimetric, structural and chemical properties during the MSA.

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