MASTER THESIS

Is powdered ochre a useful polishing material for bone tools?

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Contents

List of figures

List of tables

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Glossary

MSA - Middle Stone Age of South Africa

BBC - Blombos Cave, South Africa

IHS - Indurated Hematic Shale

FSH - Friable Shale

FSS - Ferruginous Sandstone

YO - Yellow ochre

1. Introduction

In the South African Middle Stone Age, we find evidence of rapidly developing new traditions and advancement of techniques that have come to be viewed as indications of the important development of early humans (Henshilwood, 2012, p. 205). We find heat treated lithic material, pressure flaked stone points, complex devices like bow and arrow, and we also find symbolic artefacts, like shell beads, engraved ostrich eggshell, bone, and engraved ochre (Henshilwood, 2012, p. 206).

Ochre has had many important functions for past people, and still has today to some extent, spanning from hard to grasp symbolic activities (Henshilwood et al., 2009, p. 28), to the more everyday use as a hide preservative (Watts, 2002) or for hafting tools (Lombard, 2005). As it is found in the archaeological record, on stone and bone tools, on personal ornaments, as a paint in rock art, and as a residue on a variety of other artefact types, it is interpreted as both symbolic, and functional, having a variety of practical applications (Nivens, 2020, p.56-59, Watts, 2002). Ochre is frequently encountered as a residue on tools and personal ornaments, which could either be the result of humans processing the tool with ochre, from secondary post-depositional processes from lying in an ochre-rich environment, or the tools themselves were used to process the ochre directly (Wadley, 2005, p. 587). In South Africa different types of ochres occur as part of the geological environment (Henshilwood et al., 2001a, p. 431-432). Ochre is also found in relatively large numbers at certain archaeological sites, like Blombos Cave (Henshilwood et al., 2009), Klasies River (Culey et al., 2019), and Sibudu (Hodgskiss, 2012). Even though residue of pigment is found on bone tools from some of these archaeological sites in South Africa (Henshilwood et al., 2001b, p. 661, White, 1993, p. 292, d'Errico and Henshilwood, 2007, p. 156), and experiments have showed the efficacy of using ochre to polish items made of lignite, steatite, ivory, and antler-ornaments, for example (Nivens, 2020, p. 104-106, p. 98, White, 1995, p. 38), few, or no experiments have yet tested ochre as a polishing medium on bone tools.

Bone tools found in archaeological contexts often have a polished appearance, which could derive from both conscious polishing as part of the shaping (Henshilwood et al., 2001b, p.662), or for creating a nice finish (Henshilwood et al., 2001b, p. 664), sedimentary abrasions (Reynard, 2014, p.157), as well as repeated use of the tools, leading to a polished appearance (Henshilwood et al., 2001b, p. 662) (Tartar et al., 2022, p. 24). Even though all are likely to have happened, it is conceivable that one would polish a bone tool, to create a nice glossy look as the primary purpose, as the human mind tend to give something with a beautiful glossy exterior a higher value, a trait that is linked to the development of the modern human brain (Bradfield, 2020, p. 1, p. 5).

The question then is what this process looked like and what materials where used - both the polishing material itself, as well as the items used to bind and apply these polishing materials. If ochre is found on a residue on bone tools, could it mean that ochre was used as a polishing agent?

Red ochre is often interpreted as having a symbolic/ritualistic meaning when found at archaeological sites, which is largely based on ethnographic research (Watts, 2002, p. 1-2). The way in which it often appears in archaeological contexts also indicates symbolic use: as part of paint, rock art, and playing a part in funerary traditions (Watts, 2002, p. 1). As a polishing agent, would ochre then be used exclusively because of its symbolic purposes, or does it have superior polishing properties over other polishing agents?

The goal of this MA is to test whether certain types of ochre are suitable for polishing bone. Different types of ochre, as well as sand made from crushed shells as a control medium, will be used to polish different types of bones, and the results will be compared to outline the differences and see if one medium is better for polishing. The variables used to determine this are overall effectiveness of the process, based on time used, and ease of use, but also on the gloss, colour, and microscopic appearance of the polished bones.

This will be done using an experimental approach, looking at both the processing and polishing of bone, and using microscopic analysis to track microwear and residue on the bones before and after polishing with different mediums. If ochre turns out to be an effective polishing-medium that gives a fine gloss, and/or adds colour, it strengthens the idea that oche residue on bone tools are there as a result of the tool-creation process and/or finishing. Looking at the residues and microwear created from this process could help discern and allocate traces found on bone tools in archaeological context to human processes, or to taphonomic processes.

The backdrop for my experiments will be the Middle Stone Age (MSA) of South Africa, and more specifically, Blombos Cave (BBC). This part of South Africa has naturally occurring ochre formations in the nearby Bokkeveld shale deposits (Henshilwood et al., 2009, p. 29), and BBC has provided a large assemblage of ochre pieces that were gathered and sometimes modified by human agents (Henshilwood et al., 2001a, p. 431-432). Therefore, it would be beneficial to be able to differentiate between bone tools with ochre residue because of being left in an ochre rich environment, and bone tools deliberately modified with ochre.

Understanding the design and techniques used to produce these kinds of tools and the use of ochre, would contribute towards our knowledge of the possible symbolic behaviours and level of human modernity in the MSA. My experiment will test whether ochre is useful for polishing bone, and how these bones then appear under microscopic analysis and will shed some light on the visual outcome, both macro- and microscopically, when using various methods and materials.

My main question in this thesis is:

- *Is ochre a useful polishing device for bone tools?*

Furthermore, I will explore these sub-questions:

- *How does the microwear and residue look under a microscope on the different types of bones polished with the various ochres, and the shell sand, compared to their macroscopic appearance?*
- *Is there a difference in efficiency and result, when using various types of ochre, or using shell sand?*
- *Is there difference in efficiency and result when using the ochre with water or fat, or using the ochre dry?*
- *Is there a difference in using new, old, or cooked bones?*
  And:
- *What can these results potentially tell us about the use of ochre for polishing bone tools in the Middle Stone Age of South-Africa?*

Examining the physical properties and uses for ochre and bone tools might only tell us a small part of the story behind ochre residues, as there might always be an underlying thought process that is not purely practical but might entail practices that we today would consider ritualistic or spiritual, even though these were real daily aspects of the lives of the people living in South Africa's stone age. However, these concepts are beyond our reach, which leaves us to examine the physical world as best we can. Together with ethnographic research this gives us the best chance to understand the archaeological record.

I will start my thesis by defining my hypothesis and expectations, before I describe the basics behind iron oxides, their geological descriptions and how they appear in natural contexts, and which types of ochre I will use in my experiment. I will then look at some of the previous archaeological finds of ochre, and experiments done with ochre and tools/ornaments, as well as going through some theoretical framework for my thesis.

I will then explain my experimental process, methodology, and choices and limitations, before examining my different results and then discussing the possible implications and answers to my thesis questions. Using microscopic and macroscopic images for comparison, as well as personal experiences during my experiment, I will try to extrapolate significant patterns and differences that appear through the trials. Lastly, I will provide my results and discuss their implications for the archaeological record of the South African MSA.

2. Hypothesis and expectations

As I had very little previous experience with polishing in general, I had few specific expectations for the different methods of polishing. Before the actual experiment, I tried polishing a few pieces, which helped set some of my parameters, but expectations for the results were not possible to tell from this limited perspective.

For one, I expected that using water as a binding agent might be more effective in polishing than using the ochre dry, however it was more difficult to predict which would result in more gloss. The fresh bones I would have thought to be denser and harder and offer a more even surface that might look glossier than that of the older bones. As for cooked vs. un-cooked bones I did not expect there to be much difference. Perhaps the raw bones were harder and denser than the cooked bones, somewhere between raw and old bones. I assumed that polishing with dry ochre could leave more colour, at least in a macroscopic view, as there was no water to wash the ochre away.

I did not have many specific expectations between the different ochres, as I was not very familiar with ochre before the experiment. Though I assumed their grain size and hardness would affect the process and result in some way (Nivens, 2020, p. 115-116). I expected a courser pigment to be more effective at erasing irregularities on the surface, and the finer ones to maybe create a smoother finish and gloss.

I did not expect there to be much difference between using water and fat, as they are mostly just used as a binding agent to keep the ochre in place. Perhaps a difference in practicality of the process, or how the substances handled could be determinative of which was more used rather than results alone.

I also thought shell sand would be somewhat useful for polishing; even though it would not leave much colour, I expected it to be about as efficient as the ochre when it came to creating an even surface (Nivens, 2020, p.115).

I assumed the microscopic view would vary somewhat between the different ochres used, and from using the ochre dry vs. with water and fat, the dry polish leaving coarser microscopic patterns, as I expected the ochre paste/ slurry form would be a more effective polishing medium. I also presumed that it would be possible to see a congruence between the microscopic texture and how glossy the surface looks macroscopically.

In line with previous research, the more hematite rich ochres should be more effective, when looking at both time used, and surface gloss and colour, and the yellow ochre would be the least effective of the ochres (Nivens, 2020, p. 115-116).

Overall, I did expect ochre to be useful as a polishing medium on bones, and I believed it would create a considerable gloss, and leave residues that are both macro- and microscopically visible, as seen in previous experiments using ochre as a polishing medium (Nivens, 2020, p. 114-116) (White, 1995, p. 38). I expected there to be left some considerable colour on at least the ones polished with the darker/ hematite rich ochres, and I did expect colour to be seen an alle the different bones in a varying degree.

My hypothesis was therefore that ochre is effective as a polishing agent, superior to my control medium, and that it likely could have been used for this purpose in the South African MSA.

3. Research history

3.1 Iron oxides

The term “ochre” is in archaeology used as a collective name for various earth, rock and clay oxides or hydroxides that appear red or yellow due to their content of iron (Nivens, 2020, p. 38). Their colour and properties are a result of a variety of factors, such as molecular shape, grain size, and the concentration of iron oxides and hydroxides in combination with other minerals like f. ex. quartz and kaolinite (Nivens, 2020, p. 38). Ochre can consist of e. g. hematite (Fe O) or goethite (FeOOH), amongst others, and are combined with other minerals - like clays and silicates, allowing ochre to take the form of various rock types, like shale, mudstone, siltstone, sandstone etc. (Hodgskiss, 2020a, p. 3). Iron oxyhydroxide (goethite) will, when heated, become dehydrated, and then form iron oxide (hematite/maghemite), which changes the colour of the pigment (Hodgskiss, 2020a, p. 3). While goethite is yellow in colour, the more hematite-rich ochres are in various red and even purple hues. It is the red ochre that is most commonly studied, perhaps because it is most encountered in the archaeological record (Henshilwood et al., 2009, p. 29). One could question if this is due to differences in preservation or availability, a lack of investigation and attention, or an actual lack of use of the yellow ochre-types in the prehistory.

Ochre was most likely gathered or mined from the nearby areas, in the African MSA, but was also likely traded, gifted, and potentially carried across large distances (Hodgskiss, 2020b, p. 2). This suggests that the people of the MSA would likely have had an extensive knowledge of ochres, and that they valued it enough to travel great distances to acquire various types (Hodgskiss, 2020a, p. 2).

The early use of ochre has been seen over most of the world, not only Africa, and the archaeological record shows their presence in Europe, the near east, some parts of Asia and also Australia (Hodgskiss, 2020a, p. 2). Ochre is seen in different forms in the archaeological material. We find crayon-shaped pieces, that could have been used to make marks on different materials, such as skin, hide, or wood, but also could be a result of grinding (Hodgskiss, 2020a, p. 7). We also see ochre with flake scars, or bulbs of percussion etc. that most likely stem from knapping the ochre with other rocks (Hodgskiss, 2020a, p. 8) , which means the ochre was intentionally modified in order to adapt it to their intended use. Pieces of ochre has also been seen used as knapping tools, as abraders and soft hammers when making bifacial points (Hodgskiss, 2020a, p. 9). Traces of ochre powder deposits are also found, at the sites of Sibudu for example, in South Africa, showing surface areas where ochre powder were either directly applied, or processed (Hodgskiss, 2020a, p. 9).

Microscopic traces of ochre are also observed in many MSA sites (Wojcieszak and Wadley, 2019), on both stone tools, bone tools, and grindstones (Hodgskiss, 2020a, p. 10). These residues are not always macroscopically visible, showing that ochre often could have been completely crushed to a powder before use, leaving few other traces (Hodgskiss, 2020a, p. 9).

Ochre pieces are also sometimes found to be scored and striated, which might have resulted from being used as a tool, or the tools that were used on them (Hodgskiss, 2020a, p. 9-10). Not only as a means to apply functional changes or decoration onto other artefacts, there are also ochre pieces that have themselves been cut or scratched in such a way that it is likely they have been decorated or engraved to apply some meaning or specific design to them (Hodgskiss, 2020a, p. 10, Henshilwood et al., 2009).

In modern-day contexts, we can find calcined hematite in jewellery polishing mixtures (Nivens, 2020, p. 94). Called "Jeweller's Rouge", it contains ferric oxide, hematite, and red iron oxide, and is used for polishing soft, precious metals, to give them a lustrous finish (Reade-Corp., 2020). Though other modern polishes may give a faster result, this ferric oxide is still used as it produces a superior finish (Reade-Corp., 2020). It is noteworthy that even in modern day production we use iron oxides as an effective polishing implement.

The pigment types that were used in my experiments was indurated hematic shale (IHS), friable shale (FSH), ferruginous sandstone (FSS), and yellow ochre (YO). The indurated hematic shale, as its name says, is a relatively hard rock, rich in hematite, and therefore with a red colour. The friable shale is softer and lighter in colour than the indurated hematic shale, while the ferruginous sandstone is harder and coarser, and more similar in colour to indurated hematic shale. The yellow ochre is quite soft and fine-grained, and like its name describes, more yellow in colour. Yellow ochre has to a much smaller degree been used to perform these types of experiments; it is the hematite rich pigments that are most often used in testing polishing properties on different materials. The following experiment therefore includes a little covered area in these types of experiments.

All ochre used in this experiment were collected in the southern coastal region of the Western Cape province in South Africa and may represent ochre sources that were used in palaeolithic times. Sand from crushed shells will be used as a control medium; this is from Norwegian sources but represent a similar substance as the sediments found in Blombos cave in South Africa.

Through the paper I will use the term "ochre" to describe pigments in general, or I will use the names listed above when describing their different properties through my experiments.

3.2 South-Africa and Centre for Early Sapiens Behaviour (SapienCE)

This Centre of Excellence (CoE), was established in 2017, funded by the Norwegian Research Council, led by Professor Christopher Stuart Henshilwood. The centre has an interdisciplinary approach, and consist of researchers in the fields of archaeology, psychology, and climatology (SapienCE, 2021). The sites of Blombos Cave, Klipdrift Shelter, and with the Klasies River main site are exclusively accessed by SapienCE. The sites are dated to between 120 kya and 50 kya, and the area has a particularly interesting history, with great sensitivity to both regional and global climate change. It therefore makes it ideal to research how the Homo sapiens utilized this environment, and the developing of the behavioural modernity (SapienCE, 2021).

3.2.1 Blombos Cave

One of the primary sites studied as a part of the SapienCE project is Blombos Cave (BBC). This site lies on the southern Cape Coast of South Africa, 300 km east of Cape Town, and holds extensive MSA deposits, including, among other things; bones tools and numerous ochre pieces (Henshilwood et al., 2009, p. 28). The cave lies about 100 metres from today's coastline, 35 metres above sea level, and was first excavated in 1992-1993, with several excavations since (d'Errico and Henshilwood, 2007, p. 144). The MSA levels are separated from the Later Stone Age (LSA) levels by a sterile yellow sand dune, that blew in during a period with lower sea levels, about 70 000 years ago (Henshilwood, 1990, p. 442). The MSA levels are divided into M1 , upper M2 and lower M2, and M3, with M1 typified by Still Bay type lithics, and also containing (among other things) engraved ochre and bone, M2 having bone tools and ochre, and the M3 containing the largest amount of ochre in the entire sequence (Henshilwood et al., 2009, p.28-30). The cave has relatively good preservation of organic material, as the calcrete cave formation, and the matrix are highly alkaline, though the rear wall is seasonally damp, showing more degradation of material near the back of the cave (d'Errico and Henshilwood, 2007, p. 144).

Prior to the turn of the century, a primary theory in archaeology was that the modern human behaviour emerged during the European Upper Palaeolithic. This narrative changed following the increasing amount and complexity seen in the African archaeological record, including material from Blombos Cave.

For this reason, BBC is famous for altering our perception of the cognition of the early modern humans, and it yielded some quite exceptional finds, even for the South African record, including two pieces of ochre engraved with geometrical patterns (found in the M1 level) (Henshilwood et al., 2002). These artefacts can be viewed as a result of symbolic behaviour that pushed the possible date for behaviourally modern humans further back in time than previously thought, to about 70 000 years ago (Henshilwood et al., 2002, p.1279). Anthropogenically modified ochre is found in almost all MSA sites in southern Africa, but their use is thought to have been solely utilitarian (skin protection, hide tanning), or symbolically as a pigment (Henshilwood et al., 2002, p. 1278). No depictional or abstract images has previously been seen until after about 40 000 years ago (Henshilwood et al., 2002, p. 1278), which makes this find especially interesting, as it indicates a level of near modern human cognition.

The terms "symbolism" and "symbolic" in archaeology, when applied to materials, often imply a certain systematic, continuous behaviour, making one solitary find inconclusive as to inferring symbolic behaviour (Henshilwood et al., 2009, p. 28). Further analysis of a number of engraved ochre pieces from BBC, from both M1, M2, and M3, show a possible tradition of geometrical engraving, stretching as far back as 100 000 years ago (Henshilwood et al., 2009, p. 45). The engravings show a continuity spanning over at least 25 000 years and was the longest recorded engraving tradition at the time the paper was written (Henshilwood et al., 2009, p. 45). Using microscopic analysis and comparison to previously known symbolic drawings, Henshilwood and co-authors were able to separate naturally made striations, and use-wear striations stemming from grinding and scraping from deliberate engraving, thereby substantiating the long-lasting tradition of geometrical engraving (Henshilwood et al., 2009, p. 30).

Several highly polished bone pieces are also found in BBC (Henshilwood et al., 2001b). A study of 28 bone pieces found in BBC from about 70 000 years ago, found that a few artefacts interpreted as projectile points might have been polished in its final stage of production; not as a practical technique, but rather to add a symbolic value to the artefact (Henshilwood et al., 2001b, p. 664). The interpretation of symbolic value in the polished appearance of these bone artefacts is directly relevant to the hypothesis posed in this thesis. In a later comment to the original article, they add that the differential treatment to the bones is noteworthy, and hints to a rather complex bone technology (d'Errico and Henshilwood, 2007, p. 165). Though this is not a widely found phenomenon, and general conclusions regarding bone technology in the African MSA cannot be inferred from this alone (d'Errico and Henshilwood, 2007, p. 143). The systematically worked bone material from other MSA sites in South Africa is scarce, but there are other examples of bone artefacts, e.g. in Mumbwa Cave, Broken Hill, and Klasies River (d'Errico and Henshilwood, 2007, p. 143).

Though bone tool material from the African MSA is uncommon, there are several interesting finds in BBC from this period, and d'Errico and Henshilwood (2007, p. 160-161) suggests that the regular use of bone tools, as well as deliberate markings on bone objects can be seen to have a symbolic significance, and put together with engraved ochre, marine-shell beads, and fine made bifacial points, shows a more developed cognitive-behavioural package than previously assumed for the MSA.

In addition to the bone tools and ochre artefacts, the discovery of a 100 000 year old ochre-processing toolkit in BBC provided additional evidence on some of the earliest use of ochre in the South African MSA (Henshilwood et al., 2011). Two different toolkits were discovered, consisting of abalone shells used as containers, percussor/grinding stones, and a red ochre mixture inside the shells (Henshilwood et al., 2011, p. 219-221). The inferred manufacturing process includes producing ochre powder, that was mixed with crushed bone, charcoal, stone chips, quartz grains and liquid inside the shell (Henshilwood et al., 2011, p. 222). Even though red, hematite-rich ochre often seem to be the most dominant type in many archaeological assemblages (Hodgskiss, 2012, p. 100), residue of yellow goethite on one of the grinders was seen underneath the residue of red ochre in the toolkit in BBC (Henshilwood et al., 2011, p. 222), showing that not exclusively red ochre was used.

Blombos Cave is thus a unique site and good backdrop for investigating both early human behaviour, ochre use, and bone tool production in the MSA.

3.3 Additional archaeological traces of ochre, ochre-processing, and polish

Ochre is found as manuports and residues at archaeological sites across the globe, and we find numerous traces of ochre in the Upper Palaeolithic of Europe (Velliky et al., 2021, p. 1-2). Here it was used as a mixture in paint for cave art as well as a residue on personal artefacts and processing tools (Velliky et al., 2021, p. 2). In this chapter I will describe some additional ochre-related finds in both Africa and Europe.

A bone piece found at Klasies River (most likely a tibia of a larger bovid animal), showed a polished appearance, and microscopic traces of red pigment were seen in notches on the bone (d'Errico and Henshilwood, 2007, p. 156). The polished appearance and the red pigments were interpreted as use-wear abrasions in a setting involving repeated activity and contact with other materials during the objects use (d'Errico and Henshilwood, 2007, p. 156). However, given that ochre is useful for polishing various materials, we could also see residues and abrasions like this on a bone tool polished deliberately with ochre, used in order to provide a desired gloss and/or colour.

In an analysis performed by Rosso et. al. (2016), 21 ochre processing artefacts from the Porc-Epic Cave, Dire Dawa, Ethiopia were examined. Using optical microscopy, XRD, μ-Raman spectroscopy, and SEM-EDS analysis of residues, they attempted to identify the use of the artefacts (Rosso et al., 2016, p. 1). They discovered that the grinding stones used to process the ochre consisted of a variety of rock-types, collected over a large geographic area, most likely through exchange with neighbouring groups, or they were picked up as the groups travelled across the land (Rosso et al., 2016, p. 26). Their analysis seem to suggest that larger pieces of ochre was first crushed, to reduce their size, before the smaller pieces were rubbed against a grindstone and abraded into a fine powder (Rosso et al., 2016, p. 26).

Rosso and his team also found that the variations in the rock-types used for grinding would significantly affect the resulting ochre powder, in the sense that the softer grindstones would, when used, release and incorporate a powder into the ochre pigment, diluting and changing the resulting powders colour and consistency (Rosso et al., 2016, p. 27). On the other hand, the harder rock-type would release very little or no extra particles to the pigment powder, giving a different type of powder to work with (Rosso et al., 2016, p. 27). Different types of ochre pigment were also found. This use of various rock-types, various ochre pigments, and the fact that the grindstones are acquired from a wide geographical area, suggests that the production of ochre powder was quite refined, and that different colours, shades, and consistency most likely could be made at will (Rosso et al., 2016, p. 27). This difference in the resulting powders could be due to them being adapted for different uses, as some would be more suited for body paint, and other more suitable for hafting, for example. (Rosso et al., 2016, p. 27).

One example from outside of Africa is found in southwestern Germany, from the Aurignacian period (43-35 000 years ago). Several pieces of personal ornaments made of ivory, from Hohle Fels and Vogelherd caves, were found to have residues of ochre on them (Velliky et al., 2021, p. 1). Many of the ivory beads had been highly polished, with a smooth and glossy surface. Microscopic traces of red colorant on ivory figurines might indicate that ochre was also used in the production of these figurines (Velliky et al., 2021, p. 10).

The beads could also have been in close contact with ochre-covered fabric or suspended on strings stained with ochre after their production and gained their hematite residue from this. While the two are not mutually exclusive, the use-wear and polishing patterns do suggest that the beads were likely polished with hematite-rich clay (Velliky et al., 2021, p.10).

We have similar findings in the French Aurignacian. White (1992, p. 550) describes the production sequence of French Aurignacian basket-shaped beads made from ivory or stone, and establishes hematite as the polishing medium used in the final stages of their production. Seeking to gain a better understanding of the operational chain of the production these types of beads, White used scanning electron microscopy (SEM), to look at the ivory basket-beads in high resolution (White, 1995, p. 38). He found red ochre residue in the striae of the beads, and he concluded that powdered hematite could likely have been used to polish them (White, 1995, p. 38).

P. Walter also observed residue of red hematite while investigating female figurines (Venus Statuettes/Gravettian female figurines), from several site in France (Nivens, 2020, p.100).

While examining remains of paint on these figurines, to look for indicators relating to Palaeolithic body decorations practices, he found striations on them containing red pigment. The red pigment and striations they were found in stood out from the reddish-brown sediment where figurines were buried (Nivens, 2020, p. 100). He was therefore able to distinguish between post-depositional staining from the coloured clay and the intentionally polished-remains by observing the different wear-marks and the locations of the residues. He interpreted the hematite-traces as evidence of the figurines being intentionally polished (Nivens, 2020, p. 100-101).

Ochre residue might have a few different ways to end up on tools and ornament, and the reason behind is also debatable. Residue could appear from the presence of ochre-covered garments or strings that were in frequent contact with the tools and ornaments, like pearls hanging on a string, or the object being in contact with ochre-stained clothing over a longer period (Nivens, 2020, p. 46). We know that ochre was most likely used for several purposes, e.g.: hide work, hafting, and for medicinal purposes like sun protection, pest repellent and wound healing (Lombard, 2005, Nivens, 2020, p. 56, p. 68).

It has also been questioned whether ochre and bone tools could be a part of a tattoo tradition (Deter-Wolf et al., 2017, p. 145). In Southern France, several fine bone needles have been found, together with ochre pigments, raising the question of whether tattooing was practised in Palaeolithic Europe (Deter-Wolf et al., 2017, p. 145). In Pietrele, Romania there has also been found possible tattooing kits from around 4500-4200 BCE (Deter-Wolf et al., 2017, p. 145). Bone and antler was found in large quantities, and consisted of tools, weapons, and ornaments among other things, including fine awls and pins that display superficial grooves containing red or white pigment (Deter-Wolf et al., 2017, p. 146). Several needles found together, possible originally bundled together with a string, and with traces of ochre along the edges, have also received a possible interpretation as a multipoint tool, that could have been used for tattooing (Deter-Wolf et al., 2017, p. 146). However, interpretations are difficult to substantiate, and other hypotheses of use and function also exist (Deter-Wolf et al., 2017, p. 148).

In Papua New Guinea and the Solomon Islands, handheld tools of obsidian were found in association with charcoal and ochre pigments, and could be interpreted as tools for piercing skin (Deter-Wolf et al., 2017, p. 159). Additionally, in the Orenburg region of Russia, a few different pigments thought to be used as tattoo pigments were found in burial contexts. These materials were both red and yellow ochre, and along with charcoal were found in association with mixing palettes and in leather pouches, as well as in a horse tooth receptacle, indicating that their tattoos might have been in various colours (Deter-Wolf et al., 2017, p. 228). It must be noted however that ochre-based tattooing has not yet been conclusively confirmed, as all ancient human remains found so far with tattoos have proved to be made with soot or charcoal, and no evidence exists in modern indigenous practice for ochre-based ink in tattoos (Deter-Wolf et al., 2017, p. 244). Yet, this cannot be ruled out, and it potentially ads another way for ochre to end up as residue on osseous artefacts.

If then the residues we see on stone tools, ivory objects, pearls, and other tools and ornaments are the result of deliberate processing/polishing, was this process solely for practical reasons, like the gloss and lustre it can bring to the objects, or was it also for symbolic reasons relating to the colour amongst other things? If so, was the same type of treatment applied to both bone tools and other artefacts?

Though these questions cannot be answered using experiments alone, the question the efficacy of the ochres as a polishing material can be tested directly. Experiments have been performed to help gain a better understanding of the ochre pigments found around and on archaeological material, and this thesis aims to contribute to this body of knowledge by testing ochre as a polishing agent on bone.

3.4 Previous experimental findings

Though there are currently no known experiments on ochre as a polishing agent for *bone* tools, there are several looking on polishing other materials with ochre, such as: ivory, stone, and antler (Nivens, 2020, p. 96-98, p. 104). Though the materials are different, these studies can serve as references and for comparison. The background and research questions asked in these studies vary from my own, but the experimental methods, tools, and results are partially transferable. Furthermore, it can be helpful to draw parallels between the studies.

R. White did experiments to better understand the red residues he had found on the Aurignacian basket-shaped ivory beads, as well as using powdered hematite to polish Aurignacian blades of Bergerac flint (White, 1995, p. 38). He used a limestone grinding stone, and water as a binding agent. In his experience with polish on mammoth ivory using fat as a binding agent, he found there was quite a bit of staining using this method. He therefore observed that water was a more likely binding agent as this type of staining was not found on the original Aurignacian beads (White, 1995, p. 38). He demonstrated that his results with the flint blades was comparable to the ivory beads, as similar microscopic streaks and residues were seen on both the blades and the beads. Thus he concluded that hematite powder very likely could have been used as a polishing medium (White, 1995).

For her doctoral thesis, Nivens (2020) also did experiments making and polishing lignite and steatite beads, as well as comparing polishing times and effectiveness using different polishing powders (Nivens, 2020, p. 104-105). Using naturally sourced geological samples, water, and a textile cloth for the polishing process, she found that hematite-rich powders were significantly more effective than the goethite powders in both time and effectiveness (Nivens, 2020, p. 115). She also found that the coarser grained powders were more efficient on the lignite beads than the finer grained powders, having nearly half the polishing time with the powders with larger grain size (Nivens, 2020, p. 114-116). She found that using pure sand was less effective than the hematite-rich samples, and together with grain size, concluded that hematite content was the most important factor when polishing the lignite beads (Nivens, 2020, p. 115).

P. Walter also describes an experiment performed by Rodière, where wet hide coated with hematite powders was used to polish a fragment of elephant ivory, for about half an hour (Nivens, 2020, p.96). The results equalled those of R. White (1995) and showed both red residues and micro-striations from the hematite polish (Nivens, 2020, p. 96). Rodière also communicated that this technique would be for correcting imperfections, rather than the initial shaping of an object (Nivens, 2020, p. 96). These sources are not first-hand, and should not be treated as such, but their results are in line with other experiments, showing that ochre could be useful for polishing various materials, and was most likely used in the final stage of polishing objects and not for shaping them.

In the area of bone polishing experiments, there are far fewer examples. J. P. Reynard (2014) conducted a trampling experiment to look at the surface of faunal remains that have been left in coastal environments, leading to water exposure and trampling effects (Reynard, 2014). His goal was to shed light on taphonomic processes on worked bone from the African MSA, looking at both their polished appearance, and cut marks (Reynard, 2014, p. 157). He recreated conditions of trampling, using bones treated in various ways: boiled, grilled, burnt on open fire, then left the bones out for 2 months to be exposed to the elements and be manually trampled by Reynard and his colleagues (Reynard, 2014, p. 158).

They then looked at the resulting shine, lines and grooves, and found that though trampled bone could mimic intentionally polished bone, there are often specific pitting-marks and signature patterns on the trampled bones, that are highly distinctive of bones being trampled, making it possible to distinguish between these types of bone with closer examination (Reynard, 2014, p. 168).

In other relevant experimental studies, we find an example of surface roughness evaluation and gloss congruency. Previously, roughness values were used to evaluate the surfaces of tools and personal ornaments, but it might not always be useful for measuring gloss, which can be an important factor. Bradfield (2020, p. 1) did a series of experiments looking at the relationship between surface roughness and gloss, and developed techniques for describing modified bone surfaces. Bradfield looked at surface roughness values and measured gloss. Using a Glossmeter he measured the gloss on a variety of archaeological bone tools as well as several experimental modern-made bone tools, in order to determine if there was a congruence between the two (Bradfield, 2020, p. 1). He used leather, skin, plant material (soft materials), bone, tree and metal (hard materials) to polish the experimental bone pieces for 30 minutes, and compared the results (Bradfield, 2020, p. 3).

He found that there was some correlation between surface roughness and gloss. The gloss tended to decrease as the roughness increased, but there was no direct correlation and the contact mediums used for polishing seemed to be a contributing factor (Bradfield, 2020, p. 3). He observed that the softer mediums (like leather, skin and plant material) gave a higher gloss than the harder (like bone, tree and metal), but looking at just each of the categories (hard vs. soft), the result reverses: the softest material in the soft group gave less gloss than the hardest of the soft, and the hardest of the hard group gave the most gloss in this group (Bradfield, 2020, p. 3). Neither the experimental bones, or the archaeological tools showed strong correlation between surface roughness and gloss, but it did seem to be a connection between polishing medium and gloss (Bradfield, 2020, p. 3).

None of the above-listed experiment look at ochre pigments used for polishing bones, and so far, I have not come across any experiments testing this specific scenario. This experiment therefore gives important supplementary information regarding the possible uses of ochre, and whether ochre residue on bone-tools might have conceivably ended up there because of a deliberate polishing process. And as I have previously stated, the use of yellow ochre seems to be an understudied area as well.

4. Theoretical approach

Similar to the theoretical approach outlined by Nivens (2020, p. 11), the term “paleo-ethnography” is also relevant to this project. Paleo-ethnography attempts to understand past societies by using their choice in material, tools, and techniques as a background for interpreting past behaviour. This is also closely related to the chaîne opératoire methodology, where the recreation and understanding of ancient technology through specific operational chains can help gain an understanding of ancient societies. Looking through the eyes of the maker of an object and trying to explain their choices along the way of creation can give useful insights.

This can also be a very subjective undertaking, and it is important to remember that this is not a purely scientific method that provides exclusively verifiable results. Rather, this is more of a comparative approach, and the end results could vary based on individual differences in understanding of material and process. There can still be much valuable insight gained from investigating the results of these methods, as is my intention with this project: exploring how to efficiently polish bone tools and understand marks and residues produced on tools made in similar fashion as those in South African MSA help provide valuable references and comparatives when studying material from the archaeological record.

4.1 Materiality and technological styles

Materiality is a concept that expresses how different natural materials and our interaction with them is a part of shaping social personae, and gives a cultural value to the repeated use and manufacture of objects (Martinón-Torres, 2015, p.5). This implies that different sensorial aspects of the interaction with material objects can affect how technologies are produced and valued, along with the solely practical choices.

Materiality is not only about an object or artefact, but about the physical world around us, and how we interact with it, and it with us; it’s a dynamic process (Knappett, 2014, p.4702).

For certain technologies, f. ex. clay ceramics and metal technology, it has been shown that the processes are not merely functional, but also extended in order to create an increased sensuous connection with the material, through shape, texture, colour and sound (Martinón-Torres, 2015, p.5). It follows that the symbolic aspect of ochre use could also possibly be an interactive type of experience, the act of using it could be important, not just the colour imbued, or the resulting artwork.

The term *technological choices* comes from the concept of the chaîne opératoire that arrived in the 1950s, and later, in 1977, Heather Lechtman used the term *technological style* in several studies on archaeometallurgical analysis (Martinón-Torres, 2015, p. 9).

These two terms are thought to effectively have the same implication, that there is typically more than one technology that can meet a specific need or desire, and that the resulting choice reflects social preference, and not necessarily better function (Martinón-Torres, 2015, p.6). A great example is presented in the book *Ceramic Masterpieces* (Kingery and Vandiver 1986), were we see how remarkably different the Chinese and European ceramics have developed in terms of both raw material, processing, scale of production and aesthetic preference. Working on recreating ancient technologies we must reconstruct the chaîne opératoire, as well as explain the choices within the appropriate sociocultural background (Martinón-Torres, 2015, p. 9).

By using experimental archaeology or known qualities of production techniques, we can use the different traits and "performance characteristics" of various methods to put together a "performance matrix", allowing us to compare the different technologies and their advantages to each other (Martinón-Torres, 2015, p.7). I will be using a variant of these performance matrixes in my evaluations with comparing colour, gloss, and microscopic appearance.

The further back in time we move, the harder the sociocultural context will be to understand, and so the technological choices have more uncertainty to them. Technological choices and development of techniques don't *always* seem to move in the logical evolutional direction, and varies with cultural impact, but according to Martinón-Torres (2015, p. 8) new technology has often simply been developed because it is superior to the old. Sometimes the simple answer is the right one, and change is seen because of development of a better functioning object. Superiority is not a straightforward concept though, and what makes an object superior to another, could have great variations across time and space.

The study of materiality, among other things, includes the study of the people-thing interaction from creation to discard, or studying the processes of deposition and disintegration, the end-life of artefacts (Knappett, 2014, p.4706).

4.2 Gloss-perception and the human brain development

"Gloss may be defined as the specular reflectance of a surface" (Bradfield, 2020, p.2). Quite a few ancient tools and ornaments are found to be polished, and while certain taphonomic processes might add a certain polish as the objects lie in the ground, there is also strong evidence that shows that many tools and ornaments were polished by the people making them (Bradfield, 2020, p. 1). As previously stated, polish, micro-striations, and use-wear on tools might appear as the result of use or from part of the production process, but some tools were most likely also deliberately polished in order to produce gloss. While polish might prolong the life of a tool, and therefore be a practical application (Bradfield, 2020, p. 1) in some instances the tools show polish in such a degree that the gloss would likely have added a symbolic value in and of itself. This appearance would most likely have added a symbolic aspect to either the *act* of polishing, or polished tools could also have been deemed more attractive due to their gloss and smoothness (Bradfield, 2020, p. 1).

As previously stated, there are several ways to describe gloss, in terms of f. ex surface roughness properties, but it also important to remember that the people in the past would base their view of the tools solely on their appearance and palpable feel (Bradfield, 2020, p. 1).

The ability to perceive gloss developed in an area of the brain called the temporal sulcus region. Here, we find the development of many important social skills, such as stimuli response and understanding (e.g., speech, gestures, and facial expressions). The development of language is also connected to this region of the brain, which is important for people being able to create and communicate technological choices. A nearby region of the brain, the praecuneus, is also responsible for several cognitive adaptations (Bradfield, 2020, p. 4-5). This makes it valuable to study polished objects, as finding evidence that objects might have been deliberately polished can potentially tell us about brain development in the early modern humans that produced and used the objects.

Understanding development of tool making traditions, along with what is considered symbolic behaviour, can help gain understanding to the development of the modern humans. Ultimately, the results of this project can be used as a supplemental database, to understand human behaviour starting with the production and use of artefacts, which can then be put into a wider conceptual framework to understand the social and evolutionary processes.

5. Methodology and experiment outlay

5.1 Experimental archaeology

In our attempts to understand materials in the archaeological record, it can often be useful to try to recreate the tools and objects that we find. Understanding the processes and choices behind the creation of an object can potentially inform us about those who made those items, and the world they lived in. Asking questions about choices can be a useful tool. Are the choices always made by functional criteria, or are there elements that cannot be explained by empirical reason alone? Was a tool simply created for a certain function, or for a symbolic or decorative purpose? Or was the tool-creation process in and of itself the most important aspect?

Experimental archaeology has a long history in the field of archaeological research and has been used as a means to understand the material culture in the lives of ancient peoples. The exact role and definition of experimental archaeology has varied over the years, changing along with the authors own perspectives, and the theoretical approaches that dominate the field at different times (Souyoudzoglou-Haywood and O'Sullivan, 2019, p. 1).

Archaeological experiments can take many forms and vary from sterile and precise operations performed in a laboratory, to the more experience-based tests made outside in the open air, with more changing variables, but closer to real experience. In recent years the latter method of performing experiments has gained more attention, as it has been questioned whether the "too scientific"-method might miss details that a more holistic and interdisciplinary approach might capture in a better way (Souyoudzoglou-Haywood and O'Sullivan, 2019, p. 1). We could miss important elements concerning the overall experience of a building, an object, or a course of action, and therefore not understand the processes in the same way they were understood in the past (Souyoudzoglou-Haywood and O'Sullivan, 2019, p. 1).

What could also be useful is the knowledge of modern-day craftspeople, who have expertise of a variety in crafting techniques that could compliment the information drawn from archaeological evidence (Souyoudzoglou-Haywood and O'Sullivan, 2019, p. 2-3). Having this kind of knowledge and understanding of materials and technique is not something that is always commonplace in general archaeological research, and an interdisciplinary approach would be highly useful. However, modern craftspeople are just as much a part of the modern world as archaeologists, and their skill is therefore biased by the needs and tradition of their time and society, which must always be considered (Souyoudzoglou-Haywood and O'Sullivan, 2019, p. 3).

My own experiments are more towards the "sterile-laboratory" end of the spectrum and might mean that a lot of factors are missing from my equations as to how and why choices were made when polishing a bone tool in the MSA. Sitting in a "vacuum" in a laboratory working alone, would be quite far from the original chaîne opératoire. One could imagine a group of people sitting around a fire, telling stories, learning from each other, and exchanging skill, which is far from my own experience in this experiment. I do also lack the crafting knowledge I spoke of, having no previous experience with any of the materials I worked with. Speaking with- or working with, someone with some expertise on the area could have been quite useful but was unfortunately not something I was able to do during this experiment. However, as previously stated, this may have also biased my initial experiments, so perhaps conducting further experiments with more material knowledge might provide an interesting comparison to the ones I conducted here.

Still, we can make assumptions as to approaches to polishing, material-types used, and through the variables of my experiments (different binding agents, bone-types, ochre types), I could produce useful data to further understand the processes behind this type of ochre-stained tools and objects.

As previously stated, though ochre might have ended up on tools in various ways, previous experiments have shown that hematite grains are effective and was most likely used in the polishing of various personal ornaments, like ivory beads and objects made of antler. It was probably used as a final polishing, after the objects had already been shaped with other methods. The results of this experiment will provide additional data for determining the efficacy of ochre as a polishing medium on bone.

5.2 Experiment outlay

All materials are meant to replicate the South African assemblage as closely as possible. The ochre that was used was collected from ochre sources in the southern coastal region of the Western Cape province in South Africa and the bones used was of similar animals as the types found in MSA-context. The different ochre types that used were chosen to represent different properties found in the various types of pigments. I used indurated hematic shale (a hard, fine pigment), friable shale (soft, fine), ferruginous sandstone (medium, coarse) and yellow ochre (soft, fine). Shell sand was used as a neutral agent without colour, to have a control group to the ochre-polished bones. Shell sand also mimic the sediments of BBC, making it useful for comparison with the ochres.

Indurated hematic shale	Friable shale	Ferruginous sandstone	Yellow ochre	Shell sand
				

Figure 1. Pictures of the ochres used in the experiment

The bones were chosen in order to have a varied selection, and which could represent the raw materials used in the MSA. Most MSA bone-tools from BBC from were primarily long bones from bovids, especially metapodials (Henshilwood et al., 2001b, p. 644). Modern sheep bones would probably be of the closest available to me, to the types of animals that were used in the MSA. I chose to use the femur of sheep as these are the most similar bones to those that were used in the MSA that are available in Norway. They also have larger surfaces, they are bigger than metapodials, and give a clear visual impression of the gloss and colour. With the old bones I had to use what I found, as they were not so easily available.

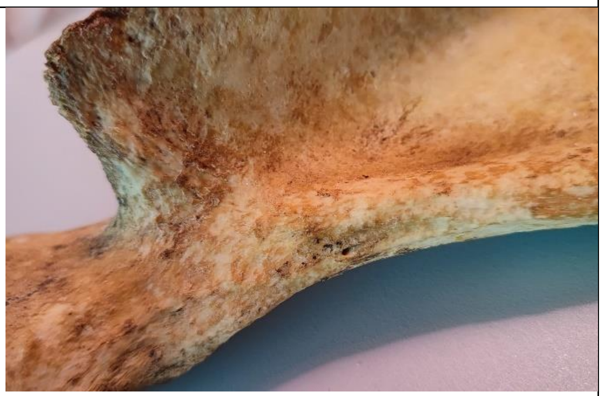
Fresh bone	Old bone
	

Figure 2. Picture of fresh and old bone

Fresh, heat-treated, and old bones could have been used in toolmaking, and they likely all react differently to the polishing process. Therefore, I include these types of bones in my experiment. Fresh bones, femurs, were acquired from a butcher, these were from relatively young animals. Acquiring old, weathered bones proved more difficult than acquiring fresh bones, so the selection was more limited. I therefore used femurs, humeri, and mandibles for the old bones. These bones had been discarded and buried superficially in the top layer of soil for about 3-5 years. Judging by size of the bones and a visibly separated epiphysis plate I assume it was a young animal, most likely not fully grown (O'Connor, 2008, p. 92), placing it in the same age group as the animals in my “fresh bone”-group.

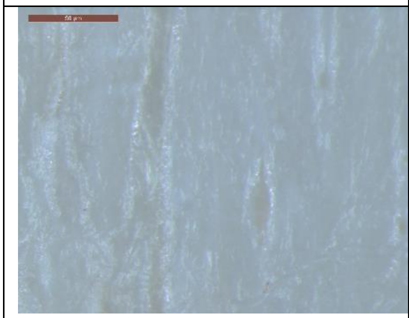
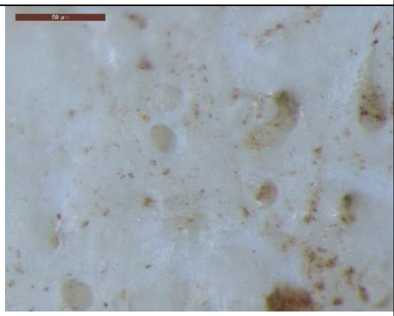
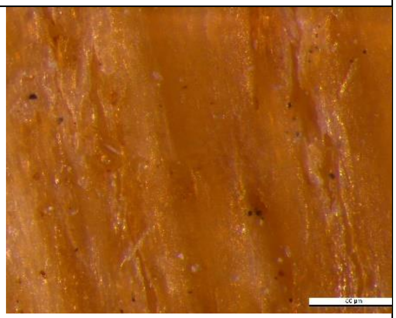
Microscopic picture of fresh raw bone	Cooked bone	Old bone
		

Figure 3. Microscopic images of the unpolished bones

I chose leather as a polishing medium as animal hides were available and likely used in the MSA. The texture of leather, though it might be more irregular and bring a more variable factor to the experiments (than a fine cloth, for example) I believe is more in line with the possible the MSA-chaîne opératoire. The leather was purchased at a hobby store, labelled “tanned animal leather”.

The ochre powder, leather, and an un-polished bone piece


Figure 4. Illustration of equipment used

As for the binding agents, both water and animal fat were likely used for tool polishing, and it would therefore be useful to test and see if they bring any significant variations to the experiment. Other materials were also likely used, such as clay, but this was not included as I had to limit the variables in my experiments. I also polished bones using only the dry ochre-powder on the leather. The pigment powders and binding agents might have consisted of several other elements as well, like quartz, charcoal and crushed bone for example (Henshilwood et al., 2011, p. 222), but as stated, variables like these would have to be limited to create a manageable experiment.

Table 1 shows all the bones and their different treatments, and their individual number listed in the column to the far left:

No. on bone	Raw	Boiled	Old	Ochre 1	Ochre 2	Ochre 3	Ochre 4	Shell sand	Water	Dry	Fat
1.	✓			✓					✓		
2.	✓			✓						✓	
3.	✓			✓							✓
4.	✓				✓				✓		
5.	✓				✓					✓	
6.	✓				✓						✓
7.	✓					✓			✓		
8.	✓					✓				✓	
9.	✓					✓					✓
10.	✓						✓		✓		
11.	✓						✓			✓	
12.	✓						✓				✓
13.		✓		✓					✓		
14.		✓		✓						✓	
15.		✓		✓							✓
16.		✓			✓				✓		
17.		✓			✓					✓	
18.		✓			✓						✓
19.		✓				✓			✓		
20.		✓				✓				✓	
21.		✓				✓					✓
22.		✓					✓		✓		
23.		✓					✓			✓	
24.		✓					✓				✓
25.			✓	✓					✓		
26.			✓	✓						✓	
27.			✓	✓							✓
28.			✓		✓				✓		
29.			✓		✓					✓	
30.			✓		✓						✓
31.			✓			✓			✓		
32.			✓			✓				✓	
33.			✓			✓					✓
34.			✓				✓		✓		

35.			✓				✓			✓	
36.			✓				✓				✓
37.	✓							✓	✓		
38.	✓							✓		✓	
39.	✓							✓			✓
40.		✓						✓	✓		
41.		✓						✓		✓	
42.		✓						✓			✓
43.			✓					✓	✓		
44.			✓					✓		✓	
45.			✓					✓			✓

Table 1. Overview of all bones and how they were treated

5.3 Equipment

Overview of the different bones, ochres and tools used in this experiment:

Ochre/control medium	**Binders**	**Bones – sheep**	**Polishing**	**Other**
Indurated hematic shale (hard, fine grained) (IHS)	Water	Fresh bones 15 pcs	Leather	Mortar/pestle for crushing ochre
Friable shale (soft, fine grained) (FSH)	Animal fat	Cooked bones 15 pcs		Cooking pot for boiling
Ferruginous sandstone (medium, coarse grained) (FSS)	Dry	Old bones 15 pcs		Brush for cleaning bones
Yellow ochre (soft, fine grained) (YO)				Saw for splitting bones
Shell sand				Optical microscope

Table 2. All equipment and tools used in the experiment

Most of the tools and equipment were common, easily obtained items. The optical microscope I was given access to by the University of Bergen, in the archaeology dry lab at AHKR. I used a Leica M205 A stereomicroscope, with a 20.5:1 zoom. The ochre was given to me by my MA-supervisor Elisabeth Velliky who collected it in South Africa.

Fat was acquired from the grocery store, where I was able to buy pure pigs fat with no additives. As mentioned, the fresh bones came from a butcher, while the old bones came from a sheep farm.

I created a database and gave each bone a unique number, to track the changes in the different methods. Each bone was labelled with permanent ink on an even place on the surface, near the end of the bone, so it would not disturb the polishing area.

Photos were taken of the surface of the different bone types using optical microscopy before and after the experiment.

5.4 Experimental process

One piece of long bone was split into several pieces, using a small saw. The old bones needed little treatment before the experiment, only a little cleaning to remove dirt. The fresh bones needed to be cleaned for remaining tissue. This was done using water and a soft nail brush, and proved to be quite time-consuming, as I was trying to impact the surfaces of the bones as little as possible, while still getting all the tissue off it. The heat-treated bones were boiled before polishing, this made the removal of meat and tissue easier than on the raw bones. Though processing in the MSA most likely consisted of roasting/grilling, likely in an open fire pit, I found that boiling the bones were the most efficient way for me to replicate processed, heat-treated bones for this experiment. I cooked the bones for about 1 hour on low heat, in order to replicate bones that had been exposed to heat from food preparation and cooking of meat.

Ochre was crushed to a powder using a mortar and pestle until it was fine enough to create a useable pigment, to a consistency like dust, or flour. It was then mixed with water/animal fat, until it was wet enough to create a workable paste, that could stick on the leather. The ochre-slurry was then be applied to a piece of leather and the bones were polished by hand. Some bones were also polished using dry ochre-powder without any water or fat added, just the pigment powder on the leather. I made sure there was a constant layer of ochre/ochre -slurry between the bone and the leather. I found that using the rougher side of the leather towards the bone made the most sense, as it could give a better "grip" for the ochre-slurry, and perhaps have a more abrasive property to help with the polishing. All bones that used in the experiment were polished with the rough side of the leather towards the bone. I held the bones in one hand and then polished them by applying the leather and slurry onto the bone with the other hand, using a quick back-and-forth motion along the length of the bones.

Slurry/ powder would have to be re-applied to the leather several times during the polishing time to keep the leather with pigment, or to have enough powder to polish with. I used the mortar with the ground up powder as a container with spare powder/slurry, to collect it as it fell of the leather, and had a glass of water/ spare fat nearby to keep mixing in when it became dry, all the while trying to keep a relatively constant amount of ochre in the polishing process. The amount of pigment used throughout the experiment was: IHS: 20,8 grams, FSH: 21,9 grams, FSS: 17,5 grams, YO: 15,4 grams. The amounts used were not decided beforehand but were simply what was needed in order to polish all of the bones. The waste was minimal during the experiment, as I used the remains of the dry powder for my experiments with water, and later the left-over pigments from my water experiments were used for my experiments with fat, so the amounts used quite realistically represent the amount of pigment I required for this number of bones.

Based on previous experiments on antlers and beads (Nivens, 2020, p. 96) , as well as a few tests I did myself, I decided to set the polishing time for 30 minutes and then compare the results of the different methods and material with this polishing time as a baseline. Another choice would have been to keep polishing until the bones were considered glossy enough, and then record used time, comparing the time needed with the different bones and variables. However, during my preliminary testing, I found that perhaps not all methods would be able to give the desired gloss or would require a very long polishing time. Therefore, I chose to have a set time and see how the results would differ after the bones had been polished for the same amount of time. I used a timer set to 30 minutes to use exactly the same time on all my bone pieces.

5.5 Analytical methods

In this chapter I describe certain analytical tools that are relevant to evaluating the results of my experiment.

5.5.1 Use-wear tracing

Use-wear analysis can be a great tool to explore how ancient tools were made and used. The main concept is that all contact between materials will lead to traces and changes in the two materials, and by studying reappearing patterns in these traces we can make theories about the objects processing and use (Bradfield, 2015, p. 3).

When it comes to the use-wear traces on archaeological bone tools, there are four main processes involved in their creation: abrasion, fatigue, adhesion, and chemical (Bradfield, 2015, p. 3). Abrasive wear can be made through working the material, such as through polishing, and is the result of frictional contact between two materials (Bradfield, 2015, p. 3). Fatigue is a form of wear that presents when a tool is put under structural strain, such as contact with other materials or use of the object. Fatigue either from the use a tool, or straining from taphonomic processes, causes micro-cracks and might eventually lead to fracture of the tool (Bradfield, 2015, p. 3). Adhesive wear, like abrasive wear, stems from frictional wear between two surfaces, but in this instance leads to material from one object being transferred to the other (Bradfield, 2015, p. 3). Chemical wear on bones comes from contact with other substances that lead to a change in the tools surface as a result of chemical action, which can arise from contact with skin, organic enzymes, and other acidic elements, to name a few (Bradfield, 2015). This type of wear often mainly occurs in a post-depositional environment (Bradfield, 2015, p. 3).

5.5.2 Surface analysis

In order to analyse residues on bones and tools found in the archaeological record, there are a few different methods, some more invasive than others. Chemical, chromometric and immunological methods, though perhaps the most accurate, all involve extracting residue from the surface of the object and will therefore cause the context to be lost, as well as the opportunity to future analysis (Bradfield, 2015, p. 8). On the other hand, morphological analysis, which non-invasively studies the shapes and structures, is more conservative, and will allow for further analysis on archaeological finds (Bradfield, 2015, p. 8).

5.5.3 Gloss

Describing gloss can be done qualitatively, by describing extent, distribution, texture, and brightness, or by using the more quantitative measurements of surface roughness values. Gloss can be accurately measured in Gloss unit (Gu), by using a glossmeter (Bradfield, 2020, p.1-2). Surface roughness measurement have often been used to describe the surface of objects, but gloss (Gu) might be more suitable when talking about polished surfaces. There have been found to be quite similar results when using descriptive methods and surface roughness measurements (Bradfield, 2020, p. 1-3).

The overall gloss and reflectiveness of the surface of at tool require an evaluation of a larger area, which is something that is lost when looking at surface roughness, as it mostly only sees a very small area of a tools surface (about 20-100 μm2) (Bradfield, 2020, p.2).

5.6 Evaluating my results

I use morphological analysis for my experimental design, using a microscope to look at the micro-traces and residues, as well as macroscopic evaluation of the gloss and colour of the bones. I took microscopic pictures on different zoom settings, to evaluate the texture in different microscopic levels, and in my final comparison of the bones I use the closest magnification, a 983x visual zoom magnification, to assess the microscopic texture.

Visual zoom magnification

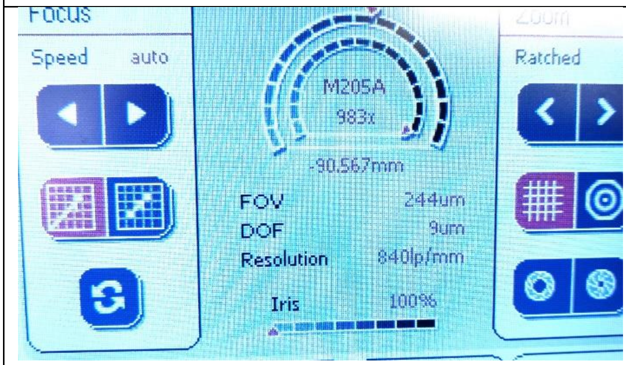


Figure 5. Microscope zoom setting

All microscopic pictures used in comparing my results was taken with this same magnification. When using the microscope, I looked at different parts of the polished area, but the pictures I chose to use in my evaluation were taken from the approximate centre of the polished area, in a section I considered representative of the bone in general. This is a relatively subjective factor that must be considered in the results, as there could be many different textures on the same bone, and it is a judgement call as to what should be considered descriptive for the entire bone.

In this experiment I mainly came across abrasive and adhesive wear. Through polishing the bones and the use of ochre, friction occurs, and the ochre leaves residue on the bones. In the archaeological record the tools we come across will most likely also have varying degrees of fatigue from their use, and chemical wear that can differ based on their post-depositional circumstances. This must be considered if one compares these types of experiments with prehistoric tools.

My evaluation of the effectiveness of the polish will focus on these variables:

- Gloss. Qualitatively described based on macroscopic shine and brightness.
- Textural differences and similarities as seen with optical microscope and compared macroscopically.
- Colour/hue added by the ochre/shell sand.

- How efficient the process was in terms of achieving gloss and/or colour, and ease of the overall process.

I will not use a glossmeter, but I will give a descriptive evaluation of perceived gloss. The way an object is perceived in a macroscopic point of view is how it would have been perceived and assessed in the MSA.

I will score each bone on a devised scale of 0-5 on each of the criteria (gloss, microscopic texture and colour), where 0 is the least glossy/ least finely textured under a microscope/ least amount of colour, and 5 is the highest value for these conditions. The scoring will be my evaluation of these bones, comparison of efficacy being exclusively within my own experiment, placing the bones on the scales relative to each other.

Many of the bones are fragments of femurs, while the old bones are from various parts of the animal, which could impact the result when considering gloss and texture, as well as the possible chemical impacts and other processes that may have affected the old bones over the years they were abandoned and buried.

The microscopic images compliment the macroscopic analysis by showing a close-up of what the various colours and textures looks like on a microscopic level, and how the bone structure of the different types of bones is affected by the treatment and polishing. Looking at the microscopic textures will help answer my additional questions posed in this thesis using a more comprehensive approach and could also give valuable information as to how bones found in the archaeological record might have been similarly treated based on their microscopic traces.

Using performance matrixes, I have evaluated the different criteria I have chosen to assess. These diagrams use an x and a y axis which each represent two different qualities of an object (microscopic texture vs. gloss for example). This will help to identify correlations between the characteristics of the different bones, and to visualise the correlation between gloss and colour, or gloss and microscopic texture. Correlations will be evident from how close the bones are to the middle/diagonal line of the diagrams. This will also help to visualise any differences between the fresh, heat-treated, and old bones, and between those polished with fat, water, or dry ochre, as these qualities also are visible in the diagrams. This will form a significant part of the foundation for answering the questions I have asked in this thesis.

My evaluation is also be based on the whole process of polishing a bone, from grinding of the ochre, to finished product, using the various methods, and seeing what is most practical. Some factors might have had a larger impact on the process than others, and the results will be compared to identify what specific technique is best to obtain a certain outcome (e.g., which binding medium gives the fastest result, or which ochre provides more gloss). Of course, this circumvents all social and symbolic aspects of a manufacturing process, which also could have had an impact on the techniques and processing, as tradition or beliefs could easily influence the chaîne opératoire in toolmaking. However, these aspects cannot be tested within the scope of this thesis and will thus not be included.

5.7 Explaining choices and limitations

In the planning and execution of this project there were several choices to make to arrive at a result that could best answer my questions; but there were also choices of limitation and practicality. An example of this is the scale and sample size. Preferably, one would have several pieces of bone polished in the same way, in order to look for patterns that reoccur when using the same methods. This would help establish consistency and rule out random artefacts. This is project is, however, limited in time and resources, and choices of limitations had to be made, and so the focus became a more comparative experiment with several different factors to evaluate. The small sample size and the representability of the experiment must be considered when assessing the results.

The person executing the polishing also plays a significant role in determining the results, as my actions will be different from another and might result in a different outcome. There is always a subjective component whit experimental archaeology, and the most effective method is determined by a variety of factors that cannot be known until actively conducting the experiment, and these methods might differ significantly from the ones that were used in the MSA. I did a few preliminary tests and polished a couple of bones before starting the actual experiment, to get a feel for the materials and the process, but the subjectivity is something that must be considered with the final interpretation, especially if one were to compare aspects of this experiment to actual archaeological material.

The choice of ochre-types gave different coloured mineral, as well as both fine/courser and harder/softer types, and in this way get some varying and comparable results, but there are of course many types of coloured mineral that could have been used, and this is just a small selection. And as mentioned, several other materials might have been added to the mix, that would give varying properties to the polishing paste and affect the result.

My diagrams and result reviews are based on my own subjective comparison of the bones, and not objectively measured data, which also leaves room for misinterpretation. However, by using scores for gloss and colour on each individual bone compared to each other, and putting the results in diagrams for comparison, this does provide significant and usable data.

There are many aspects that could not be replicated exactly to their past counterparts with this experiment, which can restrict analogies to the past. However, at the same time I think it is important to remember that our physical world is still more or less the same, with the same laws of physics. We are still “modern humans” who might have very similar thought processes, feelings, and reasoning. This does in no way make up for the vast distance of time, space, and cultural difference, but some analogical parallels could still be relatively plausible. Our understanding of the past can only be developed as we keep discovering and elaborating data, which makes any results valuable in these discussions, whether to exclude, or include new explanations and hypotheses.

6. Results and observations

The results here entail both my description of the various processes and how they varied, as well as the data produced from my assessment of colour and gloss, and performance matrixes I have produced to better visualise the different components at play. Comparing microscopic and macroscopic properties has been an important part of the project, and I will use images from the microscopic as well as the macroscopic results, to discuss my results. The performance matrixes help visualising my results. These diagrams compare two different qualities of the bones in a graphic representation using an x and y axis for each quality and then placing the item along these two axes.

Figure 6 shows various pictures of the type of bones used before any treatment was applied.

Pictures above show microscopic images. from the left: raw untreated bone, cooked untreated bone, and old untreated bone. Below are some macroscopic close-ups, from the left: raw untreated bone, cooked untreated bone, and an old untreated bone.

Figure 6. Unpolished bones

The variation between the fresh bones is not very pronounced, but the older bones are very visibly different in surface roughness, and macroscopically discoloured.

6.1 Personal observations on the ochres, the materials used, their properties, and the polishing process

The various ochres all had a distinct "feel" when working with them, making the experience of polishing slightly different each time. Going from the IHS to the FSH, I noticed a big difference in both preparation and execution. The FSH was easier to crush into a fine powder, but the fine texture also meant that it was harder to make it stick on the leather when using it dry. The overall experience was that I had to work a lot harder to use this pigment dry, it was slower to give a polished look, and gave less colour to the bone than the IHS. The IHS was giving rather a lot of colour on the other hand, and the pigments harder properties gave it more grip, even used dry. The IHS gave both a high rate of colour and gloss, depending on bone type and polish method.

The FSS was easy to crush to a fine powder, much like the FSH, but in the end, it was coarser than both previous shale ochres, giving a good grip when using it dry with the leather. I could see that the gloss came quite quickly when polishing with this ochre and water/fat, and it felt slightly more efficient than the two previous ochres.

The YO stood out as both very easily crushed to a fine powder and very efficient for making the bones glossy. The gloss came after a few minutes, and by 30 minutes it was highly smooth and glossy. These results are interesting as I found both one of the coarsest, and the finest pigment to be most effective for quick results. Perhaps further experiments would show a different result, but through using these pigments both dry, and with water and fat, I found the same results in my experiment.

The YO was also the pigment with weakest colour, as it was quite yellow and pale, and as it was so efficient, the colour was mostly washed away by the end when using water or fat. Using it dry, and/or stopping ahead of my time limit, however, does give some colour. This goes for all the ochres, polishing for a shorter amount of time would leave more colour on the bones, most likely as the coarser texture of the bone leaves more grooves for the colour to adhere to.

There were pronounced differences in the process when using the ochres and shell sand dry, or with fat/water. Using the ochre dry was simple enough, very little mess, not requiring any equipment other than something to crush the pigment with, and leather/cloth to polish with. The polishing-process was a little more frustrating, in the sense that the pigment did not have a good “grip” to the leather, and I had to keep reapplying the powder to the leather very often, as it kept falling off, in order to have ochre powder between the leather and the bone.

Polishing with water did require some more playing around with solutions. I had to have a container with me with spare water, and I used a pipette to drip small amount of new water into the mix, as it dried out relatively quickly. But the paste it created gave more long-term polishing intervals than just using the ochre dry, and the process felt smoother over a longer period. The leather did glide much better along the bone than it did with the dry method, but it was messier, and left colour not only on the bone, but on myself and my surroundings.

Using the fat gave an even more streamlined process of the polishing itself, as it was a good medium for keeping the pigment, and created a nice paste, less fleeting than the water, and with very good glide. It did however also require some re-applying of fat throughout the process, which was a bit messy. Also, like with the water, it did create some mess of the surroundings, while also being more challenging to clean up afterwards than the water paste.

The three different bone types used in the experiment each came with a somewhat different experience of the process. As for the process of using the raw bones, it was quite a bit trickier at first, particularly the process of removing remaining tissue. Using completely fresh bones directly after butchering means the tissue is very hard to remove and proved to be a bit time consuming. Leaving the bones for just a little bit, for the tissues to slightly decompose, or heat-treating the bones in some way, would make for an easier process of cleaning the bones.

This is just what I discovered as I started the next phase of my experiment with my boiled bones. This made the removal of tissue much easier. The old bones had of course no remaining tissue, and just needed to be cleaned of dirt, and were then ready to go.

The polishing process felt very similar with the raw and the cooked bones, I could not really distinguish any differences. With the older bones, I could tell they were generally coarser, and took quite a bit of time to polish before the gloss, if any at all, came. Decomposition-processes would most likely have changed the structure and integrity of the bones, making the feel quite different when polishing, and also affecting the results of the polishing process.

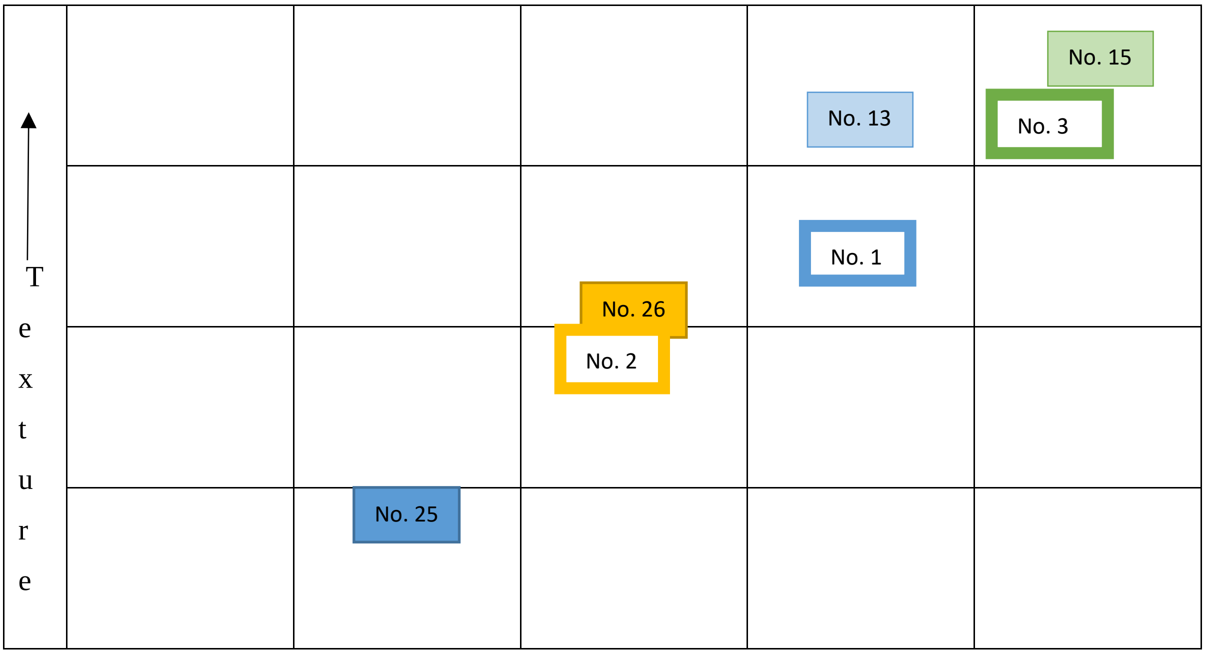
6.2 Results

The following sections contain the results of the experiments. First, I compare the microscopic images and macroscopic images of the bones, focusing on the texture and gloss. This includes all the various bone types, including raw, cooked, and old; as well as all the different ochres used, and the polish types: dry, powder mixed with water, and powder mixed with fat. I will then compare the ochres to each other, and to the shell sand.

6.2.1 Comparing microscopic texture with the macroscopic impression

In this chapter I examine the congruence between micro- and macroscopic appearance throughout my samples. I present the different ochres, and bone types, as well as the dry/water/fat component.

The following tables shows the various ochres and the bones I polished with them, put into a performance matrix, to see how, and if, the microscopic texture and macroscopic gloss correspond. The more macroscopic gloss, the higher up on the x-axis, and the finer the microscopic texture, the higher up the y-axis of the diagram. The bones following the diagonal line show the most correlation between the two qualities examined. The numbers indicate the individual number given to each bone, as seen in Table 1. Each entry in the tables also bears colour and indication of what type of bone was used, and what treatment it was given.



(y)	No. 14 No. 27				
	Gloss, (x) →				

Ochre: Indurated Hematic Shale.

Water/raw: Water/cooked: Water/old:

Dry/raw: Dry/cooked: Dry/old:

Fat/raw: Fat/cooked: Fat/old:

Table 3. Performance matrix, IHS

↑					No. 16
T					No. 18 No. 6
e x t					
u r e		No. 28			
(y)	No. 30	No. 29	No. 5 No. 17	No. 4	
	Gloss (x) →				

Friable Shale. The finer the texture, or the more gloss, the higher up on the matrix.

Water/raw: Water/cooked: Water/old:

Dry/raw: Dry/cooked: Dry/old:

Fat/raw: Fat/cooked: Fat/old:

Table 4. Performance matrix, FSH

↑		No. 33, No. 31		No. 21	No. 19
				No. 7	No. 9
T e x			No. 32		
t u r e					
(y)		No. 8	No. 20		
	Gloss (x) →				

Ferruginous Sandstone. The finer the texture, or the more gloss, the higher up on the matrix.

Water/raw: Water/cooked: Water/old:

Dry/raw: Dry/cooked: Dry/old:

Fat/raw: Fat/cooked: Fat/old:

Table 5. Performance matrix, FSS

↑					No. 22, No. 24, No. 12
			No. 36	No. 35	No. 10
T e x					
t u r	No. 34				

e (y)	No. 11	No. 23			
	Gloss (x) →				
Yellow ochre. The finer the texture, or the more gloss, the higher up on the matrix. Water/raw: Water/cooked: Water/old: Dry/raw: Dry/cooked: Dry/old: Fat/raw: Fat/cooked: Fat/old:					

Table 6. Performance matrix, yellow ochre

↑		No. 41	No. 45 No. 44 No. 42	No. 39	No. 40
	No. 38				
Texture					
(y)	No. 43		No. 37		
	Gloss (x) →				
Shell sand. The finer the texture, or the more gloss, the higher up on the matrix. Water/raw: Water/cooked: Water/old: Dry/raw: Dry/cooked: Dry/old: Fat/raw: Fat/cooked: Fat/old:					

Table 7. Performance matrix, shell sand

When looking at the performance matrix made for IHS, comparing microscopic texture and gloss, I found a relatively good correlation between the two factors (Table 3. Performance matrix, IHS).

As seen in Table 3, the bones polished with the IHS follow the diagonal line of the diagram very well, showing that those that scored low on the gloss scale, also have a less fine texture in the microscope, while the bones higher on the gloss scale, have a very fine microscopic texture. This shows a strong correlation between gloss and microscopic texture, whether the gloss and texture are on the high, or the low end of the scale. However, not all my result showed the same.

The results on the FSH did not show any clear patterns (Table 4). Especially the raw bones, which were generally coarser microscopically, even though they were somewhat, or quite glossy.

The results on the FSS (Table 5), also did not have a clear pattern, though a few of the bones follow the diagonal line at the centre of the diagram. The bones that show a correlation does not have any common factors, as they are old, raw and cooked, and both dry- and wet-polished. There is a general trend, and many of the bones are *near* the diagonal, but examples like bone no. 33 and 31, go completely the other way, showing almost no gloss, but being very fine in microscopic texture. Bone no. 31 was one of the few pieces made from a mandible, but no. 33 was a long bone like most pieces, making the type of bone less likely to be the cause of this particular anomaly.

The yellow ochre (Table 6) shows a relatively good correlation between the gloss and microscopic texture, as all bones are quite near to the diagonal axis of the diagram.

The control medium, the shell sand (Table 7), had the weakest correlation of macro- vs. microscopic appearance. Most bones polished with the shell sand appeared very fine microscopically but were not very high in gloss. This shows that all ochre-polished bones had a better congruence for these factors, than the control medium did, even though it did vary on the ochre samples as well.

An example of one of the glossiest pieces of bone was a cooked bone polished with fat and YO (Figure 7). Additionally, the microscopic texture on this bone was remarkably even. About the same level of glossy, a raw bone polished with water and FSS (Figure 8), looks almost as fine in the microscope.

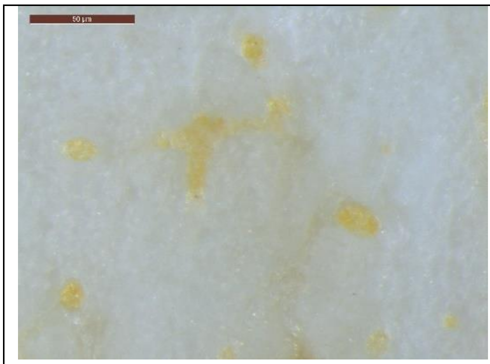
	
Bone no. 24. Cooked bone, polished with fat and yellow ochre. Microscopic view.	No. 24. Cooked bone, polished with fat and yellow ochre. Macroscopic view.

Figure 7. Example of microscopic texture vs. gloss, yellow ochre

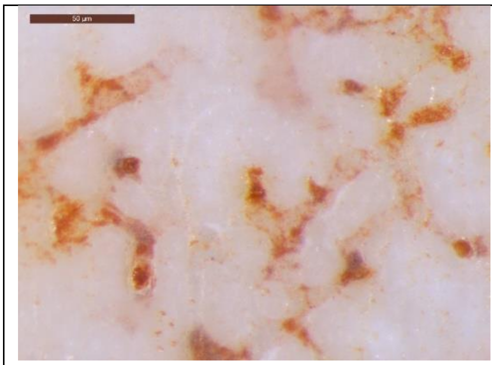
	
No. 7. Raw bone, polished with water and the FSS. Microscopic view.	No. 7. Raw bone, polished with water and the FSS. Macroscopic view.

Figure 8. Example of microscopic texture vs. gloss, FSS

	
No. 14. Cooked bone, polished dry and the IHS. Microscopic view.	No. 14. Cooked bone, polished dry and the IHS. Macroscopic view.

Figure 9. Example of microscopic texture vs. gloss, IHS

Figure 9 shows an example of a cooked bone polished dry using the IHS, which has quite a bit coarser texture in the microscope. There are more holes and striations throughout the surface of the bone (and quite a bit of colour), the macroscopic gloss is not very high.

Looking at only the raw bones, I found that they had a good correlation of gloss and microscopic texture when polished with the HIS and the YO. The correlation on the FSH was a little lower, and one of the bones were much coarser microscopically than expected based on the gloss. The raw bones in general did tend to be slightly coarser than the gloss would suggest with the FSS. As I have already mentioned, the shell sand showed little correlation between gloss and microscopic texture, and the raw bones showed little pattern within this context. A possible pattern would be that these raw bones looked slightly coarser under the microscope compared to the degree of gloss, but the dataset is too small and variable to draw any reliable conclusion.

The cooked bones also show a good correlation of micro- and macroscopic appearance with both with the IHS, and YO. The FSH also here gave a slight impression of somewhat coarser microscopic look, while the FSS had results both correlating, and slightly coarser and slightly finer microscopic view than the gloss would imply, a more varying result. Also here, there was no correlation on the shell sand-polished bones.

The old bones also showed good correlation with the IHS and YO, but perhaps a tendency to a finer microscopic texture with the yellow ochre, than the gloss would suggest. The FSH showed relatively good correlation between gloss and texture. The FSS gave slightly less correlated results, with the microscopic texture being finer than the gloss would imply. As we see in Figure 10 and Figure 11, the texture of these bones is very fine, but macroscopically they have very little gloss, and there is no correlation on shell sand-polish on these bones either. Overall, these bones tended to be less glossy than the microscopic texture would imply.

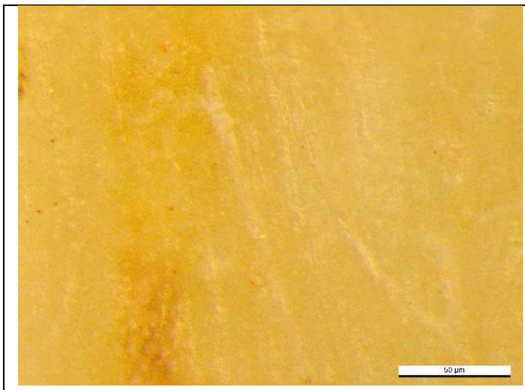
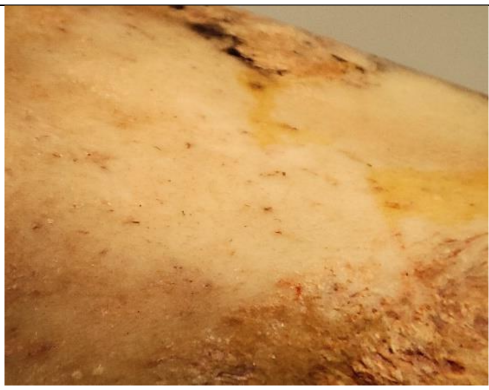
	
No. 33. Old bone, polished with FSS and fat. Microscopic view.	No. 33. Old bone, FSS and fat. Macroscopic view.

Figure 10. Example of microscopic texture vs. gloss, old bones

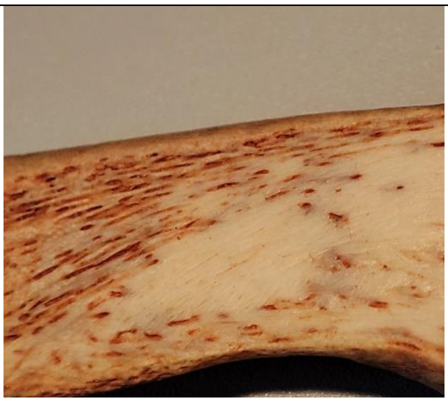
	
No. 31. Old bone, polished with FSS and water. Microscopic view.	No. 31. Old bone, FSS and water. Macroscopic view.

Figure 11. Example of microscopic texture vs. gloss, old bones

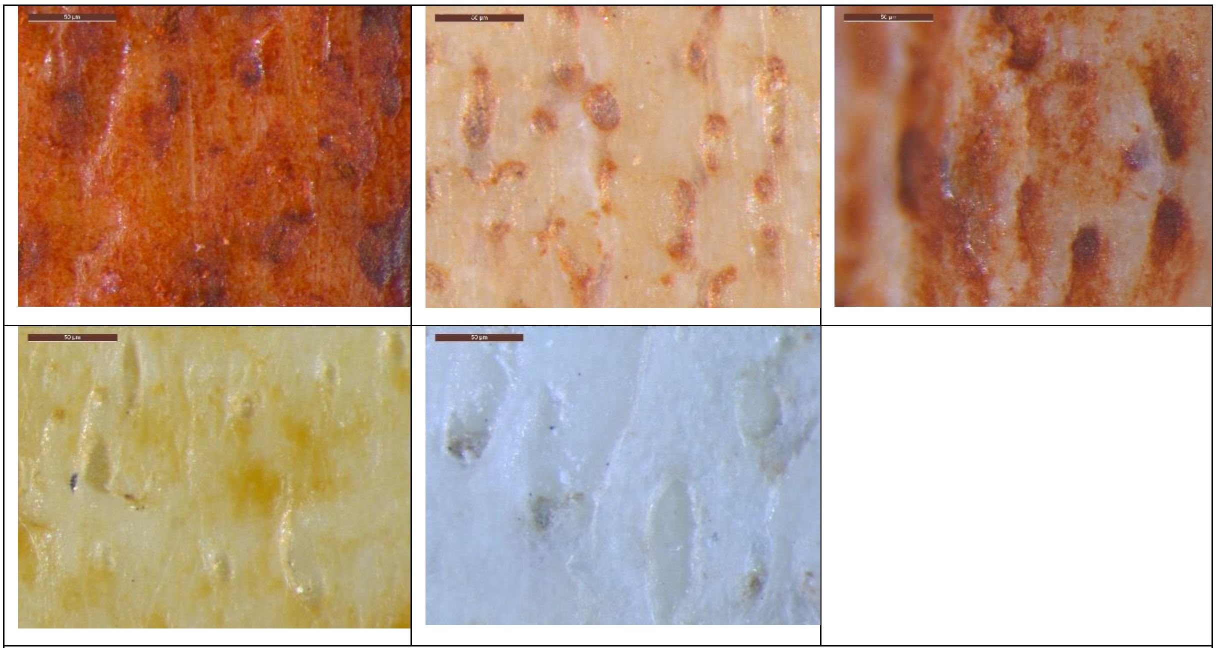
Comparing the bones polished dry, or with water or fat, it seems the dry-polished bones showed a pattern with a good correlation between gloss and microscopic texture when polished with IHS and YO, but less correlation with the remaining pigments.

The bones polished with water showed much the same, with the previously mentioned bones deviating from the other results, with bone no. 31 being much finer texture than the medium gloss would suggest, and no. 37 having quite a coarse texture despite having some gloss.

The bones polished with fat showed good correlation with the FSH, as well as with the IHS and 4 as the others. The FSS gave varying results, with bone no. 33 being very fine textured with almost no gloss. These bones were perhaps the most consistent in the shell sand-group, although not very consistent still.

6.2.2 Difference in efficiency and result, when using various types of ochre, or shell sand

The different types of ochre pigments had visibly different shades of colour even before it was used for polishing, already giving a suggestion that the results would differ in colour staining. I use the term “colour” here to refer to the amount of colour staining that remained on the bones after the polishing experiments. Along with the varying colours, the pigments also vary in grain size, giving the opportunity to see if that is an important factor to the process and result. The difference in colour on the finished polished bones is quite clear as seen in Figure 12.



The various types of pigment I used. Pictures taken with optical microscopy. Starting from top left: Indurated hematic shale (Bone no. 14), friable shale (No. 17), ferruginous sandstone (No. 20). Row two: yellow ochre (No. 23), and shell sand (No. 41).

Figure 12. The difference in colour of the various ochres, and shell sand

Each bone was scored on a scale from 0-5 on both colour and gloss. With the IHS the average score for the gloss was 3,1. The colour score also turned out at 3,1 (Table 8). A few of the bones scored significantly lower, either on colour or gloss, which pulled the score down, so overlooking these bones, the score would be even higher. All in all, the HIS left the highest amount of colour residue, and was able to produce gloss reasonably well.

IHS, gloss/colour.		
Bone no., and treatment	Gloss (macroscopic)	Colour (macroscopic)
1., raw/water	4	3
2., raw/dry	3	4
3., raw, fat	5	1
13., cooked/water	4	1
14., cooked/dry	1	5
15., cooked/fat	5	1
25., old/water	2	4
26., old/dry	3	5
27., old/fat	1	4
Average score	3,1	3,1

Table 8. IHS: gloss and colour score

The FSH also gave quite a bit of gloss, but less colour than the HIS (Table 9). The average score for gloss was 3,3 while the average score for colour was 2,1. Also with this ochre there was a tendency for some, in particular the older bones, to score lower on gloss, dragging the average down a bit. Apart from these, the FSH proved quite effective in producing gloss, but not quite so much colour.

FSH, gloss/colour.		
Bone no., and treatment	Gloss (macroscopic)	Colour 1-5 (macroscopic)
4., raw/water	4	2
5., raw/dry	3	2
6., raw, fat	5	1
16., cooked/water	5	2
17., cooked/dry	3	3
18., cooked/fat	5	2
28., old/water	2	2
29., old/dry	2	2
30., old/fat	1	3
Average score	3,3	2,1

Table 9. FSH: gloss and colour score

With the FSS I saw a good amount of gloss on many of the bones, and less colour than the IHS, but slightly more than with the FSH (Table 10). The average gloss score was 3,3, and the colour score was 2,4.

FSS, gloss/colour.		
Bone no., and treatment	Gloss (macroscopic)	Colour 1-5 (macroscopic)
7., raw/water	4	2
8., raw/dry	2	4
9., raw, fat	5	2
19., cooked/water	5	1
20., cooked/dry	3	4
21., cooked/fat	4	3
31., old/water	2	2
32., old/dry	3	3
33., old/fat	2	1

Average score	3,3	2,4

Table 10. FSS: gloss and colour score

The yellow ochre gave the highest gloss score, as well as needing shorter time to provide a good gloss, while the colour score was the lowest of the four ochres (Table 11). The gloss and colour scores were, respectively, 3,4 and 1,6. This was a yellow ochre, which is less saturated colour than the others, which left a less visible colour in a macroscopic view. Even though in a microscopic view there might be more colour pigment than the look would imply, it's the macro perspective that is important in my experiment, as it is all about how the bones´ finish would appear with the various ochres. Also important is the natural colour of the more weathered older bones, which will necessarily have something to say in the macroscopic colour assessment.

Yellow ochre, gloss/colour.		
Bone no., and treatment	Gloss (macroscopic)	Colour 1-5 (macroscopic)
10., raw/water	5	1
11., raw/dry	1	3
12., raw, fat	5	1
22., cooked/water	5	1
23., cooked/dry	2	3
24., cooked/fat	5	1
34., old/water	1	2
35., old/dry	4	1
36., old/fat	3	2
Average score	3,4	1,6

Table 11. Yellow ochre: gloss and colour score

The shell sand quite unsurprisingly, gave much less, or no colour at all, compared to the ochre pigments (Table 12), but it did give some gloss. The gloss score was 2,7, while the colour score was 0,6. This shows that the shell sand was less efficient than the ochres at producing gloss.

Shell sand, gloss/colour.		
Bone, no. and treatment	Gloss (macroscopic)	Colour 1-5 (macroscopic)
37., raw/water	3	1
38., raw/dry	1	0
39., raw, fat	4	0
40., cooked/water	5	1

41., cooked/dry	2	0
42., cooked/fat	3	1
43., old/water	1	1
44., old/dry	3	1
45., old/fat	3	1
Average score	2,7	0,6

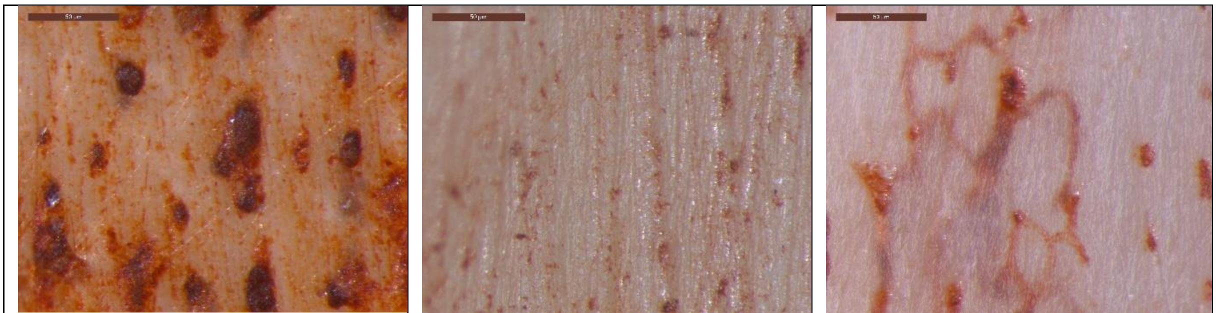
Table 12. Shell sand: gloss and colour score

In the end, of the ochre pigments, the yellow ochre produced the best gloss overall, and the IHS gave the most colour. But as presented in the data in the next chapter, a lot might come down to the use of either dry powder, water, or fat, and age of the bones, when it comes to gloss and colour, not just the ochres.

6.2.3 Differences in efficiency and result when using water or fat, or using the ochre dry

I started my experiments using the ochre dry, and then using water as a binding agent to make it into a paste. I then moved on to using fat instead of water. It became clear quite early that there was a considerable difference in using the ochre dry or using water or fat.

Using the ochres dry, it was quite evident that the polishing was much less efficient in creating a shiny, glossy surface, or at least it would require a lot more time than I spent on the individual bone. The colour though, was given a better grip, partly I believe because there was no liquid substance to wash it away, and partly because the surface of the bone remained more striated and rougher, giving the colour pigments a rougher, more porous surface. Both the macro and microscopic appearance was more saturated in coloured pigments. Under the microscope the grooves in the dry-polished bones were deeper and filled with more pigment than in the ones polished with water or fat (Figure 13).



Pigment: IHS. Picture to the left: polished dry raw bone. Middle: raw bone, polished with water. Right: raw bone, polished with fat.

Figure 13. IHS: example comparing dry/fat/water-polished

Gloss

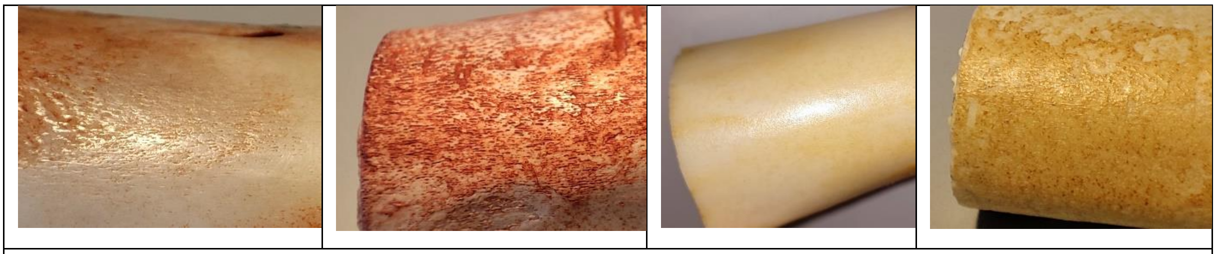
Looking at the bones macroscopically the gloss was better using water and fat than with dry ochre. The colour appeared more even on the dry-polished bone, and slightly stronger than those polished with water and fat. The properties of the ochre could also affect how the pigment responds to be used dry/with fat/with water. Finer/coarser minerals, and different pigment-properties proved to give different results between the various ochres.

On the fresher bones, raw and cooked, the gloss-score in my evaluation diagrams when using fat, throughout alle the ochres, were 5 and 4,5, respectively. While the old bones had an average gloss-score of 1,75 when using fat, water-polish gave a score of 4,25 on both raw and cooked bones, and 1,75 on the old bones. Dry polish on the raw bones had a gloss-average score of 2,25, cooked bones 2,25, while on the older bones it was 3 (Table 13).

Bone type:	Avg. gloss score, fat	Avg. gloss score, water	Avg. gloss score, dry
Raw	5	4,25	2,25
Cooked	4,75	4,75	2,25
Old	1,75	1,75	3
Score from 0-5, where 5 is the glossiest.			

Table 13 Gloss score on raw/cooked/old, and dry/water/fat-polish

Figure 14 shows how varying the results were in a macroscopic view. Colour, gloss, and texutre of the surface varied with each of the different techniques. We can especially see how much glossier the two bones polished with fat are, and how much stronger the colour is on the dry-polished bones are.



From the left: cooked bone, polished with fat and FSH (bone no. 18), cooked bone, polished dry with FSS (no. 20), raw bone polished with fat and yellow ochre (no. 12), and cooked bone, polished dry with yellow ochre (No. 23).

Figure 14. Example of fat vs. dry-polished bone

Colour

In evaluating the colour there is a trend with the dry polish having a higher score (Table 14), though the old bones again show a bit of incongruity by being more consistent in colour-score throughout fat, water or using it dry. The old bones were of course more weathered and coloured, which effects the final colour, and my judgment of the colour.

We can see that fat and water gave scores between 1,25-2,5, while using the ochre dry, gave scores from 2,75-3,25. As I have showed in the previous chapter, the ochres themselves also was an important factor in the colour-scoring.

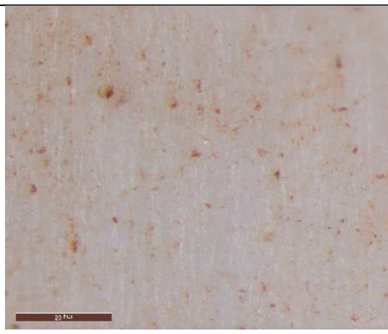
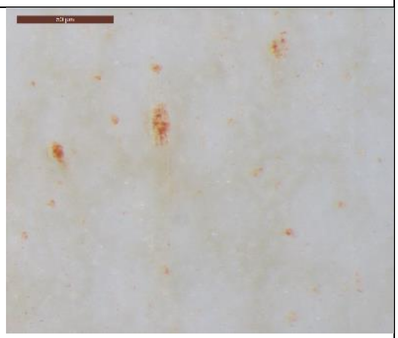
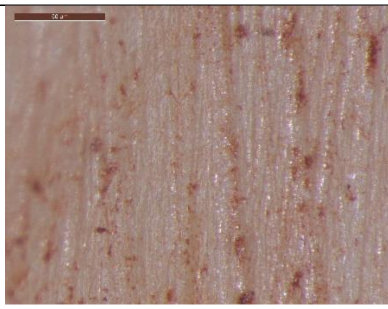
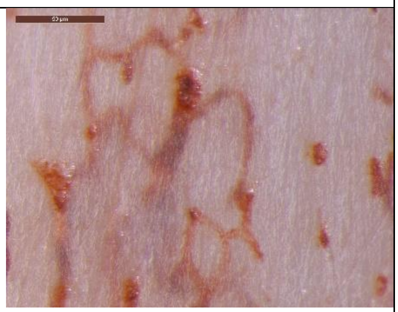
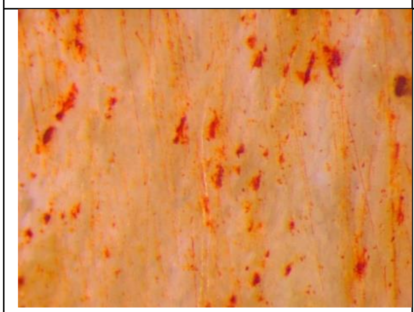
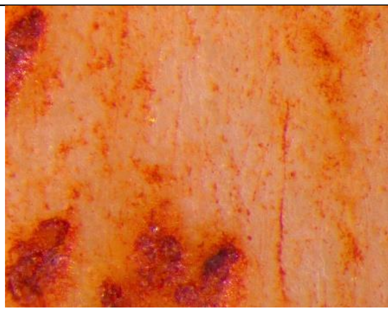
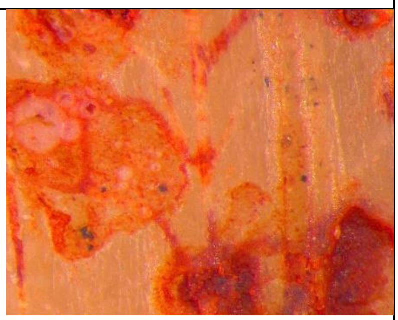
Bone type:	Avg. colour score, fat	Avg. colour score, water	Avg. colour score, dry
Raw	1,25	2	3,25
Cooked	1,25	1,25	3,75
Old	2,5	2,5	2,75
Score from 0-5, where 5 is the most colour.			

Table 14. Colour score raw/cooked/old, and dry/water/fat-polished

6.2.4 Differences in using new, old, or cooked bones

Microscopic textures

With the IHS, bones polished with dry powdered pigment, there were seemingly random differences between the microscopic textures on the various types of bones. In Figure 15, we can see the bones polished dry have a relatively coarse texture on raw and cooked bones, but perhaps slightly finer on the old bones. The fresh bones polished with water and fat show a much finer texture, while the texture on the old bones seem to be more random, and far coarser when polished with fat than the fresh bones were.

IHS		
		
Cooked bone, polished dry, no. 14	Cooked bone, water-polish, no. 13	Cooked bone, fat-polish, no. 15
		
Raw bone, polished dry, no. 2	Raw bone, water-polish, no. 1	Raw bone, fat-polish, no. 3
		

Old bone, polished dry, no 26	Old bone, water-polish, no. 25	Old bone, fat-polish, no. 27

Figure 15. Example with IHS, microscopic texture

The trend overall was for the fresher bones to have a finer microscopic texture. Many of the older bones seemed to have larger depressions, that could not as easily be smoothed out, which can also be seen with the FSH, in Figure 16.

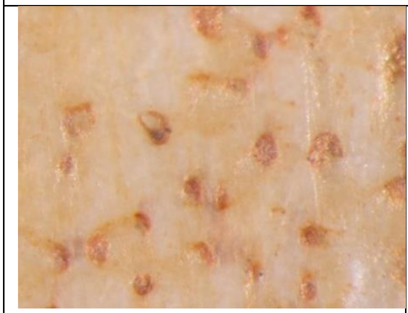
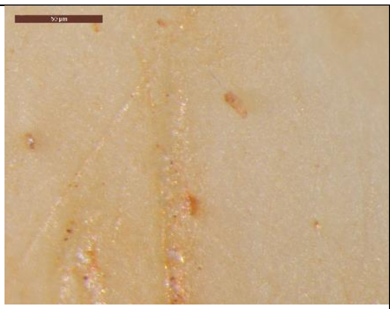
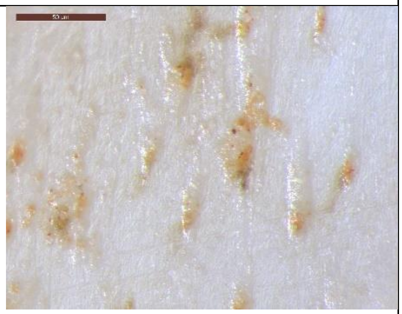
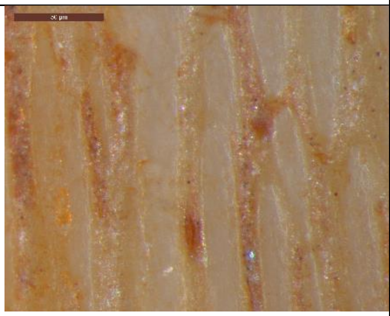
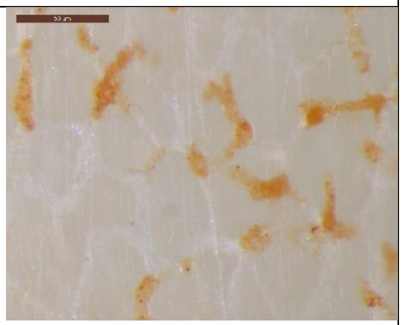
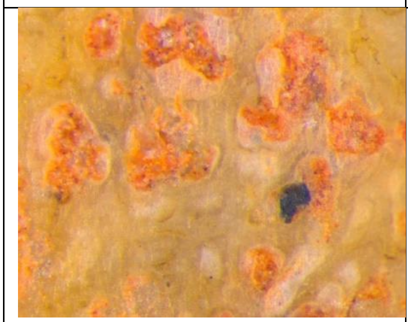
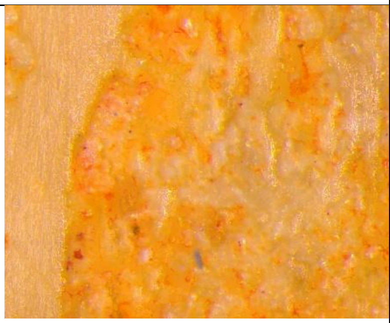
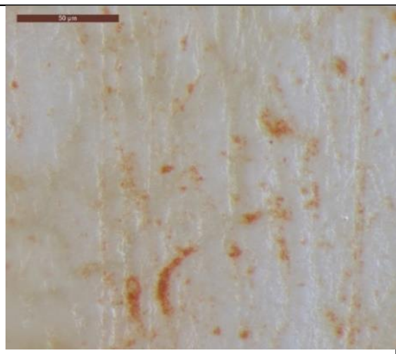
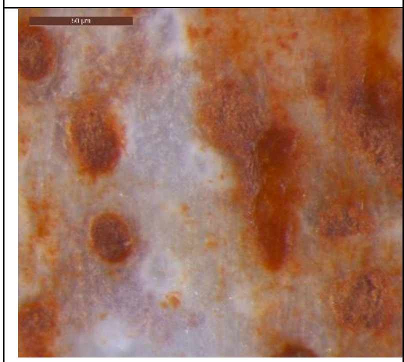
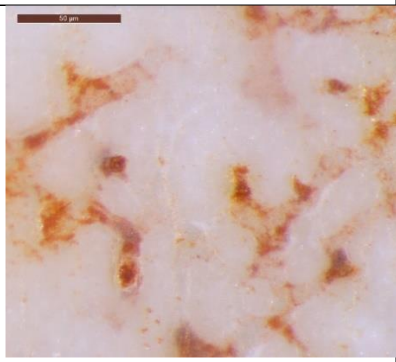
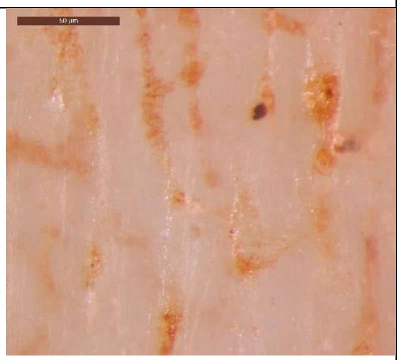
FSH		
		
Cooked bone, polished dry, no. 17	Cooked bone, water-polish, no. 16	Cooked bone, fat-polish, no. 18
		
Raw bone, polished dry, no. 5	Raw bone, water-polish, no. 4	Raw bone, fat-polish, no. 6
		
Old bone, polished dry, no. 29	Old bone, water-polish, no 28	Old bone, fat-polish, no. 30

Figure 16. Example with FSH, microscopic texture

With the FSS, I saw some varying results, with some of the old bones previously mentioned (no. 31 and no. 33) being quite fine microscopically (Figure 17), differentiating from most of my other results.

One should also bear in mind that the old bones were not all long bones, which could affect the results of polishing. Different shapes/curves of the bone, or different thickness/textures of the bone could potentially impact the polishing results. Bones no. 26, 28, 31, and 32 were part of a mandible, but I could not discern any patterns in which these four bones stood out from the patterns I saw with the long bones. Bone no. 31 had a very fine microscopic texture, but no. 32 did not, and bone no. 33, which had a similar microscopic texture to no. 31, came from a femur. No. 26 was treated equally as no. 32, only with a different ochre, and had a noticeably coarser texture than no. 32. Bone no. 28 also had a quite coarse microscopic texture (Figure 16), and looks quite similar to bones no. 29 and no. 30, which were both from femurs.

Bones no. 43 and 45 (polished with shell sand) were also a part of mandibles, and I found a relatively good correlation between microscopic texture and gloss on no 43 (polished with water), but little correlation on no. 45 (polished with fat). There therefore seem to be no considerable pattern going from long bone to mandible.

FSS		
		
Cooked bone, polished dry, no. 20	Cooked bone, water-polish, no. 19	Cooked bone, fat-polish, no. 21
		
Raw bone, polished dry, no. 8	Raw bone, water-polish, no. 7	Raw bone, fat-polish, no. 9

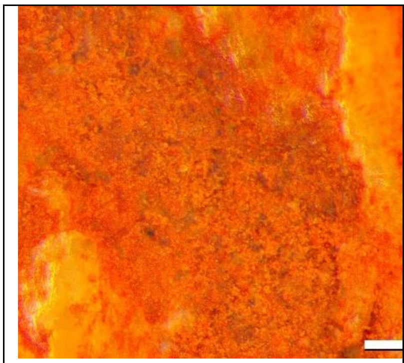
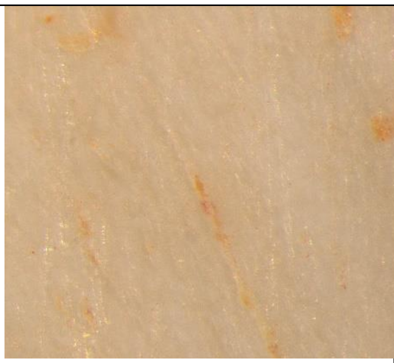
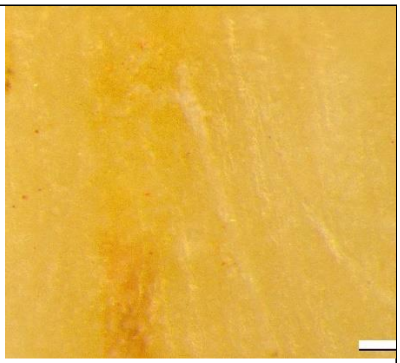
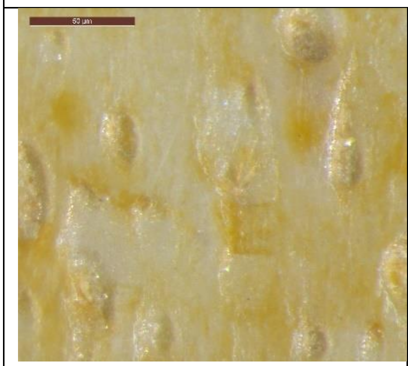
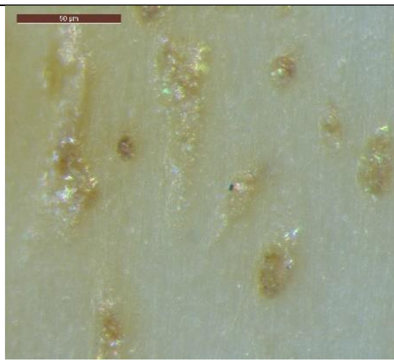
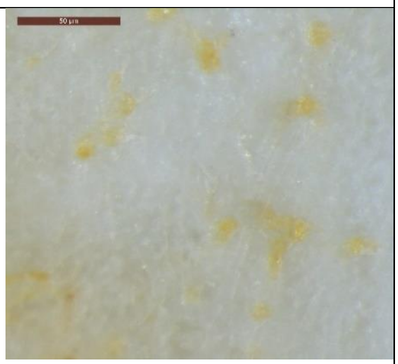
		
Old bone, polished dry, no 32	Old bone, water-polish, no 31.	Old bone, fat-polish, no. 33

Figure 17. FSS, microscopic textures

YO was quite consistent with how the different bones reacted to the process. As we see in Figure 18 the raw and cooked bones show a very similar microscopic texture, whether polished with water, fat or dry, when polished with yellow ochre. The older bones have a generally more weathered-looking microscopic texture throughout all the experiments, but it is important to keep in mind that they already had a more eroded and discoloured surface before the polish was implemented, than the fresher bones did. It makes it slightly more challenging though, to establish how fine of a microscopic texture they have, as the eye tended to be a little tricked by the discoloration and eroded changes in their surface. Yellow ochre gave a quite fine microscopic texture on all types of bones, but the gloss varied.

Yellow ochre.		
		
Cooked bone, polished dry, no. 23	Cooked bone, water-polish, no. 22	Cooked bone, fat-polish, no. 24

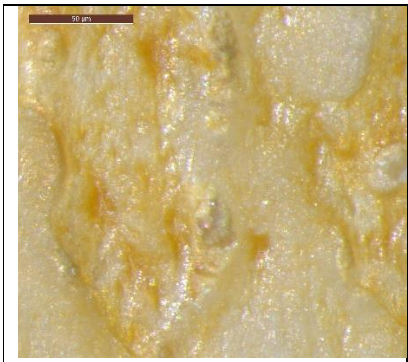
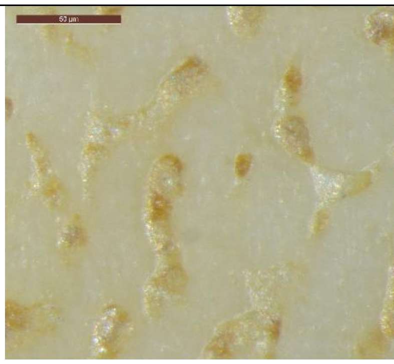
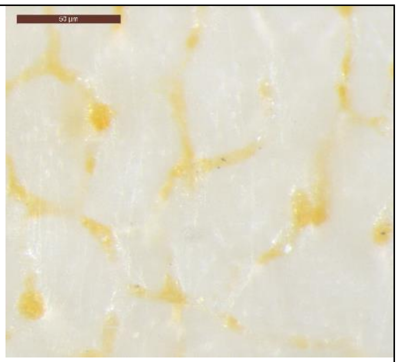
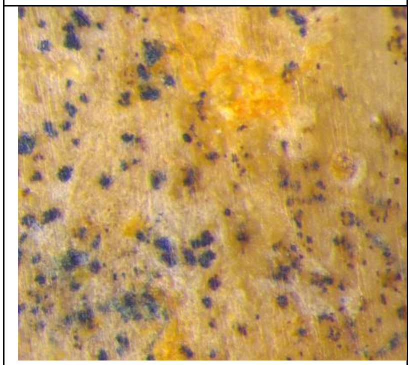
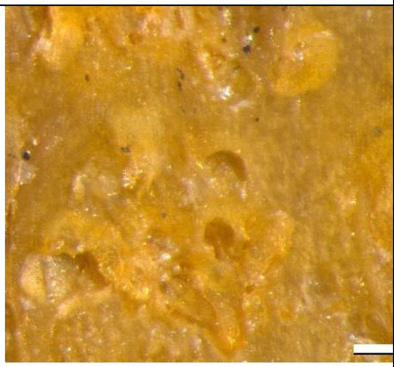
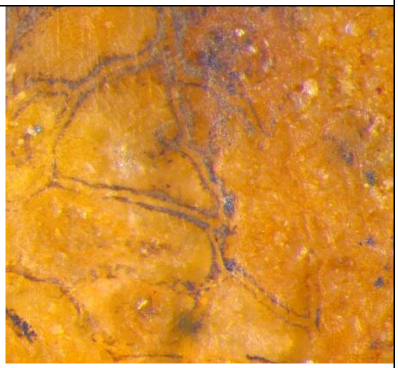
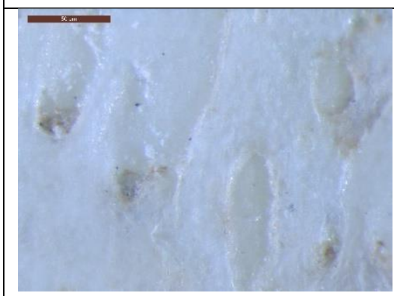
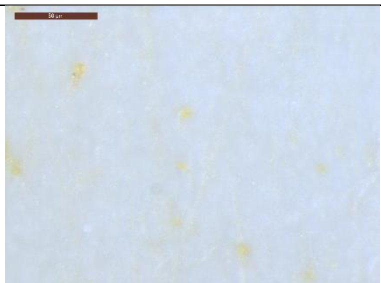
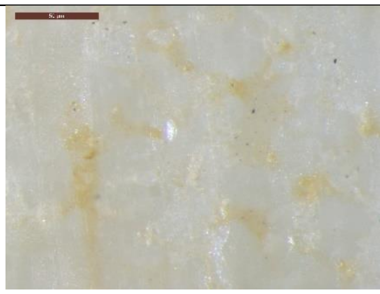
		
Raw bone, polished dry, no. 11	Raw bone, water-polish, no. 10	Raw bone, fat-polish, no. 12
		
Old bone, polished dry, no. 35	Old bone, water-polish, no. 34	Old bone, fat-polish, no. 36

Figure 18. YO, microscopic textures

As for my control medium, the shell sand, it showed a very fine texture on almost all bones, but again, the old bones show a coarser microscopic texture than the fresh bones (Figure 19). Between cooked and raw bones, there seem to be no particular pattern.

Shell sand		
		
Cooked bone, polished dry, no. 41	Cooked bone, water-polish, no. 40	Cooked bone, fat-polish, no. 42

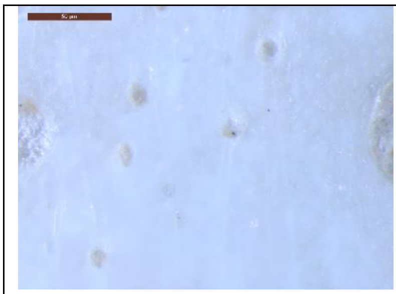
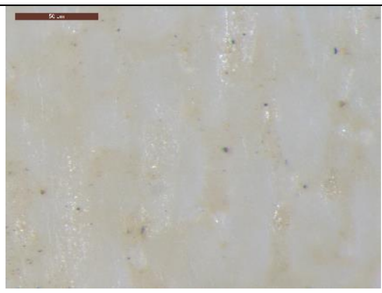
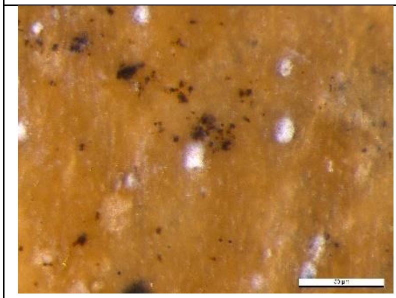
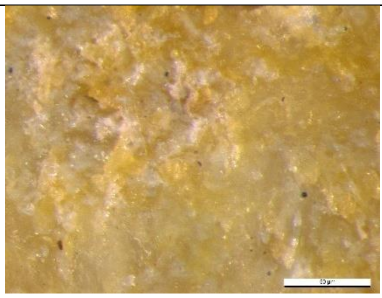
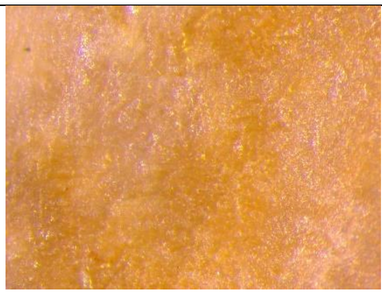
		
Raw bone, polished dry, no. 38	Raw bone, water-polish, no. 37	Raw bone, fat-polish, no. 39
		
Old bone, polished dry, no. 44	Old bone, water-polish, no. 43	Old bone, fat-polish, no. 45

Figure 19. Shell sand, microscopic textures

Gloss

Using both raw and cooked bones, the gloss scores were consistently better using fat and water as a polishing medium, while with the old bones it was just the opposite. We see this in Table 15. The old bones had hardly any gloss when polished with water or fat but were generally slightly glossier than the fresh bones when using dry pigment.

Bone type:	Avg. gloss score, fat	Avg. gloss score, water	Avg. gloss score, dry	Overall gloss score
Raw	5	4,25	2,25	3,83
Cooked	4,75	4,75	2,25	3,91
Old	1,75	1,75	3	2,16
Fig. x. Score from 0-5, where 5 is the glossiest.				

Table 15. Gloss score, raw/cooked/old, fat, water, dry-polished

When adding the overall gloss score, the older bones have a lower score than the fresh bones, the average dragged up be the bones polished dry.

Colour

When looking at colour across the various bone types, there are also certain patterns regarding old vs. fresh bones. With fresher bones, both raw and cooked, I saw scores of 1,25 up to 2, with water and fat used in the process, while using the ochre dry, the colour score was 3,25-3,75

(Table 16). The old bones had a colour score of 2,5 for polish with fat or water, and a score of 2,75 for dry polish, slightly higher, but still less than the raw and cooked bones.

Bone type:	Avg. colour score, fat	Avg. colour score, water	Avg. colour score, dry	Overall colour score
Raw	1,25	2	3,25	2,16
Cooked	1,25	1,25	3,75	1,95
Old	2,5	2,5	2,75	2,58
Score from 0-5, where 5 is the most colour.				

Table 16. Colour score, raw/cooked/old, fat/water/dry-polished

When adding an overall average score the results are evened out by the variations between dry vs. water- and fat-polished.

The take-away seem to be how the old bones vs. the fresh bones act differently to a dry polish vs. a polish with water or fat.

7. Discussion and main question

At the start of my experiment had some very specific questions in mind. Which methods are more effective, and why? Could microscopic textures tell us which bones have, or did have, a glossy surface? Can we infer polishing methods from how bones look in the microscope? Also, new questions surfaced during the experiment. How do we approach the difference in fresh vs. old bones when comparing microscopic and macroscopic views? What are we trying to accomplish with the polish; colour, gloss, a more durable surface, adding a symbolic value?

Throughout this chapter, I will work to use the results gathered from this experiment to answer these questions and explore unexpected observations that arose as part of the experimental process.

7. 1 How does the microwear and residue look under a microscope on the different types of bones polished with the various ochres, and the shell sand, compared to their macroscopic appearance?

I would expect a bone higher in gloss to be smoother, and therefore much finer in the microscopic texture, and the least glossy pieces I would expect to have a coarser microscopic texture. This is one of the aspects of polishing I was curious to explore in this experiment.

Overall, the IHS, and YO as well, showed the most correlation over alle the various bones when it came to gloss vs. microscopic texture, while my control medium, the shell sand, showed the biggest contradictions. Even though quite a few bones showed a correlation between microscopic texture and macroscopic gloss, this could do well to be reiterated in repeated testing, using the same factors for polishing several times to see if it was random, or not.

Looking at my performance matrixes, it is possible that using fat as a binding agent, gave slightly more correlating results than water and dry polish, but though it seems that they are to some extent connected, I would not be comfortable judging a bone tools potential degree of gloss from a microscopic picture.

As mentioned in the beginning of my thesis Bradfield (2020) found during his research into surface roughness and gloss, that there was some congruence between the perception of gloss and the roughness of the surface, but still no direct correlation between the two factors, concluding that the contact mediums used for polishing played an important part. Except for not using different types of contact mediums, my findings are somewhat in line with Bradfield's. I have not accurately measured surface roughness in the same way, but my evaluations are that there are certain patterns, and that the finer looking microscopic texture, often appeared on the glossiest bones. At the same time there are exceptions, making conclusions of gloss based on surface texture quite challenging.

In particular, the old bones, where the texture was sometimes finer even though they lacked gloss, made me aware that if older bones were polished in the MSA, they might not have been very glossy even though the microscopic texture seems quite fine.

There are, however, trends overall, and it should also be pointed out that the ochres were all more consistent with gloss and texture, than my control medium, the shell sand. The shell sand gave almost all the bones very fine microscopic texture, but many of the bones did not have a lot of gloss. Bone polished with ochre might therefor give a more accurate picture when it comes to original gloss, than if they were polished with shell sand or similar materials.

The residues left on the bones were most apparent on the bones polished dry, here there was large amounts of colour-pigment left in grooves in the bone, leaving little question that they were treated with ochre. The bones polished with water and fat did at times have very little residue, but still had *some*. Overall, on almost all my bones (with the exclusion of the bones polished with shell sand) it was relatively easy to see that they were somehow treated with coloured pigments, though bones polished with fat sometimes displayed only a vague hue in some of the very shallow striations left.

Bone tools found from the MSA are not directly comparable and will have been affected by taphonomic processes over a considerable period of time, changing the surface of the bone, and probably reducing the amount of pigment, but microscopic ochre residues found on MSA bone should still be taken to account as a possible indicator of them being polished with an ochre-rich medium.

7.2 Is there a difference in efficiency and result, when using various types of ochre, or using another polishing material?

There are undeniable differences when using different ochres or using another material, as seen in Figure 15-19. There are variations in both colour shades, colour amounts, gloss, and microscopic texture. There was considerably less gloss on the bones polished with shell sand, and effectively no colour. This would, in my opinion, make ochres far more attractive for polishing bone tools, than the shell sand, as it would likely give another level of perceived quality and value to the bone tool.

It is hard to say if which factors prompted which ochre to be used in the MSA. Did they have a conscious approach to the existence of many different ochre types, with different properties, giving different results? Or was it more a matter of what was available in the immediate surroundings? If they had a varied selection, I could imagine that certain ochre types could be preferred. As mentioned, ochres were mined and carried across distances, and various types of pigments, charcoal, and other traces of quartz e.g., has been discovered in ochre processing tools, making it likely that people in the MSA was very aware of the various qualities of pigments and rocks, and how to utilize them. The complex processes discovered in the Porc-Epic Cave, Dire Dawa (Rosso et al., 2016), Ethiopia, where grindstones were carefully selected for a variation in result also shows how the pigment production was a carefully planned process.

Therefore, the question is perhaps not which pigment is “the best” or most useful, but rather; which pigments were used on which occasions, and for what purpose?

Again, the yellow ochre does stand out in this experiment, not only as quite a different shade, but also as a very efficient polishing medium. If people in the MSA would have had the same experience as me, I could easily see this ochre be preferred if the goal was to efficiently produce gloss on bone material. It is interesting that this ochre proved to be so effective, as Nivens (2020) experiments showed that the larger grain sizes gave more effective polish on her lignite beads. She found however, that her softer material, the steatite beads, were best polished with the pigments with a finer grain (Nivens, 2020, p. 118) The yellow ochre I used was the ochre with the finest grain, but it gave the most efficient results. Nivens also found that the pigments enriched with hematite gave the best results on both lignite and steatite beads, which again, contradicts my result with yellow ochre on my bones (Nivens, 2020, p. 118). The fact that we are looking at different materials (bone vs. stone), could of course be very relevant here.

Comparing our results though, it is clear that grain size matters, and that it also depends on what material you are polishing.

As for my red ochres, the result seems to be more in line with the lignite trials Nivens performed. The FSS could be described as more effective than 1 and 2, as it gave slightly faster results, and the IHS was more effective than the FSH. Which is in line with their hematite level, and their grain size, as the FSS had the coarsest grains, and most hematite, and the FSH was the finest pigment, with the least amount of hematite. But still, with my results with the yellow ochre, all tests showed this ochre to consistently give faster results than all the others, and more gloss, and it would be interesting to investigate this further.

If the goal was to stain the bones as much as possible, on the other hand, I would think a similar ochre to the IHS, or the FSS would be used, though all the ochres were sufficient at producing considerable colour when used dry. The variations on the process of crushing, and working with the ochres, I would not expect to be significant enough to be a big factor for choosing ochre in the MSA. The FSH was a bit harder to work with though, especially dry, and gave less colour than 1 and 3, which would probably make it my least preferred ochre to work with in this experiment.

It certainly does matter which ochre one uses in a polishing process, and I expect the choice would depend on availability of materials, but also on wanted results, whether they be colour, gloss, both, or something else entirely. It does seem that grain size and amount of hematite matters, but yellow ochre seem to contradict this. It would be interesting to experiment with the additions of other rock particles, charcoal, and bone dust e.g., to see how that would affect the process and result.

7.3 Is there a difference in efficiency and result when using water or fat, or using the ochre dry?

I have found that we can see a clear difference in the microscopic as well as the macroscopic view when it comes to using the ochre dry or polishing mixed with fat or water. Using fat or water gives a much glossier and smoother surface and leaves much less colour pigment on the bone.

As seen, the results in gloss and colour varied between the different ochres as well, however there was a trend throughout the experiments, showing much more gloss with water, and particularly fat. There were also exceptions, such as when using friable shale using it dry had a similar effect as when it was mixed with water or could be even better for polishing and creating a more even surface using it dry, at least when looking in the microscope (Figure 20).

FSH. Left: raw bone polished dry. Right: raw bone polished with water.

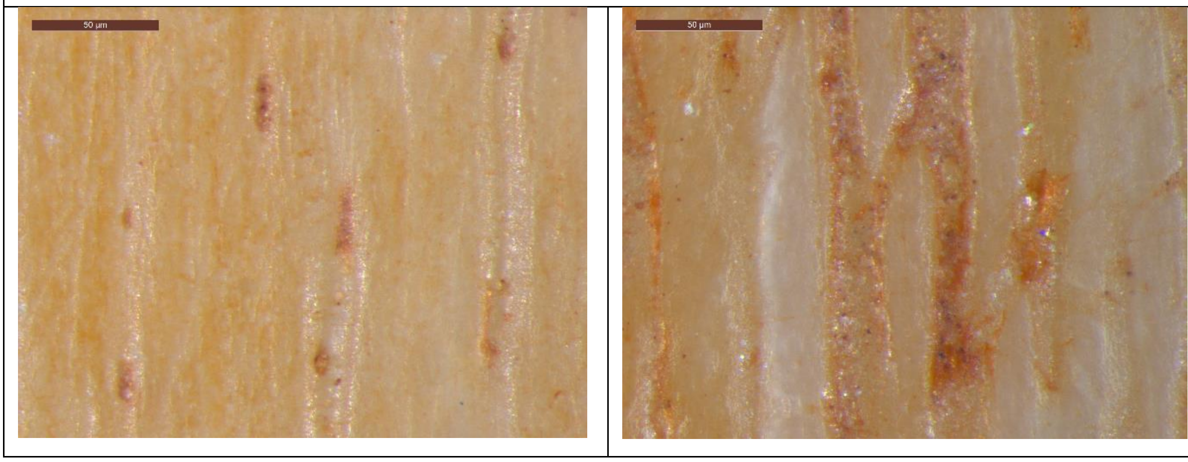


Figure 20. FSH, raw bone, dry vs. water

But these single bone results are problematic to view as givens. The small sample size of my project means there are chances that this is simply a random occurrence and repeating the same polishing-procedure several times would perhaps help confirm or debunk these exceptions.

The trend was clear, however, when looking at my evaluation scores there is a noticeably higher point score for gloss on the bones polished with water, and even more those polished with fat, than those polished dry, regardless of which ochre was used. Though there is a difference when working with the old bones.

As White (1995) noted in his experiments, he believed it was water, not fat, that was used as a binding agent for the pigment, as the resulting staining from fat was lacking from the archaeological material. The superior gloss from using fat in my experiment speaks for a different conclusion, however. We are speaking of different materials being polished though, and the question of water vs. fat, could of course be a matter of resources and access. The clear differences in these results are in my opinion something the people of the MSA could have easily used to manipulate the bone tools for their wanted result, whether it was colour or gloss.

7.4 Is there a difference in using new, old, or cooked bones?

I found little difference in the raw and the boiled bones. These had the same age and were fresh from the butcher. These two were similar both in the polishing process and they gave similar results. Heat-treating bones in a different way, e.g., roasting, with more direct contact with fire, could give different results.

Polishing the old and weathered bone did not give quite the same glossy surface and gave a somewhat different experience from using fresher bones. I would not believe discarded bones with several years of aging would be used in the creation of tools or objects that were meant to look glossy. If they used older bones like this, perhaps it would also mean the bone was likely more randomly picked up somewhere, or scavenged, meaning it was less likely to be part of a large-scale production? I assume older bones could also be more brittle, depending on their age and chemical exposure, making it a less optimal starting point for a tool.

For tool-producing in a more organized fashion I would believe relatively fresh bones were used, and that they would have been heat-treated for easier removal of tissue. Fresher bones would in my belief give a better result, than older bones.

Going back to the question of microscopic appearance, I would say that, *If* the artefacts we find from the MSA were made from relatively fresh bones, there is a certain congruence between gloss and microscopic texture, according to my experiments, but there are also a few examples of this not being true for all bones, and clear variations between the different ochres, which makes it difficult to infer gloss from what we see in the microscope.

I would say the fresher bones were also better for producing nice clear colours, and they seemed to be more predictable as for the outcome with both gloss and colour.

I would also like to have added the factor of taphonomic processes to the experiment, leaving the bones for decomposing for a few months, in different environments, to compare how the differently treated bones would appear when exposed to the chemical and abrasive wear from the environment. Leaving unpolished bones in ochre rich soil would also be interesting, to see if it is possible to distinguish between bones deliberately polished with ochre, and bones gone through taphonomic processes in an ochre rich environment. This was too extensive for this project though but could be an exciting continuation of this experiment for the future.

7.5 Is ochre a useful polishing device for bone tools? What can these results potentially tell us about the use of ochre for polishing bone tools in the MSA in South-Africa?

To conclude that ochre pigment is conceivable to have been used as a polishing medium, it is essential that the experiment demonstrates that the ochres have qualities that makes them suitable, or even superior, as a polishing implement. I believe that much has been shown in this experiment. The various ochres all had qualities that produced a nice gloss, and/or strong colour on the bones. They were effective for creating a nice smooth surface, in a short amount of time. It seems clear to me that ochre pigment has qualities that makes it suitable for polishing bone material, that is superior to my control medium, the shell sand.

Given a less limited timeframe and more resources it would have been beneficial to run the experiments several times, to get a more distinct pattern to emerge from the different methods and variables.

During my experiment I questioned whether the people of the MSA chose and separated different pigment types as carefully as I did, whether it was more random, or they chose the pigments depending on use and outcome. It could also be less realistic using the pigment alone like I have, and not mixing in other materials, such as grains and dust from stone or bone. The results from the studies of Rosso et. al. (2016), showed that various ochre types and rock types were most likely very deliberately mixed, given different properties for different uses. I find this consistent with my experiences throughout this experiment, as it became clear in relatively short amount of time, the impact all the variations could have on the results, and I do not doubt that this could be used to achieve several different types of ochre powders and pastes for polishing, painting etc. Since a variety of grindstones of different geological compositions, both harder and softer stone, often having been transported quite far, were used for producing ochre powder, it seems this type of production and processing could have been quite complex.

Red ochre is almost exclusively used in the discussion about ochre and symbolic behaviour (Henshilwood et al., 2002, p. 1278), but I find it quite noteworthy that the yellow ochre was so effective for producing gloss. It was in, my experience, the most effective when looking at both gloss and length of time of the process. I can’t help but question if yellow ochre has received less investigation and could be more commonly used than one has assumed? It is lacking the strong colour of the red hematite, but its other properties should not be overlooked. Yellow ochre would macroscopically not stand out the way red ochre does, and might be easier to overlook, if the artefact is not given the same inquiry, with microscopic analyses and a focus on residues.

The amount of pigment used also varied between the ochres, and given further testing, it would be interesting to see if some pigments require a far lesser amount in order to polish the same number of bones. According to my experiments, the FFS acquired less amount of pigment than the IHS and the FHS, and the yellow ochre required the least of all.

As for important factors on the results of bone polishing, other than using different pigments and powders, I would highlight the binding agents, as well as the use of fresh vs. old bones. The fresher bones (both cooked and raw) gave much more consistent results, and a much better gloss than the older bones. And the water, and in particularly the fat, gave a much more efficient process, as well as producing gloss very well. I believe these factors are quite basic and would be something that could easily have been utilized in the MSA for a wanted result.

Other factors that would be interesting to investigate further, is using a different medium for holding the pigment, as Bradfield (2020) stated that this had a lot to say on the outcome in his experiments. Softer vs. harder mediums gave a distinct variation to the results. Also, grilled bone, or bone subjected to open fire would give complimentary data, and it would be interesting to have some additional polishing data and evaluations on this. Open fire would bring a different aspect to the structure of the bones, and thereby probably changing the polishing process in a different way, other than the bones merely being exposed to high temperature from boiling like in my own experiment, and perhaps also be truer to the treatment of bones in the MSA.

It is quite interesting that my experiment shows such a diametrical difference in how to arrive at the glossiest vs. the most coloured bones. It is clear is that choice of binding agent has a big impact on the result of the gloss and colour of polished bone tools. If one set out to make a tool with a high degree of colour, one would use the pigments dry, on the other hand, if the goal were gloss, one would use fat in the mix, and you produce a nice gloss, but very little colour. The bones polished with water or fat are not left completely without colour though, so perhaps this hue is enough to give the wanted finish, if both gloss and colour is viewed as visually important?

As mentioned in my introduction, it is not only results that could have been important in an MSA perspective, but also the interaction with materials, the process of polishing. Our interaction with the world around us, and with objects, can hold a value in and of itself, making the focus on solely results perhaps a bit unguided. There are values that cannot be tested in an experiment, but is important to consider, as it is easy to look at results alone. Perhaps the degree of colour/staining on finished tools was not viewed as important in the MSA, but instead the tool was given a symbolic quality by the *act* of polishing with ochre? This could potentially provide polished bone tools without a lot of colour, but still with residue on a microscopic level.

The theories of technological styles/technological choices also remind us that there are often more than one technology/process that can give us a satisfying result, and that the choices made are always to a degree a result of socio-cultural preferences, not only better function. Choices might have been made in the MSA that are not the choices we find to be the absolute most effective. A certain operational chain could be viewed as important on a cultural level, without being what we would consider the most practical approach. This could theoretically mean that the reason we see less yellow ochre, though highly effective on certain materials, is perhaps due to its lack of colour, and a potentially lesser symbolic value, compared to red ochres (Watts, 2002, p. 1).

Ochre residue found on bone tools have often been viewed as a result of contact with ochre-covered materials, use of hafting material containing ochre, post-depositional processes, as well as the bones being used for working on ochre pieces. I have found that ochre is a useful polishing device for bone and could conceivably be found on bone tools as a result of a production sequence where they were deliberately polished or worked with an ochre powder.

The question remains, if we can determine polish to be deliberate, is it for a symbolic function, or simply a manner of processing and/or shaping the bone tools for functionalistic purposes? I would argue, that if ochre were a part of the process, this would point in the direction of a symbolic purpose of this process, as ochre is greatly linked to symbolic behaviour whenever it is found in an archaeological context.

In summation, when polishing a bone piece in the end-stage of the tool-creation process there are several different routes one could take to create a glossy or coloured bone tool, with a quite extensive variation in the operational chains all depending on the wanted result. Different ochres, together with other rock fragments and various binding agents could be mixed, depending on wanted results, and whether the process of polishing had a largely functional purpose, or a purely symbolic value.

Polished bone material from the South African MSA is scarce outside of Blombos Cave at this point, though it is found at some archaeological sites in the country (d'Errico et al., 2022), but it is hard to argue for an extended industry of this kind. Still, the fact remains that a variation of artefacts made of different materials are thought to have been deliberately polished with ochre pigments, making it more than possible that artefacts made of bone found with ochre residue could very well also be polished with ochre by human agents, and be part of a so-called symbolic behaviour linked to the emergence of the first modern humans in the South African MSA.

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Norsk sammendrag

Oker har hatt mange viktige funksjoner for tidligere mennesker, og har fortsatt til en viss grad i dag, fra kompliserte symbolske aktiviteter til mer daglig bruk som solbeskyttelse, eller som lim for å skafte redskap. Man finner det i det arkeologiske materialet, på stein- og beinverktøy, på personlige ornamenter, som maling i bergkunst og som en mikroskopiske rester på en rekke andre artefakttyper, og oker tolkes den som både symbolsk og funksjonell, med en rekke praktiske anvendelser. Oker-rester kan både være på grunn av menneskelig bevisst bearbeiding av redskapet ved hjelp av oker, fra sekundære tafonomiske prosesser fra å ligge i et okerrikt miljø, eller verktøyene kan ha blitt brukt til å bearbeide okeren, og dermed få okeren på seg.

Mitt hovedspørsmål i denne oppgaven er:

– Er oker nyttig for å polere for beinverktøy? Videre vil jeg utforske disse underspørsmålene: Hvordan ser mikroslitasjen og restene av oker ut under et mikroskop på de forskjellige typene bein polert med de ulike okerne, og skjellsanden, sammenlignet med deres makroskopiske utseende?

Er det forskjell på effektivitet og resultat ved bruk av ulike typer oker, eller bruk av skjellsand? Er det forskjell i effektivitet og resultat når man bruker oker med vann eller fett, eller bruker oker tørr? Er det forskjell på å bruke nye, gamle eller kokte bein? Hva kan disse resultatene potensielt fortelle oss om bruken av oker til polering av beinverktøy i middelsteinalderen i Sør-Afrika? Dette vil bli gjort ved hjelp av en eksperimentell tilnærming, som ser på både prosessering og polering av bein, og ved hjelp av mikroskopisk analyse for å spore mikroslitasje og rester på beinene før og etter polering med forskjellige medier.

For å konkludere med at okerpigment kan tenkes å ha blitt brukt som poleringsmedium, er det vesentlig at forsøket viser at okerne har egenskaper som gjør det egnet, eller til og med overlegent, til å polere med. Jeg mener at dette har blitt vist i dette eksperimentet. De ulike okerne hadde kvaliteter som ga en fin glans, og/eller sterk farge på beina. De var effektive for å skape en fin glatt overflate på kort tid. Det virker klart for meg at okerpigment har egenskaper som gjør det egnet til å polere beinmateriale, som er overlegent mitt kontrollmedium, skjellsanden.