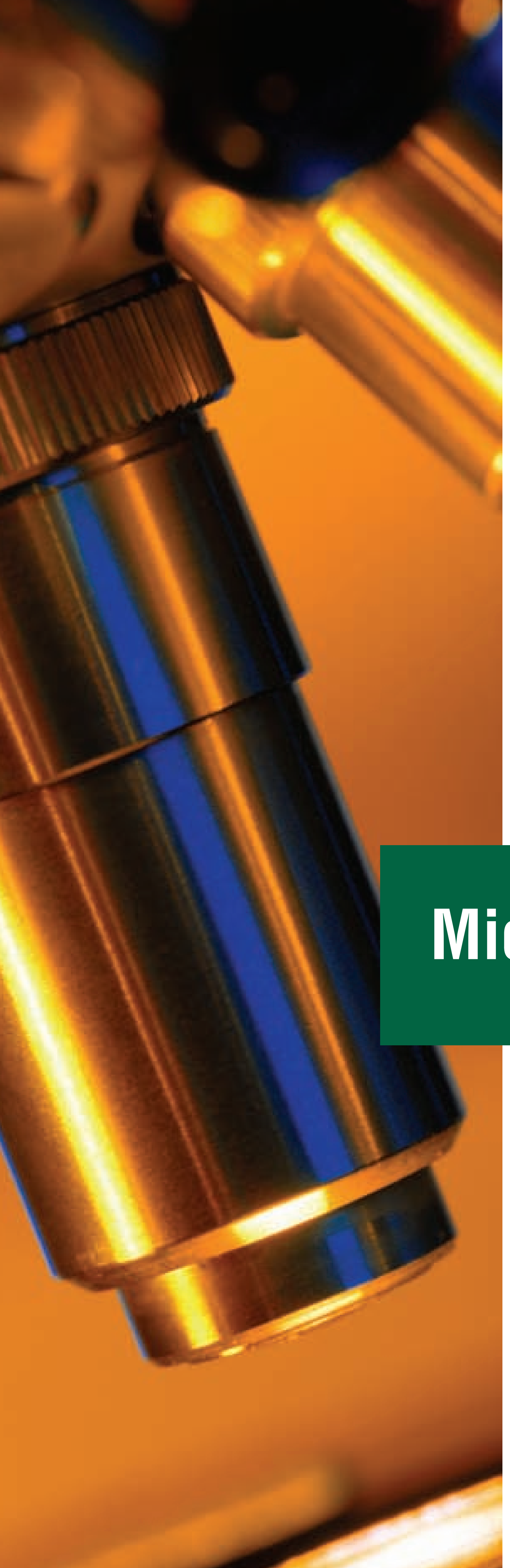


SURFACE TOMOGRAPHY AND METROLOGY IN THE QUEST TO UNDERSTAND PREHISTORIC MAN: AN APPLICATION OF LASER SCANNING CONFOCAL MICROSCOPY

A problem restricting the application of lithic microwear analysis to the study of stone tool function in archaeology is the lack of quantitative support for qualitative assessments of different wear traces.

Here reflective LSCM is evaluated as a technique for the study of microwear that can potentially resolve this problem. A comparative evaluation showed that images, rivalling that of the SEM, can be produced in similar timescales to conventional photomicrography and with no need for casting or sample preparation.

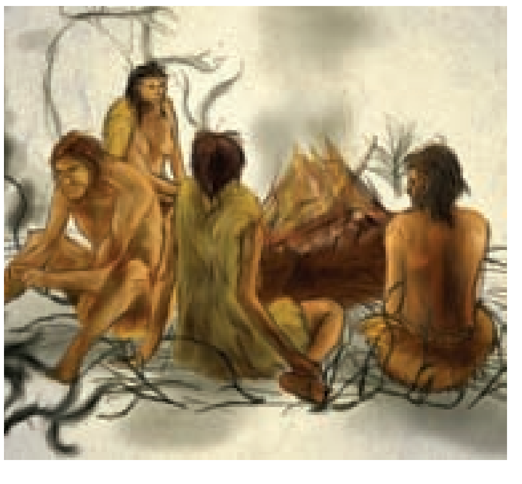
This proves extremely useful for the qualitative assessment and presentation of wear. Metrological analysis of surface data from samples used to work a range of materials demonstrates clear and measurable differences between roughness values of each wear polish.

This highlights the potential of the LSCM as a suitable approach in lithic microwear research. Whilst this experiment has limitations; a limited range of worked materials, worked over a controlled time scale.

It is argued that the results of this study are potentially groundbreaking in this field of research and a clear argument can be made that further evaluation of the method is warranted.

Adrian Evans placing a 500,000 year old biface from Boxgrove on his modified BH2 microscope stage.

Microscopy Focus



Archaeologists are charged with the task of reconstructing human evolution, prehistoric social interactions and human responses to climate change. Evidence for prehistoric activities are often limited to complex scatters of stone tools; the remnants of ancient activity. These tools and debris from tool production can be studied to answer questions of cognitive behaviour and technological change but under the microscope analysis lends itself to understanding how they were used. This allows us to take our interpretations a leap forward. The study of prehistoric stone tool use remains a key device in the examination and interpretation of archaeological site function and the behavioural operations of hominine and early human societies.

Lithic microwear analysis, along with residue analysis, has been fundamental to addressing these questions and is a technique that relies principally on the use of reflected light microscopy at a range of magnifications. Stereomicroscopy is used to study fracture damage at tool edges and can inform on hardness of material worked by the tools and the orientation of use. Higher magnifications, using metallurgical microscopes, are used to examine striations and changes in surface morphology which have resulted from the wear process.

This technique was principally developed 30 years ago by Larry Keeley at the University of Oxford. It works by producing modern replica tools which are then used to perform a wide range of tasks from reaping cereals to butchering deer. Wear traces produced from using tools on different materials appear different. Observation of traces on these modern tools can thus be compared to those seen on archaeological tools to derive tool use.

There is, however, several problems. These tools are buried for thousands of years (The oldest site in the UK is 750,000 years old) and the burial environment produces a set of wear characteristics of its own which hamper the interpretations of functional wear. The technique itself relies on interpretation by the analyst which results in errors because the differences between wear produced by different materials can often look very similar. Blind tests in the past have shown that analysts have been between 30% and 70% accurate. Errors often occur from those cases where specific worked material identification are attempted whilst scores increase for identifying motion of use or class of material hardness worked. The technique clearly needs to be improved if it is to reliably aid our interpretations of past activity.

Attempts at improving the technique have looked at using image analysis to study micrographs of wear, profilometry, and atomic force microscopy. My research has looked at the use of laser scanning confocal microscopy to aid the approach. The aim is to allow the analyst to identify the location of wear traces and then use the machine to characterise the wear using a knowledge base.

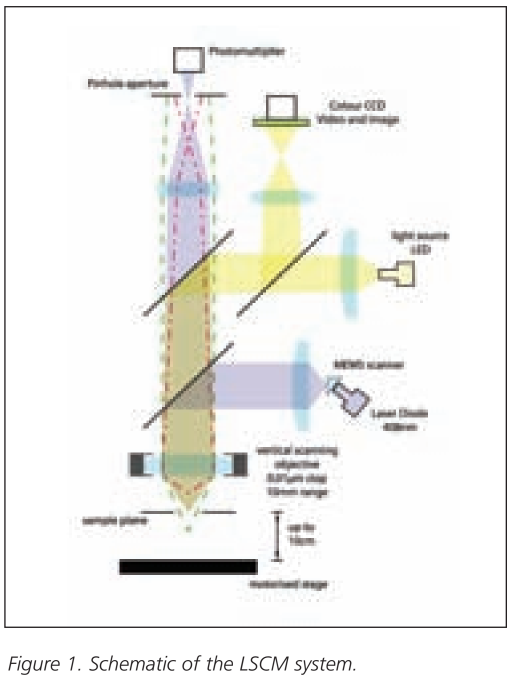


Figure 1. Schematic of the LSCM system.

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The laser scanning confocal microscope (LSCM) applied was the Olympus LEXT 3100. This system is designed differently to conventional LSCM systems which usually discard any reflected laser light and study activated fluorescence in stained biological samples. The LEXT is aimed at engineering science and uses the reflected laser to build z slices to produce tomographs of material surfaces *(Figure 1)*. It is highly suited to the task because it allows for large samples and does not require any sample preparation.

To acquire similar images using an SEM samples need to be cut down to fit in the chamber or small replica casts need to be made and they need to be gold coated for conduction. The entire process can take up half a day and is usually destructive. The LSCM reaches suitably high magnifications (up to 2000x), requires no sample preparation, and produces a surface tomograph in less than 5 minutes. The images are of much higher resolution and depth than one can achieve with conventional reflected light microscopy *(Figures 2-4)*. This alone aids the technique as new detail, essential in differentiating wear types, can be appreciated. This is not the best bit.

Owing to the data collection method and the nature of the tomographs, the system does not simply produce 3-d images or high quality 2-d micrographs, it produces x,y,z cloud data which can be studied using metrological approaches. These approaches can theoretically be used to see differences between different wear types.

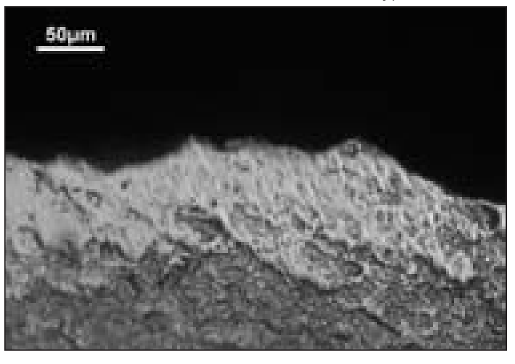


Figure 2. Typically this is the sort of image usually seen when conducting use-wear analysis. Depth of field issues and limits to resolution do not allow proper appreciation of texture though polished area is quite clear and stria in the wear can be seen.

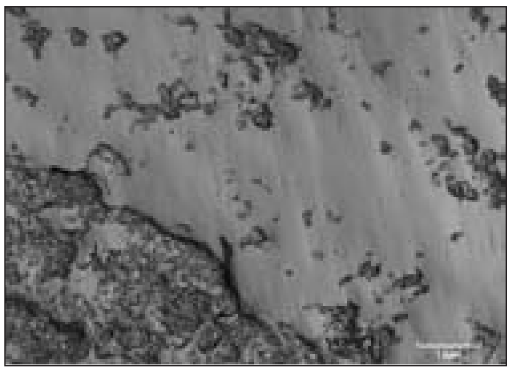


Figure 3. LSCM image of similar area to Figure 4. The resolution is good and texture is very clear. Produced with no sample preparation in less than 5 minutes.

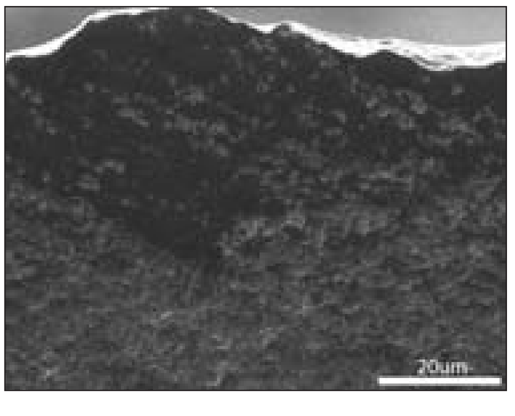


Figure 4. An SEM image of wear produced whilst working antler tine for 20 minutes. Image compares with Figures 2 and 3 taken with different instruments. To produce this image the artefact had to be gold coated and fixed to a stub. It is of high resolution but fails to highlight topographic variation within the polished surface.

I conducted a simple experiment to test this by producing a set of tools which had been used to work five different materials, each for 20 minutes. Wood, Antler, Fresh hide *(Figure 5)*, Greasy hide, and Dry hide. Wear produced by wood and antler looks quite similar and is often confused. It is easy to identify the wear as having resulting from working a hard material but additional detail to be gained by identifying which one of the materials worked is highly useful. The same can be said for the different types of hide wear. Hides are worked in different states at different times of the year. If one can differentiate the states then one moves from being able to say no more than a tool has been used to work a soft material to being specific about what task was carried out and discuss what season the site was occupied.

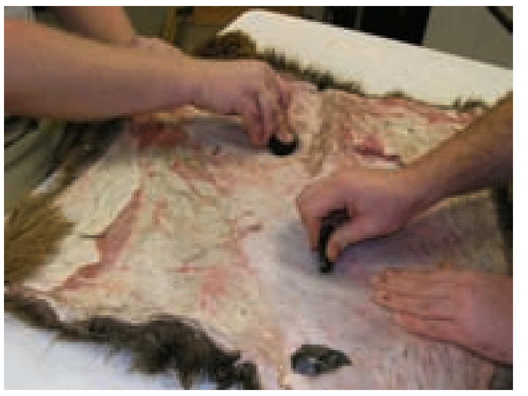


Figure 5. Red deer hide being scraped to remove soft tissue prior to tanning, a classic prehistoric task.

The tools were imaged using the LEXT and two sets of data were collected. The first was data from ≈10 micron squares and the second was from ≈ 4 micron squares. Taking data from areas rather than linear transects has the advantage that they are less biased by orientation of wear features that result from the working direction. Ten areas were measured from smoothed 'peak' surfaces at worn edges of each tool. Using two independent scales of measurement allows for better differentiation of the wear types because of the characteristics of polished surfaces produced by the various use-materials. Specifically, surface microtopography which can be appreciated as dominant features and texture, which includes stria and pitting, occur at a much smaller scale. These squares of data were subject to measurement and summised using a standard roughness parameter, Rq.

Analysis of the data has shown a very promising result and indicates that this technique can work to differentiate wear types. When plotted each of the different wear types *(Figure 6)* separate into individual clusters. The unmodified flint surface appears rough, dull and unpolished. The surface is clearly not flat, reflecting the micro-crystalline nature of the material. Unsurprisingly, both sets of roughness data suggest the natural unused surface of flint shows the greatest degree of roughness and also the greatest variability. The dry hide polished surface is visually distinct from an unused surface; the worn surface is still rough but shows signs of modification including the smoothing of high spots. The roughness measurements on the large scale indicate that the dry hide polish has a similar roughness to the unmodified surface which is slightly smoother but more variable. This fits with expectations as the roughness in troughs is unmodified and variation across the surface is vast. Also fitting with expectations is that the use of the smaller scale roughness measurement allows the two surfaces to be differentiated. Similarly in the small scale, wear from greasy hide and dry hide measure very comparably in terms of roughness and this reflects their visual appearance. Their roughness is similar at the smaller of the two scapes, however, the larger scale analysis can be used to differentiate these types of wear allowing for quantitative discrimination. The fresh hide wear is both qualitatively and quantitatively distinct to wear produced by dry hide and greasy hide. The fresh hide wear is more pronounced and more extensive; almost the entire surface has been modified and the general appearance is a series of domed features with a much smoother transition between smoothed peaks and lower surfaces. The larger scale data wear from fresh hide working overlaps only with that of greasy hide working, however, by using the complimentary data set produced through the small scale analysis these two wear types can be easily differentiated. The antler and wood polished surfaces again appear entirely different from any of the other surfaces. The polished surfaces produced on tools that worked these two materials are generally much smoother than those produced by any of the hide kinds. They also appear qualitatively distinct from each other: wear from whittling antler has an undulating character that is parallel to the working direction and also presents distinct striations. The wood polish on the other hand lacks striations, appears more flat and more reticulated than the antler polish. The large scale roughness data serve to segregate the wood and antler wear types as being clearly smoother than the other wear types studied. Through the use of the small scale data these two types can be distinguished.

The LSCM is a new tool for the imaging and modelling of artefact surfaces. This microscope combines the ease of use and speed of a metallurgical microscope, traditionally used by lithic microwear analysts, with the high focal depth, magnification and resolution of the SEM. The quality of images produced by the LSCM rival that of the SEM *(Figure 7)*, it requires no casting or coating, handles artefacts of all sizes, and is a far quicker method. The LSCM produces topographical data and preliminary results presented here show that wear, or surface polishes, produced by working different materials can be characterised using simple summary roughness measurements. These results show that the technique has great potential for the advancement of lithic microwear analysis where quantification of wear features might be carried out within a timeframe not much greater than that normally used by a lithic analyst to produce a photomicrograph of a worn surface.

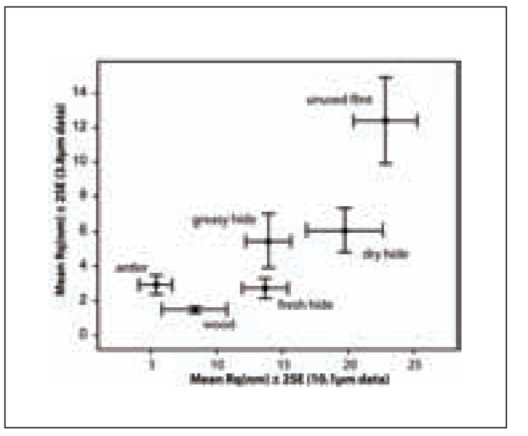


Figure 6. Chart showing how data collected from each of the different wear polishes can be used to separate the types.

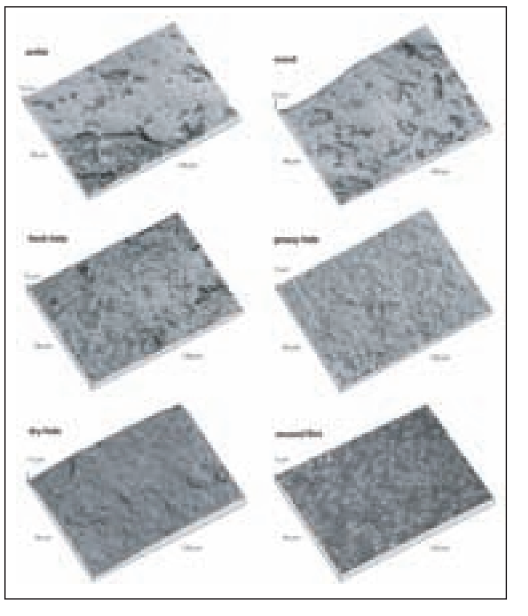
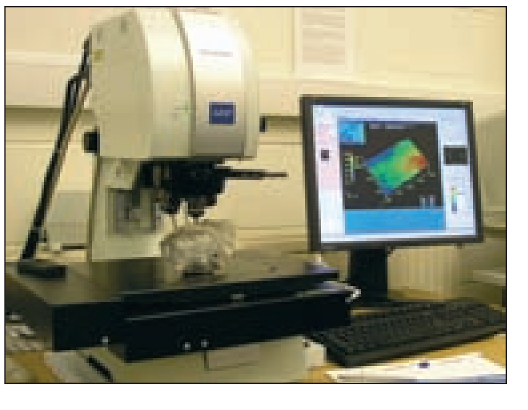


Figure 7. Micrographs produced by the LSCM of each of the different wear types studied.

Figure 8. Prehistoric tool production site at the location of Carrow Road, Norwich, created over 12,000 years ago. These are the only remains of prehistoric activity at the site.



The Olympus LEXT system being used to study a large handaxe from Boxgrove which dates to over 500,000 years ago.

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