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Aerial archaeological approaches are important in the study of sites, landscapes and regions, and are one of the major sources for discovering and understanding our past. The approach is well established, with a pedigree dating back over 60 years, though its application across Europe is not uniform. Increasingly new approaches and techniques are adding to the power of the aerial perspective, and one of the most exciting is the application of airborne laser scanning (ALS or lidar/LiDAR) to archaeology. Providing a means of recording and understanding topography from site to landscape scale and across a wide range of land use types from open agricultural land to forests, ALS is widely used in some parts of Europe, while in others its potential for archaeological research and Cultural Heritage Management has yet to be discovered. This variability in uptake lies at the core of the aims of the ArchaeoLandscapes Europe network, which seeks to promote the application of appropriate remote sensing techniques.

The ArchaeoLandscapes Europe network was established to support the development of aerial approaches and remote sensing techniques across Europe, to encourage the exchange of expertise and skills, to foster cooperation between archaeological institutions, and to enhance public awareness. ArchaeoLandscapes Europe (ArcLand; http://www.archaeolandscapes.eu) is supported by the EU under the framework of the Culture 2007–2013 programme (CU7-MULT7 Agreement Number 2010-1486/001-001). To date 58 partner institutions from 30 countries are working together to create a self-supporting network of expertise and to disseminate the methods and techniques of modern archaeological surveying to archaeological research institutions, cultural heritage management and to the general public.

The aims of ArchaeoLandscapes will be achieved through eight key actions:

1. Creating an ultimately self-supporting ArchaeoLandscapes Network.
2. Using traditional and innovative methods to publicize the value of remote sensing techniques and landscape studies amongst all those who deal with cultural landscapes and heritage sites.
3. Promoting the pan-European exchange of people, skills and understanding through meetings, workshops, exchange visits, placements and opportunities for specialist training and employment.
4. Enhancing the teaching of remote sensing and landscape studies through courses for students and teachers, and through a European Masters degree in Remote Sensing & Heritage Management.
5. Securing the better exploitation of existing air-photo archives across Europe and publicizing their potential for heritage interpretation and landscape conservation.
6. Providing support for aerial survey, remote sensing and landscape exploration in countries relatively new to their use.
7. Further exploring the uses of laser, satellite and other forms of remote sensing and web-based geographical systems in archaeological and landscape research, conservation and public education.
8. Providing technical guidance and advice on best practice in aerial survey, remote sensing and landscape studies, with a particular emphasis on conservation and heritage management.

As part of our work for Actions 2 and 7 we aim to publish a number of high-quality articles and books representing the current state-of-the-art of remote sensing and other surveying techniques. It is therefore a pleasure to be able to support this book, which has been made possible by the work of Rachel Opitz and Dave Cowley, both partners of the ArcLand network. It includes contributions from some of the leading experts in the fields of (topographical) landscape interpretation and treatment of ALS data, and draws on long-established expertise as well as more recent approaches. We are sure that this volume will become a standard text for all interested in the technological aspects of topographic research, landscape understanding and remote sensing in archaeology. I am pleased to thank Rachel and Dave for drawing this volume together, and the contributors for their invaluable work.

Frankfurt, 19 April 2012

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From lidar to LSCM: micro-topographies of archaeological finds

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Laser Scanning Confocal Microscopy (LSCM) uses similar principles as lidar to reconstruct 3D manipulable topographies of artefact surfaces. This is a relatively new technology which, when employed in archaeological material culture studies, opens up new avenues of enquiry and interpretations. Three case studies are presented to illustrate the interpretative potential of LSCM for understandings of artefact materiality. Importantly this method allows us to delve into incisions, reconstruct texture of wear and uncover residues on an object’s surface. These are traces of past performances of making, use and re-use. The benefits of this type of analysis are not just visual, but experiential, allowing us to build narratives of peoples’ engagement with objects.

The first case study explores the use of the technique to study Upper Palaeolithic stone tool function; a second case study explores the biography of an Iron Age antler object from Broxmouth Hillfort, East Lothian, Scotland; and the third case study reviews the study of tool marks on Iron Age worked osseous materials. It is hoped that the implications of employing LSCM to understand materialities discussed in this paper can be translated for applications of lidar to the wider landscape. Issues of scale, biography and identity are highlighted in these case studies.

Keywords: Laser Scanning Confocal Microscopy, artefact Biographies, antler objects, bone objects, lithic tools, Quantitative Analysis of Surface Features, tool profiles, use-wear, topographies, materiality, scale of analysis

Introduction

While the use of lidar to study sites and landscapes is now routine, this chapter looks at the use of similar technology on a much smaller scale, and consequently to a much higher resolution. Aerial lidar may achieve 60 points per metre and tripod based/bench top scanners record from around 1000 points per metre (1 cm resolution) up to 5000 points per metre (0.2 mm resolution). Laser scanning confocal microscopy (LSCM), described here, can scan 8 million points per metre (120 nm resolution). Thus, this technology allows the investigation of the micro-topography of object surfaces in the way that lidar allows the investigation of landscape surfaces, opening up a new area of the application of 3D laser scanning technologies for the investigation for object biographies. LSCM allows one to present a visual representation of surfaces that could not normally be resolved and makes the invisible visible in creating representations of the artefact surface in order to reconstruct immediate human experiences with the object over time. Thus, LSCM can provide an immediacy to physical and sensual human engagement with studied objects and has from the beginning been employed to answer questions of the immaterial.

At the scale of the artefact surface LSCM opens up the ability to study resource investment and
tool use in manufacture. It can characterize tool and wear marks, and enables an understanding of use-life through wear analysis. These capabilities come with the same benefits found in lidar: it is completely non-destructive, non-contact technology, the results can be used for display in manipulable 3D environments to support analysis or for virtual museum output, or as snapshots at intuitive orientations such as viewing along a cut mark to observe profile and any detail in profile changes (impossible with conventional and electron microscopy due to limited working distance).

The capabilities of this new technology for archaeological materials and the interpretative implications of working at this immediate scale are highlighted in three case studies. The first focuses on stone tool function and the advantages of texture measurement with a case study from Wey Manor Farm; a second explores the Iron Age biography of an antler object from Broxmouth Hillfort, East Lothian, Scotland; and the third case study explores the study of bone and antler objects from two additional sites. These case studies highlight past human engagements with artefacts and also the relationship of the researcher with the material under study.

The Laser Scanning Confocal Microscope
Laser scanning confocal microscopy is a technique that has been in use in biological sciences for imaging for quite some time (see Pawley 1995). Recently versions of this type of microscope have been developed that use similar principles for imaging surfaces for materials science, including the LEXT 4000 (Figure 10.1) used in this study. This microscope has a highly accurate vertical scanning head and horizontal scanning stage, with a highly refined optical system of panchromatic lenses at high numerical aperture which provides resolutions at the limit of optical systems and colour accuracy. The imaging system comprises the common white-light optical system for normal viewing purposes and a laser illumination system in a confocal pinhole arrangement for microscopic 3D modelling. It is this ability to produce 3D modelling of surfaces which has parallels with lidar; it provides essentially the same capability under the microscope and the opportunity to perform optical remote sensing or non-contact surface metrology (Figure 10.2).

The confocal microscope forms images by collecting reflected light from a discrete focal plane, in contrast to lidar where all laser light reflected from a surface by Rayleigh scattering is detected. To improve the resolution under the microscope a confocal system is required. This
discards most light that is not immediately in
focus at any given point across the sample surface
by using a pinhole aperture that is optically
conjugate to the focal plane. The pinhole does
not cut out all light that is out of focus and
close to the focal plane some out of focus light
does return to the detector, but with decreasing
luminosity. In this case luminosity is inversely
proportional to surface conjugation and this
diminishing return of light by depth allows the
system to estimate surface location even when
it falls between vertical slices. The incident
laser light used by the LEXT 4000 system is a
laser at 405 nm. The short wavelength light in
combination with a rapid response photodiode
allows high resolution imaging. The laser light is
scanned across the surface using a mirror linked
to a servo system. The mirror is an electroformed
(galvano) mirror which resonates in the beams
path using micro-electromechanical servos. The
objective lens is displaced through the vertical
axis and slices of optically focussed sections are
produced. As the vertical position of each slice
recorded is known, the slices can be processed
together to create 3D representations of the
object or surface data (cloud data). The planar
resolution that can be achieved with this system
is 120 nm and up to 10 nm vertical resolution.
Magnification depends on the objective lens
used and, as standard, the highest magnification
objective is 100× (0.95 NA), which allows
magnifications over 2000× to be achieved.

In practice there are a few apparent limitations
to the LEXT 4000 confocal system. Most notable
is that it does not react well to areas of darkness
in the field of view caused by a surface or areas
that do not reflect light. This is a common
problem in laser imaging systems and the LEXT
4000 attempts to negate this by using dual
pinholes with detectors of different sensitivities.
This effectively increases the dynamic range and
enables the imaging of complicated surfaces of
uneven reflectivity.

LSCM is highly suitable for the imaging of
bone, lithic and metal surfaces. Usual observation
of worn tool surfaces is by optical microscopy
or scanning electron microscopy (SEM), but
these systems have some imaging issues. Optical
microscopy suffers from very limited depth
of focus which limits appreciation of complex
textures, while SEM is cumbersome and requires
mounting and often coating of samples. Neither
SEM nor optical microscopy can produce 3D
models without complicated additional software.

For the SEM, software is available that uses
multiple images taken using a tilting eucentric
stage to produce useable surface models (e.g.
MEX, Alicona), while for the optical microscope
a vertical stage motor can be added to collect
images taken at different focal depths that can
be reconstructed using focus region detection
during image analysis. There are commercial
systems that provide this, one of which has been
used in the imaging of cut-marks and fractures
on archaeological bones (Bello et al. 2011). Free
systems are also available that can do this type
of reconstruction using any microscope (e.g.
Helicon Focus, ImageJ plugins) but the quality is
dependent on the quality of lenses and accuracy
in stage height adjustment (motorised or manual) –
which usually is not as high as purpose build
precision engineered equipment.
Figure 10.3: Laser intensity images, captured using the LSCM, of worn tool edges produced by different processes. Each pair (upper and lower) represents wear types that are traditionally hard to distinguish. Visualisation of microtopography using confocal microscopy makes this possible.

Case studies
The biographical study of archaeological artefacts is important for understanding their social, political and ideological roles in particular contexts over time, since the role and value of objects is not stable (Appadurai 1986; Gosden and Marshall 1999) and are crucial in forming and maintaining social relationships (e.g. Chapman and Gaydarska 2006; Gell 1998; Hurcombe 2007; Thomas 1996; Henare et al. 2007). In the main these studies have looked to ethnography, experimental archaeology, microwear studies and the depositional contexts in which archaeological artefacts are found. As demonstrated here, LSCM can contribute to this endeavour to unpick palimpsests of wear and reconstruct the tools which create the microtopographies of artefact surfaces. Furthermore LSCM working at the immediate scale has the potential to reveal the networks of materials (including organics) and people in which the object under study was involved.

Stone tools
Understanding of function and means of production, principally through wear analysis, are key aspects of stone tool research (Evans and Macdonald 2011; Verges and Olle 2011). LSCM offers the analysis of stone tools the power to move beyond the production of images and surfaces for morphological analysis, into the realm of surface texture investigation. This is important because it represents a crucial step towards improving the currently established
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approach of functional analysis in lithics, which has relied on subjective comparative microscopy of modern experimentally used specimens with archaeological counterparts (i.e. traceology, lithic use-wear analysis or microwear analysis (Tringham et al. 1974; Keeley 1980)). In these traditional approaches analysis is conducted at a range of magnifications, from stereomicroscopy through to SEM, and can focus on macroscopic edge fracturing, scratches, fine stria, edge rounding and polished surfaces. Features are recorded as the observer interprets them and from this conclusions of use are made through comparison of features on modern experimental tools that have been used in different processes. These approaches have become a serious point of contention amongst analysts, with experimental tests designed to question how effective the traditional approaches are in identifying tool function (Newcomer and Keeley 1979; Odell and Odell-Vereecken 1980; Gendel and Pirnay 1982; Newcomer et al. 1986; Unrath et al. 1986; Shea 1987; van den Dries 1998, 99–112; Rots et al. 2006). These blind tests were experiments where analysts were presented with modern experimental tools that had been used to perform tasks without the analyst’s knowledge in order to assess how accurately the method could be used to identify tool function. On average the method has been able to identify contact material to an accuracy of under 50% and the type of motion tools are applied in is identified correctly 73% of the time (Evans 2009, 101–5). Despite these results, this method is still applied (Hardy and Moncel 2011; Nunziante Cesaro and Lemorini 2012; Donahue and Evans in press); this in itself being a good indicator of how important understanding stone tool use is viewed.

However, the application of LSCM has the potential to put these studies on a much more secure footing, relying less on a highly subjective interpretation of a range of wear patterns and markings. The imaging capabilities of LSCM in visualizing surface texture at a high resolution (Figure 10.3) makes visual distinction of wear types far easier than it has been previously using traditional microscopy techniques. The top two images in this figure, for example, represent wear from working antler and wood. These are very similar but fine stria can be seen on the polished surface on the antler working tool, while the polished surface of the wood working tool appears to be flatter and without micro-texture. Identification of such differences increases confidence in making interpretative decisions on the use of archaeological tools. In addition, the metrology capabilities of the system can be harnessed to differentiate worn surfaces with using a quantitative approach. This is enabled through the use of texture analysis to study the 3D surfaces and identify differences in surface polish quantitatively rather than visually. Experimental work using LSCM has illustrated its potential for crystalline silicates such as flint and chert through imaging of surfaces and subsequent study using texture analysis methods derived from engineering (Figure 10.4A; Evans and Donahue 2008). The analytical technique used is the measurement of roughness (as defined by ISO standards) over areas of the surface. An
individual blind-test of this method confirmed the potential capability (Evans and Macdonald 2011) and preliminary research on its application to amorphous silicates such as obsidian may also be useful (Stemp and Chung 2011).

The example presented here is from the Upper Palaeolithic site of Wey Manor Farm (Surrey), one of only a few open air Upper Palaeolithic sites found in situ in the UK and all the more remarkable for its undisturbed contexts and good state of preservation. The tool in question is typologically a ‘burin’, that is a blade modified to have a robust chisel-like edge (Figure 10.5). ‘Traditional’ analysis suggested that this tool was used to work a hard material such as wood or bone/antler, an interpretation common when the analyst is not confident about the specific type of hard material involved. However, metrology has the most potential when differentiating broad classes of wear identification made using traditional approaches. The data produced from the analysis of the tool’s surface using the LEXT, when presented with the experimental data, clusters in an area that overlaps with four of the six processes tested (see Figure 10.4B).

However, the majority of data corresponds with antler scraping, suggesting that the tool was used to work antler (or bone, which produces a similar texture) rather than wood. The additional interpretative data derived from this analysis is of considerable use. In this case it takes a tool that has an interpretation as being used for a craft activity – working a hard material such as wood or bone/antler – and furthers this to the identification of working osseous material. Wood working and bone working, while both craft activities, represent different types of time investment and produce objects that were treated in different ways, bone objects are far more likely to have been curated owing to the additional time investment required in their production. This enables hypothesis testing/building related to retooling strategies and landscape use. In this particular case there is only one tool discussed here but, for example, this suggests the production of objects out of bone was occurring at this location. This enables reflection on material selection strategies and brings one a step closer to a good understanding of the activities at the location of discard.
**Antler drum, Broxmouth Hillfort**

The high resolution 3D mapping of visual and textural surface properties of an antler drum bearing eight incised ring and dot motifs (Figure 10.6) from Broxmouth Hillfort, East Lothian (705 cal BC – cal AD 260) (Armit and McKenzie forthcoming) allowed us to examine its specific biography over time. This artefact was an off-cut from a larger handle and subsequent wear within the perforation shows that it was re-used as a bead or suspended on a thong before deposition in association with structures 400–210 cal BC. LSCM allowed for a more detailed understanding of this object’s biography than would have been possible using other techniques by indicating that three different tool profiles had been used to create the ring and dot motifs. It also allowed us to explore the efforts of the craftspeople who made and decorated this object, since scratches and other marks represent evidence of the failure and frustration of attempts to incise.

By taking 3D measurements of the incisions it became evident that multiple points, perhaps multiple compass tools, were used to incise the ring and dot motifs of the antler drum (Figure 10.7). Compass tools with centre scribing bits were used to decorate this object, because slight sporadic variations in the width between the central dot and outer ring, along with the varying depth of the incised outer rings (average range of difference between two measurements was 129 μm–139 μm) represent differences in applied pressure. On the other hand, a cylindrical boring tool would be expected to give uniform or relative depth measurements, or a fixed double-pronged trepanning tool or bar would be expected to give relative width measurements between the central dot and outer ring, taking into account the pressure applied by the human hand. Neither of these are the case here and cannot therefore have been used to decorate the drum. A lack of precision and variability was exactly the reason why scholars have thought compass tools would have been an unlikely choice to create motifs which look concentric and precise to the eye (MacGregor 1985, 75; Tuohy 1995, 57). However, LSCM has shown the adaptability and variability of the tool used to incise the motifs. The width, depth and shape of the central dots of each motif were examined and 3-D reconstructed using LSCM, and the results show that three different tool profiles were used: a rounded bowl point, a steep-sided V-profile and a bevel bottomed point (Figure 10.7). Therefore, it could be that three different compass tools or points attached to the compass were used for decoration (Figure 10.8). Alternatively we are seeing the sharpening of a bowl point into a steep V-profile, and then blunting into a bevel point. Variations in the height and width show blunting or adaptations to inconsistencies of the antler surface whilst incising each motif, but the three tool profiles remain recognisable and form
three groups (shown in Figure 10.7). Therefore we are getting an insight into the three-stage planning of the decoration of this artefact, where the three groups of motifs are spaced at regular intervals, and between each stage either a different point/compass tool is used or the same point is sharpened.

The detailed mapping of the surfaces of the drum also brought to attention failures in, and re-attempts at incision. In particular, motif six appeared to have been particularly difficult to incise; three points of entry into the central dot are evident (Figure 10.9) corresponding with episodes of slippage during incision of the outer ring. Slippages correspond with natural variations in the antler surface, from very smooth to pock-marked and uneven. There is no evidence for smoothing of the antler tine prior to incision which may have made it easier to work. As such, a considerable investment of skill is manifested in the decoration of this object; the craftsperson, feeling through their compass, had to adapt to changes in the natural antler surface, a task not always easy to achieve (Figures 10.6 and 10.7).

The variation in tool profiles enables the consideration of a detailed understanding of artefact history. Figure 10.7 shows the three different combinations of motifs incised in three groups, either indicative of sharpening or of multiple points. It might be tempting to suggest that multiple individuals, with their own personal compass tools, may have been involved in the decoration of this artefact. The ring and dot motif may have been an owner’s ‘stamp’, similar to a trophy won at a football match with the teams name incised. Another possibility is that if we presume a time gap between each group it may be that the ring and dot motifs were incised during transitional moments over generations or in an individual’s life associated with their coming of age or change in status. Similar interpretations have been argued for Bronze Age spacer necklaces, for example one found in a cist associated with a young woman in Mount Stewart, Bute (Clarke et al. 1985, 289; Shepherd 1985, 213). The Mount Stewart necklace has a replacement toggle which is unworn (Shepherd 1985, 213), many of the beads show varying degrees of wear and some beads are argued to be made from originally larger beads (Clarke et al. 1985, 289). This antler object from Broxmouth was originally part of a larger object and was sawn down to size and subsequently worn. Therefore, it too has evidence for curation and re-use. It was argued that necklaces like this Mount Stewart example were passed down and circulated via group or family members and embellished and repaired over the course of these transitions (ibid.). The motifs incised into the Broxmouth antler object can be thought of in a similar way, as embodiments of a network of enchainment (of human relations or individual achievements). The testing of some of these hypotheses is not possible but previously such things were hard to discuss without the good understanding of variations in engravings that this research method allows, whilst repeated incision over time re-enacted and re-interpreted the materialities of the antler drum and kept it in use. If soaked for working, cast antler ‘bleeds’ a smelly red substance. Red appears to have been a powerful colour in the British Iron Age, linked to ideas of fertility, death and violence (Giles 2007) and it is therefore possible that repeated
The incising of this object was an important act of purification, bringing it back to life.

The employment of LSCM in this case has greatly added to our capability to discuss and understand the planned manufacture and biography of this antler drum. It allows for the consideration that ring and dot motifs were not haphazardly decorative, but were planned and executed with skill. It can be suggested that what has often been considered to be a mundane artefact was, in fact, maintained and embellished by more than one person through incising ring and dot motifs, thus indicating its social value, each re-working performed to mark moments of change. Furthermore the discovery of a compass tool is important as there is only one example of an actual compass tool of Iron Age date in the archaeological record from Fairy Knowe, Stirlingshire (Main 1998).

**Objects from the Uamh an Eich Bhric and Uamh an Ard Achaidh**

LSCM of worked antler has highlighted some of the potentials and limitations of the technique for the high resolution examination of tool-marks. This case study examines artefacts from two Iron Age sites on the Isle of Skye. Uamh an Eich Bhric (Cave of the Speckled Horse) is a rock shelter with extensive eroding middens and evidence of craft activities dated to between 50 BC and 250 AD (Wildgoose and Birch 2010, 8) and Uamh an Ard Achaidh (High Pasture Cave) is a late Bronze Age/Iron Age votive and feasting site (Birch and Wildgoose in prep). The well-preserved tool-marks on bone and antler provide a proxy-record for the tools being used by Iron Age people, where the actual tools are often poorly preserved or entirely absent from the archaeological record (Cruickshanks in prep.). In order to distinguish different tool-marks examination under high magnification is required, and to date, attempts to identify different tool types and materials have primarily used SEM of a silicone cast of the tool-mark (i.e. creating a positive impression of a negative feature (e.g. Olsen 1988; Greenfields 2002; Cristiani and Alhaique 2005). It is not ideal to make casts of osseous surfaces, especially fragile objects where this process can destroy the surface including any tool marks. Such a procedure is relatively crude and LSCM allows this to be avoided. As a result it is also quicker, offering much more powerful means for visualising the surface topography and opening up new possibilities for analysis.

A pin head or pegged gaming piece from Uamh an Eich Bhric (Figure 10.10 left) displays a variety of tool-marks from manufacturing and modifications through its life. Analysis focussed on two cuts across the base. Their purpose is unclear and they may represent later modification of the object. Initial visual analysis suggested the cut marks were likely to have been made by the same blade due to their similar width (c.1.5 mm), although one was considerably deeper. However, the LSCM images showed different profiles for the two cut marks (Figure 10.11). The deeper cut (cut B) has a square section with striations along the edges, which is typical of a metal saw (MacGregor 1985, 55), while the shallower cut has an asymmetric profile with slightly sloped sides and base. The shallower cut (cut A) is more difficult to classify, being somewhere between a saw profile and the typical V-shaped section of
Figure 10.11: LSCM images of cut marks from the pin head/gaming piece, showing flat base and steep sides with striations typical of a cut made with a saw.

Figure 10.12: Symmetrical, steep sided V-shaped cut mark on the antler tine, typical of a very sharp metal blade.
a knife or axe cut. It was possibly created by the same saw as the deeper cut, but slightly angled which would cause the asymmetry; perhaps a reason for abandoning the shallower cut in favour of the second, straighter and deeper attempt.

The piece examined from Uamh an Ard Achaidh is an antler tine which has been hollowed out, probably for use as a handle, and has a deep cut parallel to the end (Figure 10.10 right). It was recovered from a context dating to around 600–500 cal. BC (Birch and Wildgroose in prep). The LSCM image showed the profile to be symmetrical and V-shaped with very steep, smooth sides (Figure 10.12). This is typical of a sharp metal blade, the smooth sides suggest a chopping action from a heavy blade such as an axe or cleaver, rather than a sawing or slicing action from a lighter blade which would create striations along the edges (Walker and Long 1977, 608). The base of the cut has a hump in the middle indicating that the blade edge may have been concave. This can occur from sharpening a blade and poses the intriguing possibility that this technique could be used to match distinctive cut marks to a specific blade. Although the LSCM image clearly shows that this was made by a metal tool, more comparative work is required to conclude whether this was a copper alloy or iron tool, a particularly interesting question given the early Iron Age date.

A limitation of LSCM for the examination of tool-marks is the scale of the topography. LSCM in the case of the Olympus LEXT 4000 is limited to the study of surfaces where topography varies less than 1 cm in depth. As a result, only a section through part of the cut mark on the antler tine from Uamh an Ard Achaidh could be scanned as the depth of the cut along with the curve of the bone proved too deep to scan the entire surface. It should however be noted that this can be negated by the use of two scans at different depths and post-production manipulation.

Discussion and conclusion

These three case studies have introduced some potential applications for LSCM as a technique for addressing questions of materiality. LSCM has great potential for the analysis of tool-marks on ivory, antler and other materials (potentially organics) and seems particularly suited to shallow, micro-topography. Analysis of the burin from Wey Manor Farm enabled an understanding of the tool’s use and helps to build a picture of the activities which took place at this site in the Mesolithic. The examination of the Broxmouth drum revealed use of a specific tool set and the extent of investment for the decoration of the object, highlighting the multiple hands that may have been involved. High-resolution examination of Iron Age worked bone and antler artefacts from the Isle of Skye clearly showed the use of metal blades (a saw and a heavy chopping blade) providing rare glimpses of tools which are rarely found in the archaeological record.

Examining object surfaces at high resolution adds a different dimension to the biography of objects, shedding light on objects that no longer exist and illuminating networks of social relations and individual engagements over time. In the case of the Broxmouth drum, it demonstrates the existence of tool technology that previously might have been considered rare in the British Isles. There is only one example of an Iron Age compass tool in the UK (Main 1998) but these results indicate a much wider circulation of such specialist items. It shows the planning in manufacture and the potential circulation of an everyday antler object with ubiquitous ring and dot motif (this motif is found on many types of objects, combs, torcs, shields and mounts of bone and metal throughout the Iron Age in Europe). On the Isle of Skye further tool types are revealed that are incredibly rare in the archaeological record, perhaps through evaluation the metal tools were of high value and therefore recycled, rarely making it into the archaeological record (Taylor 1999). The discovery of these tools situates the artefacts under study within a complex assemblage of materials indicative of enmeshed social networks (Hurcombe 2007). The Wey Manor Farm burin analysis brings to light the past use of the tool and, with the analysis of other tools at the site, places it within a social context of landscape use and personal organization (the spatial patterning of activities within living spaces). These results are a direct challenge to traditional approaches to interpretation that have been the subject of heated methodological debate in material culture studies, offering an approach where qualitative and quantitative analyses can be applied with a degree of consistency at a fine-grained immediate scale to contribute to understandings of society in the past. For example, further work comparing LSCM images of tool-marks from copper alloy and iron tools could provide a new
insight into the introduction and development of iron tools, enabling the identification of individual workshops or tooling based on the identification of characteristic wear marks.

In conclusion, by working at the immediate scale to analyse textures, tool-marks and residues, LSCM has opened up new avenues of exploration into the materiality and social lives of artefacts. The immaterial becomes material at this scale of analysis.

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