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Defence and decoration: new findings on a late fourteenth-century 'kettle-hat' helmet found in London

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Summary During the conservation of a late fourteenth-century 'kettle-hat' helmet in preparation for its loan to the Royal Armouries Museum, traces of red surface decoration were discovered. This previously unrecorded feature initiated the most in-depth examination of the helmet since its acquisition by the British Museum in 1856.

The red material was identified as vermilion, and a thorough mapping of the areas in which it had survived showed it had been applied in a quartered arrangement. The presence of vermilion suggested that, despite modification of the helmet into what was assumed to be a cooking vessel, the object was not used as such after the decoration was applied. This was further confirmed when metallurgical analysis showed the metal was unlikely to have been heated after the initial forging process.

Examination of the metallographic structure showed it bears much in common with other helmets dated stylistically to the fourteenth and fifteenth centuries. The quartered decoration is similar to some depictions in Medieval illuminated manuscripts, which show brightly painted helmets, although no other examples with painted decoration are known to have survived from such an early date. It is therefore a strong possibility that the vermilion decoration relates to the original function of the helmet rather than being a later addition and that, as such, it is the earliest known survival of Medieval armour decorated in this way.

INTRODUCTION

In 1856 the British Museum purchased the substantial private collection of antiquities accumulated by Charles Roach Smith (1807–1890). Smith, an amateur archaeologist and 'gentleman scholar', had amassed a diverse assemblage of objects unearthed during the redevelopment of London in the early- to mid-nineteenth century [1; p. 108]. He meticulously recorded details relating to many of his 'London Antiquities' and by the time the collection was acquired by the British Museum, part of his notes had been committed to print in a formal catalogue and numerous additional items were recorded in manuscript [2]. This catalogue is now crucial in establishing provenance and providing contextual information for many of the objects.

Amongst the Smith collection was a helmet characteristic of the late Medieval period (1856,0701.2243), which appears to have been altered at a later date by the attachment of a length of chain to the brim, possibly to allow its use as a cooking vessel or 'kettle', Figure 1. Its use as the latter would be ironic, as this form of helmet is most commonly referred to in English as a 'kettle-hat', a term that derives from the Germanic word *cetel* or *cietel* and alludes to its deep, cauldron-like shape. Other terms for the shape include 'war-hat' and derivatives of the term *chapel-de-fer* (hat of iron), all of which refer to the helmet's open-faced, hat-like construction and characteristic downward sloping brim [3; pp. 31–32, 4; Vol. II, p. 57].

Smith's notes record that the helmet was "dug up in forming the terminus of the London and Greenwich Railway in Southwark" [2; Vol. II, p. 149]. While the exact date of discovery is unknown, construction of the London Bridge to Greenwich railway was sanctioned by parliament in 1833 and the Southwark terminus, now known as London Bridge Station, was fully operational by 1838 [5; pp. 73–74 and 603]. Throughout the Middle Ages Southwark was the only major settlement on the southern side of the river and, accordingly, finds of Medieval material from the area are not uncommon. The relatively good condition of the helmet is not surprising as the alluvial deposits of the lower Thames valley floodplain are often anaerobic and consequently provide excellent conditions for the preservation of archaeological material [6, 7; pp. 57–72].

FIGURE 1. The helmet before conservation, shown as previously displayed, suspended upside down from a handle and chain

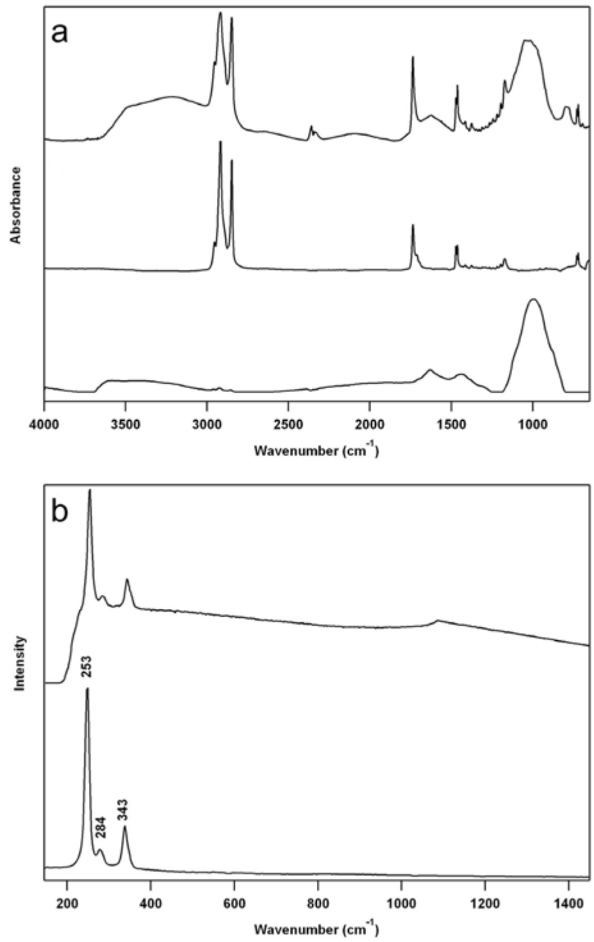

FIGURE 2. The identification of samples from the helmet: (a) ATR FTIR spectra of a sample of a mixture of waxy and green materials taken from the surface (upper trace), a reference sample of beeswax (middle trace) and a reference sample of silicaceous green earth (lower trace); and (b) Raman spectra of a sample of red material from the surface (upper trace) and a reference sample of vermilion (lower trace)

CONDITION AND OBSERVATION

The helmet was on permanent display in the British Museum for a number of years before being returned to storage in 2007. Following a decision in 2010 to place it on long-term loan at the Royal Armouries, it was subjected to the detailed examination discussed here. No previous treatment records could be found for the object.

The overall condition of the piece, and good preservation of the metal, support the hypothesis that burial had occurred in an anaerobic waterlogged environment where the effects of hydrolysis would be reduced significantly [8]. The oxidized but stable surface of the metal was found to be obscured by a thick application of a waxy substance which, when examined under magnification, was observed to have built up in surface recesses. This waxy material was discoloured, ingrained with surface dirt and had sporadic patches of a white/yellow 'bloom', a feature characteristic of the oxidation and degradation of unrefined organic waxes such as beeswax [9; p. 150]. When it was examined under ultraviolet radiation at 365 nm, the entire surface showed a dull, orange luminescence, providing further evidence for an organic surface coating. Below the coating faint traces of red/brown and grey/green substances could be seen on the metal surface. The red/brown layer was initially thought to be hematite (Fe_2O_3), which could relate to heating of the metal if it had seen secondary use as a cooking vessel. Although heating above 200°C usually leads to development of black iron oxide (magnetite or hammer scale, Fe_3O_4), when iron is heated in air at temperatures below 570°C, a two-layer scale can develop that consists of magnetite adjacent to the metal and hematite at the surface [10]. The grey/green deposit appeared in small, uneven patches over the whole object. When the surface deposits were examined under high magnification they were seen to form distinct but intermittent layers on top of the metal and, where they overlapped, the red/brown deposits were always below the grey/green material. These features had not been recorded previously and small samples of the waxy substance and the two differently coloured deposits (red/brown and grey/green) were taken for analysis using Raman spectroscopy and attenuated total reflectance Fourier transform infrared (ATR FTIR) spectroscopy.

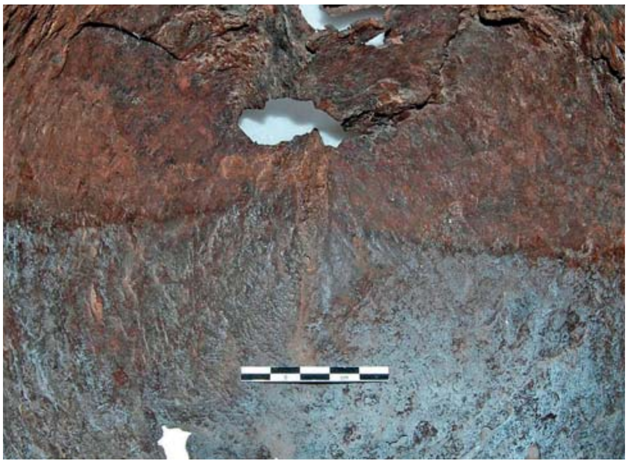

FIGURE 3. Interior surface of the helmet during cleaning to reduce the white coating of degraded wax. Scale bar shows 1 cm divisions

FIGURE 4. Map of the kettle-hat showing the locations of traces of red material: top left – front; top right – left side; – bottom left – right side; and bottom right – back. Drawing: Jamie Hood

SURFACE ANALYSIS AND CONSERVATION

The waxy substance gave an ATR FTIR spectrum that matched that of beeswax, Figure 2a. While beeswax is known to have been used as a coating and a binder since antiquity, it is unlikely that this material is contemporary with the helmet. It shows little or no structural degradation and would be unlikely to survive burial in such good condition. It was also applied over areas of passive corrosion, which strongly suggested that it was a ‘modern’ coating. Although no treatment records exist for the helmet, in this case the beeswax was most probably applied to consolidate and improve the appearance of the metal after the object was acquired in 1856 and before the 1960s, when synthetic microcrystalline waxes were introduced.

Raman spectroscopy showed the red material to be vermilion, mercury(II) sulphide (HgS: Figure 2b). There is no obvious natural process by which this could have accumulated on the metal and it must, therefore, represent the remains of a painted surface. The grain size is relatively large, suggesting that the material is either ground natural mineral cinnabar or was produced using the dry process [11]. While this tends to suggest an early date, preceding the development of wet process vermilion in the seventeenth century, it cannot be used as a conclusive indication of date, as the use of both the dry process and natural forms continued after this time. While vermilion is in general a fairly stable pigment (although blackening is possible in some circumstances) it is not thermally stable at the temperatures that might be expected from a cooking fire, converting first to the black metacinnabar form before subliming at around 600°C.

Attempts to characterize the grey/green material fully were less successful, although the ATR FTIR showed it to be silicate based. Given this and its distribution, it is thought to be natural clay related to the burial conditions.

Conservation was confined to surface cleaning. Solvent cleaning tests were carried out using white spirits, chosen as one of the few solvents in which beeswax is soluble [9; pp. 150 and 218]. The cotton wool swabs used initially to reduce the discoloured white/yellow surface bloom fluoresced under ultraviolet light as a result of the removal of wax, but the black colour of the swabs indicated that this wax also harboured ingrained dirt. After these initial cleaning trials the red surface deposit was more clearly visible and the decision was taken to reduce, rather than remove, the remainder of the bloom to uncover the surface below while

FIGURE 5. The kettle-hat after conservation with the red surface decoration clearly visible

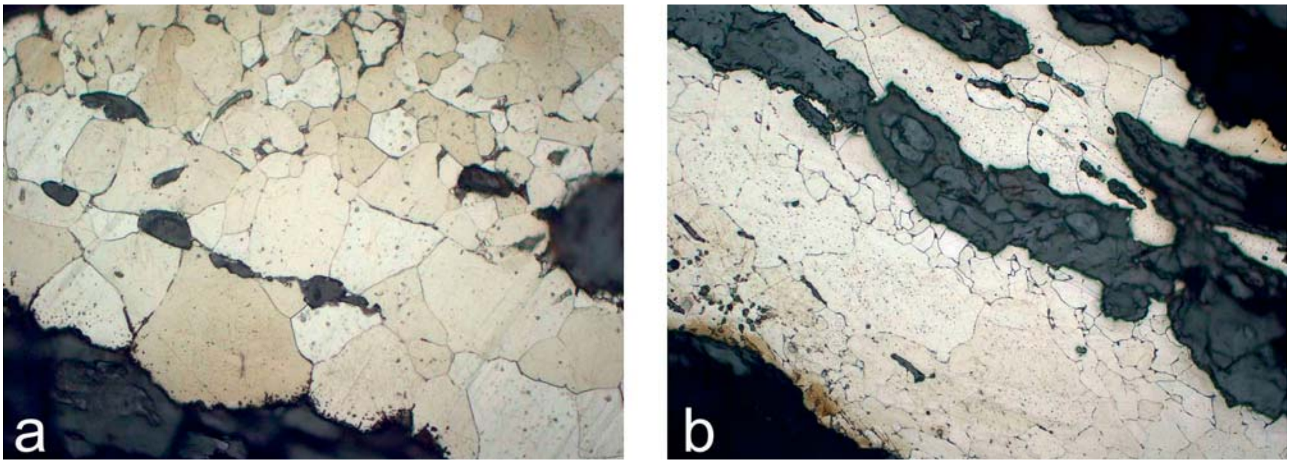

FIGURE 6. Scanning electron micrographs of samples from the kettle-hat: (a) sample SN1086 from the crown of the helmet showing slag inclusions, larger ferrite grains near the surface and small quantities of intergranular pearlite between the smaller ferrite grains; and (b) sample SN1087 from the rim of the helmet showing small slag inclusions, corrosion (large dark area) and bands of different-sized ferrite grains containing minute carbide or carbo-nitride precipitates. Width of field: 0.68 mm

still leaving enough wax in place to offer future protection to the surface, Figure 3. As a precaution the swabs were checked under magnification at regular intervals to ensure no red/brown or grey/green deposit was being removed.

Following this treatment the surface of the helmet was mapped to establish where traces of the vermilion remained, Figure 4. The overall distribution of pigment strongly suggested that it was originally applied in a quartered arrangement, dividing the helmet from front to back, along the medial line, and laterally across the sides. The front proper left and back proper right quadrants appear to have been painted with vermilion and microscopic traces identified on the underside of the brim suggested that the scheme also extended to these corresponding surfaces, Figure 5. As the grey/green silicate-based material was more elusive and less easy to characterize it was not subjected to the same mapping process.

METALLURGICAL ANALYSIS

Two small metal samples were taken from the helmet, one from a break at the crown (SN1086) and one from the rim (SN1087). These were prepared for optical microscopy by mounting in a cold-setting resin, grinding on water-lubricated carborundum paper and polishing with 6 and 1 μm diamond pastes to ensure optically flat surfaces.

Both polished sections showed mid-grey, elongated inclusions, some of which formed 'stringers' that could also be seen in the corrosion layers. These inclusions were slightly more numerous in the sample from the crown (SN1086), and appeared to be single-phased slags with some oxide (wüstite: FeO, approximately). A small amount of intergranular corrosion was visible on the crown section, SN1086. There appeared to be fewer inclusions in the rim section (SN1087), but this may simply result from the normal variation in sampling.

Etching with nital solution (2% nitric acid in ethanol) revealed a low-carbon, ferritic iron structure in both samples, Figures 6a and 6b. A very small, variable amount of carbon was present in both sections, constituting less than 0.15% by weight. This took the form of very small areas of coarse intergranular pearlite, grain boundary carbides and minute iron carbide or carbo-nitride precipitates within the larger grains. It was noticeable that the two sections responded differently to etching: the grains in sample SN1086 oxidized rapidly, while SN1087 responded more slowly, becoming discoloured in an irregular fashion. Light etching bands, parallel to the surfaces, which suggest that phosphorus is present, could be distinguished in SN1086, but were less clear in SN1087 (the rim).

The morphology of the grains differs slightly between the two samples. The grains in the crown sample (SN1086) appear to have slightly crisper, straight-line grain boundaries, while the boundaries in the rim sample SN1087, which contain more carbides, tend to be rather more rounded. This suggests, perhaps, that the rim metal was hot-worked in the final forging operation, i.e. that working continued from a forging temperature suitable for thin sheet (perhaps around 900°C) to below the austenite to ferrite and pearlite phase transformation temperature at 750°C. In both sections the grains tend to be elongated parallel to the surfaces indicating that, as might be expected, the metal was hot-worked. Where sound metal appears very close to the original surface of sample SN1086, a small area of grain distortion can be seen, indicating that some cold work had taken place (although there is no further evidence of cold work).

The grain size is variable in both sections and there is some segregation into bands of larger and smaller grains. The average size of the larger grains in sample SN1086 is in the order of 0.06 mm and the smaller grains are probably 0.02 mm or less, while those in sample SN1087 are 0.1 and 0.03 mm respectively. As the surface layers are corroded, it is difficult to be sure how the size of the grains related to the surfaces. The smaller grains are associated with the inclusion bands and pearlite in the crown section (SN1086), while the larger grains were generally nearer to the surfaces lost to corrosion. The section from the rim (SN1087) consists, however, of a large-grained band with a smaller-grained band on either side for most of its length.

The metal remaining in the metallographic sections from the crown and rim of the helmet is a low-carbon iron. A few areas show an uneven response to etching, producing 'ghost' structures characteristic of the presence of traces of phosphorus. The banding observed in the microstructure was probably the result of working an inhomogeneous piece of metal rather than using more than one piece of metal. There does not appear to have been any carburization, although corrosion might have removed any traces of this from the surface.

The metal is relatively hard (average hardnesses of 227 and 267 $HV_{0.1}$ were measured for the crown and rim respectively using a Vickers microhardness tester with a 100 g weight), partly because it contains small amounts of carbon and phosphorus and partly because it also retains some hardness as a result of warm-to-cold working. To shape the helmet, the metal would have been heated to a temperature between 750 and 900°C and then forged, using an anvil with suitably shaped stakes onto which the metal was hammered to produce the desired form. The thin metal of the helmet would have required a low forging temperature. Normally the forging process is continued until the temperature drops below 723°C and the metal becomes dull red, hard and more difficult to work. As a final process the helmet has clearly been worked while cooling and this is particularly evident around the rim, which is consequently slightly harder than the crown, although there is little visible distortion. Samuels has pointed out that a cold-worked reduction of less than 30% is not visible in the microstructure as grain distortion [12; pp. 62 and 174], but moderate cold-working at a level of around 30% causes the hardness to increase perceptibly [13, 14]. Another factor likely to have contributed to the hardness is the presence of phosphorus. Finally, as sample SN1086 was removed from a damaged area, it is possible that the distortion observed in this sample might have occurred after manufacture.

DISCUSSION AND INTERPRETATION

While the British Museum helmet was found in London, the kettle-hat is commonly depicted in Medieval art throughout Europe from the late twelfth century until it fell from wider use in the fifteenth century. Its simple but effective design is likely to be the reason for its universal popularity [4; Vol. II, pp. 57–66]. Earlier depictions of kettle-hats, from before *c*.1320, commonly show the skull constructed from several plates riveted together and the brim attached along the lower edge [3; pp. 32, 52 and 199]. Technological advances and refinement in the production of plate armour in the fourteenth century led to production from one or two large pieces. The well-made one-piece construction of the British Museum kettle-hat, with its short steep brim, rounded skull, crisp comb at the apex and numerous close-set lining rivet holes, all suggest a date of manufacture in the late fourteenth century (*c*.1380–1400) [15]. This is supported by stylistic comparison with the only other dateable kettle-hat from the period, excavated from within the courtyard of the Louvre, Paris in 1984. The Louvre kettle-hat bears devices that identify it as the helmet of Charles VI of France (1368–1422) and mean it can almost certainly be matched with a piece described in the royal inventory of 1411 [16, 17]. The Louvre example is extremely similar to the British Museum kettle-hat in overall proportions, particularly in the shape of the skull and the steeply angled brim.

A suggested date of the late fourteenth century for the British Museum kettle-hat, based on stylistic comparison, is not inconsistent with studies of the metallographic structure of helmets of similar date [18–20]. For example, while certain comparisons suggest that the present helmet shows some general characteristics in common with two objects held at the Metropolitan Museum of Art, New York – a Venetian style sallet (a type of Italian open-faced helmet) of *c*.1470 (No. 14.25.581) and an Italian kettle-hat of *c*.1450–1500 (No. 14.25.582) – the microstructures relate more closely to some earlier helmets. Although the same type of microstructure is associated with 'munition' quality armour from a later date, it can be encountered in some earlier helmets of higher quality. For example, while a helm of *c*.1300 from Madeln (Liestal Cantonal Museum No. 53.1.211) differs from the British Museum kettle-hat in that it is made from several plates riveted together, the microstructures are extremely similar [20; Figures 4 and 6]. Although the metallographic samples from the British Museum helmet contain less carbon, there is also some resemblance to the structures found in the skull and visor of a bacinet of *c*.1385 from Churburg Castle, North Italy (No. 16) [20; Figures 8, 10 and 11].

It is impossible to know when the handle and chain were added but they display a similar level of wear and surface corrosion to the helmet, strongly suggesting they were associated prior to the object being discarded or lost. The silicate-rich deposit, believed to derive from burial, occurs on the helmet, handle and chain while vermilion was only found on areas of the helmet, suggesting that the quartered decoration was specifically associated with that part of the object. Although it is possible that the vermilion was applied after excavation, it is found beneath layers of silicate-rich deposit in some areas, suggesting that it was present prior to burial. The survival of the pigment makes it less likely that the helmet was ever used as a cooking vessel because, as has been mentioned above, vermilion turns black at high temperatures and would eventually have sublimed, leaving no appreciable residue. If the helmet had been used only with liquids, i.e. as a stewing pot, the internal temperature might seldom have risen above around 100°C and there would have been less chance of the painted layer being

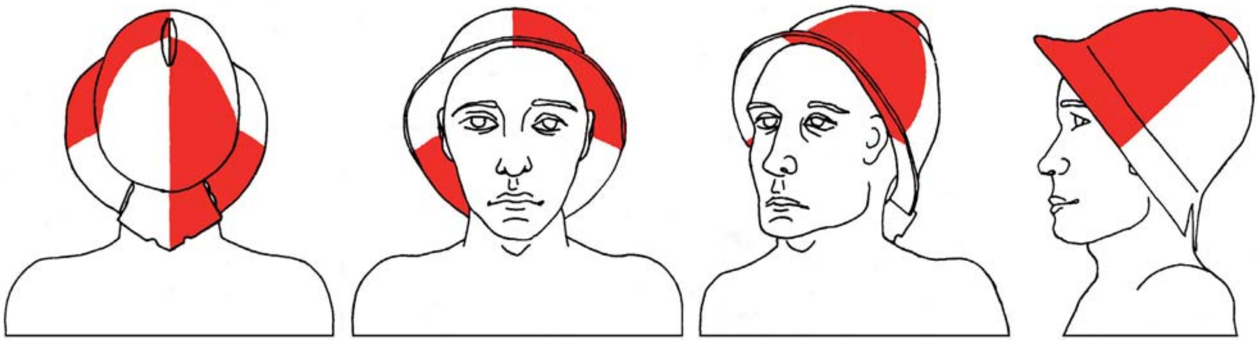

FIGURE 7. Reconstruction drawing of the helmet with a quartered decorative scheme interpreted from surviving traces of vermilion pigment. The helmet is shown pushed towards the back of head, in the manner of some contemporary depictions, to show the continuation of the decoration on the underside of the brim. Drawing: Jamie Hood

FIGURE 8. A detail from a French illuminated manuscript, contemporary with the suggested date of the British Museum kettle-hat, showing a group of men-at-arms wearing parti-coloured one-piece kettle-hats (*grande chronique de France*, *c.*1375–1379, Bibliotheque Nationale, Paris, Ms Français 2813, 409v). Image: akg-images / Erich Lessing

damaged. However, given the uncontrolled nature of most cooking fires it would be surprising if a contiguous layer of vermilion, such as is likely to have been seen on the kettle-hat, could survive such use. The microstructure of the metal further supports this view, as secondary heating would have annealed the metal and reduced its hardness.

The addition of the handle must, however, indicate a secondary use in another capacity, with carrying, storage or simply decoration all being plausible. A more speculative theory is that it was adapted so that it could be suspended over the tomb of its owner as a funerary achievement, a possibility that is discussed in greater detail elsewhere [15].

The vermilion decoration, clearly evident on the outside of the helmet, continued around the edge of the rim and onto the underside of the brim, but does not occur inside the skull, implying that only those areas that would have been visible when the helmet was worn have been painted, Figure 7. Additionally, the pigment ceases around the base of the skull just below a line of 21 rivet holes where it is likely that a padded liner or lining band of leather or textile was once fixed. The presence of such a padded liner would have made the application of paint on the inside of the helmet's skull unnecessary or impossible. The continuation of the quartered decoration on the British Museum kettle-hat around the edge of the rim and onto the underside of the brim indicates a conscious effort to integrate all the 'external' surfaces of the helmet.

Representations of armour, as well as surviving examples of armour from the late fourteenth, fifteenth and sixteenth centuries, show that numerous methods were utilized to add decoration and offer protection to the surface. These distinctive surface finishes served to identify the wearer and at the same time also prevented the formation of corrosion. While some plate armour is known to have been highly polished, other examples were left rough and black-from-the-hammer (with the marks from the armourer's hammer and a passive layer of black iron oxide from the forging process) or were heat-blued, gilded or painted. Depictions of Medieval helmets that show evidence of polychrome decoration can be found in the pages of illuminated manuscripts from across Europe [21, 22].[1] The likelihood of such surface decoration sustaining damage, or being removed unintentionally or intentionally during maintenance, would have made it particularly vulnerable to loss, so it is not surprising that while a small number of late-fifteenth to early-sixteenth-century helmets with painted decoration survive, none are known from the fourteenth century [23–26].[2] The vermilion quartering featured on the British Museum kettle-hat is reminiscent of the simple, bold heraldic or armorial schemes typical of late Medieval chivalric tradition. A notable depiction from a French illuminated manuscript that dates to *c.*1375–1379 and which is therefore roughly contemporary with the suggested date of the British Museum kettle-hat, shows parti-coloured one-piece kettle-hats being worn by a group of men-at-arms, Figure 8 [27, 28; pp. 244–248].

While natural, mineral vermilion (cinnabar) was an expensive pigment, the manufactured pigment became cheaper and more widely available following the introduction of the dry process technique for its production in the late fourteenth century. The changing use of, and attitude towards, vermilion is demonstrated by the careful use of the pigment in early Medieval manuscripts, when it was still rare and precious, compared with its more widespread application in some fifteenth-century books [29; p. 106]. As vermilion is a relatively stable pigment and the increased accessibility of the dry-processed pigment roughly corresponds with the suggested date of the British Museum kettle-hat, its use over a comparatively large surface area on a utilitarian object is not surprising.

CONCLUSIONS

The metallurgical structures clearly show that the helmet was made from bloomery iron that apparently had not been carburized. Although the metal shows slag inclusions, these were not large enough to inhibit the forging process unduly and the low carbon content would have made working easier. As a result of cold work the metal was harder than might be expected from its composition. The helmet might not have been made for 'high performance' or could possibly have been reworked from recycled metal. However, it is clear that a craft specialist made the helmet, as it would have taken a high degree of skill and experience to draw out the shape from a single piece of metal.

Significantly, the results of metallurgical analysis are consistent with the date suggested by stylistic comparisons and, when combined with the design of the decoration, add weight to the theory that the helmet was manufactured in the late fourteenth century (*c.*1380–1400).

The survival of the vermilion and the metallurgical analysis of the metal strongly suggest that the British Museum kettle-hat never saw use as a cooking vessel. While plate armour was an expensive commodity in Medieval Europe, particularly in the fourteenth century, it is plausible that the conversion into a 'hanging vessel' occurred once the helmet was outdated or already damaged.

Depictions of the kettle-hat in Medieval art show it being worn throughout Europe from the twelfth century onwards and strongly suggest that at least some thirteenth-, fourteenth- and fifteenth-century plate armour was brightly painted with geometric patterns. However, very few similar objects now survive and hardly any of those feature painted decoration. There is a strong case to be made that the vermilion quartering found on the British Museum kettle-hat is the earliest known surviving example of painted decoration on Medieval armour, further increasing the importance of this helmet.

EXPERIMENTAL APPENDIX

Raman spectroscopy was carried out using a Horiba Infinity spectrometer with a near infrared (785 nm) laser, a spot diameter of around 5 mm and a maximum power of 4 mW at the sample. ATR FTIR spectra were measured using a Smart iTR diamond accessory on a Nicolet 6700 bench spectrometer and were acquired over a range of 4000–550 cm^{-1} using 16 scans at a resolution of 4 cm^{-1} and automatic gain. During analysis the ATR crystal was in pressure contact with the sample material while air background spectra were acquired for each analysis with the crystal in non-contact. The diamond and tip were cleaned with methanol prior to each use. No further sample preparation was necessary for either technique.

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MATERIALS AND SUPPLIER

- Cotton wool and white spirits: VWR International Ltd, Magna Park, Hunter Boulevard, Lutterworth, Leicestershire LE17 4XN, UK, uk.vwr.com

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NOTES

1. Perhaps the most notable examples of polychromy on Medieval helmets in an illuminated manuscript (specifically composite construction kettle-hats painted in red and blue), can be found in the Pierpont Morgan Bible, dating to *c.*1250 (Morgan Library, New York, Ms M. 638) [21]. For other examples in the British Library see Porter [22].
2. Polychromy is known on nine helmets from two distinct types of sallet (light, open-faced helmets with tails to protect the neck and often fitted with a visor) made in Germany and dating to *c.*1490–1510. Three of these examples are of so-called 'black' sallets (named because they were supplied rough and 'black-from-the-hammer') that date to *c.*1490. The remaining six are so-called 'owl-faced' sallets (typified by flat pivoting visors with horizontal slits at the eyes and mouth) that date to *c.*1500–1510 [4; Vol. 2, p. 33, 23; Plate LXXIX-d, 24; Vol. I, p. 101 and Plate 56, 25; p. 44, 26; pp. 42–45].