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Speed dating or slow dating: Interdisciplinary analysis of knitted and other non-woven textiles

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Abstract

Radiocarbon (14C) dating with accelerator mass spectrometry (AMS) has been helpful in the study of a range of prehistoric, ancient, and early medieval woven archaeological textiles. There is less evidence of AMS's successful application to later historical non-woven textiles. This paper addresses the need to benchmark AMS analysis of early modern non-woven material. It reports a recent pilot study exploring the influence of sample sizes, archaeological and historical contexts, and storage variables on the results of radiocarbon dating knitted fabric. The results illustrate the need for open-minded interpretation through meaningful communication across the sciences and the arts, and explores the challenges and benefits of what is variously termed crossdisciplinary, interdisciplinary, intradisciplinary, multidisciplinary and transdisciplinary collaboration.

Keywords: AMS, 14C, radiocarbon dating, textiles, knitting, caps, early modern, interdisciplinary

25.1. Introduction

There is a great deal that dress history can learn from archaeological approaches to textile research. Radiocarbon (14C) dating with accelerator mass spectrometry (AMS) has been helpful in the study of a range of prehistoric, ancient, and early medieval woven archaeological textiles. There is less evidence of AMS's successful application to later historical non-woven textiles. Pioneering work by Nockert and Possnert (2002) provided some relevant results, including dates for one non-woven item (a looped mitten). Radiocarbon analysis of Egyptian material (including a sprang cap) found it to be earlier in date than that identified by art historical methods. AMS methods have satisfactorily placed some woven textiles in the medieval era: for example, the wool habits of St Francis in Italy. Others have continued to court controversy – most notably the fabric in 'Queen Margaret's golden gown' in Sweden.

This chapter looks at alternative and complementary ways of dating historical textiles to provide an overview of a recent pilot project into accelerator mass spectrometry (AMS). Two methods of investigation are contrasted here: what is sometimes referred to as 'art historical' dating, and radiocarbon dating. The first has been termed 'slow seeing' as part of an object-based research model

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(Mida and Kim 2015). Conventional art historical methods require a rigorous examination of the object, the identification of similar artefacts to compare and contrast with it, a review of any depictions of it in iconographic sources, and a search for references to the object in contemporary documentary sources (Riello 2009: 29).

Dating non-wovens is more problematic than dating woven textiles because they lack a tried and tested rigorous object-based approach and a substantial body of reference literature. It is arguable that there are some exceptions to this: a number of reference texts indicate some characteristics for dating bobbin lace (for example Earnshaw 1980; Toomer 2001) but there is no detailed guide to analysing its structures in the way that woven textiles may be described using the CIETA system (CIETA 2006). A newly developed protocol for reporting the essential characteristics of early knitted objects was developed as part of the *Knitting in Early Modern Europe* (KEME) project. It sets out the observations which permit meaningful comparisons to be made between knitted objects of similar type (Malcolm-Davies et al. 2018: 10–24). The categories of information required by the protocol include fibre, yarn structure, and fabric structure, features, and form.

The main challenges to radiocarbon dating textiles are sampling and sample treatment prior to AMS 14C analysis (Hajdas et al. 2014: 637). This is usually a method characterised by a commercial transaction. Cultural heritage researchers contract natural scientists to analyse their archaeological or historical material, and often have very little to do with how the samples are actually processed or the results interpreted.

25.2. Case study 1: Slow seeing – art historical dating

There are two miniature knitted caps at the Museum of London (UK) with single continuous brims. 'Single-brimmed' is one of five identified categories of knitted 16th century caps (Malcolm-Davies and Davidson 2015: 226). These two examples are too small even for an infant's head, but are stored with other more conventionally sized knitted caps, which would fit adult heads. Both are presumed to be early modern because of their similarity with the other knitted caps. There is no detailed information about how they came to be in the museum's collection, which makes their provenance unclear. On closer inspection, their similarities to the other knitted caps prove to be superficial. There are basic dimensions such as the crown diameter and head circumference which demonstrate their similarity to each other. Their gauges (the number of knitted loops in the horizontal and vertical directions) are not exactly the same, although the number of courses per 10 cm is. Their yarn diameters are very similar (Table 1).

Using the KEME protocol, the miniature caps were systematically compared to other similar examples, including another single-brimmed cap (inventory number 88.3/17) at the Museum of London. Although it too has a single continuous brim, the similarities end there. Not only are the dimensions very different, the gauge and the yarn diameter are much finer (Table 1). Likewise, another single-brimmed cap in Biograd-na-Moru Museum (Croatia) retrieved in 1967 from the 1583 wreck of the *Gagiana* (Flury-Lemberg 1988) is even finer in gauge and yarn diameter (Table 1). It is much closer to the previous example in its essential characteristics than to the miniature caps at the Museum of London.

During the Museum of London's recent preparations for a move to a new site at Smithfield Market, all the textiles were audited. A storage box contained what the catalogue and label described as a frieze cap (inventory number 46.69). Frieze is a fluffy woven fabric, typically used for warm outer garments during the Early Modern Era (Kerridge 1985: 19) but on closer examination the cap proved to be knitted. Its essential characteristics, such as gauge and yarn diameter, make it a close companion of

Table 1. Single-brimmed knitted caps - comparative data according to *Knitting in Early Modern Europe* protocol (Malcolm-Davies et al. 2018) with sample sizes for AMS radiocarbon dating.

	Museum of London, UK				**Biograd na Moru Museum, Croatia**
Inventory no.	5008	A15260	88.3/17	46.69	281/1
Dimensions					
Crown diameter (cm)	25.2	23	25.5	15	29
Head circumference (cm)	33	29.5	58	24	21
Gauge					
Wales per 10cm	14	24	36	20	32
Courses per 10cm	32	32	72	32	48
Yarn diameter (mm)	2.1	2	0.7	1.4	0.5
Cover factor	0.8	0.4	0.3	0.2	0.1
Source	Guildhall	London	Purchase	Donation	Salvaged
	Museum	Museum	1988	1946	1967
Provenance	Unknown	Unknown	Worship St, London (?)	Christ's Hospital (1858)	Gagiana shipwreck (1583)

the two miniature caps (Table 1). But it is very much better documented than the other two. It has a handwritten label stating "Christ's hospital 1858" and the museum catalogue records details of the donor's name, the date of donation as 1946, the original owner's name, and the date the cap was used by him (1856 calAD to 1859 calAD).

The cap was a vestigial garment in the 19th century school uniform of Christ's Hospital. This charity school, founded in the 16th century, had a characteristic bluecoat uniform which has (somewhat eccentrically) continued unchanged to this day. By the 18th century, the cap had become ludicrously small and was worn precariously perched high on the head. By the 19th century, the cap was carried or tucked into the boys' belts. This comparative evidence suggests that the other two miniature caps are much more likely to be vestigial 19th century garments than 16th century originals. It is likely that they were passed off as excavated artefacts when the City of London was undergoing extensive new building at the turn of the 20th century. At that time, an inspector at the precursor to the Museum of London was rumoured to be paying good money for artefacts emerging from these ground works (Dash 2013). 'Stoney Jack', as he was known, often acted as seller and purchaser for the metropolitan museums – a dual role that would be unacceptable today.

25.3. Case study 2: Quick answers – radiocarbon dating

The AMS method requires the collection of a sample from the object which is chemically processed into graphite before analysis. The raw data from this are interpreted using calibration curves (corrections provided by reference to wood samples dated by dendrochronology) and contextual evidence. The choice of calibration curve used to interpret the raw AMS results is critical. The curve is determined by the geographical provenance of the artefact: the current internationally agreed curves for terrestrial samples are known as IntCal13 for the northern hemisphere (Reimer et al. 2013) and SHCal13 for the southern hemisphere (Hogg et al. 2013). Reference to these curves provides what is known as the calibrated 14C date expressed as cal BC or cal AD.

AMS dating presents a major challenge since it is a destructive process twice over: the removal of a sample causes inevitable and irreversible change to the artefact and the sample itself is destroyed during the laboratory testing. Historians are not in the habit of taking samples from extant objects.

Archaeologists are much more comfortable with the notion of taking samples for useful scientific study. As a result, there are far more examples of archaeological textiles being dated by 14C AMS than there are of historical textiles, for example: a woven cloth hat from Greenland, at the National Museum of Denmark, Copenhagen (inventory number D10612) was 14C dated to between 1275 calAD and 1299 calAD (top) and between 1166 calAD & 1224 calAD (crown) – probabilities 54.2% and 68.2% (Hayeur Smith et al. 2015); the Huldremose clothing in the National Museum of Denmark (inventory number C3473) was 14C dated 350 calBC to 41 calBC (Mannering et al. 2010); and a sprang cap from Egypt in the Katoen Natie Collection, Antwerp, Belgium (inventory number 853b) was 14C dated to between 595 calAD and 665 calAD – probability 95.4%, which was earlier than expected (Van Strydonck et al. 2004).

A few examples of later historical items, which were not excavated, have been sampled and analysed by AMS. These include St Francis of Assisi's habit which is exhibited at Cortona Church, Italy. It was 14C dated to between 1155 calAD and 1225 calAD, although the probability is not stated (Fedi et al. 2008). A looped mitten from Åsle, Sweden, which is now in the Statens historiska museum, Stockholm (inventory number 20 379) is likely from the 16th to 17th centuries (Nockert and Possnert 2002). It was 14C dated to between 1510 calAD and 1640 calAD (probability 68.2%). A medallion carpet at the Palace of the Dukes of Bragança, Guimarães, Portugal (inventory number 721-01) was 14C dated to between 1485 calAD and 1668 calAD (probability 95%). This showed it to be 15th to 17th centuries in date, and therefore is not a 19th century fake (Santos 2010).

The sample sizes in these studies are not always clearly stated: for example, several samples of less than one cm square were taken from each of the wool habits of St Francis but it is not possible to calculate the total area removed without knowing how many of them there were.

The appropriate size of sample that is required for 14C dating causes anxiety among dress and textile historians. There is very little clear advice on where, how, or how much material to take as samples. The quantities used in the early days of radiocarbon dating required enormous sacrifices of material: for example, more than two-thirds of the Egyptian textiles under scrutiny were destroyed during analysis in 1957 (Van Strydonck 2014: 2). Much smaller quantities of material are required today, but should they be taken from a pristine or a damaged part of the object? What literature there is offers contradictory ideas: for example, one study selected fragments which were still attached to the object by at least one thread to be sure it was part of the original (Hayeur Smith et al. 2015: 25). Another study avoided deteriorated parts of the textiles, as these were more likely to be compromised (Van Strydonck et al. 2004: 232).

A team at the Museum of London worked on a strategy for sampling the knitted caps (in collaboration with KEME) which would preserve the integrity of the objects, minimise the impact on them, and maximise the potential benefit of analysis. The strategy helped to narrow down which caps to sample, where to take the samples, and how much it was feasible to remove from them. Key issues it considered were:

- Whether items were already damaged
- Whether the effects of sampling could be hidden from view
- The need to avoid key features in the object's structure and decoration
- The need for multiple samples if an object is made of more than one material
- Whether the object has undergone obvious conservation interventions which may interfere with its shape or with the results of analyses
- Loose material in storage boxes may be taken as samples
- The maximum acceptable size of a sample to be removed (0.5 cm x 0.5 cm or 1 cm x 2 cm)

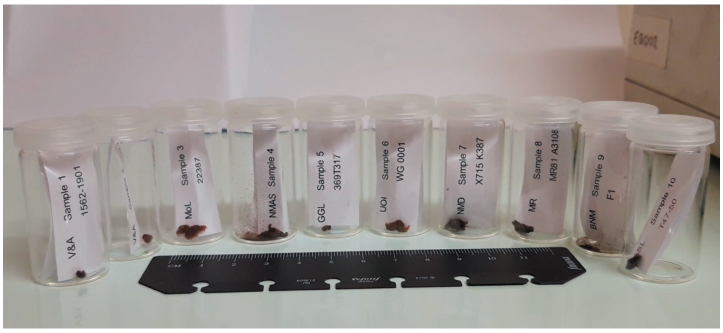

Figure 1. The ten pilot project samples ranged in weight from 18.6 milligrams (fourth from left) to 0.6 milligrams (first on left). The samples from the knitted split-brimmed cap and lining (inventory numbers 1562-1901 and 1562A-1901) are first and second from left. (Photograph: J. Malcolm-Davies)

One of the aims of this pilot study into AMS dating of historical textiles was to consider the size of the sample required. The weight range of the ten samples taken from knitted caps was 18.6 milligrams to 0.6 milligrams (Figure 1). The mid-range sample weighed 5.3 milligrams. A guideline for sampling suggests that five milligrams of wool yields one milligram of viable carbon, although the proportion of carbon extracted from it very much depends on the state of the textile (Hajdas et al. 2014: 639).

25.4. Results

A pair of samples in the pilot study came from associated objects (Figure 2): a knitted cap (inventory number 1562-1901) and its lining (inventory number 1562A-1901) which were found together in Worship Street, London (UK) during building work in the early 20th century. Despite a lack of appropriate excavation notes, they are thought to be 16th century in origin. The museum catalogue states they are 1500 calAD to 1599 calAD. Stylistically, this cap and its lining would be expected to date from the 1520s to the 1560s. The results were very unexpected. The analysis dated the knitted items from 1405 calAD to 1490 calAD, which is a whole century earlier than the date recorded for them in the museum. The dating charts (Figure 3a and Figure 3b) are examples of clear single narrow peaks, which are easily interpreted against the 14C calibration curve. The results showed that the method offered internal consistency since the dates for the paired cap and lining were within a similar 85-year range in the 15th century.

There are some credible explanations as to why these may be reasonable results despite their contradiction of the contextual evidence (see below). However, it is worth noting that the AMS laboratory did not process these pilot samples as wool or even as textile but as charcoal (the most usual

Figure 2. Knitted split-brimmed cap (V&A Museum, London, inventory number 1562-1901) found in Worship Street, London, UK. (Photograph: J. Malcolm-Davies)

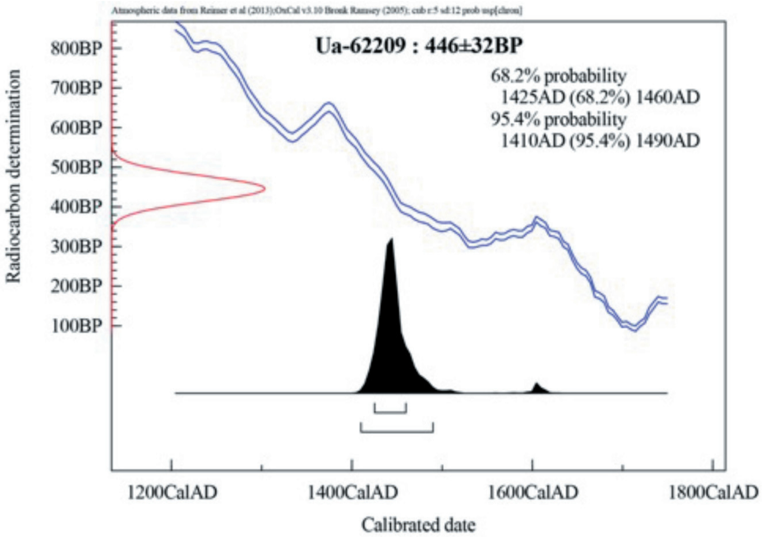

Figure 3a. AMS dating of a knitted split-brimmed cap (V&A Museum, London, inventory number 1562-1901) found in Worship Street, London, UK. (Image: Tandem Lab, Uppsala University & Jane Malcolm-Davies)

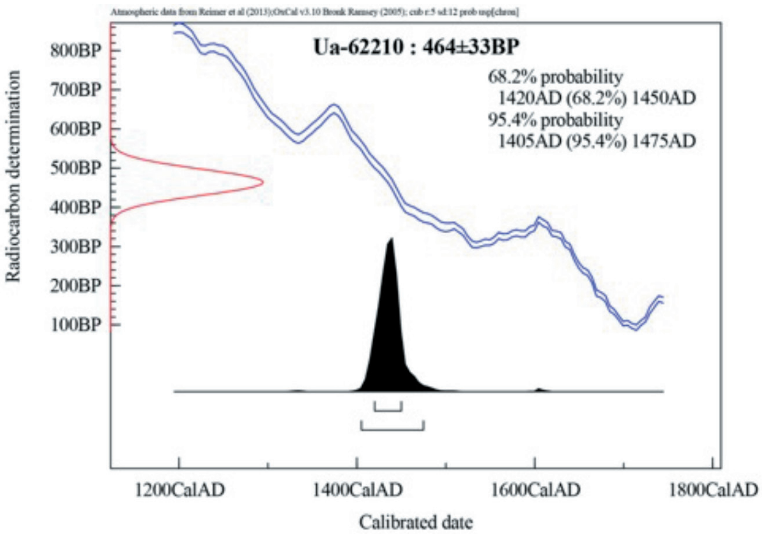

Figure 3b. First phase AMS radiocarbon dating of a knitted cap lining (V&A Museum, London, inventory number 1562A-1901) found in Worship Street, London, UK. (Image: Tandem Lab, Uppsala University & Jane Malcolm-Davies)

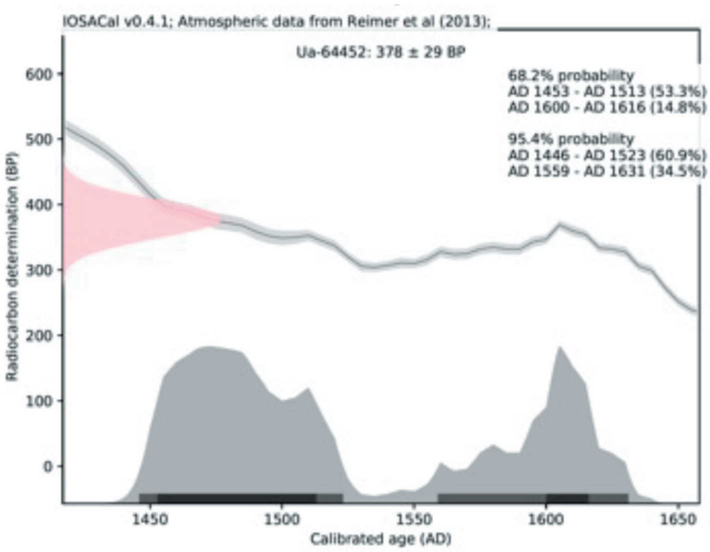

Figure 3c. Second phase AMS radiocarbon dating of a knitted cap lining (V&A Museum, London, inventory number 1562A-1901) found in Worship Street, London, UK. (Image: Tandem Lab, Uppsala University & Jane Malcolm-Davies)

material submitted for dating). The pretreatment of textile samples with an acid-alkali-acid protocol known as Soxhlet removes extraneous material including contaminants (Hajdas 2014: 638-639). Pretreatments result in the loss of non-carbon material. A sample weight minimum of 3 milligrams of material is advisable, but 10 milligrams permits more than one analysis to be performed (Hajdas et al. 2014: 639).

The absence of such a specialist pretreatment may explain why the results for the cap and lining are potentially dubious. This lack is not without precedent, although re-analysis of the samples concerned soon followed using a pretreatment with hexane, acetone and ethanol (Chanialaki et al. 2018: 120). The pilot samples which had sufficient residual material after the first analysis were processed again with an appropriate pretreatment. Not all the samples were large enough for a second run, but the cap lining yielded a new later date (Figure 3c), which pushed it further into the 16th century. This time the result did not produce a single peak but a more complex double plateau/peak. This provides an illustration of how contextual and comparative data help to interpret the AMS results. The second peak (1559 calAD to 1631 calAD) on the chart is less likely on stylistic grounds than the first peak (1453 calAD to 1513 calAD), but this still suggests an early date between 1446 calAD and 1523 calAD, which is a 77-year range from the late 15th to the early 16th centuries (Table 2).

Table 2. Knitted items with sample sizes for AMS dating and results (pilot study phases 1 and 2).

V&A Museum, London	Inventory number: 1562-1901	Inventory number: 1562A-1901	
	Knitted split-brimmed cap	Knitted cap lining (Phase 1)	(Phase 2)
Sample size	0.6 mg (smallest in study)	4.2 mg	2.2 mg
Calibrated dates	1410 to 1490 calAD	1405 to 1475 calAD	1446 to 1523 calAD
Date range (years)	80 (ca. 15th)	70 (ca. 15th)	77 (ca. 15th to ca. 16th)
Probability	95.40%	95.40%	60.90%
Source	Purchase 1901	Purchase 1901	
Provenance	Worship St, London	Worship St, London	
Date by context	1500 to 1599	1500 to 1599	

25.5. Discussion

There has been a general mistrust of 14C dating of textiles among art historians in the decades since well-publicised rejections of it in the late 1950s (Van Strydonck 2014: 1). There are still challenges to accurate AMS dating, including the effects of the original context, subsequent handling of artefacts, contamination from storage arrangements (for example, packing materials), and conservation treatments. These are likely to suggest later dates than more accurate earlier ones. It is possible to mitigate these problems by carrying out microscopic examinations for visible contaminants and other quality control measures. The sample's carbon to nitrogen ratio (which is recorded in an elemental analyser after graphitisation) confirms if a sample is silk or wool, the intermingling of more than one fibre, and/or indicates whether chemical contamination has occurred (Hajdas et al. 2014: 639). Fluorescence spectroscopy (which is non-destructive) screens textiles for humic contaminants which may result in unreliable 14C dates (Boudin et al. 2011: 430). Fourier transform infrared (FTIR) spectroscopy likewise assesses the quality of the carbon by revealing any contamination in the processed sample before it is dated (Chanialaki et al. 2018: 119–120). These quality controls may indicate that rigorous and repeated pretreatment is required before analysis.

25.6. Interpretation of results

Radiocarbon dating which provides results earlier than anticipated from the find context or details of provenance are more challenging than those of a later date. The latter may be explained by unidentified and persistent contaminants despite quality controls and the best efforts with pretreatments. Dates which are earlier than expected might be explained by contaminants from the find context which predate its main interpretation; for example, earlier sedimentary layers or items in them which have come into contact with the samples. However, there are other possible interpretations.

There is a potential time lag between harvesting raw materials and the manufacture of textile artefacts which is worthy of consideration. The storage, remaking, recycling, and recovering of materials over time are important factors in the careful husbandry of textiles in the past. It is also possible that the useful life of a textile as a wearable garment was much longer than previously supposed. Critical questions for the interpretation of results from AMS dating of textiles are:

- How long did raw materials lie in storage before they were processed into garments?
- How often were old garments recut and sewn into new garments?
- To what extent were raw materials recovered from worn garments for reuse?

There is evidence of extensive and repeated reuse of woven textiles during the Early Modern Era with even the smallest offcuts of fabric repurposed for fastenings and repairs as illustrated, for example, by evidence from Groningen, Netherlands (Zimmerman 2007) and Tours, France (Henri 2017). The 1520 regulations on cappers in Coventry, UK, permitted journeymen to thick and press old knitted caps and for them to "ffreshe and scower old bonettes" (Tawney and Power 1924: 108).

AMS dating of a bodice used to dress a statue of a saint in Turku, Finland showed different elements (the fabric and sewing threads) ranged in date from the 12th to the 17th centuries, demonstrating the reuse of old material over a long period (Kirjavainen 2015: 329–330). Another spectacular and instructive example of 14C dating which has been the source of much speculation is that of the 'golden gown' at Uppsala Cathedral, Sweden. Its AMS dating did not tally with its presumed provenance (Geijer et al. 1994). Fabric in the gown was dated to between 1403 calAD and 1439 calAD with a probability of 95.44% (Geijer et al. 1994). There is evidence (including the cut and style of the gown) that it may have been made for a royal wedding in 1469, but the AMS date places it much earlier in the century. The gown may have been remade from an earlier garment (although it lacks tell-tale signs of having been made over). Alternatively, a purchase or gift of such expensive fabric may have been carefully stored in the royal wardrobe awaiting a suitable occasion for it to be made up into a garment. Was the fabric purchased when the opportunity arose, saved for later, and/or remade into a new gown for a later bride?

Now that reuse and recycling of materials are more often on our consciences than it was the case in the recent past, perhaps it is time to be open-minded about early AMS dates for historical textiles. They may be indicative of textiles' long and sustainable lifecycles, which are not surprising given the growing evidence for the immense resources put into textile production in the past.

25.7. Conclusion

There are a range of issues which make AMS dating of textiles challenging. Identifying where and how much to sample from an original artefact is contentious. Contaminations (such as chemical conservation treatments) are likely to push the results later in date. It is possible to examine the samples for quality in a number of ways and pretreat them accordingly. Another important issue is the choice of the calibration curve used to correct the raw results from the AMS lab. Double-peaked or plateaued calibration charts demand careful interpretation. Only with firm contextual or other corroborative evidence is it possible to dismiss one peak in favour of another or narrow a plateau to a closer range of dates. The more textile researchers collaborate across the art/science disciplines and the archaeological/historical divides, the more nuanced the interpretations of AMS results will be.

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