Karen Loomis, Ticca Ogilvie and Lore Troalen

Reidentifying the wood of the Queen Mary and Lamont harps

Of the iconic harp native to Ireland and Highland Scotland, Francis Bacon wrote 'No *instrument* hath the sound so Melting and Prolonged as the *Irish harpe*'.[1] From the medieval era through the end of the 18th century, the Irish harp was heard and admired both in its native lands and abroad.[2] The sound and sustain noted by Bacon is a consequence of the characteristic construction of the instrument, which has a robust wooden frame, wire strings and a thick-walled soundbox customarily hollowed out from a single large timber.

A substantial repertory for the Irish harp survives, much of it in the 18th- and early 19th-century manuscripts of the collector Edward Bunting, although individual pieces can be found in other sources.[3] These include the 17th-century Scottish lute manuscripts, and a number of 18th-century printed collections of Irish, Scottish and English music.[4] In the late 16th and early 17th centuries, the Irish harp was played in consort with other instruments at courts in England and on continental Europe, and its repertory may have included the consort music of Cormack MacDermott and the harp consorts of William Lawes.[5] Although nothing survives of the medieval repertory for the instrument, the closely related Welsh medieval harp repertory survives in the Robert ap Huw manuscript, and echoes of the early Irish harp idiom can be heard in *pìobaireachd* for the Scottish bagpipe.[6]

While there are a number of recordings of early music for the Irish harp, realization of the historical repertory is very much work in progress. This has driven interest in the known extant instruments, of which there are 18, including two that are incomplete.[7] Unfortunately, all of these are too fragile to be played, so exploration of the music and performance practice associated with them relies on reproductions. Many reproductions have been modelled on the Brian Boru harp of Trinity College, Dublin (TCD), and the Queen Mary harp of National Museums Scotland (NMS), arguably two of the most-copied historical harps of any type. Several other Irish harps, including the Downhill owned by Diageo, the Otway of TCD and the Lamont of NMS have also been used as exemplars.

The musician's realization of a repertory is directly influenced by the instrument's timbre, resonance and volume, and if the goal is to achieve a re-creation of an historical performance, then these should resemble those of the historical instrument. This requires an intimate understanding of the materials and craftsmanship that were used in the instrument's construction, including, where relevant, the choice of wood. The acoustics and mechanics of the instrument depend not only on the preparation, cutting and shaping of the wood, but on physical properties such as its density and elastic modulus, which vary significantly between species.[8] Consequently, luthiers have customarily used care in its selection, often showing a preference for a specific species of tree. For this reason, it is important to identify accurately the woods used in the construction of the surviving Irish harps.

This article investigates a set of wood species identifications that have played a significant role in modern attempts to construct instruments modelled on two of the earliest extant Irish harps. Undertaken in the 1960s, these identifications have been a source of controversy and scepticism for a generation of harp-builders and musicians. Our investigation into the

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method and analysis has resulted in a complete re-evaluation. Aided by the modern analytical tools of X-ray computed tomography and scanning electron microscopy, we provide some insight into and resolution of the controversy.

Background

Until recently, detailed information on the construction of Irish harps has been limited. New research is remedying this, however.[9] Two harps in particular, the Queen Mary and Lamont (illus.1), have been the subjects of a comprehensive study undertaken by the authors as part of a team of collaborators at NMS, the University of Edinburgh and the Clinical Research Imaging Centre of Queen's Medical Research Institute (CRIC).

The Queen Mary and Lamont are significant on account of being two of the oldest extant Irish harps, and representative of the earliest surviving form of the instrument. Dating from around the 15th century, both belonged to the Robertson family of Lude in Perthshire, Scotland for a number of generations before eventually being acquired by the National Museum of Antiquities of Scotland (now the NMS).[10]

Due to the age and rarity of surviving Irish harps, the investigation of their construction is constrained by the requirement to impact minimally upon the instruments themselves. The recent project to study the Queen Mary and Lamont thus combined techniques used for non- and minimally destructive analysis of archaeological wooden artefacts with non-invasive medical diagnostic imaging, to result in the most in-depth study to date of any surviving historical harps.

Both instruments underwent preliminary visual and microscopic examination, a photographic survey and analysis of materials in the Conservation Laboratories of the NMS Collections Centre. This was followed by X-ray computed tomography (commonly known as 'CT scanning') at CRIC.[11] The initial results of this work were published in 2012.[12] More recently, extensive follow-up analysis has been undertaken at the Collections Centre.

Investigation of the wood identification

There has been speculation regarding the wood used in the construction of the Queen Mary and Lamont harps for as long as there has been interest in these two instruments. John Gunn (1807) stated that the forepillar and neck of the Lamont were made of plane tree (*Platanus spp.*), and Joseph Anderson (1881), then *Custodier* of the National Museum of Antiquities in Edinburgh, commented that the soundbox of the Queen Mary was made of willow (*Salix spp.*), information that was later quoted by Robert Bruce Armstrong (1904).[13]

The mention of willow for the soundbox of the Queen Mary is significant. A number of sources note that Irish harps were traditionally made of willow, a choice considered by some to be an important characteristic of their construction.[14] To what extent the surviving harps reflect this tradition is an open question, however. Two recently conducted studies have undertaken microscopic identification of wood samples from the Bunworth and Downhill, two early 18th-century Irish harps. All parts of the Bunworth frame were identified as willow; however, all parts of the Downhill frame were identified as alder (*Alnus spp.*).[15]

Prior to this, the principal source identifying the wood of Irish harps was *The Irish harp*, published in 1969 by Joan Rimmer. This listed the woods of nine surviving instruments, of which six were deemed to be wholly constructed of willow, or constructed with a willow soundbox (with other woods for the rest of the frame).[16] The three that were not were the Downhill, noted above, and the Queen Mary and Lamont. All parts of both the Queen Mary and Lamont were identified as European hornbeam (*Carpinus betulus*).[17] In contrast to willow, this is an exceptionally hard, rigid and dense wood, and its identification as the material used for two important early exemplars of the Irish harp had far-reaching implications for understanding the construction of these instruments.

There has been scepticism regarding the 'hornbeam identification' since it first appeared in *The Irish harp*. The plausibility of hornbeam as a choice of wood for hand carving a large hollowed-out soundbox has been questioned, as has the likelihood that a wood not normally associated with the Irish harp was used to construct all parts of two instruments that, based on stylistic differences, were probably made by different builders. Additionally, the forepillar of the Queen Mary harp is of a visibly lighter wood than the neck and soundbox, raising the question as to whether all of the frame members were constructed from a single species.

1 The Queen Mary harp (left) and Lamont harp (right) of National Museums Scotland (photo: I. Wagner, ©National Museums Scotland)

Somewhat problematically, *The Irish harp* does not specifically cite the sources of the wood identifications, and this omission may have further fuelled scepticism and uncertainty.[18] A general acknowledgement in the book's foreword thanks Maura Scannell, Assistant Keeper of Natural History at the National Museum of Ireland, and Dr Hayes of the Edinburgh University Forestry Department 'for wood identifications', and it can be surmised that it was Hayes who provided the identifications for the Queen Mary and Lamont.[19] This is confirmed by documents archived at NMS, which report that wood samples from the soundbox, forepillar and neck of each were taken and examined microscopically by Alan Hayes in 1969, resulting in the identification of European hornbeam.[20]

Hayes's identifications notwithstanding, there has been a longstanding interest in having the wood of these two harps re-identified. Was there sufficient justification for extracting another set of wood samples from these two rare musical instruments? An examination of Hayes's comments, and of the harps themselves, provided the answer to this question.

In his letter to the museum he writes:

> After a considerable amount of difficulty I have now succeeded in identifying the wood from which both the Lamont and Queen Mary Harps were constructed. I think that I mentioned to you, that my first impression was a Rosaceous timber, possibly hawthorn or apple, but microscopic examination shows this not to be the case. I am now 99% certain that the timber used was hornbeam (*Carpinus betulus L.*).[21]

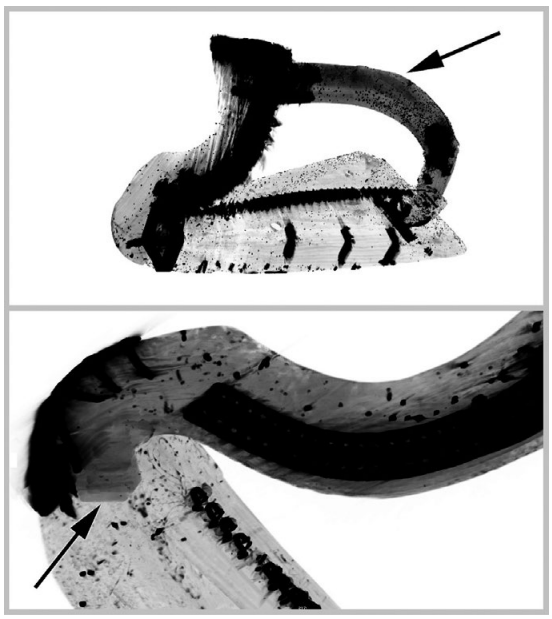
He further states that 'the wood used in the sounding box, forepillar, and harmonic curve was identical in both cases'.[22]

Microscopic wood species identification is carried out by examining samples cut along each of the three diagnostic planes: transverse or cross-section (TS), radial (RLS) and tangential (TLS). These planes are orientated across the timber, from the centre to the outer edge, and tangentially to the outer edge, respectively. The recognition of diagnostic anatomical characters visible in the variety of cell types which make up wood, and which vary from species to species, requires examination of the wood from different perspectives, gaining a three-dimensional view of these cells. Without all three sectional cuts, it is likely that key diagnostic features will be missed.

Hayes's letter indicates that identification had been difficult, and that he may have had lingering doubts about his results. Elsewhere in the letter, he describes the cellular structures upon which he based his identifications.[23] Crucially, it is apparent from the information he provides that his set of diagnostic characteristics is incomplete, and the information that is missing points to a likely issue with the wood sampling. The identifying structures he notes suggest that he may have only been able to examine the transverse plane, thereby missing key differentiating characteristics and microscopic features. When we inspected the two harps, it was evident where careful wood samples had been taken and, significantly, these were orientated only to the transverse plane.

The CT scans of both harps raised further doubts about the wood identifications. Upon visual examination of the tomograms, it was apparent that some frame members were more dense than others, as can be seen in illus.2. This seemed to be at odds with the identification of a single species of wood for all parts of both harps.

While the tomograms were visually compelling, it was deemed more useful to obtain measured densities for comparison. Stoel and Boreman have demonstrated that it is possible to use CT to measure the density of wood in musical instruments.[24] To determine the density of each member of the two harp frames, the average radiodensity was measured in several virtual sample volumes of wood taken from the scans. These were chosen away from the surface of the wood to avoid possible contamination of the data by surface treatments, such as varnish, and were chosen to include both early and late wood at different locations to obtain an average representative



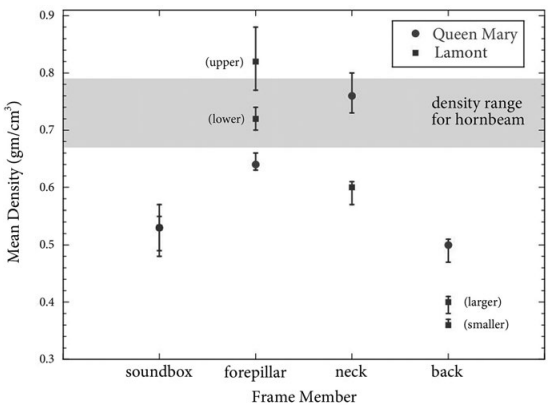
2 Tomograms of the Lamont harp (top) and the Queen Mary harp (bottom). Areas of higher density are rendered as darker shades of grey. The wood of the Lamont harp forepillar (arrowed, top), and of the Queen Mary harp neck (arrowed, bottom) appears to be more dense than that of the other frame members (©National Museums Scotland)

density over as much of each piece of wood as possible. Care was also taken to avoid including areas of insect damage, rot, metal fragments and image artefacts.[25] The mean radiodensity over all of the virtual samples in each frame member was then converted to density in g/cm³ using the relation

$$\rho\left(\mathrm{g/cm^3}\right) = \left(\mathrm{HU}/1000\right) + 1.0$$

where ρ is the density in g/cm³, and HU is the radiodensity value of each voxel (the three-dimensional analogue of a pixel) in Hounsfield units.[26] By utilizing the CT scans in this manner, it was possible to obtain 'samples' from anywhere inside the instruments without cutting into the wood, making the measurement entirely non-invasive and non-destructive. The densities obtained are plotted in illus.3, along with the expected range of densities for air-dried European hornbeam for comparison.[27]

Some of the densities clearly lie outwith the expected range for European hornbeam. As noted, however, the wood of the harps has been compromised in places by insect damage and fungal rot. Although every effort was made to avoid including damaged wood in these measurements, it is not known to what extent this has affected the densities, and therefore a direct comparison with European hornbeam may not be possible. What is notable, though, is that the measurements reveal a wide range of distinctly different densities, calling into question the identification of the wood of all parts of the two harps as a single species. This, and the possible issues with Hayes's sampling and analysis, was sufficient to justify resampling the wood for identification.

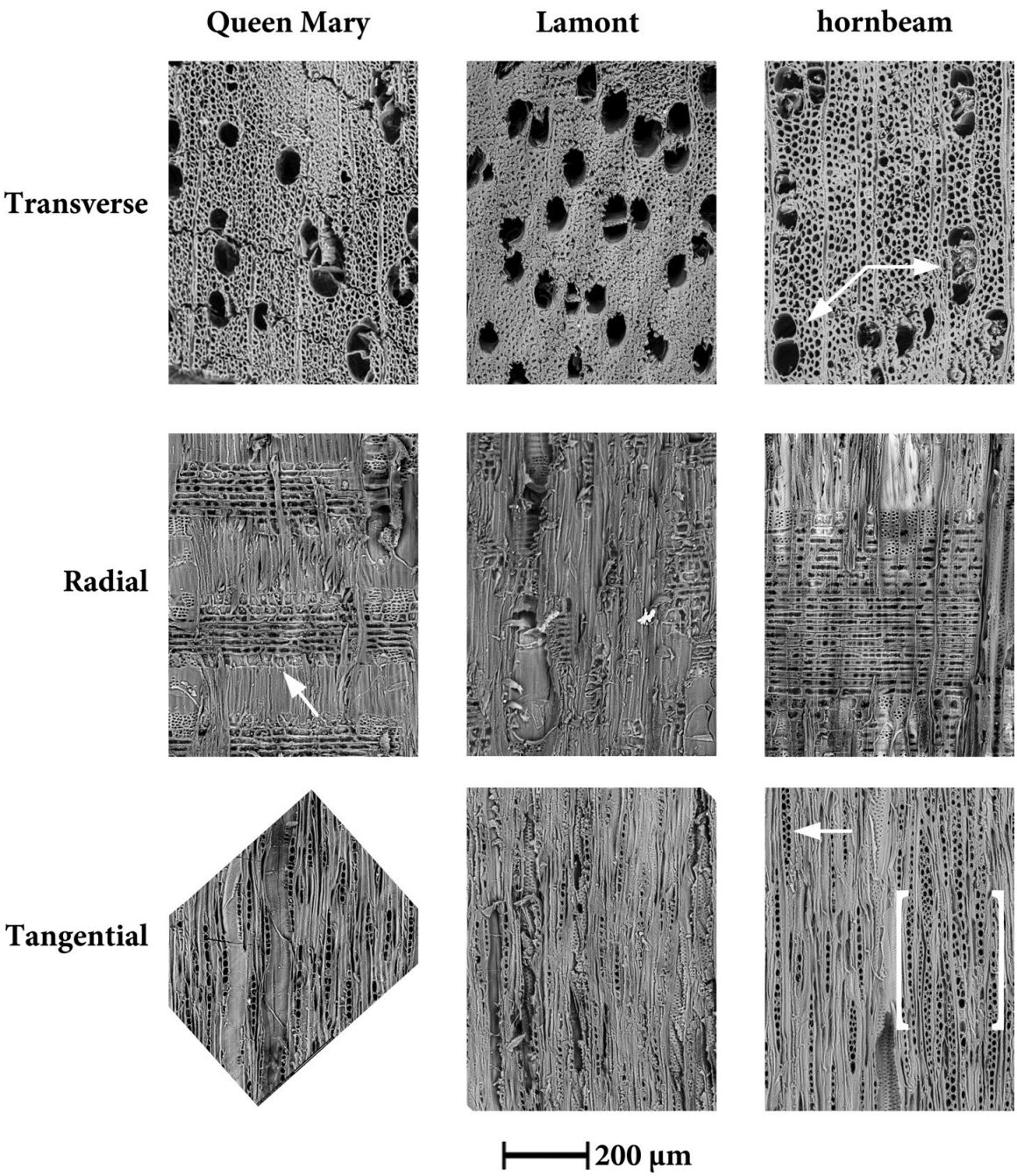


3 Densities of the frame members of the Lamont and Queen Mary harps, as calculated from the measured radiodensity in sample volumes of CT data. For each data point, the bar indicates the range of densities for each set of samples, and the point indicates the mean value. The grey band represents the expected density range for air-dried European hornbeam. The data points labelled 'upper', 'lower', 'larger' and 'smaller' refer to the separate parts of the Lamont forepillar and back cover respectively

Resampling and analysis

New samples were taken at the NMS Collections Centre conservation laboratories. Due to the age and fragility of the wood, and the importance of both harps, every effort was made to minimize visible impact while ensuring useable samples were obtained. It was evident that if the interiors of the soundboxes could be accessed, there would be more options for sampling sites for both the soundbox and the neck (which extends into the soundbox) than had been available to Hayes. In the characteristic style of construction for Irish harps, the soundboxes of the Queen Mary and Lamont were hollowed out from the back, with the opening enclosed by a separate wooden cover. The Queen Mary soundbox cover is considerably compromised by insect damage, which may have discouraged Hayes from taking advantage of accessing the interior. With the CT scans as a guide, it was possible to remove both covers safely without damaging the harps.[28]

Where the importance of the object precludes taking large samples, thin shavings (referred to as 'sections') may be taken, orientated to the three primary planes of wood tissues. Upon removal of the first sample from the Queen Mary soundbox it was apparent that this approach would be problematic due to the degraded state of the wood, explaining some of Hayes's difficulty. Although initially apparently sound, prepared sections tended to disintegrate upon mounting onto glass slides for microscopy. A change of approach was called for, and it was decided to carry out the identification by scanning electron microscopy (SEM) rather than the usual transmitted light microscopy. Instead of thin sectioning, a surgical micro-scalpel was used to remove small blocks (2–3mm on a side) from appropriate areas of each frame member. These were prepared to expose precise alignment with the diagnostic planes of the wood. This approach preserved the structural



4 SEM-BSC micrographs of the transverse, radial and tangential planes of the soundbox wood samples from both harps and of the European hornbeam sample. Notable differences include the presence in hornbeam of files of pores aligned radially along the rays in the transverse plane (arrowed, top right), the presence in willow of exclusively upright parenchyma cells in the ray borders in the radial plane (arrowed, middle left), and the presence in hornbeam of rays that are more than one cell thick (multiseriate) (arrowed, bottom right), and large aggregations of rays in the transverse plane (in brackets, bottom right) (©National Museums Scotland)

integrity of the sample and, more importantly, of the exposed fragile cellular structures. A further advantage of using SEM for the wood identification was the significant increase to both magnification and depth of field for observing diagnostic cellular features.[29]

Analysis of the samples is currently in progress; however, a definitive identification of the wood of both soundboxes has been obtained, following the standard identification keys and terminology determined by the International Association of Wood Anatomists (IAWA).[30] The wood of both the Lamont and the Queen Mary soundboxes is willow, not European hornbeam. Micrographs of each plane are shown in illus.4, along with an identified sample of European hornbeam for comparison. A full list of the anatomical characters observed in our samples from the two soundboxes is provided in the Appendix.

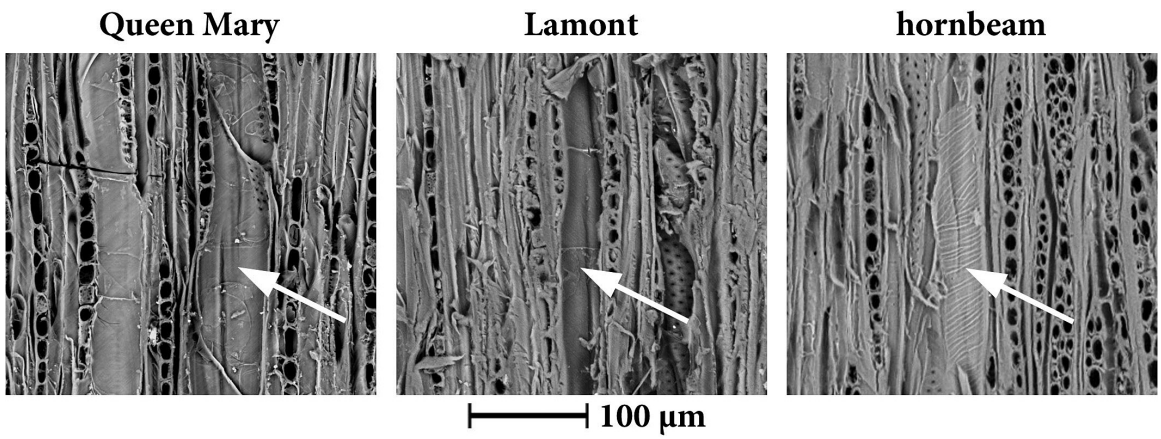
Although the features Hayes observed were largely consistent with European hornbeam, they were insufficient for an accurate identification and it is likely that he was limited both by where he was permitted to sample, and by the fragility of the wood. Crucially, the cellular structures we observed in the radial and tangential planes do not match European hornbeam.[31] Some notable differences are shown in the micrographs in illus.4 and 5.

The question of whether Hayes was correct in his identification of all parts of both harps as a single species of wood has also been answered. Examination of samples taken from both forepillars has determined that the wood is definitely not the same as that of the soundboxes. This is evident in the micrographs of the soundbox and forepillar wood samples shown in illus.6. These identifications are still in the process of being confirmed, but the nearest matches to either forepillar are whitebeam (*Sorbus spp.*) and apple (*Pirus malus*).[32] An initial examination of the samples from both necks also indicates that these woods are different from that of the soundboxes. Furthermore, the wood used for the neck of the Queen Mary has been determined as different from that of its forepillar.

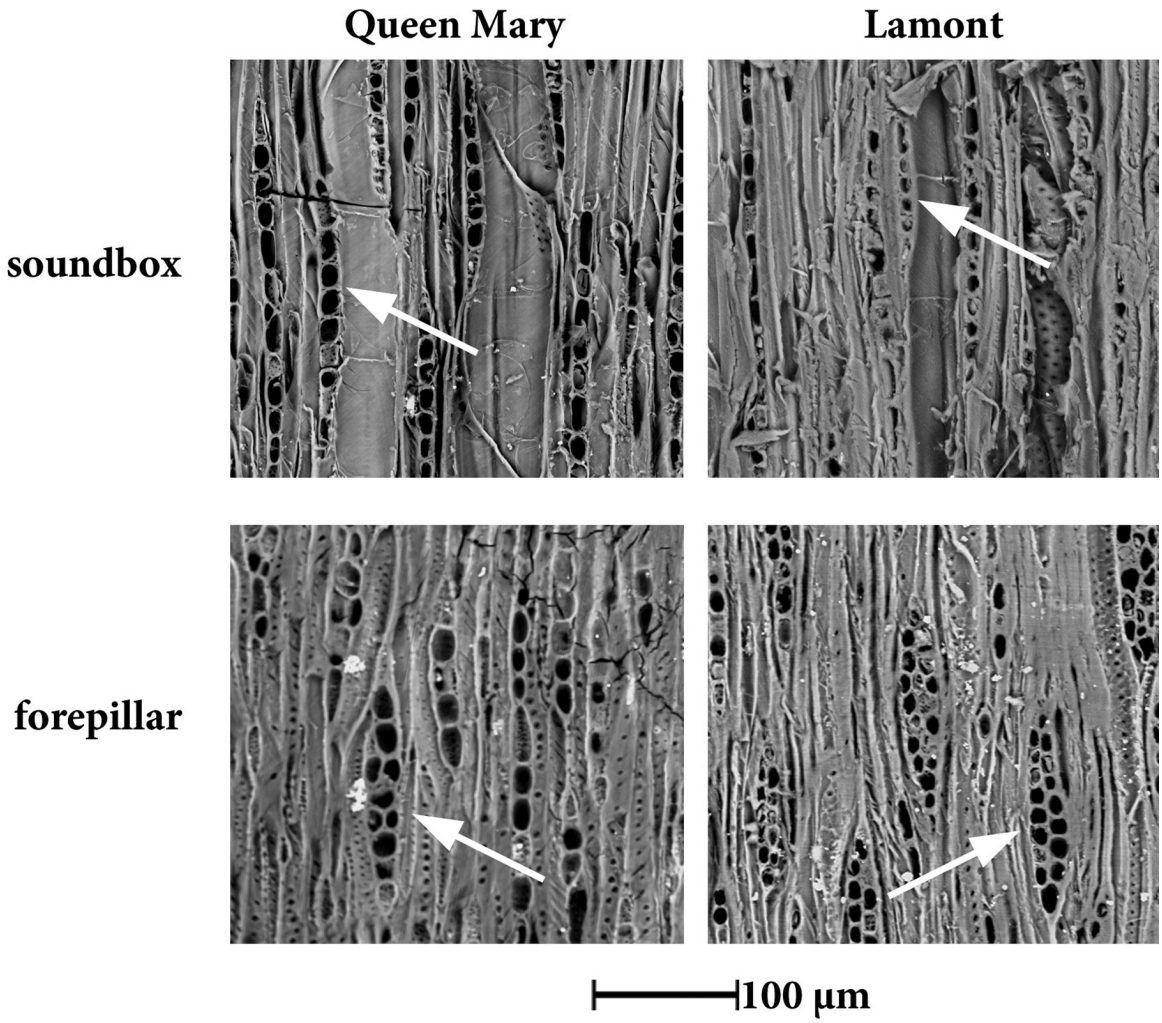
Discussion

The identification of the wood of the soundboxes as willow, rather than hornbeam, is in agreement with what has been said to be the wood traditionally used in the construction of Irish harps. Confirmed species identifications for the neck and forepillar woods remain to be completed; however, preliminary results are clear that these parts of the frames of both instruments are definitely not willow.

Our results refute Hayes's single-species identification for all parts of both harps. In contrast, the Bunworth and Downhill harps noted earlier have frames made wholly from a single species of wood. Both were constructed over 200 years after the Queen Mary and Lamont, however, and it would be an oversimplification to group together the construction practices for Irish harps spanning this entire time period. Perhaps a more nuanced approach of



5 SEM-BSC micrographs showing a detail of the tangential plane of the soundbox wood of both harps and of the European hornbeam sample. The vessel walls of European hornbeam have helical thickenings (arrowed, right). This structure is absent in the wood samples from the Queen Mary and Lamont harp soundboxes (arrowed, left and middle) (©National Museums Scotland)



6 SEM-BSC micrographs showing a detail of the tangential plane of the soundbox and forepillar wood of the Queen Mary and Lamont harps. The rays in the soundbox wood of both harps are exclusively uniseriate (one cell thick) (arrowed, top row), characteristic of willow. Both multiseriate and uniseriate rays are present in the forepillar wood of both harps (arrowed, bottom row), however, a feature that is not present in willow

selecting different woods was employed for the earlier Irish harps, reflecting the different structural and acoustical functions of each frame member.[33] Information is at present limited, but it is possible that the use of a single wood may have been more typical for 18th-century Irish harps, when the construction tradition was in decline.[34] Confirmed wood species identifications are needed for the remaining instruments in order to investigate this further.

Understanding the choice of woods used, and how that may have changed over time would provide valuable insight, as well as being fundamental to building informed reproductions for the use of musicians interpreting historical repertory. It is hoped, therefore, that this research will continue, and that the methods employed in the current study demonstrate that the age and rarity of the harps need not be a barrier to conducting this analysis.

APPENDIX

Wood identification—microscopic wood features noted[35]

Table 1 Queen Mary harp soundbox—[Match: willow, *Salix spp.*]

Anatomical character	*Present/Absent/Group*	*Section in which feature observed*
Vessels	Present	TS
Phloem	Absent	TS
Pore arrangement (macro)	Diffuse porous	TS
Vessel grouping	Diffuse porous with clusters or short radial files, some solitary	TS
Radial multiples	Yes	TS
Tyloses	Absent	TS
Parenchyma	Not observed	TS
Ring boundary	Not obvious	TS
Ray seriation	Uniseriate exclusively	TLS
Ray width (max)	1 (uniseriate)	TLS
Ray height (range)	6–15	TLS
Sheath cells	Absent	TLS
Intervessel pitting	Alternate	TLS
Ray anatomy (macro)	Heterogenous, type II/III	RLS
Perforation plates	Simple	RLS
Spiral thickening	Absent	RLS
Libriform fibres	Present	RLS
Fibre tracheids	Absent	RLS
Vascular tracheids	Absent	RLS
Crystals	Absent	RLS

Note: (TS) Transverse section; (TLS) Tangential section; (RLS) Radial section

Table 2 Lamont harp soundbox—[Match: willow, *Salix spp.*]

Anatomical character	*Present/Absent/Group*	*Section in which feature observed*
Vessels	Present	TS
Phloem	Absent	TS
Pore arrangement (macro)	Diffuse porous	TS
Vessel grouping	Clusters or short tangential oblique bands of 2–3 vessels	TS
Radial multiples	Yes	TS
Tyloses	Absent	TS
Parenchyma	Not observed	TS
Ring boundary	Not obvious	TS
Ray seriation	Uniseriate exclusively	TLS
Ray width (max)	1	TLS
Ray height (range)	6–15	TLS
Sheath cells	Absent	TLS
Intervessel pitting	Not observed	TLS
Ray anatomy (macro)	Heterogenous Type II/III	RLS

Table 2 *Continued*

Anatomical character	*Present/Absent/Group*	*Section in which feature observed*
Perforation plates	Simple	RLS
Spiral thickening	Absent	RLS
Libriform fibres	Present	RLS
Fibre tracheids	Absent	RLS
Vascular tracheids	Absent	RLS
Crystals	Absent	RLS

Note: (TS) Transverse section; (TLS) Tangential section; (RLS) Radial section

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1 Francis Bacon, *Sylva Sylvarum: or A Naturall Historie in ten Centuries*, published posthumously by W. Rawley (London, 1627), p.62. For an overview and discussion of the Irish harp, see S. Chadwick, 'The early Irish harp', *Early Music*, xxxvi/4 (2008), pp.521–31.

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3 Edward Bunting, *Bunting Manuscript Collection*, Queens University Belfast Library, Special Collections, Ms.4.

4 For a discussion of sources of Irish harp repertory, see Chadwick, 'Early Irish harp', pp.527–8, and S. Chadwick, 'Sources', www.earlygaelicharp.info/sources/. The Scottish lute manuscripts include Straloch, which survives as a 19th-century copy (National Library of Scotland (NLS) MS Adv.5.2.18), Skene (NLS MS Adv.5.2.15) written for mandore, and Wemyss (NLS Dep. 314, No.23). Eighteenth-century printed sources include the collections of John and William Neal, James Oswald and Burk Thumoth.

5 Chadwick, 'Early Irish harp', p.527. M. Billinge and B. Shaljean, 'The Dalway or Fitzgerald harp (1621)', *Early Music*, xv/2 (1987), pp.175–87, at pp.175 and 183. J. Cunningham, 'A tale of two harps: issues arising from recordings of William Lawes's harp consorts', *Early Music Performer*, xxi (2007), pp.15–26. Holman, 'Lawes's harp consorts', pp.188–203. Cunningham and Holman discuss both Lawes and MacDermott.

6 For a discussion of the Robert ap Huw manuscript (British Library Add. Ms.14905), see S. Harper, *Music*

in Welsh culture before 1650: a study of the principal sources (Aldershot, 2007), pp.135–55. Chadwick notes the relationship between early Irish harp musical forms and *pìobaireachd*. Chadwick, 'Early Irish harp', p.527.

7 Chadwick, 'Early Irish harp', p.522. Chadwick lists the locations of the surviving harps. Fourteen are in museums, with eight currently on public display.

8 U. G. K. Wegst, 'Wood for sound', *American Journal of Botany*, xciii/10 (2006), pp.1439–48; V. Bucur, *Acoustics of wood* (New York, 2006), pp.173–4; and I. Brémaud, 'Acoustical properties of wood in string instruments soundboards and tuned idiophones: biological and cultural diversity', *Journal of the Acoustical Society of America*, cxxxi (2012), pp.807–18, at p.807.

9 The Trinity College, Downhill, and Bunworth harps have been the subjects of recent studies. See P. Dooley, 'Reconstructing the medieval Irish harp', *Galpin Society Journal*, lxvii (2014), pp.107–42; and M. Billinge, 'Building a reproduction of the Downhill harp (the Harp of Denis Hempson) for the Irish television documentary *Banríon an Cheoil*', *Bulletin of the Historical Harp Society*, xx (2010), pp.6–19. The study of the Bunworth harp has not yet been published.

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11 Both harps were scanned on the CRIC 320-multidetector row Toshiba Medical Corporation Aquilion One CT scanner. The scans were run at 135 kVp for the Lamont harp, and at 120 kVp for the Queen Mary harp, with a data bit depth of 16 bits.

12 K. Loomis *et al.*, 'The Lamont and Queen Mary harps', *Galpin Society Journal*, lxv (2012), pp.113–29.

13 Gunn, *Historical Inquiry*, p.2. J. Anderson, *Ancient Scottish Weapons, etc.: A Series of Drawings by the Late James Drummond, R.S.A.* (Edinburgh, 1881), p.25. R. B. Armstrong, *Musical Instruments Part I. The Irish and the Highland Harps* (Edinburgh, 1904), p.180.

14 E. O'Curry, *On the Manners and Customs of the Ancient Irish, Vol. III* (London, 1873), p.271. J. Rimmer, 'James Talbot's Manuscript (Christ Church Library Music MS 1187): VI. Harps', *Galpin Society Journal*, xvi (1963), pp.63–72, at p.67. H. G. Farmer, 'Some notes on the Irish harp', *Music & Letters*, xxiv/2 (1943), p.101. See also Anderson, *Ancient Scottish Weapons*, p.123.

15 M. Billinge, 'Reproduction of the Downhill harp', p.10; The Bunworth wood was identified by John Koster in 2009, on behalf of the Museum of Fine Arts, Boston. Darcy Kuronen, Pappalardo Curator of Musical Instruments, Museum of Fine Arts, e-mail message to first author.

16 J. Rimmer, *The Irish harp* (Cork, 1969), pp.75–8.

17 Rimmer, *The Irish harp*, pp.76–7.

18 In Rimmer's defence, *The Irish harp* was not written as a technical monograph, but as an overview aimed at a general audience.

19 Rimmer, *The Irish Harp*, foreword. Scannell was principally a botanist, although Rimmer does not mention this.

20 A. J. Hayes, letter to C. E. Curran, National Museum of Antiquities of Scotland, 18 February 1969, NMS, H. LT2 archive.

21 Hayes, letter to C. E. Curran.

22 Hayes, letter to C. E. Curran.

23 For evidence of the species identification, Hayes notes: 'a predominance of pores arranged in radial multiples, simple rays, small fibres and not very much soft tissue, although there was some suggestion of terminal parenchyma. In addition both ray and pore size are similar to those of hornbeam.' These features are not unique to European hornbeam. Hayes, letter to C. E. Curran.

24 B. Stoel and T. Boreman, 'A comparison of wood density between Classical Cremonese and modern violins', *PLoS ONE*, iii (2008), pp.1–7.

25 The average virtual sample volume ranged from 0.13–0.45cm^3. Finding suitable sampling locations in the back cover of the Queen Mary harp and the upper section of the Lamont harp forepillar was difficult due to extensive insect damage, necessitating small sample volumes.

26 P. Brinkmann, W. Frobin and G. Leivseth, *Musculoskeletal biomechanics* (Stuttgart, 2000), p.162. The authors also wish to thank Martin Connell, Clinical Scientist, CRIC, Queen's Medical Research Institute, for confirming this relation.

27 Based on published values, the density of European hornbeam ranges from approximately 0.67–0.79 g/cm^3. H. G. Richter and M. J. Dallwitz, 'Commercial timbers: descriptions, illustrations, identification, and information retrieval', http://delta-intkey.com.; A. E. Zanne *et al.*, 'Global wood density database', Dryad, http://hdl.handle.net/10255/dryad.23.

28 This soundbox cover appears to be original, and as such may be the only one of its kind, making its preservation even more imperative.

29 The scanning electron microscopic images were obtained with an MX 2500 CamScan microscope working in Envac mode. Micrographs were recorded using the Backscattered detector (BSC) without coating or surface preparation. SEM analysis has been used for species identification of archaeological woods in instances where identification by other methods has been problematic. See, for example, C. Cartwright, L. R. Spaabæk and M. Svoboda, 'Portrait mummies from Roman Egypt: ongoing collaborative

research on wood identification', *The British Museum Technical Research Bulletin*, v (2011), pp.49–58.

30 See, for example, F. H. Schweingruber, *Microscopic wood anatomy* (Birmensdorf, 3/1990).

31 Key cellular features that are present in hornbeam which are not present in willow include multiseriate and aggregate rays, and spiral thickening of vessel walls. Key features of willow are its exclusively uniseriate (one cell thick) rays, composed of both procumbent and marginal upright cells, and its large ray-vessel pits.

32 The Lamont harp forepillar is broken, and the lower portion has been repaired with a different piece of wood. Our identification is for the upper portion of the forepillar. There is evidence that the forepillar of the Queen Mary harp may be an early historical replacement, which would mean the wood of its original construction is unknown. K. Loomis, 'Organology of the Queen Mary and Lamont harps' (PhD diss., University of Edinburgh, 2015), pp.350–1.

33 Chadwick employed this concept in his replica of the Queen Mary harp, built in 2006–7. S. Chadwick, 'A historical reproduction of the Queen Mary harp', *Newsletter of the American Musical Instrument Society*, xxxvi/2 (Summer 2007), p.16.

34 The National Museum of Ireland wood identifications conducted by Maura Scannell would, if confirmed, support this theory.

35 Schweingruber, *Wood anatomy*. J. G. Hather, *The identification of the northern European woods: a guide for archaeologists and conservators* (London, 2000). R. B. Hoadley, *Identifying wood: accurate results with simple tools* (Newtown, 1990). W. Schoch, I. Heller, F. H. Schweingruber and F. Kienast, *Wood anatomy of central European species*, www.woodanatomy.ch.