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The Lamont and Queen Mary Harps

'Here are two harps: the largest one is the loudest, but the small one is the sweetest; which do you wish to hear played?'
(John Robertson of Lude, on the Lamont and Queen Mary harps)¹

For nearly one thousand years, the harps of Ireland and the Highlands of Scotland were musical instruments of high status in Gaelic society.² The unique sound of these instruments was highly regarded, historically,³ and their characteristic construction was readily recognized and noted.⁴ In recent years, growing interest in historically informed performance of the repertory has created a need for new research into the construction of the surviving harps. Of these, the Lamont and Queen Mary are two of the three most important examples (see Figure 1 in the colour section). The third is the iconic Trinity College Harp of Trinity College, Dublin, commonly known as the 'Brian Boru' harp. Together, these harps represent the instrument in

its earliest surviving form.⁵

For much of their working lives both the Queen Mary and Lamont harps belonged to the Robertson family of Lude, in Perthshire, Scotland.⁶ Usually dated to the fifteenth century,⁷ their last historical player was John Robertson of Lude (died 1731),⁸ whose description of their sound is quoted at the beginning of this paper.⁹ They are now two of the most important cultural artefacts in the collections of National Museums Scotland, and are on permanent display in the National Museum in Edinburgh. The primary source of information on the construction of these two instruments is Robert Bruce Armstrong's *The Irish and The Highland Harps*, which is still the standard reference work on

¹ Quoted in Donald Mackintosh, *Collection of Gaelic Proverbs, and Familiar Phrases* (Edinburgh: William Stewart, 1819), p.200. The authors would like to thank Simon Chadwick for pointing out the original printed source of this quotation.

² Robert Bruce Armstrong, *The Irish and the Highland Harps* (Edinburgh: David Douglas, 1904); facsimile reprint (New York: Praeger Publishers, Inc., 1969), pp.1–54.

³ Geraldus Cambrensis, quoted in Christopher Page, *Voices and Instruments of the Middle Ages* (London: J. M. Dent & Sons Ltd, 1987), pp.229–30.

⁴ For example in Michael Praetorius, *Syntagma musicum* (1619); facsimile reprint, A. Forchert ed., (Kassel: Barenreiter-Verlag Karl Votterle GmbH & Co. KG, 2001), p.54; and Joan Rimmer, 'James Talbot's Manuscript (Christ Church Library Music MS 118): VI. Harps', *The Galpin Society Journal* XVI (1963), pp.66–67.

⁵ For an overview of the surviving harps, see Simon Chadwick, 'The Early Irish Harp', *Early Music* XXXVI (November 2008), pp.521–31.

⁶ Keith Sanger and Alison Kinnaird, *Tree of Strings* (Temple, Midlothian: Kinmoor Music, 1992), p.53.

⁷ The date of these harps is yet to be determined with any certainty.

⁸ Sanger (1992), p.150.

⁹ Armstrong (1904), p.181.

the subject. With recent advances in imaging and analytical tools, however, it is now a good time to resurvey these harps to see what new information we can discover and insights we can gain concerning their history and construction.

In 2010, a collaborative research project on both the Queen Mary and Lamont harps was undertaken by the authors at the University of Edinburgh, National Museums Scotland, and the Clinical Research Imaging Centre (CRIC) of Queen's Medical Research Institute. The museum kindly granted permission to the first author to have access to both harps and to the Conservation and Analytical Research staff and facilities at the National Museums Scotland Collection Centre in Edinburgh. Permission was also kindly granted to have both harps CT scanned at CRIC.

CT scanning, formally referred to as x-ray computed tomography, builds a three-dimensional x-ray, or tomogram, that can be viewed from any angle or in any cross-section. For the two harps, this meant it would be possible to look into and through the wood to see the interior construction and to see inside the joints. The Queen Mary and Lamont harps were CT scanned on 17 June and 8 July 2010, respectively, on the CRIC 320-multidetector row CT scanner.¹⁰ The data was rendered and analyzed with the OsiriX DICOM viewer software package.¹¹ Prior to CT scanning, each harp underwent technological analysis at the Conservation and Analytical Research labs at the National Museums Collections Centre. The harps were examined, photographed, and selected areas of interest analyzed with x-ray fluorescence (XRF) and scanning electron microscopy – energy dispersive x-ray spectroscopy (SEM-EDX) to determine materials composition.¹²

Thanks to the combined approach of the CT scanning and laboratory analysis, we now have a vast body of new information concerning these two instruments. The CT scanning has indeed made it possible to see the interiors of these harps and into

their wooden members to survey their construction, assess the state of the wood, and discover any interior damage and repairs. This work was complemented by a visual and photographic examination in the conservation lab, which provided a record of the exterior of the instrument, flagged up areas of particular interest, and also generated some new insights of its own. These interior and exterior surveys were supplemented by the XRF and SEM-EDX, which provided information on some of the materials used in the construction and repair of the harps.

In this paper, we report on many of the new findings for each harp. This is the first step in the process of analysis and interpretation of all of this new information. The first part of this paper surveys the new findings for the Lamont harp, with a section devoted to each of the three members of the frame, plus an additional section devoted to the neck joint at the soundbox. The second part uses the same approach for the Queen Mary harp. The final part of this paper takes a further look at some of the CT data to map the thickness of the soundboards, which is a very important topic and central to our understanding of these instruments. The soundboard mapping represents a 'first go' at some of the analysis that will be undertaken in the coming months with the new data on these two harps.

Before commencing with the report of the new findings, it is useful to briefly review the basic construction of the harps. The Lamont and Queen Mary harps are of the form described as 'small low-headed' by Rimmer.¹³ The construction of these instruments is described in detail by Armstrong and is summarized here.¹⁴ The frame is constructed of three parts: soundbox; forepillar; and neck. The three members of the frame are joined by mortise and tenon joints and are intended to be held together by the tension of the strings. Each part of the frame is constructed from a single piece of wood, including the soundbox, which is made from

¹⁰ Aquilion ONE, Toshiba Medical Corporation, Nasushiobara, Japan. The scans were run at 135kVp for the Lamont harp, and at 120kVp for the Queen Mary harp. The bit depth of the data is 16-bits, and the diameter of the scans is 50cm.

¹¹ OsiriX is an open-source image processing application for DICOM format images, www.osirix-viewer.com, consulted 11 January 2011.

¹² Jim Tate and Suzanne Kirk, 'Analytical Research Section Report No. AR 2010/39: XRF analysis of the Queen Mary and Lamont harps' (National Museums Scotland, 12 July 2010). XRF data was obtained with an Oxford Instruments ED 2000, running Oxford Instruments software ED 2000SW v. 1.31. SEM-EDX data was obtained with a CamScan MX2500 SEM using a Noran Vantage EDX system running Vista software.

¹³ Joan Rimmer, *The Irish Harp* (Cork: Mercier Press, second edition, 1977), p.2.

¹⁴ See Armstrong (1904), pp.168–80.

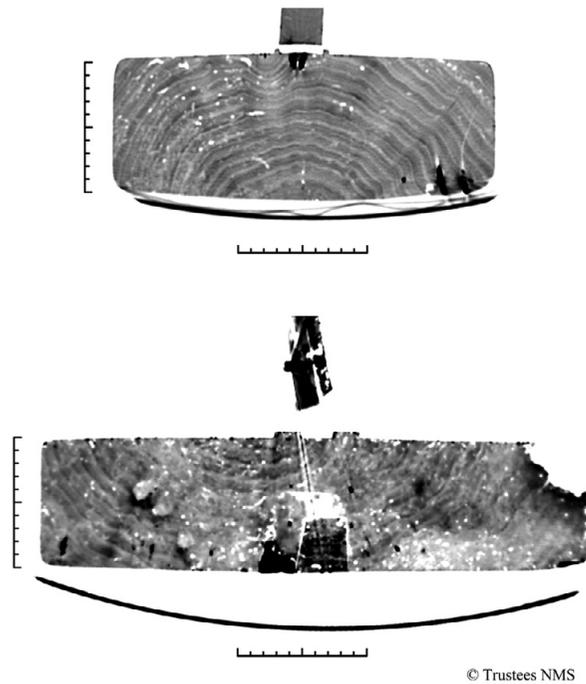
a large block of wood hollowed out from the back.¹⁵ A separate board encloses the opening in the back of the soundbox. The strings pass through the front of the box, which is reinforced down its centre by a raised band of wood with metal reinforcements (referred to as 'string shoes') at the string holes to prevent the strings from tearing through the wood. The soundbox is mortised to the forepillar at its bass end. The forepillar, which is under compression from the tension of the strings, has an elongated flange-like 'T-section' in its centre for added structural strength and is joined to the neck with a tenon at its top end. The neck, through which the tuning pins pass, is reinforced on each side with metal cheekbands. The tuning pins are inserted into the neck from the right hand side, and the strings are strung to the exposed ends of the pins on the left side of the neck. To complete the triangular frame, the neck is tenoned into the top of the soundbox. In this paper, the following conventions are used to refer to the sides and ends of these harps: 'left' and 'right' are from the harp's perspective (as viewed by the player holding the harp), 'forward' is towards the forepillar, 'back' is towards the back of the soundbox, and 'down' is towards the bass end of the soundbox.

The current set-up of the two harps is as follows. The Lamont harp has holes for 32 strings in its soundbox and holes for 31 tuning pins in its cheekbands, with an additional hole directly beneath the bands at the bass end. The Queen Mary harp has holes for 29 strings in its soundbox, with a metal loop added for an additional string at the bass end. It has holes for 29 strings in its cheekbands, with an additional hole directly beneath the bands at the bass end. The numbering convention for the string and tuning pin holes starts at #1 from the treble end of each harp.

THE LAMONT HARP

SOUNDBOX

The CT scans have revealed extensive woodworm damage, particularly to the foot of the harp, where a replacement block has been let in. The grain of the wood can be seen, so the pattern of the growth rings



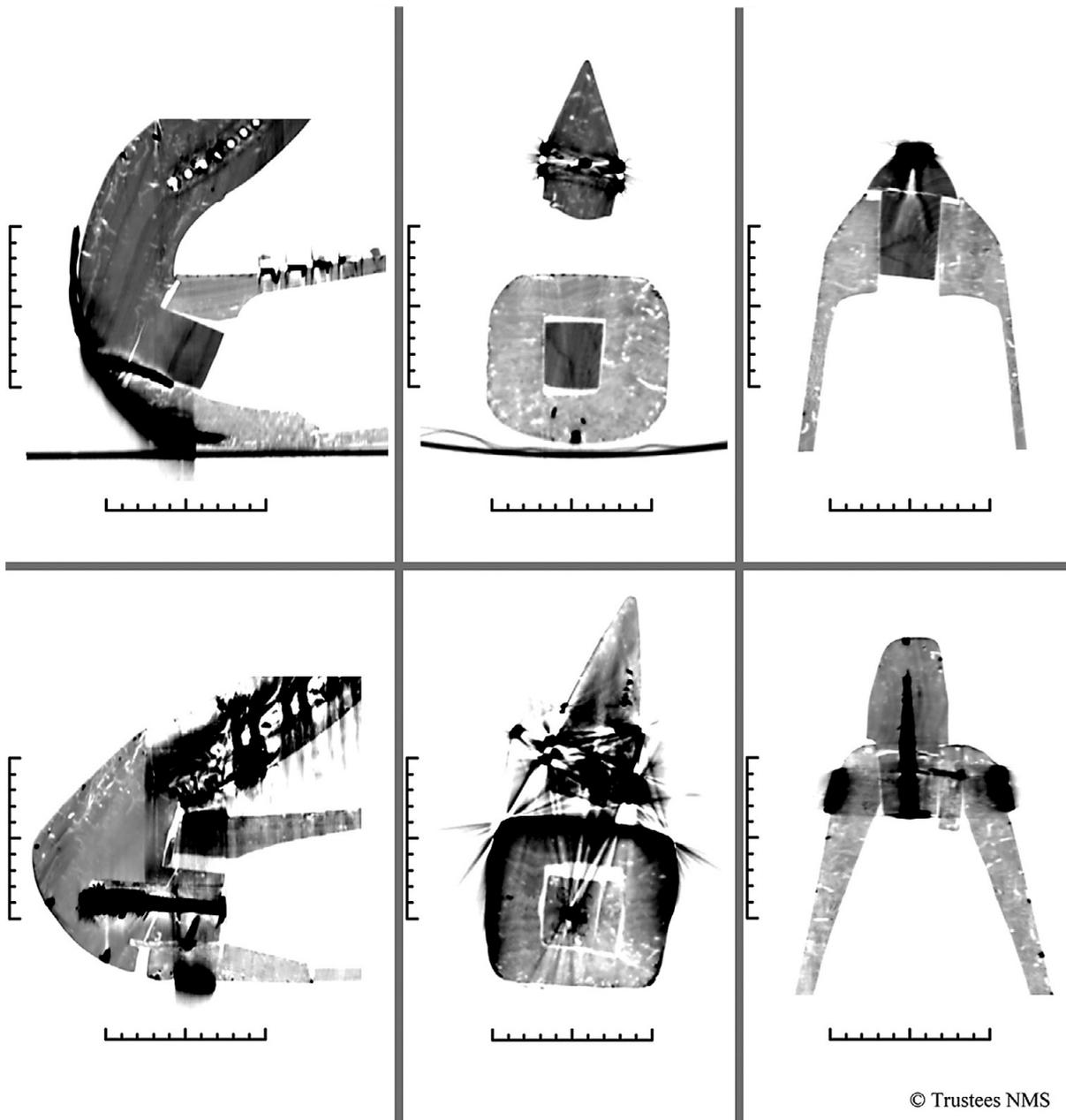
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Figure 2. Tomograms of the Queen Mary harp (top) and Lamont harp (bottom), showing the direction of the growth rings in the soundbox wood; scale: 1 tick: 1cm.

is visible on the tomograms. These clearly show that the soundbox is constructed from a half sawn boxed timber, with its central growth rings oriented towards the front, or playing surface (Figure 2). The centre-line of the tree lies 5cm to the right of the centre of the string band, so the box is not quite centred in the log from which it was cut.

The tomograms have revealed that the front of the soundbox varies in thickness; the gradations have been mapped and are discussed later in this paper. The walls of the sound holes are straight, while the inside edges and corners of the box are not rounded over, with the exception of the treble end of the cavity. Here the soundbox cavity gradually constricts to transition to the mortise for the neck joint, which is open to the interior of the box (Figure 3). The mortise is cut parallel to the long axis of the box. Examination of the tomograms suggests that the mortise may have originally been offset towards the right-hand side of the harp, and was later enlarged as part of a repair to the neck joint. The top end, or shoulder, of the box appears to

¹⁵ The wood of the frame members of both harps was sampled in 1969. All parts were identified as European hornbeam, *Carpinus betulus* L. This identification has subsequently met with considerable skepticism amongst researchers and instrument builders, and a re-identification of the wood is planned for both harps. Alan J. Hayes, letter to C.E. Curran, National Museum of Antiquities of Scotland, 5–6 Randolph Crescent, Edinburgh, H. LT2 archive, National Museums Scotland, 18 February 1969.



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Figure 3. Three orthogonal views of the neck joint at the soundbox for the Queen Mary harp (top) and the Lamont harp (bottom). These tomograms are (from left to right) sagittal, axial, and coronal views (sideways, end on, and parallel to the top of the soundbox, respectively). Both harps have visible damage and repair work to this joint; scale: 1 tick: 1cm.

be cut at a slight forward angle, such that the back of the box is a little higher than the front. The face of the neck that seats against the box is likewise cut at an angle, and the tenon is cut at a slight angle to this face. When seated in the joint it is parallel to the long axis of the box.

The back cover of the soundbox was removed and the interior examined and photographed (Figure 4

in the colour section). The inside of the soundbox had previously been examined by Hobrough, who described the following important findings in a report to the National Museum of Antiquities of Scotland: the tool marks; the undercutting of the treble end of the box; the visible interior portion of the neck joint (with repair work and grass); the damage and repair at the bass end of the box; and marks left by the string

toggles.¹⁶ The current examination of the soundbox has confirmed Hobrough's earlier findings, and our observations are described below.

The inside surface of the soundbox is smooth up to the point at the treble end at which the original opening in the back of the box would have terminated (the opening has enlarged due to extensive damage to the wood). The remainder of the box has been undercut up to the joint with the neck. The inside surface at this end is covered with long gouge marks aligned with the long axis of the box. Evidence from the tool marks suggests that at least two sizes of gouge were used. The ends of the gouge marks extend into the smoothed area of the box, indicating that at least some of the gouge work was undertaken after the surface of the rest of the box had been smoothed. There are also numerous indentations that appear in circular patterns around the string holes on the inside of the soundbox (see Figure 5 in the colour section). These indentations are on average 2.5cm in length, and were probably made by string toggles, as they are consistent with their expected size, shape and location. An initial count taken around a few representative holes places the number of toggle marks at approximately 30 to 40, but a closer examination will be undertaken to get a more precise count. These marks are an important clue to the age of the instrument, as they are a direct indication of the number of times the strings have been replaced. Closer in to the string holes, there are other indentations that appear to be from wire strings. There are also verdigris stains associated with some of these wire indentations, indicating that copper alloys were used for at least some of the wire stringing for this harp. It should be noted here that the bottom string hole in the bass, #32, does not appear to have any toggle or wire marks around it. The top string hole, #1, also does not appear to have any toggle or wire marks around it. String hole #2 has some toggle marks, but fewer than the other string holes (approximately 12–16, but this is a very rough estimate). The neck of this harp is cracked through the top two tuning pin holes, and Armstrong notes that these two tuning pins were probably not usable after the crack formed.¹⁷ There may be a link between this and the number of toggle marks around string

holes #1 and #2, as well as the apparent addition of a 32nd tuning pin at the bass end of the harp.

One additional mark of interest inside the soundbox is a set of semi-circular and linear scratches around and pointing to the lower left sound hole. These may be the result of wires having been fished for and pulled through the sound hole prior to being threaded up through the string holes to replace strings on the harp. There are historical references to this method of restringing, but this would be the first direct evidence of it having been used.¹⁸

At the bass end of the interior of the box, an iron strap in the shape of a letter pi is nailed across the box directly above the foot (visible in the tomogram in Figure 6, in the colour section). The replacement block of wood that has been let into the foot is visible on visual inspection, as is a crack extending from this repair.¹⁹ There are two holes through the foot intended for dowels to secure it to the original wood. It is evident from the tomograms that these dowels are now missing and that the block has shifted upwards slightly under the weight of the harp. The iron strap has been partially forced out by the movement of this block. From a conservation standpoint, this is an important observation, because the harp is currently displayed upright with all of the weight of the instrument resting on the foot. There are now plans to redesign the display stand to take the weight off the foot and redistribute it over the base of the soundbox.

Some new discoveries were made in the current examination of the soundbox. Upon visual examination of the string holes, a fragment of wire was discovered in hole #14. It is 3cm in length and is partially embedded in the wood. The visible portion is covered in copper corrosion products (verdigris) and is bent and twisted. The size, shape, and the degree to which it is embedded in the wood were determined from examination of the tomograms. There are plans to analyze this fragment to determine its physical properties. This wire fragment is an exciting and significant discovery, as there is little historical information on the stringing for any of these harps. Prior to the current study, only one other wire fragment had been discovered

¹⁶ Tim Hobrough, 'Notes on the 'Queen Mary' and 'Lamont' Harps', Letter to Stevenson, R. B. K., Keeper, National Museum of Antiquities of Scotland, Queen Street, Edinburgh, H. LT2 archive, National Museums Scotland, 23 January 1979.

¹⁷ Armstrong (1904), p.164.

¹⁸ Armstrong (1904), pp.28–29, n.7.

¹⁹ This is described in Tim Hobrough's letter to the National Museum of Antiquities of Scotland, Hobrough (1979).

on an Irish harp.²⁰ The location of this fragment *in situ* in its string hole makes it even more interesting because we know where on the harp this particular wire was strung.

Looking at the exterior of the soundbox, an approximately 35cm long crack runs along the right hand side of the box, following the grain of the wood. The presence of this crack was previously known, as were three equally spaced lines of nail marks running perpendicular to the crack and extending over onto the front surface of the box. Corresponding to the location of the nail marks, the tomograms have revealed three metal straps on the interior of the soundbox (see Figure 6 in the colour section).²¹ The straps were inspected visually when the soundbox was open: they are coated in copper corrosion products and are decorated with a geometric design of dots, lines, and circles. The end of the lowest strap is cut in the shape of a fishtail. These straps appear to have been cut from a single, longer strap that has been reused from elsewhere, and are nailed over a vellum document. The vellum, discovered when the soundbox was examined for the current project, is glued to the inside of the soundbox, over the crack, as part of the repair. This document has writing on it in what may be an early seventeenth-century hand.²² It appears to be the endorsement for a charter, presumably written on the other side, which is facing the wood.²³ The writing on the exposed side is partially legible and reads as follows: 'Chart_ / Grantit be Ge_ / Wt consent of his sp_ / To / Alexr McKenzie in / ... / 6...'²⁴ The line below the name Alexander McKenzie contains a place name that is currently indecipherable, but it is hoped that further examination may enable the identification and date of the document, and thus place a lower limit on the date of the repair.²⁵

Near the treble end of the instrument, there are additional cracks in the soundbox. Two run underneath the external iron strap at the top end of the box. One of these, on the right hand side

of the box, towards the back of the instrument, extends for 13cm from the shoulder of the box. This crack is visible from the exterior of the soundbox, but its full extent is more readily visible on the tomograms. The other crack extends from the left side of the neck joint at the front of the box towards the string band; it is 5cm in length, is not visible externally, and therefore was not known to exist prior to the CT scanning of the harp. A third crack, hidden underneath thin strips of brass covering a section of the string band, was also revealed on the tomograms and later inspected visually from the interior of the soundbox. Armstrong, supposing that the metal strips had been added as reinforcement, had examined this portion of the string band and reported that he was unable to detect the presence of any cracks along the string holes.²⁶ It would not have been possible for him to see this crack, however, because it is completely covered by the strips of brass. Measurements taken from the tomograms indicate that the crack is 30cm long and extends from string holes #8 to #22, running down the centre of the string band, through the string holes. The strips of brass are evidently a repair to this crack and serve to reinforce the string band, which would have been vulnerable to splitting, due to being perforated by the string holes and being pulled upwards by the tension of the strings.

Looking at the finish of the wood on the outside of the soundbox, small traces of paint or varnish are evident in crevices on the front of the box. Photographs in the National Museums Scotland archives (possibly taken in the 1960s or 1970s) show the Lamont harp in the process of having its layers of wood finish removed down to bare wood.²⁷ The harp currently has a clear finish, but appears dark in photographs taken in the early twentieth century, and in the later photographs it also appears dark on the areas of wood that had not yet been stripped.²⁸ All of these photographs are black and white, so the colour of the finish is unknown. The exterior of

²⁰ Robert Evans, 'A Copy of the Downhill Harp', *The Galpin Society Journal* L (1997), p.124. The wire fragment was discovered on a tuning pin belonging to the Balinderry harp fragments.

²¹ The straps appear just below the string band, evenly spaced along the side of the soundbox.

²² David Caldwell and Keith Sanger, personal communication (July 2010).

²³ Caldwell and Sanger (July 2010).

²⁴ Caldwell and Sanger (July 2010).

²⁵ The writing is currently being investigated by Keith Sanger.

²⁶ Armstrong (1904), p.160.

²⁷ National Museums of Scotland H-LT2 Archive. The photographs also show the metalwork in the process of being polished. A report relating to this conservation work has not yet come to light.

²⁸ National Museums of Scotland H-LT2 Archive.

the bottom end of the box is currently covered in a thin layer of brown paint and the inner edges of the sound holes have surviving traces of a reddish-brown pigment. The first author and Simon Chadwick observed the pigment in the sound holes prior to the commencement of the current study, while the harp was in its display case at the National Museum. This pigment and the brown paint on the bottom end of the harp probably predate the stripping of the harp to bare wood. A small sample of pigment from inside the sound holes was analyzed with SEM-EDX and found to be primarily composed of carbon and oxygen, together with traces of other elements, suggesting it is an organic compound.²⁹

A final important detail on the soundbox is the string shoes. As mentioned earlier in this paper, the function of the metal string shoes is to reinforce the edges of the string holes to prevent the wire strings from cutting through the wood. The string shoes on the Lamont harp appear to be made of a copper alloy and are in a variety of shades of yellow to reddish-yellow, suggesting that they are composed of differing proportions of copper with other elements. The inner edges of most of the shoes have vertical grooves in them. Some shoes have two or three distinct grooves. Some string shoes show signs of repair at these locations, with grooves on top of the repair work. The position of these grooves is consistent with them having been made by the strings, and the location of the grooves shifts for the shoes in the treble end of the harp in a manner consistent with the changing angle of the line of strings at that end of the instrument.³⁰ In light of the observations of the toggle marks around the string holes on the interior surface of the sound box, it is interesting to note that there do not appear to be any grooves on the topmost string shoe, and there is only

one light groove on the #2 string shoe; there may also be one light groove on the lowest string shoe. While it is plausible that the observed grooves were created by the strings, it should be noted that inside some string holes grooves are also evident in the wood and some of these do not align with the grooves in the shoes. Additionally, there are also some deeply grooved shoes with no corresponding grooves in the wood where the wire would have cut into the string hole. Perhaps the shoes were recycled from another harp, or have been moved (as some would have been when part of the string band was reinforced with strips of brass).³¹

FOREPILLAR

The forepillar of the Lamont harp displays prominent and dramatic visible damage and repair work. The forepillar is broken and has had the bottom portion replaced below the T-section (see Figure 1 in the colour section). The replaced section is joined to the original part of the forepillar by a scarf joint secured by four rivets and a pair of iron straps, as discussed by Armstrong.³² The forepillar is depicted with this break and repairs in engravings made for John Gunn's 1807 treatise on the Lamont and Queen Mary harps.³³ Visible damage to the wood at the scarf joint resulting from pivoting of the joint indicates that the harp was brought up to tension after this joint was made, suggesting that this is an old repair made during the working life of the instrument.³⁴

The tomograms of the forepillar have made it possible to see inside the repair work and have revealed an additional metal post underneath the iron straps. The post passes directly through the midpoint of the break in the forepillar, and has a washer at one end. This could be an additional rivet, but it is also possible that it is a pin attached at one

²⁹ Tate and Kirk (2010), p.5.

³⁰ Joan Rimmer observed 'friction marks' on the string shoes of the Trinity College harp, and noted that when she restrung the harp, the position of the strings aligned with the observed marks on the string shoes. Joan Rimmer, 'Report on Stringing the Trinity College, Dublin, Harp'; unpublished report dated 16 October 1961, p. 2.

³¹ Ann Heymann has suggested that the grooves could have been filed into the shoes to remedy buzzing of the strings. Ann Heymann, personal communication (28 April 2011).

³² Armstrong (1904), p.165.

³³ John Gunn, *An Historical Inquiry Respecting the Performance on the Harp in the Highlands of Scotland* (Edinburgh: Archibald Constable, 1807); facsimile CD (Scotdisc, 2005), plates I and III.

³⁴ Simon Chadwick has written a discussion of the damage and repair work to the forepillar, presenting the possibility (originally suggested by harpmaker David Kortier) that the scarf joint attaching the lower portion may have been part of the original construction and that shifting of this joint under the string tension could have led to the observed break and the need for subsequent repairs in the form of the iron straps. Chadwick also discusses damage to the wood as evidence of the harp having been brought back up to tension subsequent to the repair work. See Simon Chadwick, 'The Lamont Harp: Damage and repairs', <<http://www.earlygaelicharp.info/harps/lamontdamage.htm>>, consulted 5 September 2011.

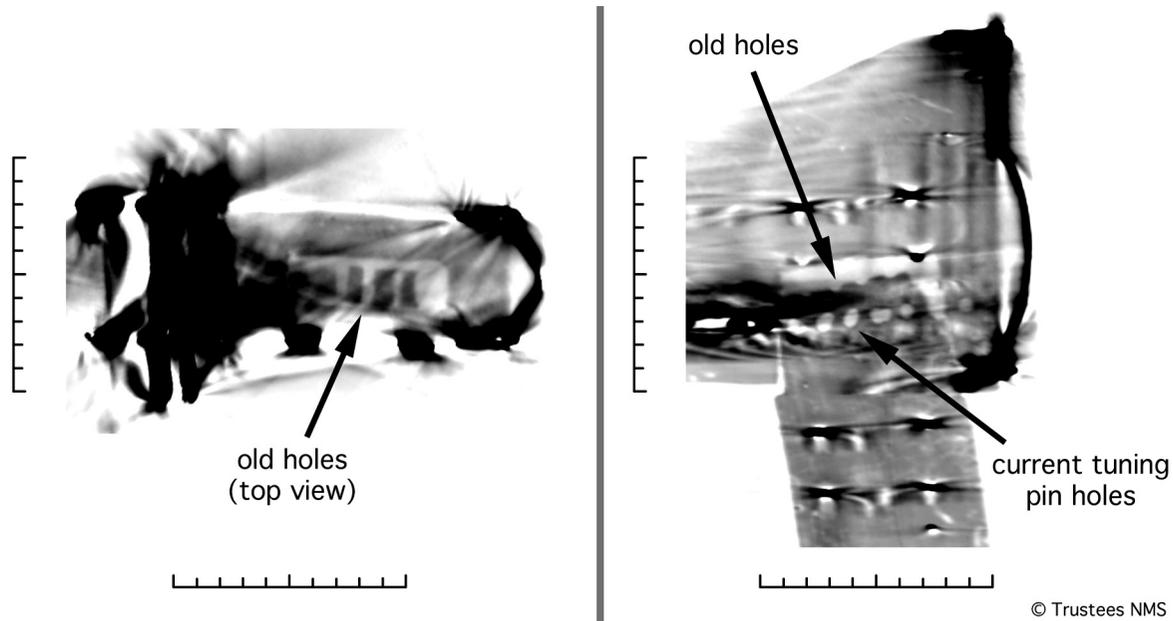


Figure 7. Two tomographic views of the forepillar tenon of the Lamont harp in the joint with the neck. The left-hand image is the view looking down from above the end of the tenon. The right-hand image is the view from the side. There appear to be the remnants of a second set of tuning pin holes on the end of the tenon. Scale 1 tick: 1cm.

end to the underside of one of the straps, as it is not clear from the tomograms if it is just touching the strap or if it is attached to it.³⁵

The lower section of the forepillar ends in a tenon for the joint with the soundbox. This tenon is held in the mortise in the foot by three wooden dowels. The tomograms reveal that the back and middle dowels are broken and that the tenon has rotated forward out of its joint by 1cm at the back of the forepillar. This is additional evidence that the harp was brought up to tension after the lower portion of the forepillar was replaced.

At the top end of the forepillar, where it joins with the neck, hidden damage and repair to the forepillar tenon were discovered on the tomograms of the inside of the joint. On both the Queen Mary and Lamont harps, the tuning pin holes pass through the tenon in this joint. These holes are visible in the tomograms. On the Lamont harp, however, in addition to the expected line of tuning pin holes, the end of the tenon is scalloped by what appears to be the remains of a second line of holes, 1.7cm above the others (Figure 7). A possible explanation for this is that the original end of the tenon sheared off through the perforations created by these holes, and that the tenon was re-cut and resealed in the joint.

This will have resulted in this end of the forepillar being shortened by 1.7cm, and consequently, any estimates of original string lengths and scaling will need to take this into account.

The damage to the tenon may have been caused by the lateral force applied to the joint by the twisting of the neck towards the left side of the harp as a result of the string tension. There are two large brass straps placed across this joint on the right-hand side of the forepillar. They are each affixed to the neck and forepillar with four large rivets, and prevent any further motion of the neck in this direction. Examination of the other side of the forepillar shows that the rivets have not been repositioned. If the tenon was re-cut and the forepillar shifted up by 1.7cm, these straps must have been put on the harp after the repair was completed. This is an interesting and potentially important point, as the Irish harp depicted by Praetorius in his *Syntagma musicum* and the Ballinderry harp fragments in the National Museum of Ireland are both equipped with similar straps in the same location.³⁶

Looking beyond the damage and repairs to examination of the wood grain in the forepillar of the Lamont harp, it is evident from the tomograms that the grain of the wood in the upper section follows

³⁵ Keith Sanger, personal communication (2010).

³⁶ Praetorius (1619), plate XVIII. For a photograph and description of the Ballinderry fragments, see Armstrong (1904), pp. 63–64, and plate facing p.62

the curvature of the forepillar. This is not easily discernable upon visual inspection of the forepillar. The wood grain of the lower section of the forepillar is straight. This piece of wood also has fewer wood worm holes and a wider grain than the upper section.

NECK

As with other parts of the harp, the neck has extensive woodworm damage. There is also evidence of considerable structural damage and repair to the wood in the vicinity of the joint between the neck and the soundbox. This is discussed in detail below. Looking first at the metal work on the neck, there is a decorative cap covering the end of the neck where it extends beyond the forepillar. XRF analysis has shown that this end cap is of a copper alloy, consisting of 80% copper, 15% zinc and 3% tin. The cheekbands on each side of the neck are thick plates of an alloy of 88% copper and 11% tin, with trace amounts of other elements.³⁷ Several of the tuning pins have grooves worn into their shafts where they have rubbed against the cheekband. The tuning pins on the Lamont harp vary in colour and decoration. Though all have the same general decorative design (with the exception of two later replacements), several distinct variants were observed. Four pins were analyzed with XRF and were found to be copper alloys with varying amounts of zinc (10 to 21%), tin (1.5 to 3%), and traces of lead and other elements.³⁸

A notable physical feature of the end cap is that its sleeve is too long to allow it to fit onto the end of the neck, due to the position of the forepillar near the neck end. One side of the cap sleeve has been cut and bent backwards to allow it to fit.³⁹ This has led to some speculation as to why the cap doesn't fit properly and the condition of the end of the neck underneath it. A plausible explanation is that the end of the neck has been shortened, perhaps as a result of damage. The placement of the last tuning pin hole beneath the cheek bands, out of line with the others, would seem to support this theory. It is just possible to see through the cap in the tomograms (Figure 7). Underneath it, the end of the neck is neatly finished with no sign of having been damaged, and the cap fits snugly onto the wood on the front and sides. The ends of the cheekbands can also be seen under the cap. They terminate right at the end of the neck on each side. There is no partial hole for a 32nd tuning

pin at the end, suggesting that they probably have not been shortened.

The neck as a whole has suffered significant damage, which appears to be the result of the string tension. It has twisted along its long axis and has rotated in its joint with the soundbox. At the treble end, a large crack has opened up on the left side, where the wood has torn along the grain (Figure 1 in the colour section). As with the forepillar, the visible damage and repair is described in detail in Armstrong.⁴⁰ Two thin metal straps are nailed across the crack. One of these has been analyzed and is an alloy of 67% copper and 31% zinc, a different composition from the other metalwork on the neck. This strap runs under the neck to the right side where the crack extends through to that side. There is another brass patch and an iron strap on the underside of the neck. The tomograms reveal the extensive internal damage and repair work to both the neck and the neck joint at the soundbox (Figure 6 in the colour section). The crack in the neck is 16cm in length and extends through it at the end closest to the joint with the soundbox, and nearly through it along most of its length. In addition to the metal patches three large nails have been driven up into the neck from underneath. These are 6–7cm in length and each has a washer. One of the nails is bent as if it has encountered very hard wood. The neck would have had to have been removed from the harp in order to drive in these nails.

NECK JOINT AT THE SOUNDBOX

Continuing to the joint at the soundbox, there is visible evidence of distress and repair. The neck has rotated in the joint; it has also pivoted forwards due to shortening of the forepillar, and has twisted due to the tension of the strings pulling down on its left side. These will have caused the tenon to rotate and pivot forwards and to the left in the mortise in the box. The end of a block of wood is protruding from the left side of the joint, suggesting that an effort has been made to reinforce the tenon. The tomograms reveal the full extent of the internal damage and repairs made to the joint (Figure 6 in the colour section and Figure 3). The tenon has sheared off completely, and the joint has been re-secured with four wooden dowels reinforced by a 9cm long spike. The spike and one of the dowels have each caused a

³⁷ Tate and Kirk (2010), p.5.

³⁸ Tate and Kirk (2010), p.5.

³⁹ See Armstrong (1904), p.163.

⁴⁰ Armstrong (1904), p.164.

crack to form in the neck. A thin piece of wood has been slotted into the neck at the back and nailed to the back of the tenon. A block of wood has also been nailed to the left side of the tenon to strengthen it and to reinforce it against the twisting of the neck downwards and towards the left. This is the block whose end is visible from the outside of the joint. Looking at the cross-sections of this joint on the tomograms (Figure 3), the mortise appears to have been enlarged to make room for the block. The neck has lifted 0.5cm out of the joint and tilted slightly towards the left. A shim has been inserted in the gap between the neck and the top of the soundbox.

The neck joint was also visually examined from the interior of the soundbox when the box was opened. The ends of the spike and dowels are visible from the inside of the box, as is the reinforcing block nailed to the side of the tenon. There are gaps between the tenon and the front and right sides of the mortise. These are packed with dried grass, many with their seed heads still attached (see Figure 4 in the colour section).⁴¹ The grass is packed deeply into the joint and may have been put there to keep the neck from shifting while the harp was being brought back up to tension after the joint was repaired.⁴²

THE QUEEN MARY HARP

SOUNDBOX

The grain and pattern of the growth rings of the wood is visible in the tomograms of this harp. They show that this soundbox is constructed from a half sawn boxed timber, with its central growth rings oriented towards the back of the soundbox. The front and sides of the soundbox are of varying thickness and will be discussed later in this paper. The CT scanning has revealed extensive woodworm damage, particularly in the back cover and at the treble end of the box on the left-hand side.

The interior of the soundbox has not been opened due to the fragile state of the back cover, but evidence of tool marks inside the soundbox is visible on surface renderings of the tomograms. These show what appear to be shallow linear grooves, consistent with the use of a gouge, on the inside surface of

the front. The grooves appear to be angled slightly towards the diagonal, from the lower left of the harp towards the upper right.

The interior edges and corners of the soundbox are not significantly rounded over, with the exception of the inside of the front surface at the treble and bass ends, where the edge rolls over rather than coming to a sharp angle. The sound holes are cut straight into the box. They are not angled or undercut. The front of the soundbox is arched along both its long and short axes. This arching, referred to here as the 'belly', is centred approximately on the mid-point of the length of the box, but falls off more quickly in the treble than in the bass (Figure 8). Along the width of the soundbox, it is centred near the mid-point of the string band, but is higher to the left of the string band, giving the belly a slightly skewed profile. The sides of the soundbox are pulled in, as can be seen in cross-sections of the box (Figure 9). This has probably been caused by the front of the box being pulled upwards, and is taken as evidence that the belly is the result of the string tension bending the wood.⁴³ It is not yet clear if there is visible evidence of this in the wood grain. At the treble end of the soundbox, the cavity constricts at the transition to the mortise for the neck joint, which is open to the interior of the box. The mortise comes up at an angle to the front of the box, and is offset towards the right-hand side of the harp. Where the neck seats against the soundbox the outside surface of the box is angled to be perpendicular to the mortise. The neck tenon, in turn, is cut perpendicular to the side of the neck seated against the top of the soundbox (Figure 8). There is visible damage and repair work to this joint, which is discussed in more detail in the section on the neck joint at the soundbox.

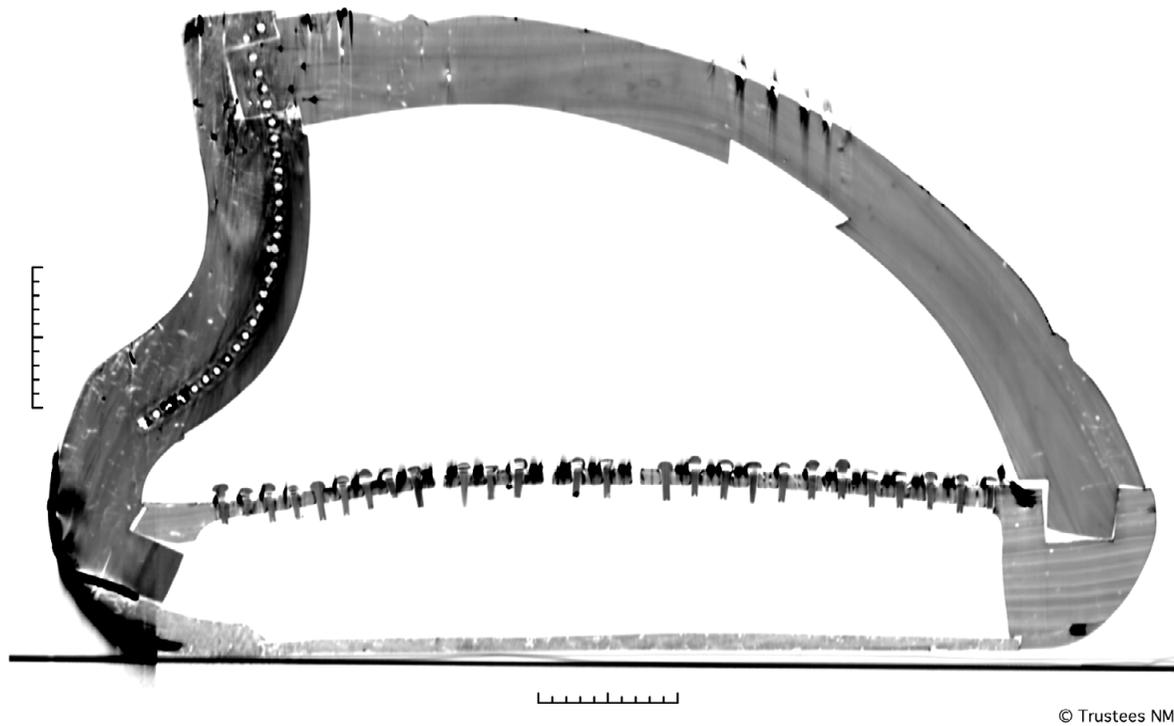
On the surface of the soundbox, the geometrical decorative lines appear to have been either cut or burned in. In their current state, they have an 'embossed' appearance, as if they were pressed into the wood, but it is not clear how this effect was accomplished.⁴⁴ The lines are filled with a dark waxy substance (as yet not analyzed); the same or similar substance is found in cracks and crevices on all parts of the harp. It is clearly visible in the tomograms as a dense material, and may therefore contain a

⁴¹ Hobrough, 'Notes on the 'Queen Mary' and 'Lamont' Harps'.

⁴² Guy Flockhart, personal communication (December 2010).

⁴³ Simon Chadwick, personal communication.

⁴⁴ The first author gratefully acknowledges Simon Chadwick for discussions relating to the decorative lines on the Queen Mary harp and possible methods for their construction, and for pointing out that their visual appearance may not be consistent with the use of pyrography. Personal communication (6 September 2011).



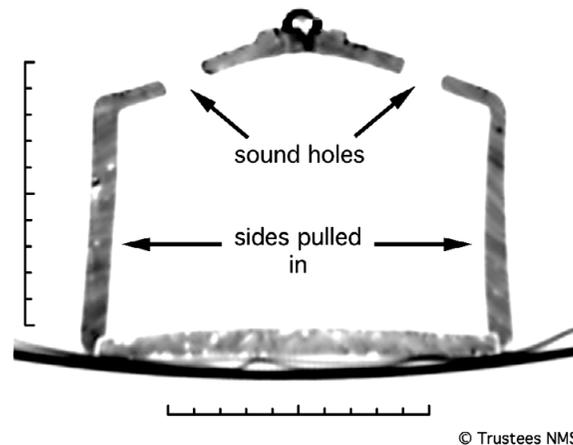
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Figure 8. *Sagittal tomogram of the Queen Mary harp. The soundbox cavity, joints, and wood grain are all visible in this cross-section. In order to show all three joints, the cross-section is angled slightly to the long axis of the soundbox. Scale 1 tick : 1cm.*

metal (see the tomogram on the left in Figure 15 in the colour section). Layout lines scored onto the soundbox for the pattern of decorative work were observed and photographed.⁴⁵ The centre of each circle in the design contains a dot, which shows on the CT scans as a prick mark, consistent with the point of a compass having been positioned there. The surface of the soundbox also has numerous nail marks, which are visible to the eye under close examination but are more easily seen on the CT scans due to traces of metal corrosion or small fragments of metal left behind in the nail holes. There are two loose clusters of nail marks symmetrically located on either side of the string band 4cm above the lower sound holes (Figure 15 in the colour section). Above these there are two small holes through the wood, also symmetrically located either side of the string band, 7cm above the lower sound holes. Around each of these holes is a partial circular impression, 2cm in radius, which may have been left by decorative medallions.

The tomograms of the Queen Mary harp show what appears to be a fragment of wire 0.6cm in length embedded in the interior of the front of the

soundbox, along the string band next to string hole #13.⁴⁶ The tomograms also show what appears to be a second, smaller, fragment embedded in the end of the wooden knob inserted in string hole #15. If the back cover of the harp can be safely removed, the fragments will be inspected and possibly removed



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Figure 9. *Axial tomogram of the Queen Mary harp. This cross-section across the soundbox shows the straight-sided profile of the sound holes, the arch of the belly, and the pulled-in sides of the soundbox. Scale 1 tick : 1cm.*

⁴⁵ The scored lines are described in Armstrong (1904), p.173.

⁴⁶ Discovered by Simon Chadwick during examination of tomograms of the Queen Mary harp (December 2010).

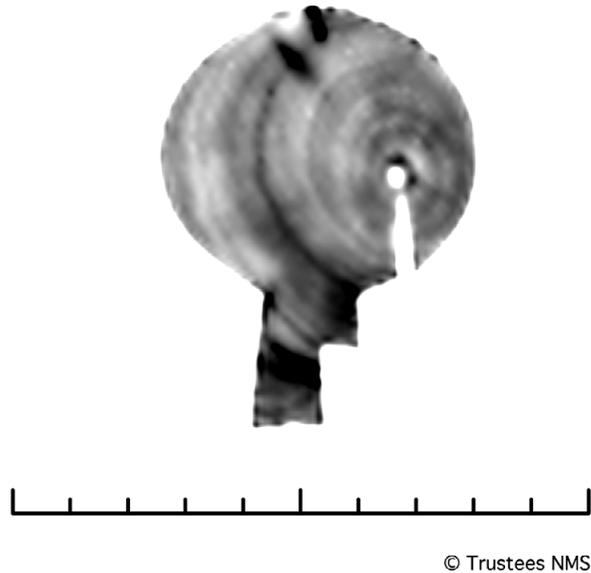
for analysis. It is not known if these fragments are historical, or if they date to the restringing of the harp with brass wire in 1806.⁴⁷

The back cover to the soundbox has the most extensive wood damage of any part of the Queen Mary harp. Some of this has been cosmetically repaired with what appears to be modern filler. The wood is darker in colour than the soundbox and has traces of decorative work that matches that on the box in both design and execution.⁴⁸ This suggests that the back cover of this harp may be original. The wood has been flat sawn, as evident from the grain that is visible in the tomograms. Several nails have been driven into the wood around the edge of the cover, in order to affix it to the back of the soundbox. Some of the nails appear to have been either cut or broken.

FOREPILLAR

The forepillar is carved from a timber that includes the centre of the wood, and the pith is visible in the tomograms (Figure 10). The curvature of the forepillar closely follows the grain of the wood, which is itself curved, so it is likely that this member was fashioned from a curved limb. A crack 19cm in length on the left side of the T-section opens up from the pith at the centre of the wood and follows the grain. This is undoubtedly an instance of 'checking' as a consequence of including the centre of the wood in the finished piece. A 10cm cut-out section on the left side underneath the T-section has a crack at the back which is not related to the larger crack in the T-section. Traces of what appears to be glue can be seen in the tomograms of this smaller crack.

The decorative carving on the forepillar contains traces of a red pigment (see Figure 11 in the colour section). XRF analysis has shown that the pigment contains significant amounts of mercury, indicating that it is almost certainly vermilion.⁴⁹ A red pigment is also embedded in nail holes in the centres of the carved decorative eyes on the T-section, suggesting that they were originally painted red and that something was nailed into the centres after they were painted. The pigment in the eyes was analyzed with XRF and also found to contain a significant amount



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Figure 10. Tomographic slice across the forepillar of the Queen Mary harp. The growth rings of the wood are visible, and the pith can be seen to the right of centre in the forepillar. Some checking is also apparent. Scale 1 tick: 1cm.

of mercury. Vermilion pigment has so far only been detected on the forepillar, but the dark waxy substance found in the decorative work and surface crevices on the soundbox also appears in cracks and crevices on the forepillar.

The front of the T-section has four very worn decorative bosses and two posts (which may have originally held two additional bosses). Close examination has revealed that the bosses were originally hemispherical caps. XRF analysis was conducted and has shown that they are composed of a silver copper alloy with traces of lead, zinc, tin, and gold. They are attached to brass posts with a solder containing lead and tin.⁵⁰

Areas of the decorative work on the sides and inside curve of the forepillar are highlighted by contrasting shades of wood, which is due to pigmentation of the wood, rather than inlay. Two contrasting areas on the inside curve of the forepillar were examined with

⁴⁷ This was done by Muir Wood and Co. at the request of the Highland Society for a performance by the Swiss pedal harpist, Joseph Elouis. Elouis replaced the brass wire with gut, fragments of which are still on the harp. Sanger (1992), p.203; and Sanger, personal communication (6 June 2011).

⁴⁸ Armstrong (1904), p.179.

⁴⁹ Tate and Kirk (2010), p.2.

⁵⁰ Tate and Kirk (2010), p.2.

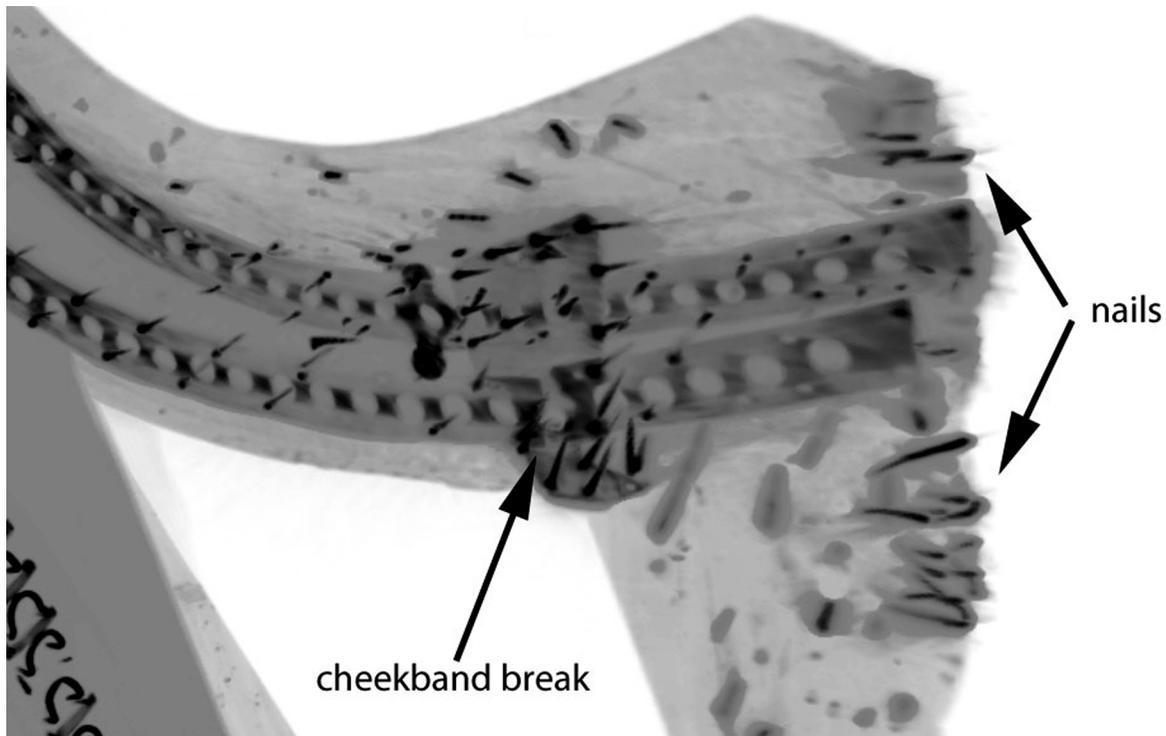


Figure 12. Tomographic three-dimensional projection of the end of the neck of the Queen Mary harp, where it joins with the forepillar. This three-quarter view shows the break in the cheekband and the long nails in the forepillar and neck end. These reportedly once held gold medallions with a portrait of Mary Queen of Scots and the arms of Scotland.

XRF and compared.⁵¹ The surface of the darker area had slightly elevated levels of iron, but more data would need to be taken to confirm whether this is due to a pigment containing iron. The Queen Mary harp has four decorative roundels on its forepillar, two on each side at the top and bottom ends. The tomograms revealed a central pin-prick extending 2–3mm into the wood in each roundel, suggesting the use of a compass to construct the design. These construction marks are not readily visible to the naked eye, but stand out in the tomograms. They appear to be filled with the same dense dark waxy substance found in other crevices of the harp.

Above the T-section, numerous nails are embedded in the wood on the front and sides of the forepillar and are prominently visible on the tomograms (Figure 12). The nails on the front face extend 1–1.5cm into the wood. These and similar nails embedded in the end of the neck are consistent with Gunn's report of the top of the forepillar and/or front end of the neck having at one time been decorated with gold medallions of the queen's portrait and the arms of Scotland.⁵² The end of one of these nails was

analyzed with XRF and found to be a copper alloy with a relatively high zinc content.⁵³

Looking at the workmanship of the joints, neither of the tenons at the ends of the forepillar fits its mortise particularly well (Figure 8). The tenon at the bottom of the forepillar has rotated slightly out of its joint, but even if it were not rotated, there would still be a gap between the tenon shoulder and the foot of the soundbox because the tenon is angled such that it cannot seat completely in the joint. The tenon at the top of the forepillar is also angled in its joint with the neck. The holes for the tuning pins pass through this tenon, and it is apparent from the line of holes visible in the tomograms that the tenon has not moved or rotated significantly since the forepillar was installed on the harp and the holes were bored through the tenon.

NECK

The neck is carved from a single piece of wood, with the grain running lengthwise along the long axis; the grain does not appear to be curved as it is in the forepillar. Numerous nails and nail fragments are

⁵¹ Tate and Kirk, unpublished data.

⁵² Gunn (1807), p.14.

⁵³ Tate and Kirk, unpublished data.

embedded in the wood along the sides and at the end of the neck at the forepillar as may be seen in Figure 12. The nails at the end of the neck extend 1–1.5cm into the wood. Internal cracks extend from two of the nail ends and follow the grain of the wood. These may have been caused by the nails, but similar cracks near the end of the neck where it joins with the forepillar are not associated with any nails. One moderately sized crack runs diagonally through the 25th tuning pin hole. On the right side of the neck, a metal patch is nailed over the cheek band at the 24th tuning pin hole. Armstrong noted this in his description of the Queen Mary harp and suspected that the patch was covering a break in the cheekband, based on the visible jog in the otherwise smooth curvature of the band.⁵⁴ Indeed, the tomograms reveal a clear break in the cheekband underneath the patch (Figure 12). Armstrong also suggested that the cracks in this end of the neck might have been the result of the forepillar pushing up on the end of the neck, which is being pressed against it by the tension of the strings.⁵⁵ The internal cracks visible in the tomograms tend to support this theory. Farther up the neck, towards the treble end of the harp, there are additional internal cracks. In the middle section of the neck, where the angle of the line of tuning pin holes is closely aligned with the direction of wood grain, a crack runs from the 8th or 9th hole to the 16th hole (Figure 8). It extends almost completely through the wood in places. The presence of the metal cheek bands may have prevented this section of the neck from sheering off under the tension of the strings. The cheek bands themselves are thin plates found upon analysis with XRF to be of a copper zinc alloy, with a high copper content.⁵⁶ One of the tuning pins has also been analyzed and found to be of nearly the same composition.

The tomograms reveal that some of the tuning pin holes contain thin irregular sheets of a dense, possibly metallic material (Figure 8). In some instances the material looks like it is lining the inside surface of the hole, in others it appears to be crumpled. In her examination of the Trinity College harp, Rimmer reported that several tuning pin holes were 'lined with thin metal to get a better fit' for the tuning pins,⁵⁷ so it is possible that this is what is

visible in the tomograms of the tuning pin holes of the Queen Mary harp.

NECK JOINT AT THE SOUNDBOX

A sturdy iron strap has been nailed across the neck joint at the soundbox and a small wooden wedge inserted at the back. Six heavy iron nails are driven through the strap: three into the neck and three into the back of the soundbox. The strap is clearly a repair (or remediation), as it covers up some of the decorative work on the neck. The CT scanning has revealed the full extent of the damage and repairs (see Figure 13 in the colour section). The tenon has a crack that opens up from the back right-hand corner and follows the grain of the wood. The neck has lifted about 3mm out of its joint and has tilted slightly forwards and towards the left side of the harp. A metal rod extends through the neck and into the joint. The three nails driven through the iron strap into the neck extend deep into the wood. The nails driven into the soundbox are bent, following the grain of the wood. The small wooden wedge fills the gap that has opened up at the back of the joint.

The iron strap is preventing the neck from rotating forwards out of the joint. This, in turn, is preventing the tenon from sheering off, or pushing through the back of the soundbox.⁵⁸ The metal rod is wedged between the mortise and tenon, and extends up through the back of the neck to just under the iron strap. This object, which was discovered upon examination of the tomograms, is not one of the nails driven through the strap, and is completely hidden underneath it. It could be a pin attached to the underside of the iron strap, or it might be an earlier attempt to stop the tenon from sheering off the neck.

THE SOUNDBOARD THICKNESSES OF THE QUEEN MARY AND LAMONT HARPS

In addition to having an unprecedented view of the interiors of the harps from the CT scans, it is now possible to take measurements of all of their parts, particularly interior measurements, which were previously unobtainable. One of the most important acoustical elements of these instruments is the soundboard, formed by the front of the hollowed out

⁵⁴ Armstrong (1904), p.178.

⁵⁵ Armstrong (1904), p.178.

⁵⁶ Tate and Kirk (2010), p. 2.

⁵⁷ Rimmer (1961), p.2.

⁵⁸ Guy Flockhart, personal communication (December 2010).

soundbox. Until now we have only had Armstrong's soundboard thickness measurements taken at the sound holes: $\frac{3}{8}$ -inch (10mm) at both the upper and lower sound holes for the Lamont harp; $\frac{1}{4}$ -inch (6mm) and $\frac{5}{16}$ -inch (8mm) at the upper and lower sound holes, respectively, for the Queen Mary harp.⁵⁹ A data sheet in the National Museums Scotland archives lists these measurements, with the addition of ' $\frac{11}{32}$ – $\frac{3}{8}$ inch' (9–10mm) for the thickness of the Lamont soundboard.⁶⁰ With the data from the CT scans, we can now measure and map the thickness of the entire soundboard of both harps, providing us for the first time with a complete picture of this vitally important aspect of their construction.

To obtain these measurements, axial slices from the CT scans were taken across each soundbox and cross sections were then taken at individual points through the soundboards. The thickness at each point was determined from the FWHM of the cross-sectional profile across the soundboard, normal to the surface, and the location of each measurement was taken from the inside face of the soundboard.⁶¹ The resolution of these measurements is 0.5mm. For the Queen Mary harp, measurements were taken in a 2cm x 2cm grid with additional measurements along the edges of the soundbox and in areas of sudden change in thickness (for example at the edge of the string band). For the Lamont harp (which has a larger soundboard) a 3cm x 3cm grid was used, with similar additional measurements. One limitation of CT scanning is image artefacts in the form of streaks that can appear in the tomograms in the vicinity of metal objects. Due to image artefacts from the metal string shoes, it was only possible to take a limited number of measurements on the string bands. The mapping of the soundboard thickness in this area is therefore much less reliable. For the Lamont harp there was also the issue of the piece of vellum glued to the right hand edge of the interior of the soundbox, which added to the thickness of the soundboard.⁶² The vellum and layer of glue measure approximately

0.5mm thick and measurements taken through the vellum have been adjusted by this amount.

The resulting contour maps generated for each harp are presented, along with a tomogram of the soundboard for comparison. These are shown in Figures 14 and 15 in the colour section.⁶³ On the contour maps, each line represents a change in thickness of 0.5mm. Areas of equal thickness have been mapped using the same colours for both harps. Thinner areas are represented by the blue end of the spectrum and thicker areas are represented by the red end.⁶⁴ The coordinate system is that of the CT scanner, with the exception that the scanner's z-axis is referred to here as the y-axis.⁶⁵ For reference, the positions of the string holes and sound holes were measured and added manually.

Looking at the contour map of the Queen Mary harp soundboard, some notable features are apparent. The soundboard is thinner in the treble, decreasing in thickness from 8mm just below the top sound holes to 6mm along the sides of the soundbox above the sound holes. In the mid-section of the harp there is a large area of the right-hand side of the soundboard that is thinner than the left-hand side. Here, the thickness of the soundboard is about 7.5mm compared to 9mm in areas of the middle of the left-hand side. At the bass end of the soundbox, the soundboard thickness rapidly increases from about 8.5mm just below the lower sound holes to 10.5mm close to the bottom edge, where it rolls over into a rounded corner.

The contour map of the soundboard of the Lamont harp also has some interesting features. As with the Queen Mary harp, the soundboard is thinner in the treble, decreasing in thickness from approximately 10mm at the upper sound holes to around 8.5mm on the right-hand side and 8mm on the left-hand side. This area of the soundboard appears to be thinner overall on the left-hand side, possibly as a result of the mortise being enlarged on that side for the repairs to the neck tenon. The midsection of the soundboard is

⁵⁹ Armstrong (1904), p.161, and pp.168–69.

⁶⁰ Data sheet, 'Harp Measurements' (H. LT2 archive, National Museums of Scotland, undated).

⁶¹ The measurements were obtained from the tomograms with the OsiriX v. 3.9 software package.

⁶² The vellum extends from the upper sound hole to just below the lower soundhole. It is affixed at an angle to the edge of the box and covers 2cm to 5cm of the front surface from the right-hand edge of the soundbox, starting from the upper sound hole.

⁶³ The contour maps were generated using the Aabel v. 3.0.5 graphing programme.

⁶⁴ It was necessary to wrap the colour mapping to allow for a few very thick areas, such as the ends of the string bands, and the bottom edge of the soundbox of the Queen Mary harp.

⁶⁵ For the Queen Mary harp, the signs of the x and y coordinates have been reversed for the purpose of plotting the contour map with the top of the harp facing up.

thinner on the right-hand side than the left, however, similar to the soundboard of the Queen Mary harp. In addition to being about 1mm thicker overall on the left side, the thickness of the soundboard increases from 11mm to 13.5mm towards the left-hand edge of the box. At the bass end of the soundboard, where the soundboard of the Queen Mary harp thickens, there are two areas, symmetrically located on either side of the string band, where the thickness of the soundboard decreases by about 1mm.

These contours may have resulted from a combination of the practicalities of working the wood, the need for mechanical stability of the box, and some intentional tuning of the soundboards. Although we don't know the original intentions of the builders of these two harps, we can now at least see the results of their handiwork, and while it is beyond the scope of this paper to analyze and discuss the full acoustical effects of the soundboard profiles, there is at least one obvious feature. The thinned treble, in particular, reduces the stiffness of the soundboard at that end of the soundboard, enabling it to vibrate more easily. This is a standard feature of the soundboards of modern harps, and it is plausible that the soundboards of these harps were intentionally thinned in the treble for this reason.⁶⁶ The reason for the left-right asymmetry in the mid-ranges of both soundboards is less obvious. This asymmetry may or may not have been built in intentionally, but the acoustical and mechanical effects should be examined as they could prove to be very interesting. In very general terms, with its thick and presumably stiff bass and thin treble, the soundboard of the Queen Mary harp probably favours the treble end of the instrument's range. In contrast, the Lamont harp has a relatively thinner, and therefore more flexible, soundboard in the bass. This, along with the proportionately wider bass end to the soundboard, may produce a relatively louder bass. While both harps are too fragile to be strung and played, the soundboard mapping helps us to understand how they may have sounded and may make it possible to build replicas that behave more closely like the original instruments.

CONCLUSION

As is evident from the findings presented in this paper, there is now a vast body of new information concerning the construction and current state of the Lamont and Queen Mary harps. For the first

time it is possible to view the interiors of the joints of the instruments and to take measurements. We can look at how the members are fitted together, and see any internal damage and hidden repairs. It is also possible to identify some of the choices made by the maker in terms of the orientation of the wood grain, and we can see the extent of woodworm damage. The photographic survey has given us an updated and much deeper knowledge of the exterior construction and decorative work and has pointed us towards potential areas for further research. Finally, the laboratory analysis has provided us with some of the first information on the materials used to construct, decorate, and repair these two instruments.

For the Lamont harp the CT scans reveal an instrument strained to the point of failure in all parts of its frame and repaired to continue its useful life. Previously unknown damage and repair work was discovered in each of its members. We now also have a photographic record of the interior of the soundboard, which alone holds enough physical clues to the setup and use of this instrument to keep researchers occupied for some time.

For the Queen Mary harp the laboratory analysis with XRF reveals that it has a forepillar that was richly decorated in vermilion paint and silver metalwork. The CT scans show previously unknown characteristics of the interior construction that will make it possible to build new harps that can more closely reproduce its sound. They also show that hidden underneath its fairly well preserved exterior, this harp also has evidence of internal damage.

Based on what has been learned from the current work, there are plans to re-examine both harps and to conduct additional laboratory tests to ultimately create a complete corpus of information on their materials and construction. The analysis and interpretation of the existing data is just beginning. There is a lot of information, and it holds many clues to the construction of these instruments and the history of their working life. It also raises just as many very interesting new questions, which will be considered and explored as this research continues.

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⁶⁶ Chris Waltham, and Andrzej Kotlicki, 'Vibrational Characteristics of Harp Soundboards', *Journal of the Acoustical Society of America* CXXIV (2008), p.1775.

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The Lamont and Queen Mary Harps



Figure 1. The Queen Mary harp (top) and Lamont harp (bottom), two of the earliest surviving Gaelic harps. The bottom photo shows damage and repair to the forepillar of the Lamont harp. Both harps are shown at the same scale. (National Museums of Scotland, Edinburgh) Top photo: K. Loomis; bottom photo: M. Goodwin. © Trustees NMS.

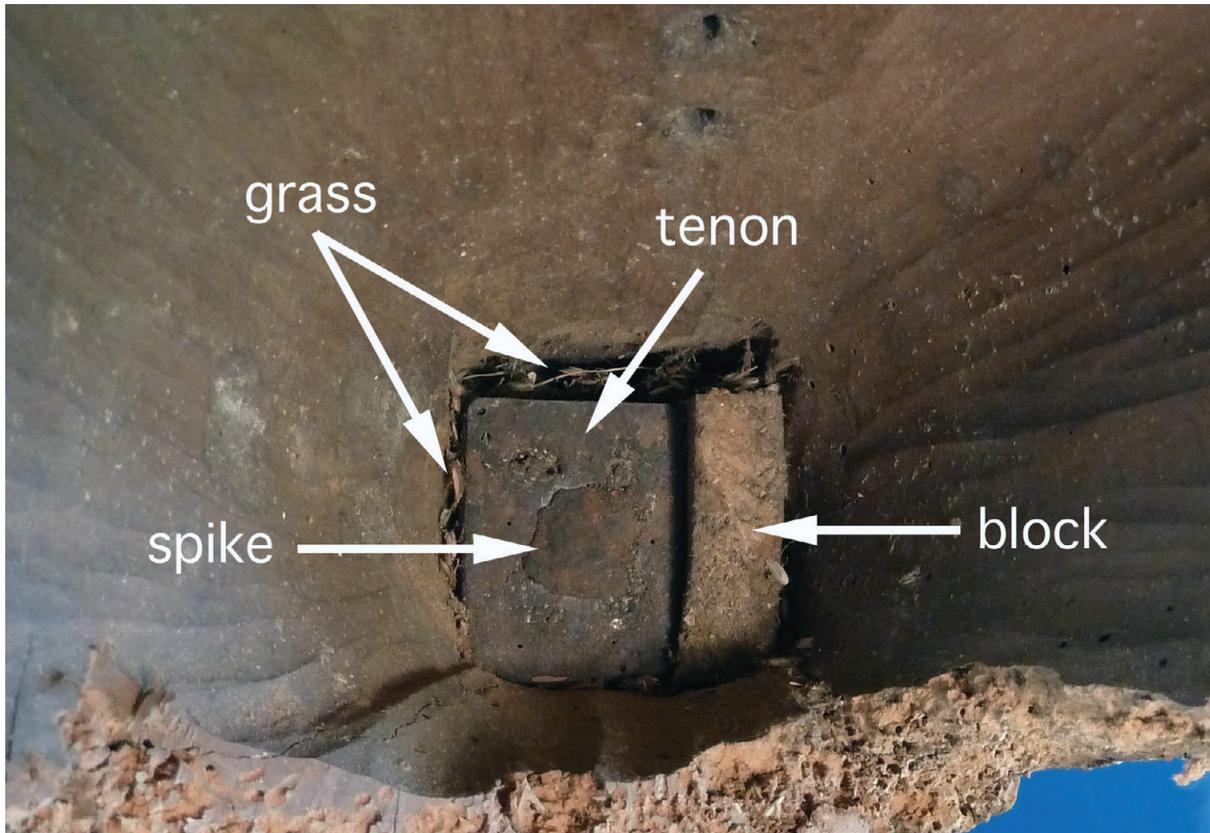


Figure 4. Interior of the soundbox of the Lamont harp showing toolmarks and repairs to the neck (photo by Karen Loomis, courtesy National Museums Scotland).



Figure 5. String toggle indentations, wire impressions, and verdigris stains around the string holes on the inside of the soundbox of the Lamont harp (photo by Karen Loomis, courtesy National Museums Scotland).

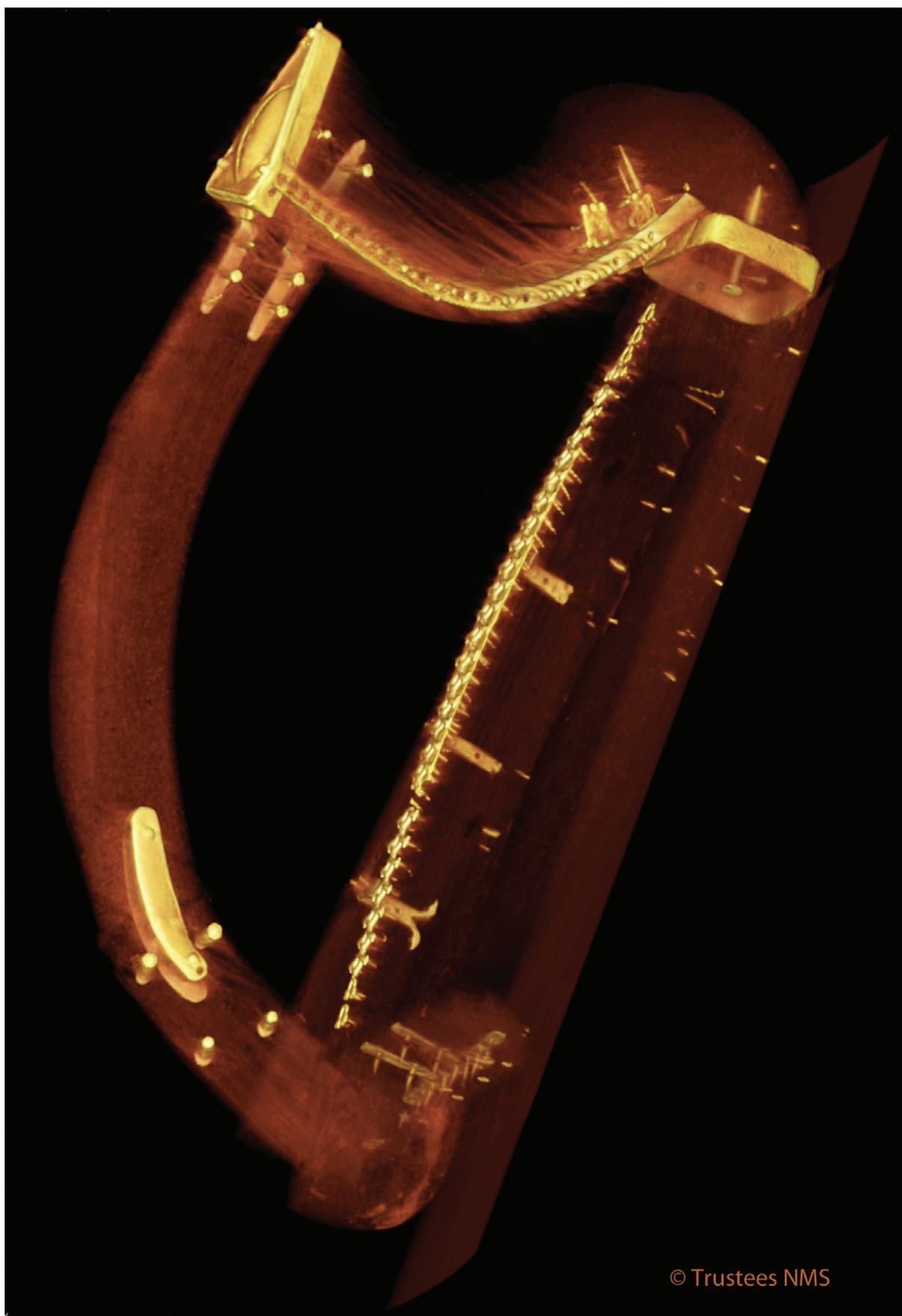


Figure 6. Tomographic volume rendering of the Lamont harp, showing metal repair work on the inside of the harp.



Figure 11. *Photographic (top) and tomographic (bottom) views of a section of the forepillar of the Queen Mary harp revealing traces of vermilion (photo by Karen Loomis, courtesy National Museums Scotland).*

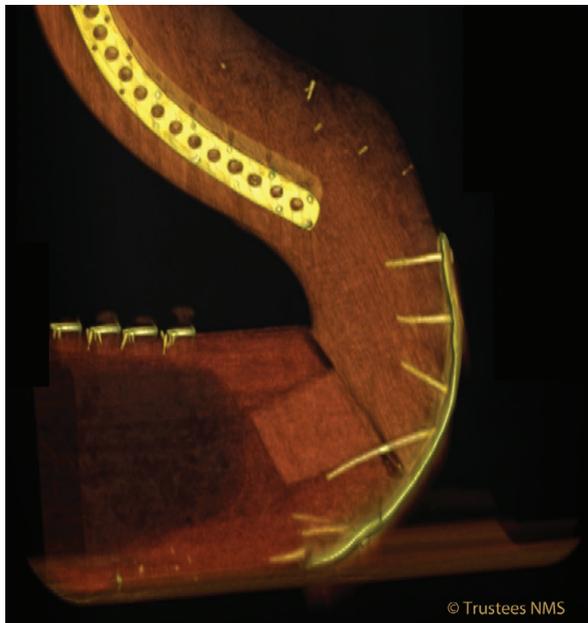
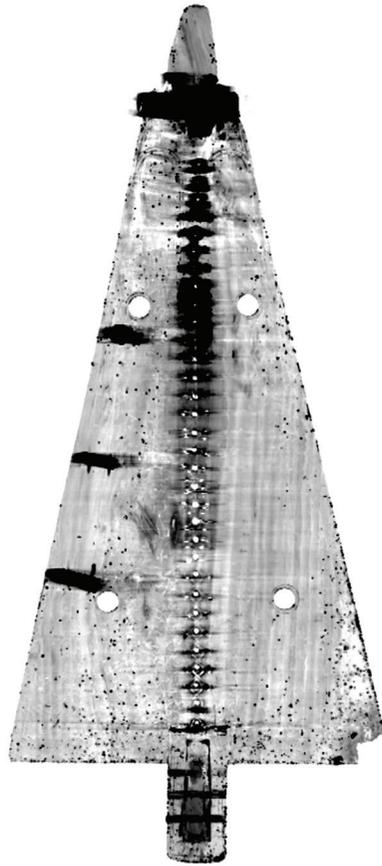


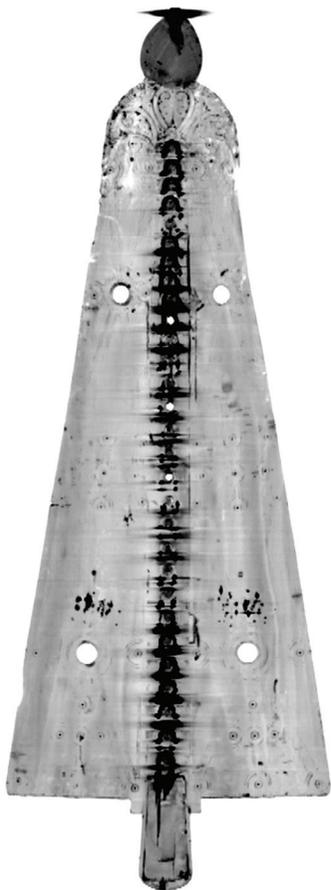
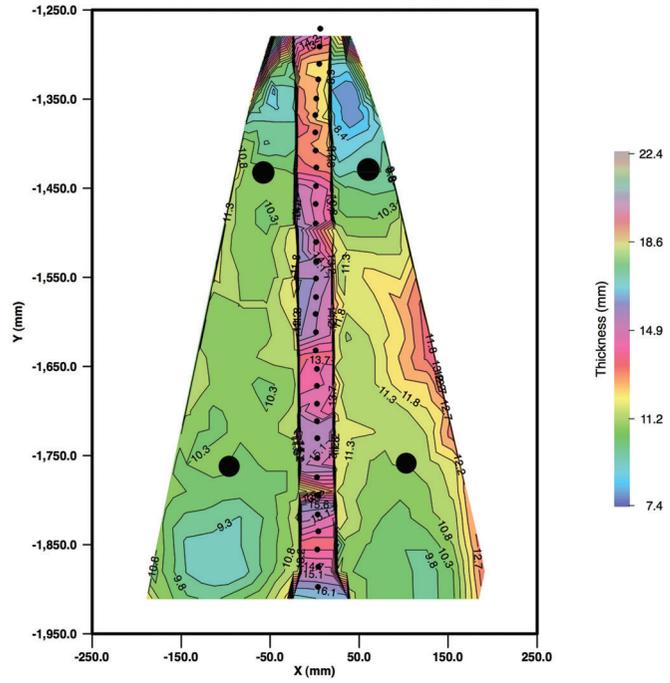
Figure 13. *Tomographic volume rendering of the neck joint at the soundbox of the Queen Mary harp. The nails holding an iron strap in place can be seen, as well as a crack in the tenon. A metal rod, not driven through the strap, is visible at the back of the joint, wedged in between the mortise and tenon.*

Figure 14. (Facing page, top) *Contour map of the soundboard of the Lamont harp. Thickness increases towards the red end of the colour spectrum (with the exception of the thickest contours on the string band, which had to wrap back around to the blues). Each contour represents a change in thickness of 0.5mm. The colours used in this map represent the same thicknesses in the contour map of the soundboard of the Queen Mary harp. A tomogram of the soundboard is included in the figure for comparison with the appearance of the wood. (Tomogram © Trustees NMS).*

Figure 15. (Facing page, bottom) *Contour map of the soundboard of the Queen Mary harp. Thickness increases towards the red end of the colour spectrum (with the exception of the thickest contours in the extreme bass of the soundbox, which had to wrap back around to the blues). Each contour represents a change in thickness of 0.5mm. The colours used in this map represent the same thicknesses in the contour map of the soundboard of the Lamont harp. A tomogram of the soundboard is also included in the figure for comparison with the appearance of the wood. (Tomogram © Trustees NMS).*



Lamont Harp
soundboard thickness



Queen Mary Harp
soundboard thickness

