THE ORGANOLOGY OF THE QUEEN MARY AND LAMONT HARPS

Karen A. Loomis

VOLUME ONE

PhD

The University of Edinburgh

2015

I declare that this thesis has been composed by me and is entirely my own work. I also declare that it has not been submitted for any other degree or professional qualification.

Karen A. Loomis

Karen A. Loomis

To the memory of Robert Bruce Armstrong

Abstract

The metal strung harp indigenous to Ireland and Scotland from the Medieval period to the end of the 18th century was widely admired throughout its time period, and is now an important part of the cultural and musical heritage of both of these countries. This type of harp, known as the 'Irish harp', *cláirseach*, or *clàrsach,* currently has 18 known surviving instruments, including two sets of fragments. All of these harps are now too fragile to be played, therefore musicians and audiences wishing to explore the performance practice and repertory associated with them must rely on faithful replicas. The extensive knowledge and understanding of the construction of the surviving harps that is crucial to building these replica instruments is currently very limited, however.

Although harps of this type enjoyed a long period of use dating back to the Medieval period, most surviving instruments post-date the beginning of the 17th century. Two harps belonging to the National Museum of Scotland, the 'Queen Mary' and 'Lamont', generally dated to circa the 15th century, are understood to be two of the oldest extant examples, making a study of their construction of particular interest. This dissertation presents the results of a comprehensive study of the construction of these two harps. A methodology was developed to address the issue of their uniqueness and fragility by combining the techniques used for non- and minimally destructive analysis of archeological artefacts with non-invasive medical diagnostic imaging. This study has utilized CT-scanning to provide three-dimensional radiography of each harp; XRF and SEM-EDX analysis to identify woods, metals, and pigments; photography and microscopy to record the decorative work, visible damage, repairs, and modifications; and a visual examination to assess the current state of each harp and to identify areas of interest for further analysis. The CT scanning was conducted at the Clinical Research Imaging Centre of Queen's Medical Research Institute, and the remainder of the analysis was conducted at the National Museums Scotland Collections Centre. Staff at both centres kindly facilitated the acquisition of the data for this study.

Part I of this dissertation discusses the stringing of the instruments, presenting materials analysis of wire fragments, analysis of the effect of damage to the frames on the length and number of strings, and proposed reconstructions of the 'as-built' string lengths. Possible solutions for the pitch and gamut of each harp are also discussed. The construction of the harps is discussed where it is relevant to understanding the stringing. Part II presents a general discussion of the construction of each harp, including materials, decorative work, modifications, and signs of wear. This section also discusses evidence that may help establish dates of construction and timelines of modifications. Diagrams showing the dimensions of each harp are also presented. The implications of the results of this study for current understanding of these harps are discussed in detail and the methodology employed is discussed in terms of its applicability to future research of other surviving instruments.

TABLE OF CONTENTS

VOLUME ONE:

Acknowledgements xi

Introduction 1

Background 1

Methodology 6

Materials analysis 7

Medical imaging 8

Construction of the instrument 9

Organization of the dissertation 13

List of abbreviations 13

List of terms 14

Intended research outcomes 15

Part I. Stringing 17

Chapter 1. Wire Fragments 21

Queen Mary harp fragments 21

Fragment 'A' 23

Fragment 'B' 27

Lamont harp fragment 36

Analysis discussion 49

Zinc 50

Trace elements 50

Nickel 51

Lead 52

Iron 52

Silver and tin 52

Summary 53

Chapter 2. Stringing Regimes 56

The frame of the Lamont harp 57

Number and arrangement of strings 57

String lengths for the Lamont harp 69

Reconstruction of string lengths for the frame in its current state 78

Reconstruction of string lengths for the 'straightened frame' 79

Stringing regimes for the Lamont harp 92

The frame of the Queen Mary harp 116

Number and arrangement of strings 116

String lengths for the Queen Mary harp 123

Current and reconstructed string lengths 135

Stringing regimes for the Queen Mary harp 143

Comparison with the Trinity College harp 156

Summary 159

VOLUME TWO:

Part II. Construction 162

Chapter 3. The Lamont Harp 162

Forepillar 162

Damage and repair (further to Loomis 2010) 164

Cross-sections 171

Direction of wood grain 176

Decorative work 178

Neck 179

Tuning pins 180

Composition 188

Comparison with other tuning pins 194

Cheekbands 203

Dimensions 213

End cap 218

Neck – forepillar straps 226
Metal repair patches 232
Summary 238
Cross-sections 238

Soundbox 244
String shoes 244
Stringing marks inside the soundbox 255
Tool marks 262
Inscriptions 266
Wear marks 292
Soundboard thickness 296
Decorative work 300
Summary 301
Cross-sections 303

VOLUME THREE:
Part II. Construction (continued)
Chapter 4. The Queen Mary harp 317
Forepillar 317
Decorative work 318
Materials analysis 333
Nails 342
Wood grain 344
Forepillar joints 346
Summary 352
Cross-sections 352

Neck 359
Tuning pins 359
Tuning pin string holes 372

Tuning pin holes 375

Cheekbands 380

Decorative work 386

Summary 395

Cross-sections 395

Soundbox 401

Decorative work 401

Decorative workmanship 410

Decorative work materials analysis 414

Nails 417

Soundbox interior 418

Interior modifications 426

Stringing marks inside the soundbox 427

String shoes 429

Back cover 432

Wear marks on the soundbox exterior 440

Soundboard thickness 444

Summary 448

Cross-sections 450

Chapter 5. Wood Identification 463

Queen Mary harp soundbox 476

Lamont harp soundbox 484

Summary 488

Conclusion 491

Research outcomes 491

Methodology review 497

Further research 498

The Lamont and Queen Mary harps 498

Other Irish harps 499

Other instruments 500

Appendix A:

Method for determining string lengths for the Lamont harp with a "straightened" frame 501

Appendix B:

Some solutions for the compass and pitch of the Queen Mary harp 511

Bibliography 513

Additional Material

Loomis, Karen, David Caldwell, Jim Tate, Ticca Ogilvie, and Edwin van Beek. "The Lamont and Queen Mary Harps." *The Galpin Society Journal* 65 (2012): 113 – 29 [offprint: included with permission of the publisher].

Acknowledgements

This project owes a debt of gratitude to the dedication and expertise of a number of talented individuals and to the institutions whose collaboration made it possible. Foremost, I would like to thank National Museums Scotland for supporting this extensive study of two of their most important cultural artefacts, and for putting their impressive curatorial and conservation staff and facilities at its disposal. I would also like to thank the Clinical Research Imaging Centre of Queen's Medical Research Institute for making their facility available for the groundbreaking CT scans of these two historical harps, and for providing expertise and support during this phase of the project.

I would particularly like to thank Dr. David Caldwell, former Keeper of Scotland and Europe at the National Museum of Scotland, Dr. Edwin van Beek, SINAPSE Chair of Clinical Radiology at the University of Edinburgh, and Director of the Clinical Research Imaging Centre, Dr. Jim Tate, former Head of the Department of Conservation and Analytical Research at National Museums Scotland, and Dr. Ticca Ogilvie, Head of Artefact Conservation at National Museums Scotland for their support of this project from its inception, for the significant contributions of their expertise, and for coauthoring with me the first published paper on the results of this study. I would also like to thank Dr. Darryl Martin for his excellent tuition on stringing analysis, which was the foundation of Part I of this dissertation.

I would like to express my gratitude to George Dalgleish, Keeper, Scottish History and Archaeology, and Dr. David Forsyth, Principal Curator, Medieval-Early Modern Collections at National Museums Scotland for their continued wholehearted support of this project. I would also like to thank Jackie Moran, Assistant Curator, Scottish History, for her assistance with archival materials at the museum.

The staff at the National Museums Scotland Collections Centre deserve particular acknowledgement. Their tireless work and dedication over a number of long days in the laboratory is evident in the extensive analytical data that was acquired for the two harps. Dr. Lore Troalen (Analytical Scientist), Verena Kotonski (former Assistant Artefacts Conservator), Dr. Suzanne Kirk (former Analytical Scientist), and Isabell Wagner (Curatorial Intern), led by Dr. Ticca Ogilvie and formerly Dr. Jim Tate merit special recognition. I would especially like to note the exceptional contributions of the expertise of Dr. Ticca Ogilvie for the sampling and identification of the woods and of Dr. Lore Troalen for conducting the scanning electron microscopy. I would also particularly like to thank my sister, Maripat Goodwin, for volunteering her time and expertise as a professional photographer to conduct the photographic survey of the Lamont harp at the Collections Centre, and for her moral support during this project. Additionally, I would like to thank Dr. Justine Bayley for her expert advice on sample preparation and analysis of the wire fragments found in the Lamont and Queen Mary harps.

The CT scans of the two harps are the cornerstone of this study, and the work of the staff at the Clinical Research Imaging Centre in acquiring these scans was a major contribution to its success. I would like to thank Tessa Smith (former Radiographer), Danielle Bertram (Radiographer), and David Brian (Superintendent Radiographer). I would especially like to thank Dr. Martin Connell of Queen's Medical Research Institute for his expertise in acquiring the scan data, and for his continued support and advice.

A number of dedicated individuals have also contributed to this study. Foremost among these is Keith Sanger, who volunteered his time and expertise researching archival materials related to the history and provenances of these two harps, and who shared his extensive knowledge in a number of particularly informative conversations and emails. I would also like to thank National Records of Scotland for their assistance with Keith Sanger's archival work.

I would like to thank Amanda Munday, Jonathan Letcher, and Mike Parker for bringing the Montgomery tuning pins to my attention, and would also like to thank Amanda Munday for hosting my visit to Montgomery. I would especially like to thank the Old Bell Museum in Montgomery for permission to photograph the tuning pins, and the curators John and Ann Welton, for their assistance.

I would like to thank Janet Ambers, British Museum, Department of Conservation and Scientific Research for retrieval of the museum's conservation report on the Trinity College harp, and Dr. Jennifer Goff, Curator of Furniture, Music, Science & the Eileen Gray Collection, National Museum of Ireland, for permission to examine the Cloyne harp fragments. I would also like to thank Sarah Nolan, Assistant Curator, for her help.

During the course of this study, it has been my pleasure to meet and discuss harps with a number of researchers, musicians, and luthiers. I have learned much from these conversations, and I would like to thank the community of people who have a dedicated interest in these instruments for their support and enthusiasm for this study, and for their valuable feedback while it has been in progress. I would particularly like to thank Paul Dooley for sharing his knowledge and insight in a number of enlightening conversations, and for setting the bar quite high in his work with the Trinity College harp, which was the inspiration for Part I of this dissertation. I would also particularly like to thank Simon Chadwick for sharing his extensive knowledge of the harps, for countless lively discussions, and for his support and encouragement.

Lastly, and most importantly, I would like to thank my daughter Vivian for her unwavering patience.

Karen Loomis
November 2014

Introduction

Figure 0.1: *The Queen Mary harp (left), and the Lamont harp (right), National Museum of Scotland H.LT1 and H.LT2, respectively. Photograph: Isabell Wagner*

<u>Background</u>

From the Medieval Period to the end of the 18th century, the harp of Ireland and Highland Scotland, known variously as an Irish harp, *cláirseach* (in Irish), or *clàrsach* (in Scottish Gaelic), was a highly regarded musical instrument. During its long period of use, it was enjoyed in the houses of the chieftains in Gaelic society as well as at court in England and on the continent.[1] The substantial construction of its frame, and its metal stringing played by striking with the fingernails, imparted this instrument with a distinctive resonant sound that was greatly admired.[2]

It is not known when this harp first appeared in Ireland and Scotland. Harps are depicted on Pictish stone monuments in Scotland from the 8th – 10th centuries, but these are not identifiably of this type.[3] A possible early depiction appears on the Irish Breac Mhaodóg (the Shrine of St Mogue), which dates to the second half of the 11th century.[4] What may be the earliest written reference to the instrument appears in the 12th-century *Topographia Hibernica* of Giraldus Cambrensis, in which he comments on the *cithara* played in Ireland, pointing out the brass (or bronze) stringing, while remarking on the sound of the instrument and skill of the players.[5] A possible early representation of particular note is a harp depicted in detail in the late 13th-century Angel Choir of Lincoln Cathedral that closely resembles the earliest surviving instruments.[6]

As Rimmer (1963) notes, iconographic depictions of harps with the characteristic form of the 'Irish harp' were in evidence by the end of the 14th century.

> "From the plethora of harps, real, symbolic and imaginary, which appear in medieval iconography, two distinct forms are recognisable by the end of the fourteenth century. One is the European form, which Sachs rather loosely called Romanesque; the other is the Irish harp."[7]

---

[1] Ann Buckley, "Music and Musicians in Medieval Irish Society," *Early Music* 28, no. 2 (2000): 165 – 66. Cólm Ó Baoill, "Highland Harpers and their Patrons," in *Defining Strains: The Musical Life of Scots in the Seventeenth Century*, ed. James Porter (Bern: Peter Lang AG, International Academic Publishers, 2007), 181. Peter Holman, "The Harp in Stuart England: New Light on William Lawes's Harp Consorts," *Early Music* 15, no. 2 (1987): 188 – 92.
[2] Joan Rimmer, "Harps in the Baroque Era," *Proceedings of the Royal Musical Association*, 90 (1963 – 64): 61 – 62.
[3] Keith Sanger and Alison Kinnaird, *Tree of Strings: A history of the harp in Scotland* (Temple: Kinmor Music, 1992), 14 – 30.
[4] Buckley, "Music and Musicians," 168.
[5] Christopher Page, *Voices and Instruments of the Middle Ages* (London: J. M. Dent & Sons, Ltd., 1987), 229 – 30.
[6] Jeremy Montagu and Gwen Montagu, *Minstrels & Angels: Carvings of Musicians in Medieval English Churches* (Berkeley: Fallen Leaf Press, 1998), 3, Plate 1. Montagu and Montagu label this instrument an "Irish-type" harp.
[7] Rimmer, "Harps in the Baroque Era," 59.

Spanning their long history of use, there are many historical references to the individuals who played these harps as professional musicians, as noted by a number of authors.[8] It thrived as a musical instrument through the end of the 16th century and into the Stuart era of the early 17th century, until political upheavals in Ireland and Scotland in the 17th and 18th centuries resulted in the decline and loss of the old Gaelic nobility and their patronage of the harpers.[9] This, along with changing musical tastes as well as competition from other instruments, may have contributed to a slow decline in use that continued through the 18th century until the instruments fell out of use altogether. Notably, the last generation of 18th-century harpers was observed and interviewed first-hand by Edward Bunting, whose publications and extensive field notes, including descriptions of performance practice, tuning, and a large body of music transcribed directly from performances by the musicians, are a significant repository of information on the music and performance of this instrument.[10]

The surviving harps are now an important part of the cultural and musical heritage of both Ireland and Scotland. There are currently 18 known extant instruments (including two sets of fragments).[11] All of these are now too fragile to be played, so musicians and audiences wishing to explore the performance practice and repertory associated with them must rely on faithful reproductions. The knowledge and understanding of the materials, construction, and craftsmanship of the original instruments that is crucial to building these reproductions is currently somewhat limited, however. The primary source of information has been Robert Bruce Armstrong's *The Irish and The Highland Harps*, which was published over 100 years ago.[12] More recently, in depth studies have been undertaken for the Downhill, Bunworth, and 'Brian Boru' (a.k.a. the Trinity College) harps, adding to present

---

[8] Edward Bunting, *The Ancient Music of Ireland, Arranged for the Piano Forte* (Dublin: Hodges and Smith. 1840), 67 – 82. Robert Bruce Armstrong, *Musical Instruments Part I. The Irish and the Highland Harps* (Edinburgh: David Douglas, 1904), 1 – 23, 139 – 54. Sanger and Kinnaird, *Tree of Strings*, 78 – 152.
[9] Ó Baoill, "Highland Harpers," 183 – 84.
[10] Colette Moloney, *The Irish Music Manuscripts of Edward Bunting (1773 – 1843): An Introduction and Catalogue* (Dublin: Irish Traditional Music Archive, 2000), 3 – 16.
[11] Simon Chadwick, "The Early Irish Harp," *Early Music* 36, no. 4 (2008): 522.
[12] Armstrong, *Irish and the Highland Harps*.

knowledge of these instruments.[13] There is, however, a need for additional extensive and detailed research of all of the surviving harps.

Most of the extant instruments post-date the beginning of the 17th century. Three instruments, the Trinity College harp of Trinity College, Dublin, and the Queen Mary and Lamont harps of the National Museum of Scotland, are generally dated to circa the 15th century, and are understood to be the oldest surviving harps of this type, making a study of them of particular interest.[14] In consideration of the need for more research into the construction of these harps, particularly the earliest examples, this author approached the National Museum of Scotland and the Clinical Research Imaging Centre of Queen's Medical Research Institute in 2010 to propose a study of the Queen Mary and Lamont harps.

The history of these two harps has been extensively researched by Sanger and Kinnaird (1992) and Sanger (2013).[15] Both harps belonged to the Robertson (formerly Tarlochson) family of Lude, in Perthshire, Scotland, and were handed down in that family for a number of generations before eventually being acquired by the National Museum of Antiquities of Scotland (now the National Museum of Scotland).[16] The earliest published information on them comes from Gunn (1807), as related to him by General William Robertson.[17] According to Gunn, the Lamont harp is so named because it is supposed to have been acquired through the marriage of a lady of the Lamont family of Argyll into the house of Lude in Perthshire around

[13] Michael 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* 20 (2010): 6 – 19. David Kortier, "Replicating the Bunworth Harp," accessed 19 November, 2014, http://www.kortier.com/subpages/bunworth.htm. Paul Dooley, "Reconstructing the Medieval Irish Harp," *The Galpin Society Journal* 67 (2014): 107 – 42. The Downhill harp, built in 1702, is owned by Diageo. The Bunworth, built in 1734, is owned by The Museum of Fine Arts, Boston, and the Trinity College harp, usually dated to circa the 15th century, is owned by the Trustees of Trinity College, Dublin.
[14] Chadwick, "Irish Harp," 523.
[15] Sanger and Kinnaird, *Tree of Strings*, 71 – 77. Keith Sanger, "The Robertson Family and Their Harps." last modified 7 June, 2013, http://www.wirestrungharp.com/harps/lude/lude_robertson_tarlochson.html.
[16] Sanger, "The Robertson Family and Their Harps."
[17] John Gunn, *An Historical Inquiry Respecting the Performance on the Harp in the Highlands of Scotland* (Edinburgh: Archibald Constable, 1807), 1 – 17, 73 – 84.

1460.[18] Bell (1880), quoting *Burke's Landed Gentry*, names her as Lilias Lamont, and the year of marriage as 1464.[19] This provenance for the harp is unconfirmed, however. The Queen Mary harp is so named because it is supposed to have been given as a gift to Beatrix Gardyne (the wife of John Tarlochson), by Mary, Queen of Scots (during a hunting expedition in Perthshire in 1563, according to Gunn's somewhat florid account).[20] This provenance is also unconfirmed. It is unknown if these two harps were in continuous use throughout their long working lives, but their last historical player is understood to be John Robertson of Lude, who died in 1731.[21]

Both harps remained in the Robertson family until the death of Colonel James Robertson in 1874, at which point they passed to his close friend John Steuart of Dalguise.[22] Sanger (2013) has surmised that by this time the two harps had already been at the Dalguise estate for a number of years, where they were kept in a storage cupboard in Stewartfield House.[23] The harps eventually passed to a J. N. D. Steuart of Dalguise, and were put up for auction in 1904, after his death.[24] The Queen Mary harp was purchased by the National Museum of Antiquities of Scotland, but as there were insufficient funds for the Lamont harp, this was purchased by the antiquarian Moir Bryce, who bequeathed it to the museum upon his death in 1919.[25]

The two harps were first examined and described by Gunn in 1805, on behalf of the Highland Society, and the earliest engravings of them were published in his 1807 report.[26] They were next examined in 1880 by Charles Bell, on behalf of the Society

[18] Gunn, *Historical Inquiry*, 1, 73. Sanger and Kinnaird, *Tree of Strings*, 72.
[19] Charles Bell, "Notice of Two Ancient Harps and Targets," *Proceedings of the Society of Antiquaries of Scotland* 15 (13 December, 1880): 28. See also, Sanger and Kinnaird, *Tree of Strings*, 72.
[20] Gunn, *Historical Inquiry*, 77 – 81. See also Sanger and Kinnaird, *Tree of Strings*, 72.
[21] Sanger and Kinnaird, *Tree of Strings*, 150.
[22] Sanger, "The Robertson Family and Their Harps."
[23] ibid.
[24] ibid. A copy of the auction catalog is archived at National Museums Scotland, "Queen Mary harp archive," H.LT1 (National Museums Scotland Library).
[25] Moir Bryce, *Moir Bryce to Scott Moncreiff*, 25 October, 1918. Letter, National Museums Scotland, H. LT2 archive. Sanger, "The Robertson Family and Their Harps." Sanger notes in a footnote that Bryce died on 2 August, 1919, according to the National Archives of Scotland records. His year of death has been misquoted elsewhere as 1918.
[26] Gunn, *Historical Inquiry*, v.

of Antiquaries of Scotland.[27] In his report the harps are described and illustrated in some detail, with particular attention given to the decorative work on the Queen Mary harp.[28] Bell is also fairly critical of Gunn's earlier report, pointing out its inaccuracies and shortcomings.[29] The most comprehensive and detailed examination of them prior to the current study was conducted by Armstrong, and published in his 1904 volume, *The Irish and the Highland Harps*. Armstrong examined, photographed, and measured both harps, and in particular, provided accurate, detailed drawings of the decorative work on all parts of the Queen Mary harp.[30] His work has been the primary source of information on the construction of these two harps, to date.

At the time of Bell's 1880 report the harps were permanently loaned to the Society of Antiquaries, and were placed on display at the National Museum of Antiquities, where they both remained (excluding a brief loan for exhibition) until they were auctioned. The Lamont harp then went to its new owner, Moir Bryce, until it was returned to the museum after his death. Both harps have remained with the museum (now the National Museum of Scotland) to the present day.

Methodology

Due to the age and uniqueness of the Lamont and Queen Mary harps, any study of them must be conducted with minimum physical impact. To address this issue, a methodology was developed to combine non- and minimally invasive materials analyses, as used in conservation and research of museum artefacts, with non-invasive medical imaging, supported by a thorough visual assessment and complete photographic survey of each instrument. The materials analyses and the visual and photographic surveys were conducted at the National Museums Scotland Collections Centre, in collaboration with museum conservation staff. The medical imaging was

[27] Charles Bell, "Notice of Two Ancient Harps and Targets," 10 – 33.
[28] ibid., 13 – 23.
[29] ibid., 16 – 18.
[30] Armstrong, *Irish and Highland Harps*, 158 – 83.

conducted at the Clinical Research Imaging Centre (CRIC) of Queen's Medical Research Institute (QMRI), in collaboration with CRIC staff. Both of these facilities are located in Edinburgh, Scotland.

In June and July of 2010, each harp underwent two days of preliminary examination, materials analysis, and a photographic survey at the Collections Centre, followed by medical imaging at CRIC.[31] The medical imaging was initially used for the author's MMus thesis, "The Queen Mary and Lamont Harps: A Study of Structural Breaks and Repairs," which was concerned specifically with the evidence of damage and repairs to these harps. The current study has significantly expanded upon that work to comprehensively examine their construction.

An extensive examination and analysis of both harps was undertaken at the Collections Centre over a period of two weeks in December 2012. This consisted of a visual examination and survey (both unaided and under magnification), photography of the interiors and exteriors of the instruments, macrophotography of specific areas of interest, photomicroscopy, sampling, and materials analysis. Additional analysis of samples was undertaken in April and July of 2013. The analysis tools used are discussed below.

Materials Analysis

X-ray fluorescence (XRF) spectroscopy was used for non-destructive identification of the elements comprising materials in specific areas of interest. In nearly all instances the analysis was conducted on materials in situ on the harps. The analyser used was an Oxford Instruments ED 2000 with Oxford Instruments software ED 2000SW version 1.31. The operating voltage was 46 kV, with a current up to 1000μA. The beam size was 4mm × 2mm. For analysis of the Lamont harp, the system was

[31]Karen Loomis, "The Queen Mary and Lamont Harps: A Study of Structural Breaks and Repairs" (MMus thesis, University of Edinburgh, 2010).

calibrated for semi-quantitative analysis using the GM8B and B10F blocks of 'Copper Alloys 2008'.[32]

The penetration depth of XRF depends upon the target material and the beam energy, and can range from a few microns to a few millimetres. For the XRF analyses presented here, it should be assumed that the results represent the composition at or near the surface of the material.

Scanning electron microscopy with energy dispersive x-ray spectroscopy (SEM-EDX) was used for high resolution imaging (SEM) of small samples taken from the harps, and for identification of composition (EDX). The instrument used was a CamScan MX2500 SEM in controlled pressure mode. A Noran Vantage EDX system with Vista software was used for identification of elements via spectral analysis.[33] Two imaging modes were used: secondary electron imaging (SEI), which is sensitive to surface topography, and backscattered electron imaging (BSC), which is sensitive to the atomic mass of the elements comprising the material.[34]

Medical Imaging

X-ray computed tomography (CT) was used to scan each harp. The scanner used was a Toshiba Medical Corporation 320-multidetector row Aquilion ONE, operating at 135 kVp for the Lamont harp and 120 kVp for the Queen Mary harp.[35] The output data is in DICOM format, with a bit depth of 16-bits. The full diameter of the scans is 50 cm, and

---

[32] Jim Tate and Susanna Kirk, "Analytical Research Section Report No. AR 2010/39: XRF analysis of the Queen Mary and Lamont harps." Internal Report. National Museums Scotland, 12 July, 2010, Appendix 1.
[33] ibid.
[34] "SEM Illustrative Example: Secondary Electron and Backscatter Electron Images," last modified 30 October, 2014, http://www.andersonmaterials.com/sem/sem-secondary-backscatter-images.html.
[35] A higher kVp was used for the Lamont harp in order to penetrate the thick metal cheekbands and the metal end cap.

the resolution is 0.5 mm.[36] The scans were rendered and analysed with the OsiriX DICOM viewer software package, version 5.6, 64-bit, on an Apple MacBook Pro running Mac OS 10.7.5. A set of three full scans was taken for each harp.

CT scanning has successfully been used since the early 1980's as a powerful non-invasive analysis tool for the study of musical instrument construction.[37] CT effectively generates a three-dimensional 'x-ray' (referred to as a tomogram) that can be viewed from any angle, or in any cross-section, allowing examination and measurement of all parts of the construction. The specific uses of CT for this project are discussed below in the Intended Research Outcomes section.

Construction of the Instrument

This section provides a brief description of the basic construction of these harps, noting the terms used for the parts of the instruments.

As noted at the beginning of this introduction, the historical harp of this type is referred to variously as an Irish harp, *cláirseach* (in Irish), or *clàrsach* (in Scottish Gaelic). The names all refer to the same instrument, as there is no organological difference between these harps in Ireland and Highland Scotland.[38] The choice of term is left to the discretion of the user, and depends on the context. This dissertation uses the term Irish harp, but only when referring to these instruments as a group, as that is the term

---

[36] Karen Loomis et al., The Lamont and Queen Mary Harps," *The Galpin Society Journal* 65 (2012): 114.
[37] Steven Sirr and John Waddle, "CT Analysis of Bowed Stringed Instruments," *Radiology* 203 (1997): 801– 05. Steven Sirr and John Waddle, "Use of CT in Detection of Internal Damage and Repair and Determination of Authenticity in High Quality Bowed Stringed Instruments," *Radiographics* 19, no. 3 (1999): 639 – 46. Arnd Both, "3D-Computed Tomography and Computational Fluid Dynamics: Perspectives in the Non-Contact Organological and Acoustical Research of Ancient Musical Instruments," in *Studies in Music Archaeology: VI: Challenges and Objectives in Music Archaeology*, ed. A. A. Both, et al. (Rahden: Marie Leidorf, 2008), 383 – 88. Terry Boreman and Berend Stoel, "Review of the Uses of Computed Tomography for Analyzing Instruments of the Violin Family with a Focus on the Future," *Journal of the Violin Society of America* 22, no. 1 (2009): 1 – 12.
[38] Joan Rimmer, *The Irish Harp* (Cork: The Mercier Press, 1969), 35.

most often used by historical and modern commentators in this context. Specific instruments are always referred to individually by name.[39]

The frame of the Irish harp is constructed of three members: soundbox, forepillar, and neck. Mortise and tenon joints connect the members of the frame, which is designed to be held together by the tension of the strings. Each frame member is constructed from one piece of wood, including the soundbox, which is made from a single large timber hollowed out from the back, oriented with the wood grain running parallel to its long axis. The opening in the back of the soundbox is enclosed by a separate board. The soundbox has a flat back upon which it rests when the harp is not in use, and a single projecting foot at its base upon which the harp balances while it is in playing position.

The front face of the soundbox has a raised string band with metal reinforcements, referred to as 'string shoes', at the string holes. The raised string band enlarges at the treble end of the soundbox to form a pair of arches, commonly referred to as the 'eyebrows'. The harp is strung with wire strings, and each is held in place at the soundbox by a toggle knotted to the end of the string inside the box. The forepillar is curved and has a reinforcing T-section along its central portion. The sides of the neck are reinforced with metal cheekbands, through which the tuning pins pass. The line of tuning pins on the neck is referred to as the harmonic curve.

The parts of the harp frame are illustrated in the figure below.

---

[39] When referring specifically to the harps in Scotland, it is most appropriate to use the term *clàrsach*.

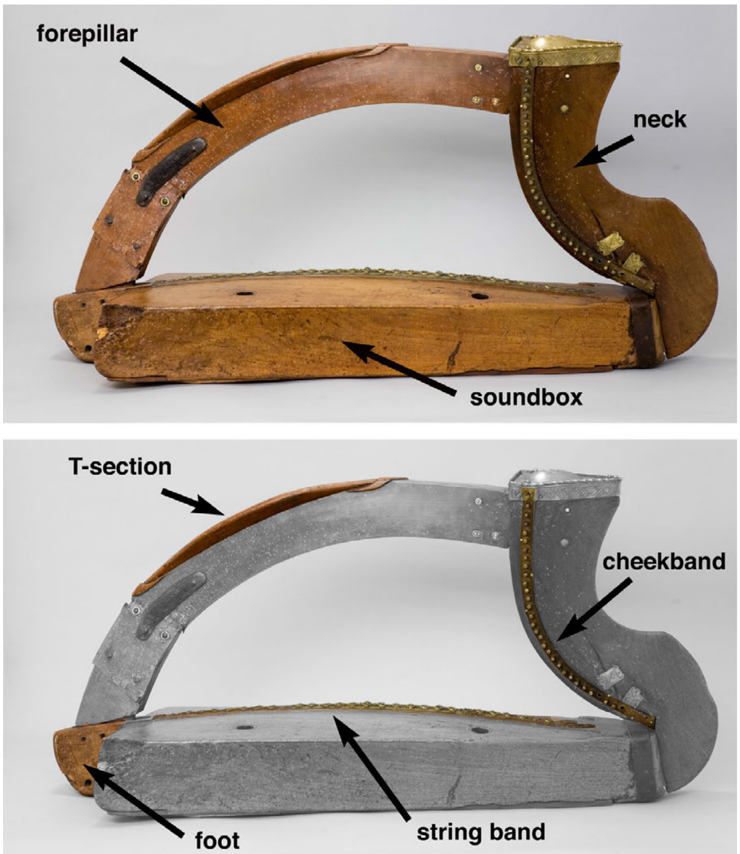


Figure 0.2: *The Lamont harp, illustrating the parts of the frame. Photograph: Maripat Goodwin, edited by the author.*[40]

The Lamont and Queen Mary harps are of the form described as 'low-headed' by Rimmer (1964).[41] The low-headed Irish harp is characterized by a comparatively short string scaling in the bass. When the instrument is in playing position, the bass end of the neck is nearly level with the treble end, hence the designation 'low headed'. An additional distinguishing characteristic of the construction is the forepillar joint at the neck, which has the neck mortised on top of the end of the forepillar. The 'low-headed' Irish harp is understood to be the form of the instrument prior to the mid to late 17th century, as contrasted with the later 'high-headed' Irish harp.[42]

[40] This figure is adapted from two figures in Loomis, "Structural Breaks and Repairs," 7 – 8.
[41] Joan Rimmer, "The Morphology of the Irish Harp," *The Galpin Society Journal* 17 (1964): 39 – 40. Rimmer further subdivides this group into 'small low-headed' and 'large low-headed'.
[42] Rimmer, "Morphology of the Irish Harp," 44.

In the later 'high-headed' form, the bass strings are proportionately longer, resulting in a neck that sweeps upwards towards the bass end of the frame. When the instrument is in playing position, the bass end of the neck is higher than the treble end, hence the designation 'high headed'. In contrast to the low-headed harp, the end of the neck is joined to the side of the forepillar, with the end of the forepillar extending above the neck.[43]

The convention used for referring to locations on the harps is illustrated below. Left and right are always from the perspective of the player holding the harp. Tuning pins and string holes are numbered from #1 in the treble, increasing towards the bass.

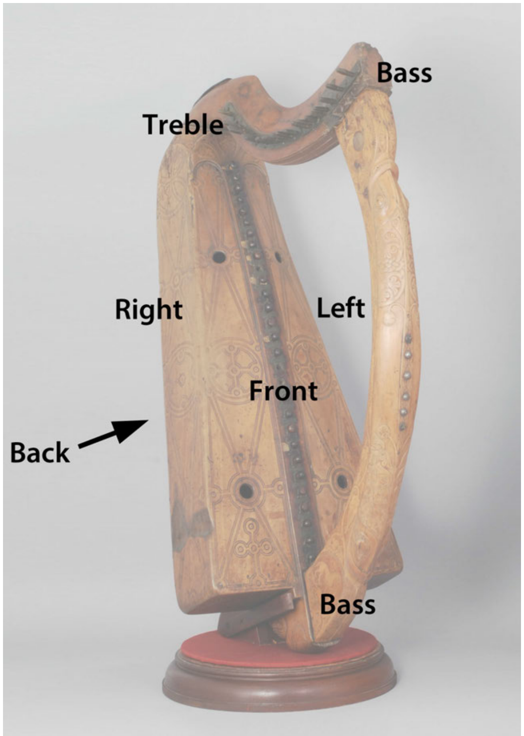


Figure 0.3: *Convention used for referring to locations on the harps*

[43] For comparison, the Bunworth (Museum of Fine Arts, Boston) is an example of a 'high-headed' Irish harp.

Organization of the Dissertation

This dissertation is divided into two parts. Part I discusses the stringing of the instruments, presenting materials analysis of wire fragments, analysis of the effect of damage to the frames on the length and number of strings, and proposed reconstructions of string lengths for the straightened frames. Possible solutions for the pitch and gamut of each harp are also discussed. The construction of the harps is discussed where it is relevant to understanding the stringing. Part II presents a general discussion of the construction of each harp, including materials, decorative work, modifications, and signs of wear. This section also discusses evidence that may help establish dates of construction and timelines of modifications. Diagrams showing the dimensions of each harp are also presented.

List of Abbreviations

BSC	Backscattered electron imaging
CT	X-ray computed tomography
DICOM	Digital imaging and communications in medicine
EDX	Energy dispersive x-ray spectroscopy
f (Hz)	Frequency in hertz
FWHM	full width at half maximum
kgf	kilogram-force
kVp	Peak kilo-volt
SEI	Secondary electron imaging
SEM	Scanning electron microscopy
wt%	percent by weight
XRF	X-ray fluorescence
σ	standard deviation

List of Terms

CT scan	see above, under Methodology: medical imaging
Jeton	a metal token used for counting
Photomicroscopy	imaging with a microscope
Photomicrograph	an image taken through a microscope
Scanning electron microscopy	imaging with a scanning electron microscope
Scanning electron micrograph	an image taken with a scanning electron microscope
Surface rendering	a depiction of the surface of an object in three dimensions (in this study, generated from the CT scans)
Tomogram	an image generated from a CT scan
Volume rendering	a depiction of an object as a solid in three dimensions (in this study, generated from the CT scans)
Voxel	a volume element in a tomogram, three-dimensional analogue of a pixel
X-ray fluorescence	see above, under Methodology: materials analysis

This dissertation uses Helmholtz pitch notation for naming musical notes on the scale: c′ is Middle C.

Intended Research Outcomes

This dissertation is intended to provide a comprehensive survey and analysis of the Queen Mary and Lamont harps, including the knowledge and understanding of the materials, measurements, modifications, and historical construction practices necessary for building faithful reproductions. These reproductions are essential to effective interpretation and reconstruction of the repertory associated with the historical instruments. It has also been the intention of this project to develop a useful methodology for the study and analysis of the other surviving historical harps of this type, none of which has been studied this comprehensively.

This research is for the benefit of present day luthiers, musicians, and other researchers, and consequently the general public who may wish to explore and experience the cultural heritage associated with these harps, either through performance of historical repertory on faithful reproductions, or through enhanced interpretive material for the instruments themselves at the National Museum of Scotland.

The body of data generated by this research project will be archived at the National Museum of Scotland, where it will be accessible to current and future luthiers and other researchers of these and similar harps. This data will include, particularly, the photographic surveys and the complete CT scans. Due to the age and uniqueness of these harps, access to them is necessarily limited. This database addresses the on-going issue of frequent requests by luthiers for access to the instruments by providing the information they require, and by enabling them, via the CT scans, to take accurate measurements themselves without handling the harps.

In the process of this examination and analysis of the Lamont and Queen Mary harps, this study ultimately endeavours to address four fundamental questions that are of importance to scholars, musicians, and luthiers with an interest in these harps. These questions are as follows:

What are the dimensions of these harps?

With regard to the dimensions, although these harps have previously been measured, the internal dimensions of the soundbox and of the joinery have been unknown, as it has not been feasible to fully access these areas.

What are the original string lengths?

Due to shifting and twisting of the frame members, the current string lengths are significantly different from what they would have been when the frames were straight, making it difficult for luthiers to faithfully reproduce these instruments with their intended string lengths and scaling.

What are they made of?

With regard to the materials used to construct the harps, although samples of wood have previously been taken from both harps for microscopic identification, the results have been questioned by a number of researchers and luthiers. No additional materials analysis had been conducted to date on either harp.

How old are they?

The ages of these two harps are not known with any certainty. Even the century to which they belong has been somewhat uncertain. This has made it difficult for researchers studying the development and evolution of the instrument, and for musicians who would like to explore historical repertory that is contemporary with these two harps.

These questions are revisited in the Conclusion to this dissertation, and discussed in the context of how the findings of this study have addressed each of them.

Part I. Stringing

As discussed in the addendum to the author's MMus thesis, there is limited historical information pertaining to the stringing of Irish harps.[44] Several contemporary references do exist, however. These have been discussed, for example in Page (1987), Heymann and Heymann (2003), and in a comprehensive compilation in Chadwick (2004-2009).[45] Historical sources note the use of wire as a point of distinction from other harps. For example, Sir John Pettus, writing in 1683, remarked that

> "most of the choice *Instruments* of *Musick* were and still are either in the whole or in parts composed of *Metals ... viz.* the strings of the *Harp* (which we now call the *Irish Harp* (being strung with wire) in distinction of the *Welsh Harp* strung with *Guts strings*)."[46]

The metal nearly always referred to is a copper alloy, either brass or bronze, with possibly the earliest known reference being Giraldus's 12th-century mention of stringing for the *cithara* in Ireland, as noted in the introduction to this dissertation.[47] Giraldus observed that, "actually, bronze [*aeneis*] strings are used, not strings made of hide."[48] Vincenzo Galilei, Michael Praetorius, and James Talbot all noted brass as the stringing material for the Irish harp, with Galilei also mentioning the use of iron in the treble."[49] Praetorius, writing in the early 17th century, describes the strings of

---

[44] Loomis, "Structural Breaks and Repairs," 77 – 79.
[45] Page, *Voices and Instruments*, 218 – 19 and 229 – 30. Ann Heymann and Charlie Heymann, "Strings of Gold", *Journal of the Historical Harp Society* 13 (2003): 9 – 15, revised 2004, http://www/annheymann.com/gold.htm. For a comprehensive list of sources see Simon Chadwick,"Stringing: history," http://www.earlygaelicharp.info/stringing/history.htm.
[46] Sir John Pettus, "Essays on Metallick Words" in Lazarus Ercker, *Fleta minor the laws of art and nature, in knowing, judging, assaying, fining, refining and inlarging the bodies of confin'd metals",* trans. Sir John Pettus, 2nd edition (London: Thomas Dawks, 1685).
[47] Page, *Voices and Instruments*, 230.
[48] ibid. The Latin in square brackets has been added. The version of the Latin text quoted in Page reads "*AEneis quoque utuntur chordis, non de corio factis*". The Latin word *aeneis* can be translated as copper, bronze, or brass.
[49] "They commonly have strings of brass with some steel in the higher pitches in the manner of the harpsichord [*gravicembalo*]." Vincenzo Galilei (1581), *Dialogue on Ancient and Modern Music,* trans. Claude V. Palisca (New Haven: Yale University Press, 2003), 357. The original Italian text reads "*hanno comunemente le corde d'ottone, & alcune poche*

the "*Harpa Irlandica*" as "*grobe dicke Messings*" (coarse thick brass), which could suggest that the gauges used were thick in comparison to other wire strung instruments of the time.[50] Some of these historical commentators mention compass and tuning as well. Interestingly, the tuning Praetorius gives appears to be partially chromatic, whereas writing later in the same century, James Talbot describes a tuning that is diatonic with a pair of unison strings.[51]

In addition to the use of copper alloy and iron as stringing materials, silver is also mentioned, historically. A harp string of silver appears in the late 12th-century *Acallam na Sénorach* (Tales of the Elders) from the Fenian Cycle. The reference is to a harp with three strings, each of a different metal: "A string of iron, a string of noble bronze, and a string of entire silver."[52] Given the literary context, however, it is possible that these metals have simply been chosen to make a point within the text, and therefore do not necessarily reflect actual stringing used at the time. A more straightforward reference to silver stringing appears much later, in the early 17th century. Writing in 1625, Philip O'Sullivan Beare states that the strings of the harp are "never of iron, but are of brass and silver" (in contrast to Galilei's earlier mention of iron stringing).[53] Recent research by Chadwick (2013) has uncovered further

---

d'acciaio nella parte acuta à guisa del Gravicembalo." (Fiorenza: Giorgio Marescotti 1581), 143.

50 Michael Praetorius, *Syntagma musicum*, facsimile reprint, ed. A. Forchert (Kassel: Barenreiter-Verlag Karl Votterle GmbH & Co. KG, 2001), 54, and Plate XVIII. Praetorius also provides a tuning that appears to be partially chromatic.

51 Praetorius, *Syntagma musicum*, 54 and Plate XVIII. Joan Rimmer, "James Talbot's Manuscript (Christ Church Library Music MS 1187): VI. Harps," *The Galpin Society Journal* 16 (1963): 67.

52 Eugene O'Curry, *On the Manners and Customs of the Ancient Irish, Vol. III* (London: Williams and Norgate, 1873), 223. The original Middle Irish reads "*téad diarann, teud duṁa an, an ceadna darccod iomlean*." The term used for the musical instrument in the poem is "*cruit*", which can mean either a lyre or a triangular frame harp. Buckley (2005) notes, however, that the use of this term to refer to a lyre was superseded in the late 10th – 11th century with its use to refer to a triangular frame harp. See Ann Buckley, "Music in Ireland to c. 1500," in *A New History of Ireland, Volume 1: Prehistoric and Early Ireland*, ed. Dáibhí Ó Cróinín (Oxford: Oxford University Press, 2005), 750.

53 Philip O'Sullivan Beare (c. 1625), *Zoilomastix,* quoted in Simon Chadwick, "Stringing history: 16th-17th century," last modified May, 2006, http://www.earlygaelicharp.info/stringing/history2.htm. The original Latin reads "*nunquam ferreas, sed aeneas, vel argentas lyrae*." O'Sullivan Beare's remark was written as a rebuttal to statements made by Richard Stanihurst in *De Rebus in Hibernia Gestis*. See Alan J.

evidence of the possible use of silver strings in an early transcription of a late 18th-century letter written by Ralph Ouseley, owner at the time of the Trinity College harp. Ouseley states in his letter that this harp had silver strings on it when it was acquired by the previous owner, Matthew MacNamara, in the mid 18th century.[54] Heymann and Heymann (2003) have hypothesized that silver and gold strings could have been used historically to compensate for the characteristically short scaling in the basses of the low-headed Irish harps, and have carried out experiments with silver and gold strings on harps modeled after the surviving historical instruments.[55] Although to date no direct physical or historical evidence has been found, many modern reproductions of the historical low-headed Irish harps now employ silver and/or gold strings in the bass.[56]

Beyond what has been noted above, there is little additional historical information pertaining to the stringing of low-headed Irish harps. There are a few additional references to number of strings and stringing material for the later, high-headed harps, however.[57] Among these is a letter from James MacDonnell to Edward Bunting giving the number of strings for Charles Fanning's harp, and noting the number in the treble that are iron.[58] He does not indicate the string gauges, though, and because this harp has not survived, the string lengths are also not known. In his 1840 volume of *The Ancient Music of Ireland,* Bunting gives the compass and tuning for Dennis

---

Fletcher, *Drama and the Performing Arts in Pre-Cromwellian Ireland: Sources and documents from the earliest times until c. 1642* (Cambridge: D. S. Brewer, 2001), 519.

[54] Simon Chadwick, "Silver Strings on the Trinity College Harp," http://earlyclarsach.blogspot.co.uk/2013_09_01_archive.html. Precious metal stringing of historical instruments has been discussed by other authors, most recently in Patrizio Barbieri, "Gold- and Silver-Stringed Musical Instruments: Modern Physics vs. Aristotelianism in the Scientific Revolution," *Journal of the American Musical Instrument Society* 36 (2010): 118 – 154. For the medieval psaltery, Page notes that the 13th-century writer Bartholomaeus Anglicus mentions silver strings in addition to copper alloy, and that the 15th-century writer Jean de Gerson mentions silver, as well as brass and gold strings. Page, *Voices and Instruments*, 217.

[55] Ann Heymann and Charlie Heymann, "Strings of Gold," *Journal of the Historical Harp Society* 13 (2003): 9-15, revised 2004, http://www/annheymann.com/gold.htm.

[56] Barbieri, "Gold- and Silver-Stringed Musical Instruments,"147.

[57] Simon Chadwick, "Stringing history: 18th-19th century," last modified January, 2009, http://www.earlygaelicharp.info/stringing/history3.htm.

[58] James MacDonnell, undated letter to Edward Bunting, quoted in Charlotte Milligan Fox, *Annals of the Irish Harpers* (London: Smith, Elder, & Co., 1911), 281.

O'Hampsey's harp (now known as the 'Downhill' harp), which includes a pair of unison strings and a gapped bass.[59] It is notable that the tuning is known for this instrument, because it has survived intact, and although there is some ambiguity due to the presence of two extra string holes in the soundbox, a complete set of string lengths is known.

Because only limited information regarding stringing practices has been available, present day builders of harps modeled after the historical instruments have had to decide how to string their instruments without knowing the gauge or alloy of the wire used historically, and often without knowing the tuning and compass. This has been further complicated by having to estimate 'as-built' string lengths from the distorted and damaged frames of the surviving historical instruments.

An important piece of physical evidence for the stringing of the low-headed harps came to light in the 1990's with the discovery by Robert Evans of a wire fragment adhered to a tuning pin belonging to the surviving metalwork of the Ballinderry harp.[60] This wire fragment was analysed and found to be a 0.7mm diameter wire of copper alloy containing 10% zinc.[61] Until the commencement of the current study of the Lamont and Queen Mary harps, this was the only known wire fragment associated with a low-headed Irish harp. As noted in Loomis (2010), a second fragment of wire has been discovered embedded in a string hole in the soundbox of the Lamont harp.[62] Two additional small wire fragments have since been discovered in the Queen Mary harp. The analysis of these three fragments is discussed in Chapter 1. Chapter 2 proposes reconstructed string lengths for 'straightened' frames, and discusses possible tuning regimes based on the string scaling.

---

[59] Bunting, *Ancient Music of Ireland*, 23.
[60] Robert Evans, "A Copy of the Downhill Harp," *The Galpin Society Journal* 50 (1997): 124. The Ballinderry harp (National Museum of Ireland, Antiquities Ref: WK.372) consists of the metal fittings for a 36 string low-headed harp, found in the 19th c. in the crannog of Ballinderry, Co. Westmeath, Ireland.
[61] Evans, "Downhill Harp,"124.
[62] Loomis, "Structural Breaks and Repairs," 77 – 90.

Chapter 1. Wire Fragments

Queen Mary Harp Fragments

Examination of the CT scans of the Queen Mary harp revealed the presence of two small metal fragments in the soundbox. Their location in the area of the string holes suggested that they might be fragments of wire strings.[63]

The position of both fragments as they appear on a tomographic cross-section of the harp is shown in figure 1.1, below.

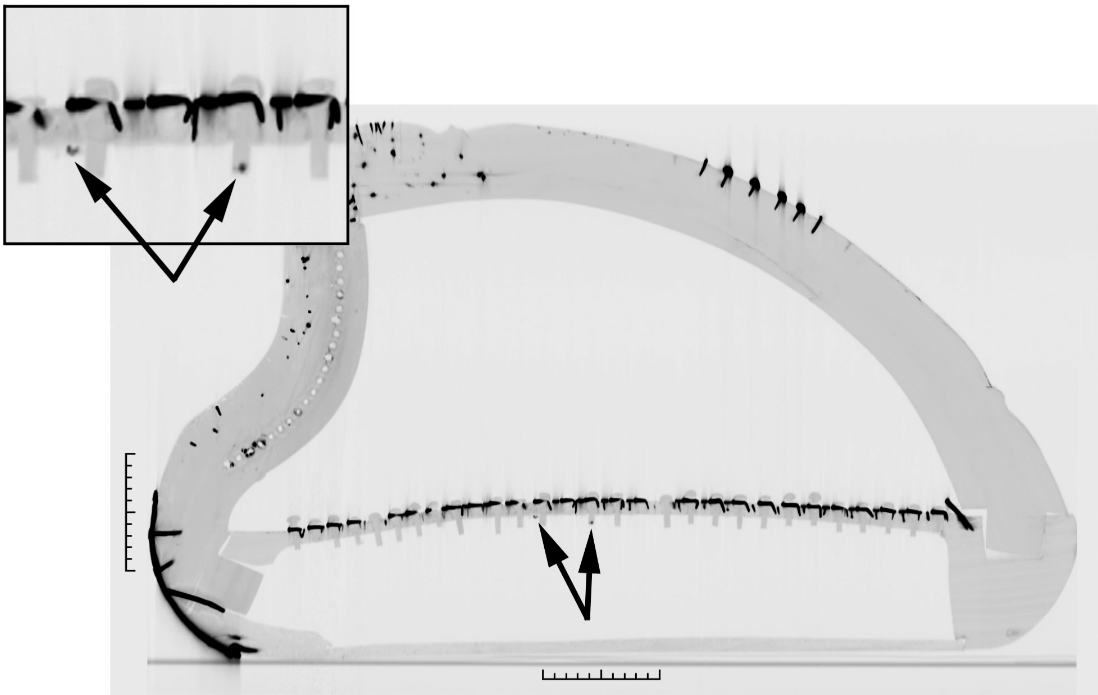


Figure 1.1: *tomogram of the Queen Mary harp in cross-section showing the location of two metal fragments in the soundbox. The fragments are near the string band (arrowed and inset, arrowed). Scale 1 tick : 1cm.*

[63] The image of one fragment, apparently lodged in the end of a wooden string hole peg, was noticed by the author (figure 1.1 inset, right-hand side). A second, larger fragment was subsequently observed by Simon Chadwick (figure 1.1, inset, left-hand side).

In December 2012, the open soundbox was visually examined for the presence of these metal fragments, and both were located. One, a small fragment approximately 3 mm in length, was found embedded in the end of the wooden peg in string hole #15. The other, an approximately 5 mm long c-shaped fragment of wire, was found wrapped around a wad of textile adhered to one side of string hole #13. The location of both fragments is shown in the photograph in figure 1.2. A detail of the interior of the soundbox showing the fragments in situ is shown in figure 1.3.

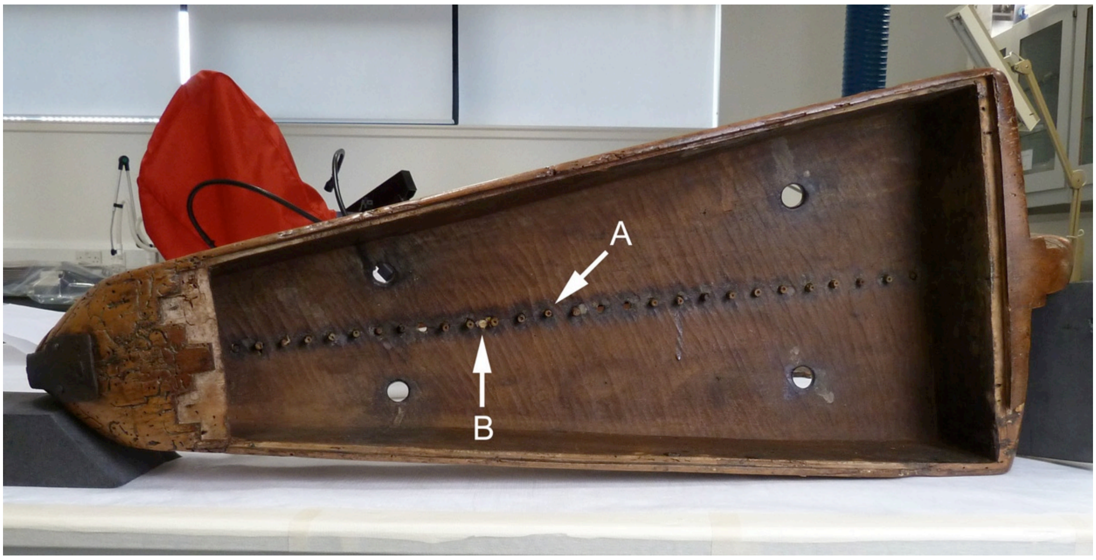


Figure 1.2: *location of two wire fragments in the soundbox of the Queen Mary harp. A ~3 mm fragment ('A', arrowed) was found embedded in the end of the wooden peg in string hole #15, and a ~5 mm fragment was found wrapped around a wad of textile to one side of string hole #13.*

Figure 1.3: *detail of the interior of the Queen Mary harp soundbox showing the two wire fragments. Fragment A is embedded in the end of a wooden string hole peg, and fragment B is wrapped around a wad of textile. The treble end of the soundbox is towards the left of the photo.*

Fragment 'A'

As noted above, the smaller of the two metal fragments (labeled 'A' in figures 1.2 and 1.3) was found embedded in the end of a wooden string hole peg located in string hole #15. As discussed below, these wooden pegs probably date to a restringing of the harp in 1805.[64] Gunn (1807) reported that the harp was initially restrung with brass wire, as per the wishes of the Highland Society of Scotland, before being restrung again with gut at the suggestion of the Swiss harpist John Elouis, who was resident in Edinburgh at the time.[65] Elouis subsequently played the instrument strung with gut for members of the Society, and fragments of gut string found attached to three of the wooden pegs may date from this time (see figure 1.4).[66]

[64] Sanger and Kinnaird, *Tree of Strings*, 58.
[65] Keith Sanger, "John Elouis," WireStrungharp.com, accessed 29 April, 2014. http://www.wirestrungharp.com/harps/harpers/elouis/elouis_john.html#_ednref2.
[66] Gunn, 18 – 20.

Figure 1.4: *a wooden peg from string hole #8, of the Queen Mary harp soundbox. A fragment of gut string is knotted around the shaft.*

Prior to Elouis's involvement, Gunn had consulted with Andrew Wood of Muir, Wood and Company, a prominent Edinburgh musical instrument manufacturer, for advice on tuning and stringing the harp in brass wire.[67] Gunn describes Wood as "an ingenious and experienced mechanic, and a manufacturer of the Harp, and other musical instruments".[68] According to Cranmer (2003), Wood "directed manufacture, tuning and repairs" at the company, which primarily made square pianos but also made other instruments, including pedal harps.[69] The wooden soundbox pegs currently in the soundbox of the Queen Mary harp are, notably, of the style used on pedal harps. Microscopic examination of some of the pegs by Ticca Ogilvie at the National Museums Scotland Collections Centre revealed that they were made from tropical woods, and it is probable that they were supplied by either Wood or Elouis in 1805. As noted above, the metal fragment was found lodged in the end of one of these pegs. Some of the pegs have a channel cut into the end of the shaft, and one of the remaining gut string fragments was found pressed cross-wise into one of these as

[67] Gunn, 18. For Muir, Wood and Co., see John Cranmer, "Muir, Wood and Company," in *The Piano: An Encyclopedia*, ed. Robert Palmieri (New York: Routledge, 2003), 243.
[68] Gunn, *Historical Inquiry*, 18.
[69] Cranmer, "Muir, Wood and Company," 243.

shown in figure 1.5. It is possible that these pegs were used in a similar manner when the harp was strung with wire.

Figure 1.5: *the end of the wooden peg in hole #4, as viewed from the interior of the soundbox. The peg has a channel cut across the end of the shaft, with a fragment of gut string in it.*

Figure 1.6 shows the end of the wooden peg for string hole #15. In the top right-hand photo, the metal fragment is just visible embedded in the end of the peg. A photomicrograph of the fragment (bottom, centre) reveals the characteristic balloon shaped corrosion that identifies this metal as iron.

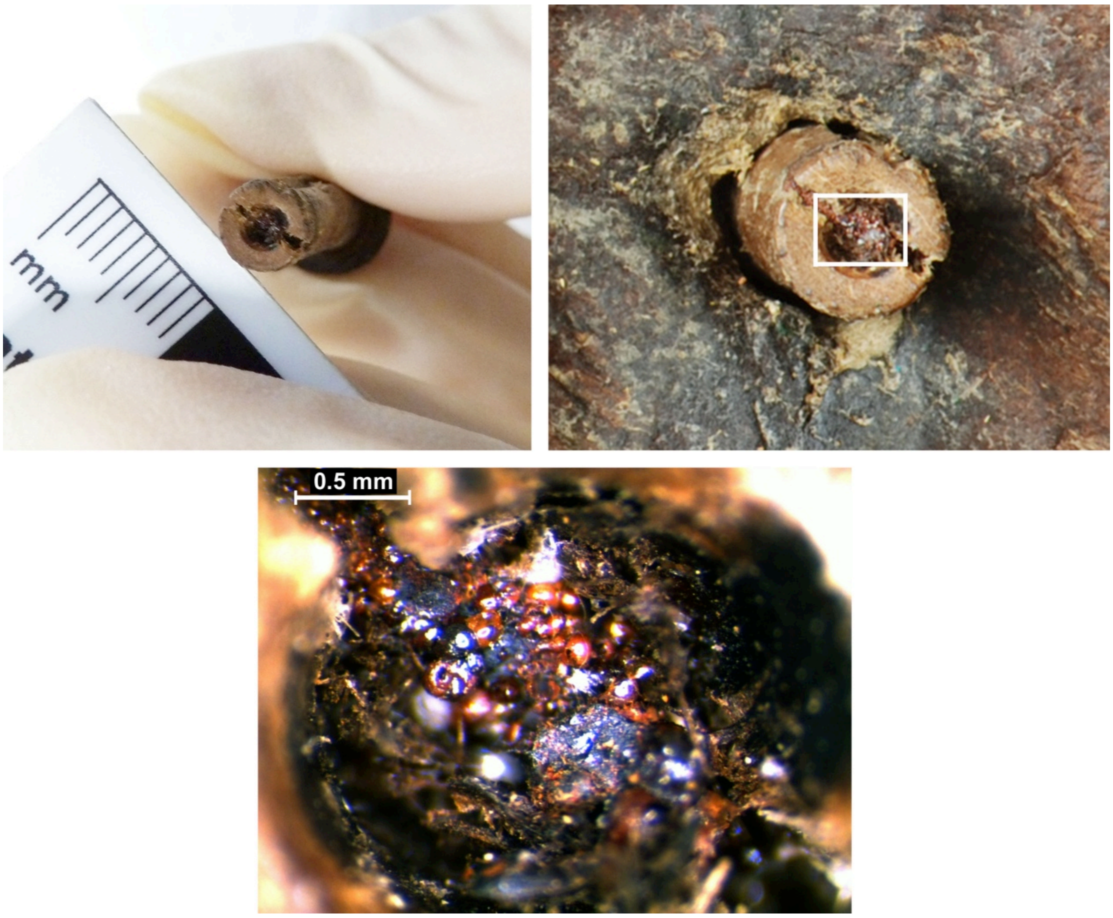


Figure 1.6: *the end of the wooden peg for string hole #15 of the Queen Mary harp soundbox. In the photo at top right, the peg is shown in place in the soundbox. A fragment of metal is just visible embedded in the end. At bottom centre is a photomicrograph of the metal fragment. The area of this image is indicated by the white box in the photo at top right. The photomicrograph shows the characteristic 'balloon shaped' corrosion that identifies this metal as iron.*

The photomicrograph in figure 1.7 shows one end of the fragment visible from the side of the peg. Viewed in cross-section, the fragment appears to be a thin wire. Due to the degree of corrosion, it was not possible to ascertain the original diameter. The current diameter is approximately 0.5 mm. As discussed, the pegs were probably put on the harp for the restringing in 1805. It is likely that this iron wire fragment dates to this time, and therefore does not date to the historical period of this instrument. Although Gunn doesn't mention using iron wire to restring the Queen Mary harp, it is plausible that iron would be tried in the treble with brass in the bass. The location of this soundbox peg in the middle of the compass doesn't preclude this as all of the pegs are loose and can easily be moved around.

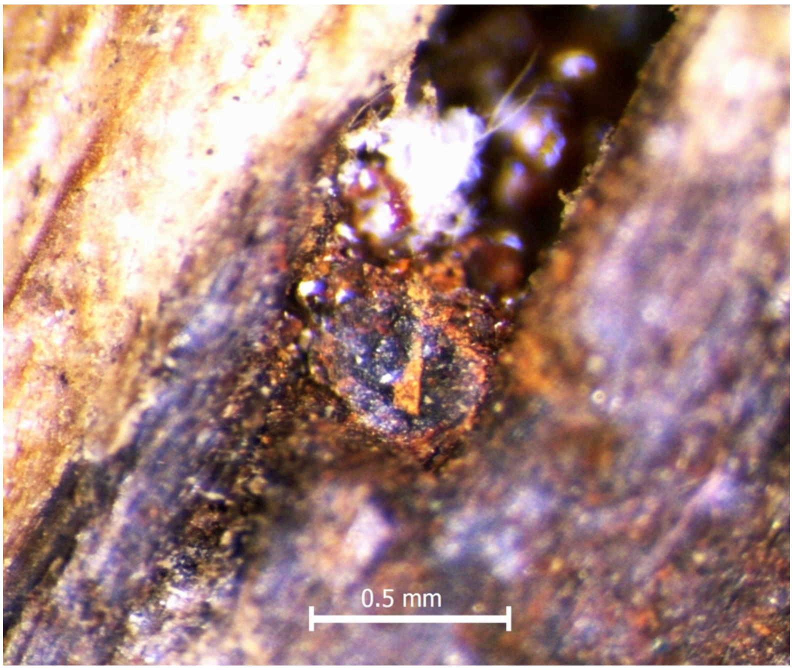


Figure 1.7: *photomicrograph of the side of the wooden soundbox peg for string hole #15 of the Queen Mary harp soundbox. This image shows the end of the iron fragment (at centre), which appears in cross-section to be a thin wire.*

Fragment 'B'

The larger of the two metal fragments was found attached to a wad of textile adhered to one side of string hole #13, as discussed above (see figures 1.2 and 1.3). This fragment is a curved piece of wire approximately 5 mm in length. It is green in colour, indicating that it is probably a copper alloy. Stains on the textile suggest it was originally wrapped all the way around it. The textile would have been too flexible to serve as a string toggle, so this wire fragment was probably not part of a string.

The textile was found adhered to a layer of varnish that had dripped into the string hole from the exterior of the soundbox. This varnish was apparently applied to the exterior of the soundbox with the pegs in place, as it had run into several of the string holes and down some of the peg shafts. It therefore postdates their addition to the harp. When the interior of the soundbox was examined, the textile was found pushed inward, with one end still adhered to the string hole. This presumably happened at some point when the peg was removed and reinserted.

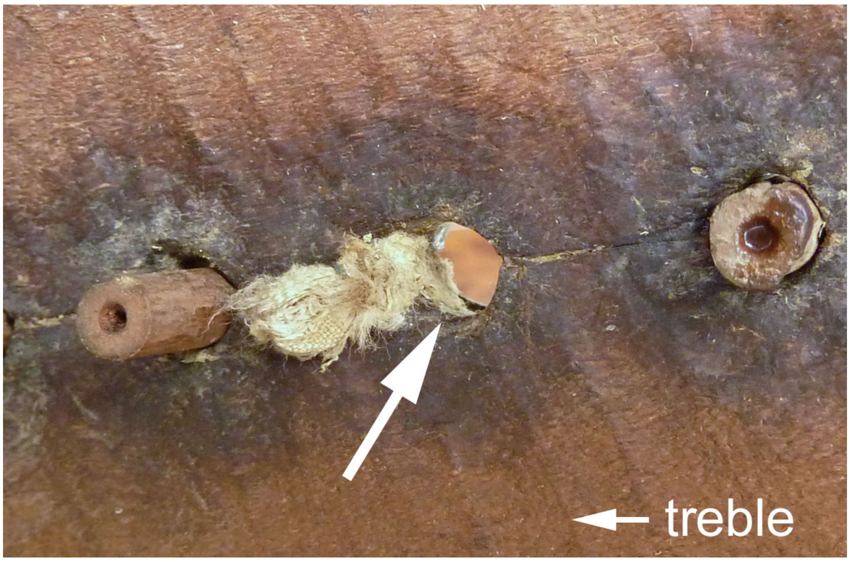


Figure 1.8: *the textile found adhered to string hole #13 of the Queen Mary harp, as viewed from inside the soundbox. The treble end of the soundbox is towards the left of the photo, as indicated.*

The textile with attached wire fragment was removed from the harp by Ticca Ogilvie for analysis. Figure 1.9 shows them together, after they were removed from the harp. As shown in figure 1.10, the string hole is enlarged on one side where the textile had been located. This enlargement is on the treble side of the string hole, and is aligned with an area of deep wear on the string shoe. The textile wad was apparently an attempt to fill this space.

Figure 1.9: *the textile with wire fragment after removal from the soundbox of the Queen Mary harp.*

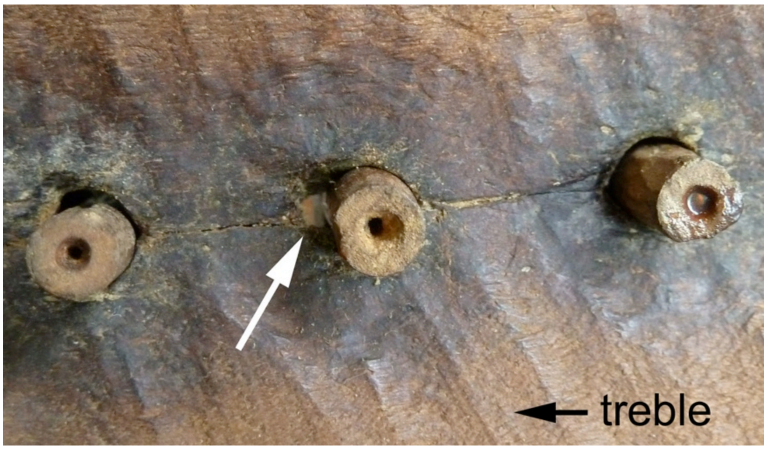


Figure 1.10 *string hole #13, showing enlargement on the treble side where the textile was located (arrowed), as viewed from the inside of the soundbox. The treble end of the soundbox is towards the left of the photo, as indicated.*

After removal from the harp, the textile and wire fragment were examined microscopically and imaged with SEM. The textile is constructed of a coarse over-under natural weave, with a z-twist in both the warp and the weft fibres.[70] A photomicrograph is shown in figure 1.11.

Figure 1.11: *a photomicrograph of the Queen Mary harp textile and wire fragment. The textile is a natural fibre, with a coarse over-under weave. The green corrosion on the wire suggests it is a copper alloy. Corrosion stains on the textile indicate that the wire was probably wrapped entirely around it. Photomicrograph: Jim Tate and Lore Troalen.*

Under examination with SEM, the distinctive nodes characteristic of flax were visible on the textile fibres, identifying it as linen, as shown in figure 1.12.

[70] Observed by Ticca Ogilvie under microscopic examination.

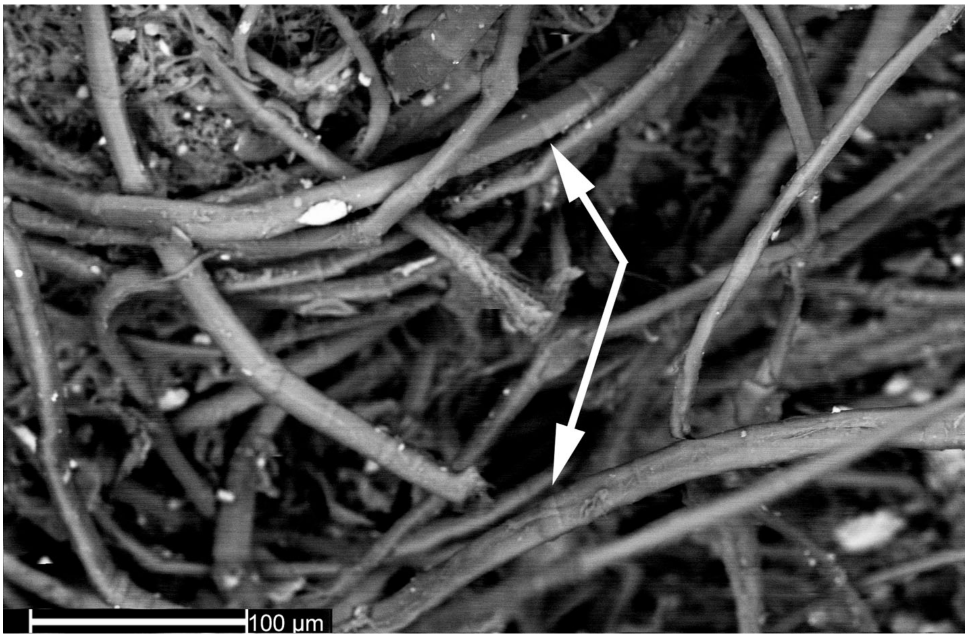


Figure 1.12: *a back-scattering scanning electron micrograph of fibres in the Queen Mary harp textile. Nodes characteristic of flax (arrowed), identify this textile as linen.*

Imagery of the wire revealed that the corrosion, although copper based, is of an unusual form that may involve an organic, possibly bacterial, process.[71] The textile and wire were probably exposed to damp conditions for a number of years when the harp was in storage in Stewartfield House at Dalguise during the 19th century, and this may have been a contributing factor. A photomicrograph and scanning electron micrograph (SEM image) of the corrosion are shown in figure 1.13.

[71] Flavia Pinzari, Agricultural Research Council, Research Centre for Soil-Plant System Studies, Rome, Italy, e-mail message to Lore Troalen, National Museums Scotland (forwarded to author), 8 December, 2012.

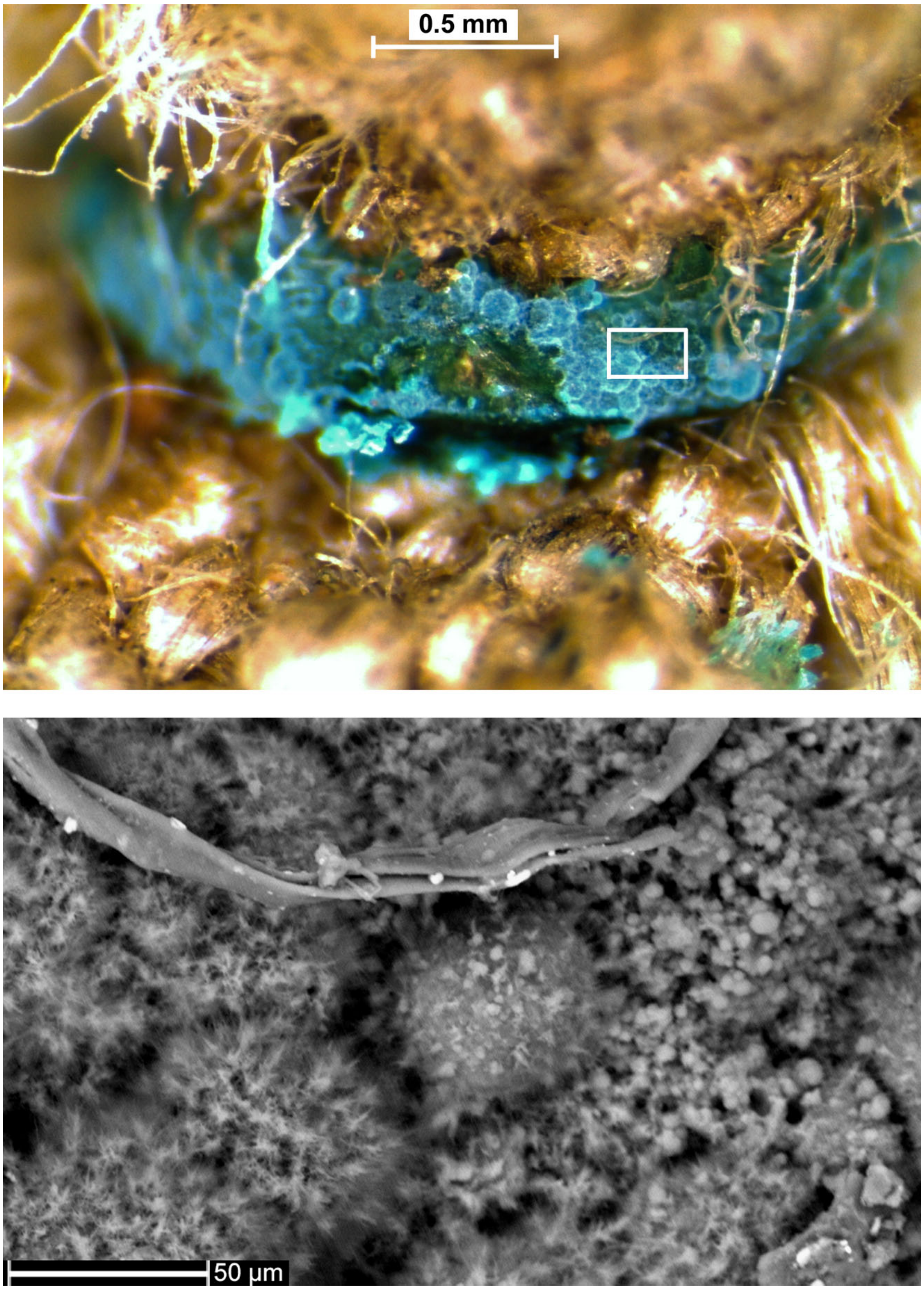


Figure 1.13: *photomicrograph (top) and back-scattering scanning electron micrograph (bottom) of the wire fragment (B) from the Queen Mary harp. The white box in the photomicrograph indicates the area imaged in the scanning electron micrograph. The corrosion is of an unusual form that may involve a bacterial process.*

The composition of the corrosion on the surface of the wire was analysed with SEM-EDX and found to contain a significant amount of carbon, suggesting an organic process.[72] Copper was also present, as were traces of silicon, sulfur, chlorine, potassium, calcium, and zinc.[73] This result may provide a clue as to the conditions to which this fragment has been exposed. Notably, it highlights the importance of preparing a clean cross-section of the wire for compositional analysis. While every effort was made to employ non-destructive analysis for the study of these harps, for this wire fragment and the wire fragment from the Lamont harp (discussed later in this chapter), it was necessary to take and prepare samples in order to avoid analyzing the surface corrosion instead of the wire. On old wire, it is difficult to judge the depth of corrosion from visual examination of the surface alone. Additionally, the process of corrosion changes the composition of the alloy near the surface by depleting some elements more than others, so simply removing the powdery outer layer of corrosion is not sufficient preparation for measuring the composition of the interior of the wire.[74]

The wire fragment was prepared for SEM-EDX analysis by cleaning the surface and embedding a sample in an epoxy resin plug, which was then polished to expose a cross-section of the wire.[75] Due to the small size of the fragment, it was necessary to use most of it for the sample. A back-scattering scanning electron micrograph of the polished, exposed cross-section of the wire is shown in figure 1.14. In this image, brightness is proportional to atomic number of the elements in the sample. Areas of corrosion, which include lighter elements, are visible on the lower right-hand side of the cross-sectional surface as darker patches. For the analysis of the composition three areas 0.1 mm in diameter and 0.1 mm from the outer edge of the cross-section were sampled non-destructively with energy dispersive x-ray spectroscopy (EDX). Each area underwent three iterations of measurement. The composition, in percent by weight (wt%), and the measured diameter of the wire are given in table 1.1, below.[76] For each element, the value given in the table is the average for the three areas

[72] Lore Troalen, "Queen Mary harp EDX analysis, 10th-13th December, 2012," (internal report, National Museums Scotland, 2012).
[73] Troalen, "Queen Mary harp EDX analysis."
[74] Justine Bayley, e-mail message to author, 22 November, 2012.
[75] The samples were prepared by Lore Troalen using the procedure recommended by Justine Bayley. Bayley, e-mail message to author, 22 Novemeber, 2012.
[76] EDX analysis courtesy of Lore Troalen, National Museums Scotland.

analysed. The uncertainty is given as the average of each of the standard deviations for these three areas. In every case this was larger than the standard deviation of the three values from which the average wt% was computed.

For this analysis, the minimum detectable level for an element is defined as twice the measurement uncertainty (2σ), after Mitchiner et al (1987).[77] Those elements whose measurements fall below this threshold are signified by a bar in the table. Aluminium was also detected at a level of 1.0 wt% (with the exception of a fourth measurement with a detection at 3.1 wt%). The presence of this aluminium is believed to be due to contamination from the epoxy resin or from the polishing process.[78] It is not included in the tabulated composition. If taken into account it does slightly affect the proportions of the other elements, however.[79] All other elements had no measurable presence.

[77] M. B. Mitchiner, C. Mortimer, and A. M. Pollard, "Nuremberg and its Jetons, c. 1475 to 1888: Chemical Compositions of the Alloys," *The Numismatic Chronicle* 147 (1987): 123.
[78] Hannes Vereecke et al. also encountered aluminum contamination in their SEM analysis of historical brass. See Hannes W. Vereecke, Bernadette Frümann, and Manfred Schreiner, "The Chemical Composition of Brass in Nuremberg Trombones of the Sixteenth Century," *Historic Brass Society Journal* 24 (2012): 70.
[79] With the inclusion of aluminium, the average wt% of the detected elements are as follows: Cu 70.68%, Zn 27.18%, Al 1.05%, Ni 0.25%, Fe 0.15%.

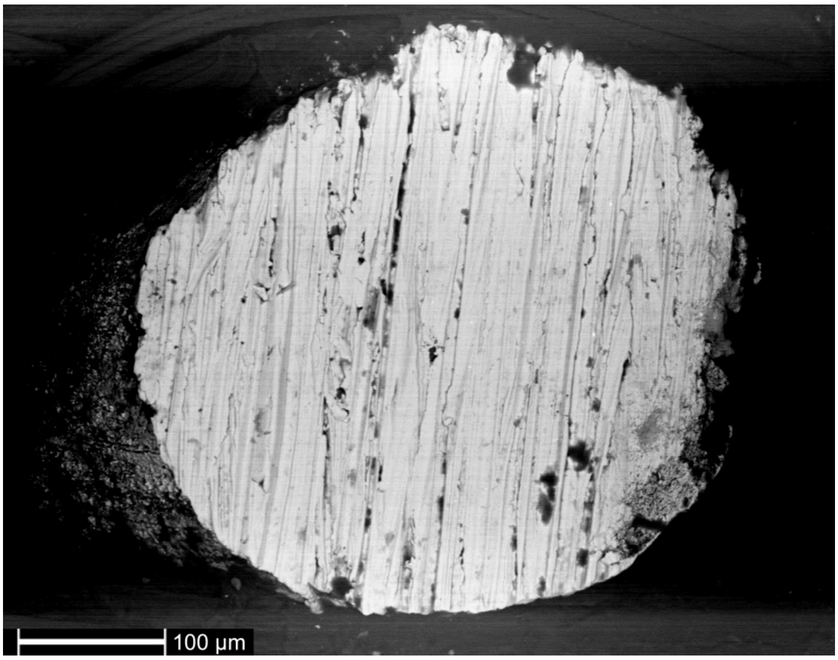


Figure 1.14: *back-scattering scanning electron micrograph of a cross-section of the wire fragment (B) from the Queen Mary harp. The vertical ridges on the face of the cross-section are due to the polishing. The darker areas near the lower right-hand edge of the cross-section are corrosion in the wire.*

Table 1.1.

Composition of Queen Mary harp wire fragment (B)

element	average wt%	average σ
Cu	71.60	0.62
Zn	27.71	0.61
Ni	0.31	0.12
Fe	0.17	0.07
Pb	-	-
Sn	-	-

(note: remainder is trace elements detected at levels < 2 σ)

diameter: 0.40 mm
density: 8.39 g/cm^3 (calculated from the composition)

Based on the results of the analysis, this wire is a 28% zinc brass with traces of nickel and iron. The composition of this brass is discussed in the context of known historical brasses along with the results of the analysis of the wire from the Lamont harp later in this chapter.

Lamont Harp Fragment

As reported in Loomis (2010) and Loomis et al. (2012), a fragment of wire was discovered inside string hole #14 of the Lamont harp soundbox. A photograph of the fragment in the string hole is shown in figure 1.15. The verdigris coloured corrosion on its surface suggests a copper alloy wire, which would be consistent with historical information for the stringing of Irish harps. One end of the wire appeared to be embedded in the wood, and upon initial observation it had not been determined if it could be extracted without causing damage to either the wood or the wire.

Tomograms from the CT scans of the harp were used to determine the overall shape of the wire, as well as its position in the hole and the surrounding wood, as shown in the cross-section in figure 1.16 and in the three-dimensional rendering in figure 1.17. In a second photograph, taken in December 2012, one end of the wire can be seen embedded in the wood just below the point at which a crack in the soundbox intersects with the string hole (see figure 1.18). The other end of the wire can be seen resting against the inside of the string hole.

Figure 1.15: *photograph of the wire fragment embedded in string hole #14 of the Lamont harp soundbox. The view is from the interior of the soundbox, and the treble end of the harp is towards the right.*

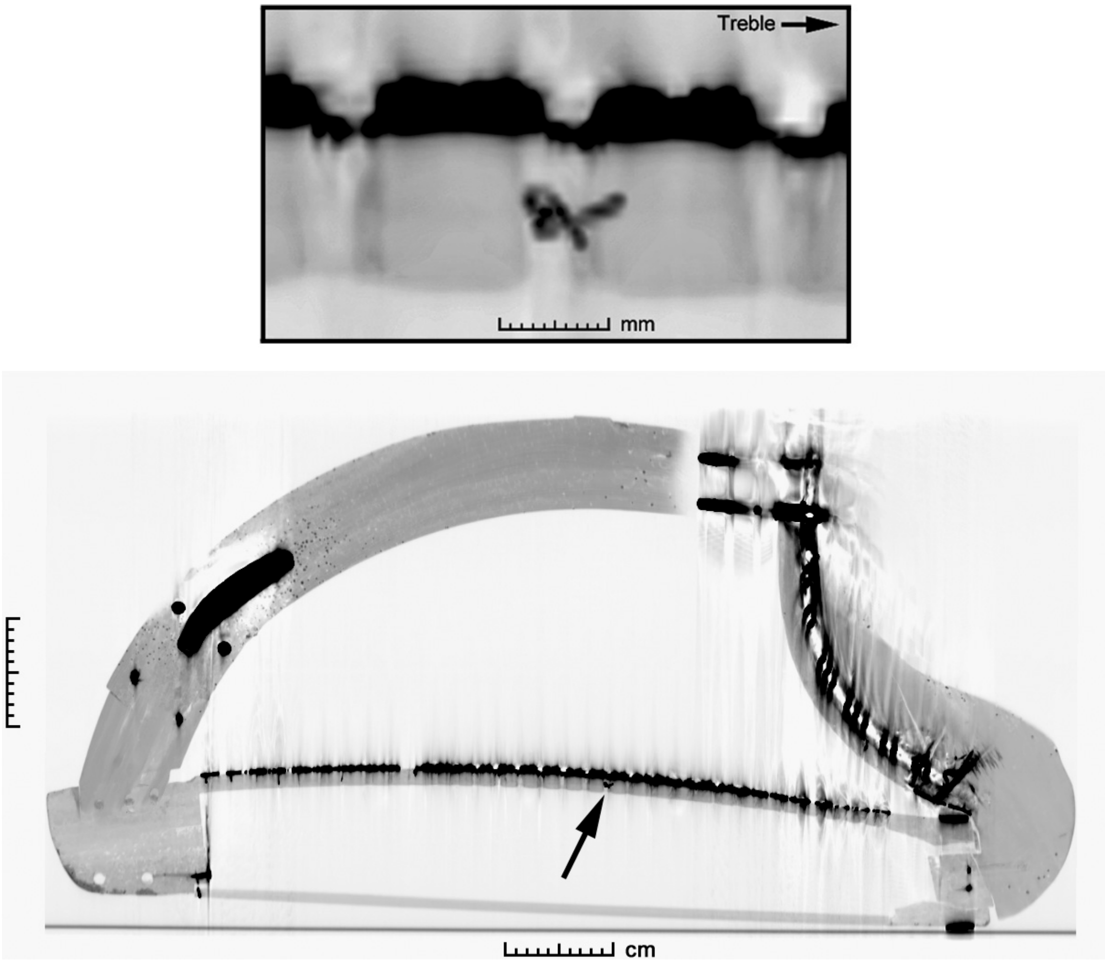


Figure 1.16: *tomogram of the Lamont harp in cross-section showing the location of the wire fragment in the soundbox (bottom, arrowed). A close-up of the wire in the string hole (top) shows its shape and the extent to which it is embedded in the wood.*

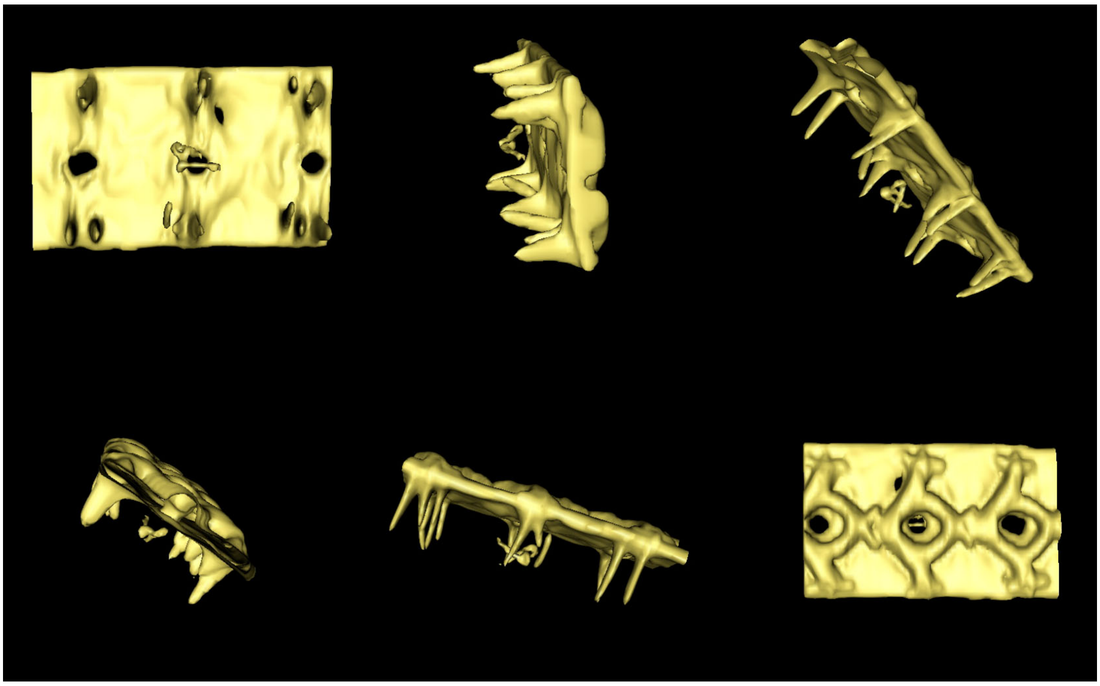


Figure 1.17*: snapshots from a surface rendering video of a section of the string band of the Lamont harp soundbox at the location of string holes #13 – 15. At upper left the wire fragment is in roughly the same orientation as the photograph in figure 1.18, below. The fragment is shown from different angles, revealing its shape and position. For clarity, the wood has been rendered invisible.*

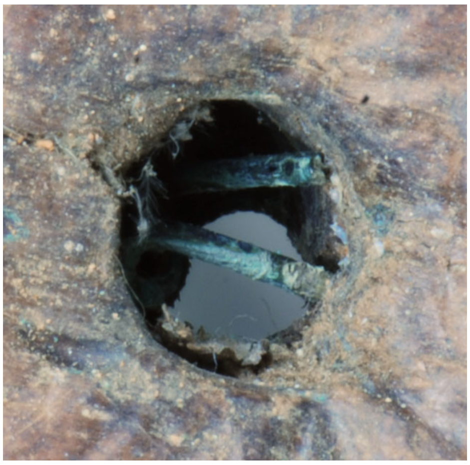


Figure 1.18: *photograph of the wire fragment in string hole #14, taken from a slightly different angle to the photograph in figure 1.15 (see above). One end of the wire is embedded in the wood just below a crack. The other end is not embedded, and can be seen resting against the inside of the string hole. The treble end of the harp is to the right in this photograph.*

By consulting the tomograms and examining the wire in the string hole, it was determined that, with care, it would be possible to safely remove it from the harp. This task was undertaken by Ticca Ogilvie in December 2012, at the National Museums Scotland Collections Centre. It was important to accomplish this without damaging the surrounding wood, but also preserving the twisted shape of the wire fragment, as it might be part of an historical toggle knot. The form of the knot used is not recorded in any contemporary sources, so the shape of this fragment is therefore of interest.[80]

Current replicas of historical Irish harps often use a toggle knot of the form shown in figure 1.19, based on the knot described in Heymann (1988).[81] A few of the surviving 18th-century harps have toggled wires on them, some of which could date to the historical period for these instruments (although this needs to be established). Figure 1.20 shows some of these toggles inside the soundbox of the Sirr harp, a mid 18th-century instrument at the National Museum of Ireland. Here the wire is simply looped once around the toggle and back over itself, with the end left under the toggle. The Sirr harp and the Lamont harp were made in different centuries, and are of different design, though, so the style of knot used may have been different as well (and may have changed over the working life of the harp).

---

[80] Talbot describes the knotted toggle as "a noose drawn over a bit of wood". Rimmer, "James Talbot's Manuscript," 67.
[81] Ann Heymann, *Secrets of the Gaelic Harp* (Minneapolis: Clairseach Productions, 1988) 123 – 24.

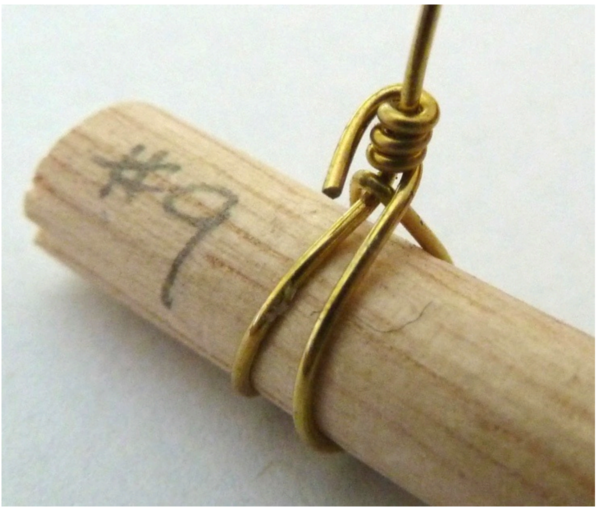


Figure 1.19: *a modern toggle knot made by the author, based on Heymann (1988). Photograph reproduced from Loomis (2010).*[82]

Figure 1.20: *string toggles inside the soundbox of the 18th-century Sirr harp (National Museum of Ireland). The wire is fastened by a single loop over and under the toggle. It has not been ascertained whether these toggles date to the historical period of this instrument. Image reproduced with the kind permission of the National Museum of Ireland.*

[82] Loomis, "Structural Breaks and Repairs," 89.

Figure 1.21 shows two photographs of the wire after it was extracted from the Lamont harp. These were taken at two different orientations to further illustrate the overall shape of the fragment.

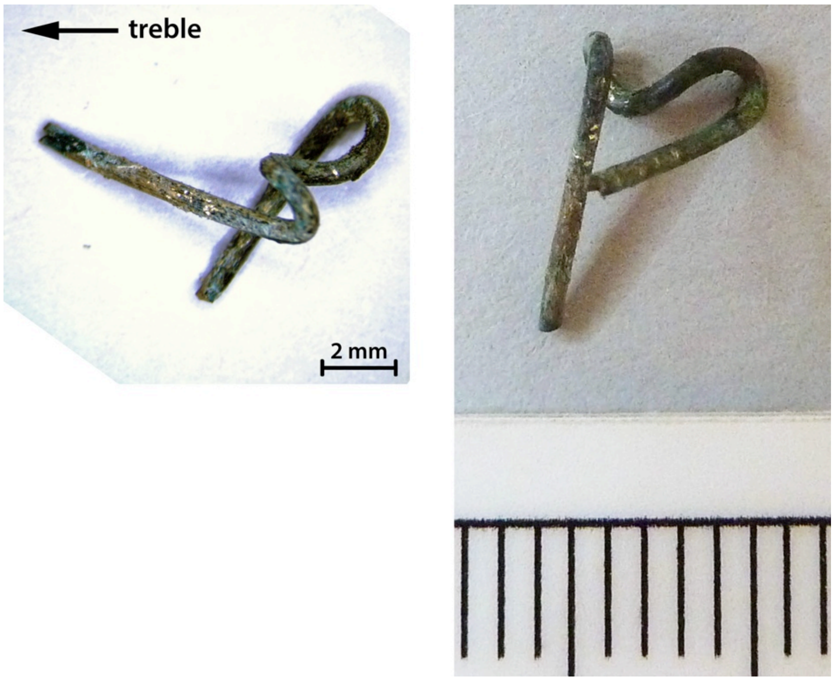


Figure 1.21: *Two views of the Lamont harp wire fragment after extraction from the soundbox. The left-hand image is a photomicrograph in the same orientation as the fragment in the string hole (see figure 1.16). The right hand image was taken with a handheld camera. Both images are shown at the same scale. The scale shown in the right hand image is in mm.*

The left-hand image in figure 1.21 shows the fragment in the orientation in which it was found in the string hole. The end pointing towards the left in both images is the end that was embedded in the wood. The shape of the fragment is consistent with it having been coiled around a thin rod, not more than ~1.5 mm in diameter, which could have been the toggle. A wooden toggle this thin would break under the tension of the string, however a metal toggle would be sufficiently strong, and metal toggles are sometimes used in modern built harps modeled after the historical instruments.[83] Figure 1.22 illustrates this with a mock-up of the fragment.

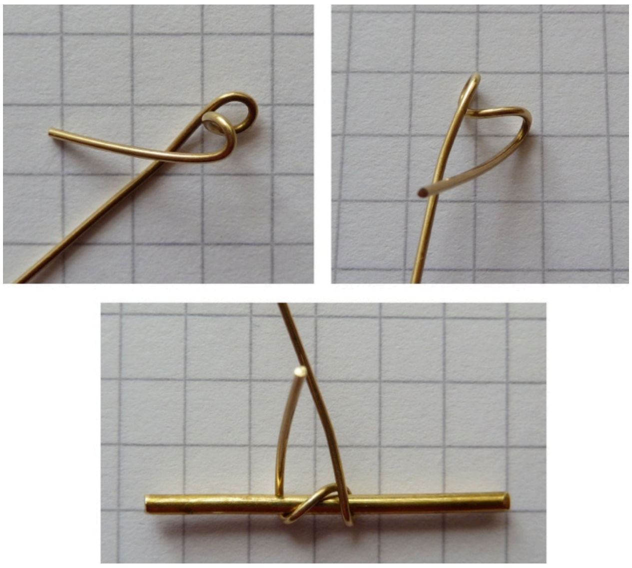


Figure 1.22: *A mock-up of the wire fragment, demonstrating the width of toggle that would fit through the coils. The scale is 1 square: 5 mm.*

If the shape of this wire fragment is due to its having been coiled around a toggle, the question remains as to how this coil came to be lodged inside its string hole with one end of the wire embedded sideways in the wood and the other pointing down into the soundbox. The string toggle normally rests against the inside surface of the soundbox and prevents the end of the wire from pulling up into the string hole. When wires break, they usually do so either at the tuning pin or at the string shoe. If a wire breaks at the string shoe, the length of wire left attached to the toggle will be equal to the depth of the string hole. Neither end of this fragment is long enough to span this distance, however. So, if this section of wire was wrapped around a toggle, the toggle was up inside the string hole when the wire broke. The toggle could have been pulled into the string hole if it had been bent, or broken, or the wire had slid to one end of it. This could also explain the position of the embedded end of the wire. The free end of the wire would have found the crack adjacent to the string hole (an easy entry point), and would have been forced inward as the rest of the wire was pulled upwards. The

[83] The use of metal versus wooden toggles is discussed further in Chapter 3, page 264.

end of this wire fragment is deeply embedded in the wood and would have been difficult to dislodge. The other end of the wire, which would have been left pointing outwards when the string broke, could have been forced inward in the process of trying to dislodge the wire from the string hole, leaving it pointing into the soundbox in the position in which it was found.

After the wire fragment was examined and photographed, an approximately 1.5 mm sample was taken from the end for analysis. The sample was embedded in resin and polished to expose the wire in cross-section. The sampling and preparation were conducted by Ticca Ogilvie and Lore Troalen, at the National Museums Scotland Collections Centre. The prepared sample and the remainder of the fragment were both imaged and analysed with SEM-EDX to examine the condition and diameter of the wire, and to determine its composition. Figure 1.23 shows a scanning electron micrograph of a portion of the wire fragment. This is a secondary electron image (SEI), which highlights the topography of the surface. The large irregular patches are corrosion. The thin parallel lines running the length of the surface are the result of the wire having been drawn, and can be seen following its twist. Of particular note is what appears to be a cleft in the surface of the wire. This is a defect that runs the length of the fragment. It is more easily visible in the scanning electron micrograph in figure 1.24. This is a backscattering image (BSC), which is sensitive to the atomic number of the elements that make up the material. Figure 1.25 shows a close up of the end of the wire that was cut for analysis. Here, in cross-section, the cleft is visible as a crack that extends deep into the interior of the wire.

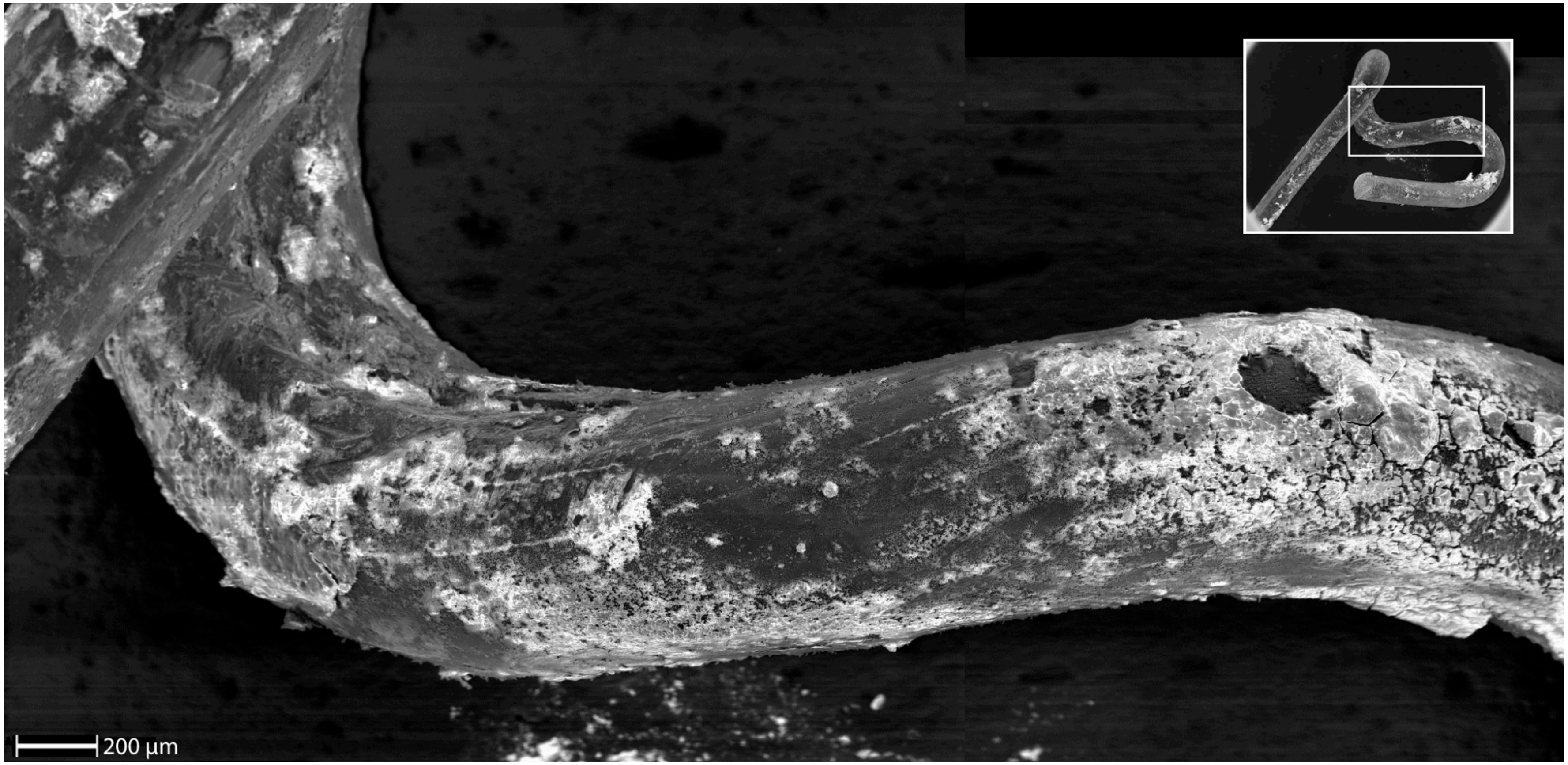


Figure 1.23: *SEI scanning electron micrograph of a detail of the Lamont harp wire fragment. The area imaged is shown in the box in the inset. This image highlights the surface topography. Surface corrosion is visible as large irregular patches. Thin parallel lines left by the drawing of the wire are also visible. A cleft on the inside curve of the bend is a defect in the wire.*

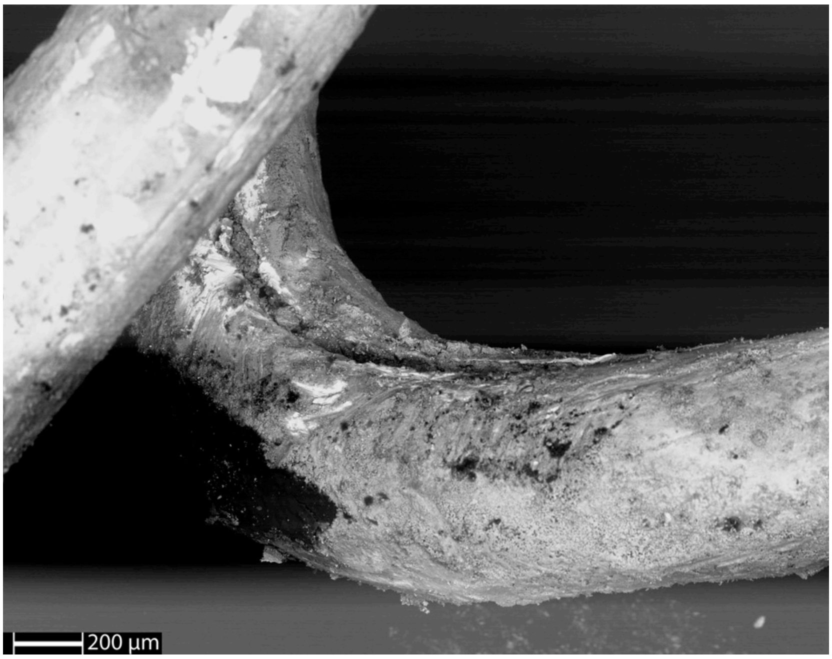


Figure 1.24: *BSC scanning electron micrograph of a detail of the Lamont harp wire fragment. In this image, the defect in the wire is easily visible in the surface of the fragment at the bend.*

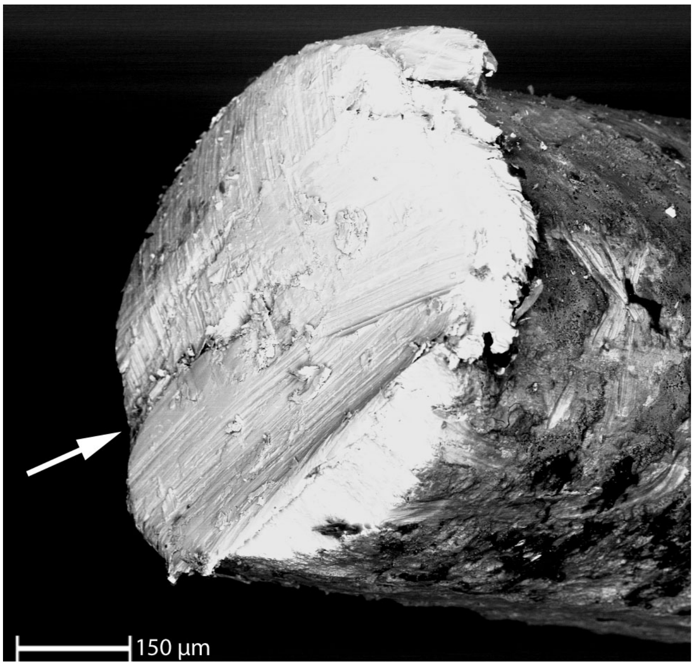


Figure 1.25: *BSC scanning electron micrograph of the end of the wire after cutting for analysis. Viewed in cross-section, the defect (arrowed) can be seen extending deep into the interior of the wire.*

As discussed above, the sample taken from the wire was embedded in an epoxy resin plug and polished to reveal the wire cross-section for analysis. Figure 1.26 shows the cross-section in both SEI and BSC electron micrographs. A portion of the surface is eclipsed by an air pocket in the resin, which indicates that some resin remains on at least part of the polished surface. This is an issue for the analysis of the composition due to possible contamination from aluminium in the resin, as discussed above for the wire fragment from the Queen Mary harp.

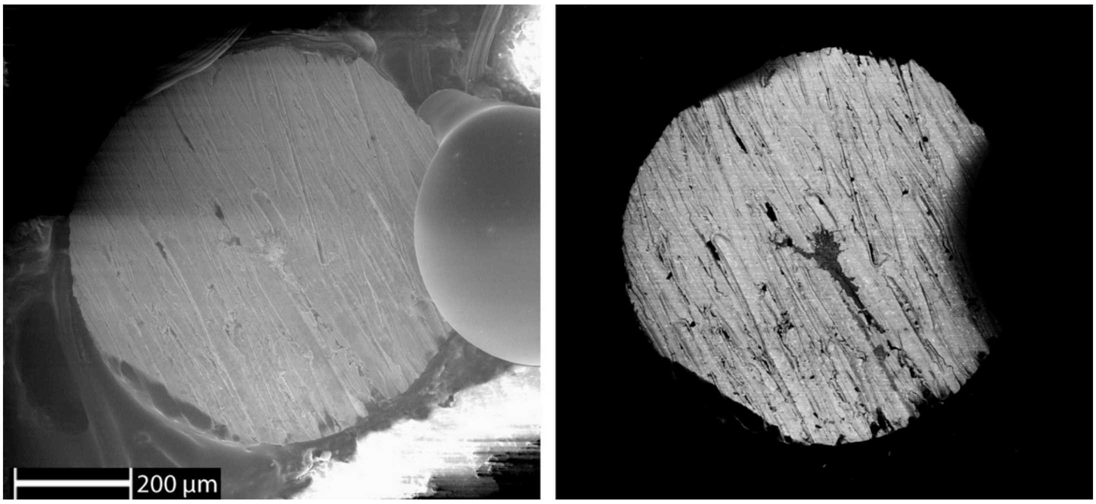


Figure 1.26: *SEM images of a sample cross-section of the wire fragment found in the Lamont harp. The sample has been embedded in resin and polished to expose the end of the wire. An air bubble in the resin is overlapping the edge of the end of the sample on the right-hand side. The SEI image, sensitive to topography, is shown on the left; the BSC image, sensitive to atomic number, is shown on the right. The defect in the wire is visible in this image as a darker, less dense feature extending to the centre of the wire.*

The composition of the exposed cross-section of the wire sample was analysed with EDX at four points, each at a distance of 0.08 – 0.10 mm in from the outer edge of the cross-sectional surface to avoid analyzing possible areas of corrosion. Aluminium was detected in all of the analysed areas, at an average level of 3.0 ± 0.1 wt% in three instances, with a high value of 8.3 wt% in the fourth analysed area. The data from this last area has been excluded.[84]

As with the Queen Mary harp wire sample, the detected aluminium is suspected to be due to contamination from the epoxy resin or the polishing process. Before excluding it from the analysis, however, it is important to check independently if there is any aluminium present in the wire. Prior to the analysis of the sample, semi-quantitative EDX analysis was performed on the exposed end of the wire from which the sample was cut. A spectrogram of the composition is shown in figure 1.27.[85] The height of the peaks is indicative of the quantity of the element present, as is evident in the strong peaks for copper and zinc. Aluminium was detected, but at a level only marginally above the system noise. It is therefore not present in the wire in a measurably significant amount, which indicates that the aluminium detected in the analysis of the sample does not come from the wire itself.[86] It would, however, be advisable to re-polish and re-analyse the embedded sample to confirm the analysis presented here.

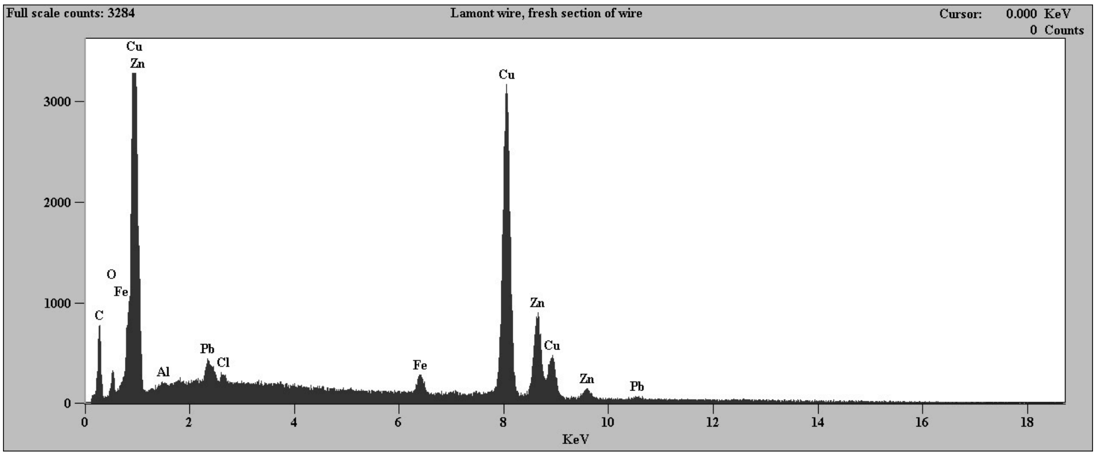


Figure 1.27: *semi-quantitative compositional analysis of the exposed end of the wire after sampling. Spectrogram: Lore Troalen*

[84] A high percentage of carbon was also detected in the analysed area with the highest percentage of aluminum.

[85] This is a plot of the energies of x-ray photons ('x-rays') emitted by the material as a result of excitation by an x-ray beam. Each chemical element emits photons at a unique set of multiple energies.

[86] The carbon and oxygen detected are due to surface contamination.

The average composition derived from the three sampled areas, excluding aluminium, is given in table 1.2, below.[87] The same criteria used for the presentation of the results for the wire from the Queen Mary harp are also used here.

Table 1.2.
Composition of Lamont harp wire fragment sample

element	wt%	average σ
Cu	74.30	0.65
Zn	23.03	0.58
Pb	2.07	0.20
Ni	0.32	0.13
Fe	0.18	0.08
Sn	-	-
Bi	-	-

diameter: 0.69 mm
density: 8.55 g/cm^3 (calculated from the composition)

Based on the results of the analysis, this wire is a 23% zinc brass with 2% lead and traces of nickel and iron. The composition of this brass is discussed in detail below. The diameter of the wire was also measured on an SEM image of the sample, and found to be 0.69 mm. For comparison, the wire fragment found on the Ballinderry harp was a 10% zinc brass with a diameter of 0.7 mm.[88] This wire fragment was found corroded to a tuning pin, which had been underground in a crannog with the rest of the Ballinderry harp until it was discovered in the 19th century, so the

[87] With the inclusion of aluminium, the average wt% of the detected elements are as follows: Cu 71.46%, Zn 22.15%, Al 3.03%, Pb 2.12%, Ni 0.30%, Fe 0.18%.
[88] Evans, " Downhill Harp," 124.

composition and diameter may have been affected by the conditions to which it was exposed.[89]

The defect in the Lamont harp wire fragment was also analysed. This defect is visible in figure 1.26 as the darker grey linear feature extending to the centre of the wire. It was found to be composed of 72.6% copper, 25.4% zinc, 1.2% iron, and 0.44% lead. The percentage of iron in the defect is six times higher than in the rest of the wire. This is most likely the result of incompletely melted iron contaminating the brass during the alloying process.[90] This defect would have seriously weakened the wire and may have caused it to break. Furthermore, the wire is split along this defect. So, in addition to being weak, this wire would have sounded false.

Analysis Discussion

Historically, brass has been produced with a range of percentages of zinc and trace elements across different time periods, as well as within a single time period.[91] It is therefore not possible to say anything conclusive about the dates of these two wire fragments based on their compositions. Some compositions were more common than others within a particular time period, however, so it is worth discussing the wire fragments in terms of this information. Even if a date of manufacture cannot be established from this, we can at least know when similar brass was most likely to be in use. The studies by Mitchiner et al. (1987) and Pollard and Heron (2008) present comprehensive analyses and discussions of a large body of data on the composition of brass in Europe from the medieval era through the industrial revolution.[92] These

[89] The discovery of the Ballinderry harp fragments in a crannog is discussed in W. G. Wood-Martin, *The Lake Dwellings of Ireland: Or Ancient Lacustrine Habitations of Erin, Commonly Called Crannogs* (Dublin: Hodges, Figgis, & Co., 1886), 125 – 26.
[90] Iron melts at a higher temperature than both copper and zinc.
[91] Mitchiner et al., "Nuremberg and its Jetons," 114 – 55. See also e.g. Jean-Marie Welter, "The Zinc Content of Brass: a chronological indicator?" *Techné* 18 (2003): 32 – 33; and Vereecke et al., 67 – 68.
[92] Mitchiner et al., "Nuremberg and its Jetons," 114 – 55. Mark Pollard and Carl Heron, "The Chemical Study of Metals – the Medieval and Later Brass Industry in Europe," in *Archeological Chemistry* (Cambridge: The Royal Society of Chemistry, 2008), 193 – 234.

studies show definite groupings and trends in composition over time that also correlate with the historical information on brass production and trade in Europe. It should be noted that the results are largely based on the analysis of brass jetons. While their composition may be representative of brass in common use, different formulations of brass may have also been produced for other purposes.[93]

Zinc:

As shown in table 1.2, the wire fragment from the Lamont harp is a 23% zinc brass. Brass artefacts with approximately this percentage of zinc were produced over a long time period, from at least the early 15th century to the end of the 18th century.[94] It is a composition particularly typical of brass produced in the 17th century, as well as some late 15th-century brass.[95] Brass produced in the 16th century had less zinc on average, around 19%, while brass with less than 25% zinc was uncommon after 1700.[96]

The wire fragment from the Queen Mary harp is composed of a brass with 27 – 28% zinc (see table 1.1). While brass containing 28% zinc was being produced in Europe as early as the mid 15th century, it was more common from the late 17th century onwards.[97] After the mid 18th century, high zinc brass (> 33% zinc) begins to come into common use as well, and predominates after the mid 19th century.[98]

Trace elements:

Each of the two wire fragments also contains trace elements. The studies mentioned above have shown some correlations between the presence and quantity of trace

---

[93] Pollard and Heron also present the results of analysis of brass scientific instruments and of clock mechanisms. Pollard and Heron, "Medieval and Later Brass Industry," 215 – 25.

[94] Pollard and Heron, "Medieval and Later Brass Industry," 212.

[95] Mitchiner et al., "Nuremberg and its Jetons," 141 and 130 – 31; and Pollard and Heron, 210 – 12. The percentage of zinc increased from ~20% to ~23% in brass jetons produced by the younger members of the Lauffer family of Nuremberg after 1612.

[96] Mitchiner et al., "Nuremberg and its Jetons," 132 – 36, and 143 – 44. Mitchiner et al., attribute the rise in percentage of zinc after 1700 to the widespread adoption of the use of granulated copper in the alloying process. See also Pollard and Heron, 228.

[97] Pollard and Heron, "Medieval and Later Brass Industry," 210 – 13. Mitchiner et al., "Nuremberg and its Jetons," 141 – 43.

[98] Mitchiner et al., "Nuremberg and its Jetons," 151 and 155.

elements and the location and time period of manufacture.[99] This is a complex topic, however. A number of factors influence the presence of trace elements, including the use of recycled material, so it is only possible to make some general (but potentially important) observations.

Nickel:

Both wire fragments contain 0.3% nickel. The proportion of nickel present in historical brass primarily falls into two distinct groups. These are the 'high nickel' brasses, with typically 0.1% – 0.5% nickel, and the 'low nickel' brasses, with less than 0.05% nickel.[100] This is understood to be due to the source of the copper used in the brass.[101] From circa 1200 – 1450, the primary source of copper for brass production in Europe was the non-nickel bearing ore from the Falun mine in Sweden, and 'low nickel' brass is predominant in artefacts from this time period.[102] In the mid 15th century, the primary source of copper shifted to nickel bearing copper ore from mines in present day Austria and Hungary as well as the Harz in northern Germany, after which time 'high nickel' brass predominated (although 'low nickel' copper continued to be supplied from Sweden).[103] Over the course of the 18th and 19th centuries, production of 'low nickel' brass increased again as output from the nickel bearing copper mines decreased and was replaced with copper from non-nickel bearing ores. These were mined in the Harz and in Mansfield in the Halle district of present-day northern Germany, as well as in Cornwall in England.[104]

---

[99] See e.g. Pollard and Heron, "Medieval and Later Brass Industry," and Mitchiner et al., "Nuremberg and its Jetons."

[100] Mitchiner et al., "Nuremberg and its Jetons," 126 – 27. Pollard and Heron, "Medieval and Later Brass Industry," 210 – 13.

[101] Pollard and Heron, "Medieval and Later Brass Industry," 210 – 14.

[102] ibid., and Mitchiner et al., "Nuremberg and its Jetons," 126 – 27.

[103] Mitchiner et al., "Nuremberg and its Jetons," 127, and Pollard and Heron, "Medieval and Later Brass Industry," 213.

[104] Pollard and Heron, "Medieval and Later Brass Industry," 212 – 13, and Mitchiner et al., "Nuremberg and its Jetons," 126 – 27. There is also an observed spike in numbers of 'low nickel' brass artefacts from the 17th century England corresponding to a brief period of domestic production and an embargo of imported brass. See Pollard and Heron, "Medieval and Later Brass Industry," 203.

Lead:

The Lamont harp wire fragment contains 2% lead whereas the Queen Mary harp wire fragment does not contain any measurable traces of lead. Prior to circa 1450, brass produced in Europe typically contained 1 – 2% lead.[105] A lead content of less than 1% is typical of later brass.[106] The reduction in lead is part of an overall change in the composition of brass that occurred at this time, which includes a corresponding drop in tin and the previously mentioned rises in nickel and zinc.[107] There is a further reduction in lead content in the 19th century, which correlates with a shift in the manufacturing process for brass from the cementation of copper with zinc bearing calamine ore to alloying directly with metallic zinc.[108]

Iron:

Both wire fragments contain essentially the same percentage of iron. The iron content of the Lamont brass wire was measured at 0.18% and the iron content of the Queen Mary brass wire was measured at 0.17%. The amount of iron in brass remained fairly constant from the 13th century through the mid 18th century, with percentages typically ranging between 0.1 – 0.4%.[109] Brass with less than 0.1% iron begins to become common after circa 1750 and is increasingly common in the 19th century, although higher iron content is still seen.[110] The lower percentages of iron are more commonly seen in 'high zinc' brasses. As with the 19th-century reduction in lead mentioned above, this may be a result of the shift from the use of calamine ore to direct alloying with metallic zinc.

Silver and Tin:

The above are all of the trace metals that were detected in the two brass wire fragments at measurable levels. Two other metals worth mentioning are silver and tin, which are notable by their absence. As discussed by Mitchiner et al. (1987), if the copper used came from a silver bearing ore, the resulting brass will contain traces of

105 Pollard and Heron, "Medieval and Later Brass Industry," 212.
106 ibid.
107 ibid.
108 Mitchiner et al., "Nuremberg and its Jetons," 124.
109 ibid., 130 – 55.
110 ibid.

silver, even if the ore has been refined to recover it.[111] Based on their analysis, de-silvered copper can be expected to have retained 0.1 – 0.15% silver, historically.[112] Pollard and Heron (2008) note the presence of silver at 0.1 – 0.2% in pre-1450 brass, which is likely to be due to the silver bearing copper ore of the Falun mines in Sweden.[113] Mitchiner et al. note that the presence of silver in brass in the late 15th century followed by a drop in the occurrence of silver bearing brass thereafter may be due to a shift at that time in the predominant source of copper from the silver bearing copper ore of the Harz mines to the non-silver bearing ore of the Austro-Hungarian mines.[114]

The significant change in overall composition of brass that occurred in the mid 15th century, as noted above for nickel, lead and silver, also affected the percentage of tin present. Both Mitchiner et al. (1987) and Heron and Pollard (2008) note that brass made before the mid to late 15th century contained significant traces of tin, primarily above 2%.[115] Pollard and Heron report 3.7% tin, on average, from the analysis of pre-1450 brass jetons.[116] Later brass jetons were found to have, on average, less than 0.2% tin. Pollard and Heron propose that the drop in average levels of tin may have been due to eliminating the practice of using scrap bronze in the manufacturing process.[117]

<u>Summary</u>

Taking into consideration the information on all of the elements discussed above, some comparisons can be made with regard to the composition of the wire fragments

---

[111] ibid., 124 – 25.
[112] ibid.
[113] Pollard and Heron, "Medieval and Later Brass Industry," 212. See also Mitchiner et al., "Nuremberg and its Jetons," 125. Copper ore from the Falun mines was being refined to recover the silver.
[114] Mitchiner et al., "Nuremberg and its Jetons," 125.
[115] ibid., 115, Pollard and Heron, "Medieval and Later Brass Industry," 210. Mitchiner et al. date the change to the 1480s. Pollard and Heron date it to circa 1450.
[116] Pollard and Heron, "Medieval and Later Brass Industry," 210.
[117] ibid., 213.

from the two harps. These are only general comparisons, however, and not definitive determinations of the age of the wire. Similarities to brass common to a particular time period do not necessarily mean the wire was made in that time period.
For the Lamont wire fragment, the observed percentages of nickel and iron and the absence of any measurable tin and silver are typical of brass made at any time from the late 15th century to the beginning of the 19th century. The percentage of zinc present is most typical of brass made in the 17th century. The percentage of lead is high, however, and suggests the possibility that this brass may include recycled material from a cast object.[118] As discussed previously, the location of this wire fragment in the string hole strongly suggests that it was part of a wire string for the harp. Since it is unlikely that this harp was used after the death of John Robertson in 1731, it is plausible that this wire dates to the 17th century. The possibility that the brass may have been made with recycled material, as suggested by the high lead content as well as the large iron defect, is interesting in this context. In the British Isles, brass was scarce during the English Civil War, a circumstance that was exacerbated by the floundering domestic brass industry in 17th century England.[119] One could easily imagine a scenario in which scrap cast brass was being melted down to be repurposed (or sold), for example as rods for wire drawing.

The Queen Mary wire fragment contains more zinc than the Lamont wire fragment, and no measurable lead. The percentage of zinc is typical of brass made from the late 17th century onwards. The absence of lead is more common for brass made after the beginning of the 19th century, although the presence of appreciable iron and especially nickel were more common before the 19th century. It is plausible, therefore, that this wire dates to no earlier than the late 17th century, but the composition is not clearly suggestive of either a pre- or post- 19th-century date. The most convincing evidence for dating this wire is the circumstance of its location in the string hole. In order to be held in place, the textile wad it was wrapped around had to have been wedged between one of the wooden soundbox pegs and the side of the string hole. The only other thing preventing the textile from falling out of the

118 Lead is added to brass for casting to improve the flow. See Mitchiner et al., "Nuremberg and its Jetons," 124.
119 Pollard and Heron, "Medieval and Later Brass Industry," 203.

string hole was the varnish it had adhered to, which was applied sometime after the wooden soundbox pegs were added to the harp. The connection with the wooden soundbox pegs strongly suggests 1805 as the date for the use of this wire, which means it was likely to have been made within a few years prior to that date.

Chapter 2. Stringing Regimes

Little is known about the pitch and compass of the surviving low-headed Irish harps. Based on extant historical information, we can surmise that they were tuned diatonically, possibly with a single pair of strings tuned to a unison.[120] More detailed information survives for the 18th-century instruments, as recorded by Edward Bunting.[121] As discussed in the introduction, these later Irish harps are of the design referred to as high-headed by Rimmer (1964).[122] Their frames are of a different design to the earlier form of the instrument, and in particular they have a longer string scaling in the bass. Historical information regarding their pitch and compass may therefore not be applicable to the earlier, low-headed Irish harps.

Investigations of the pitch and compass of the low-headed harps, and attempts to faithfully reproduce their stringing regimes, have been hampered by the state of the frames of the surviving instruments. Distortions due to twisting and shifting of the members, cracks and deterioration, as well as repairs and modifications, have combined to alter the original string lengths. In order to study the stringing of any of these harps, it is necessary to reconstruct the original geometry of the frame. It is also necessary to examine surviving evidence on the frame related to the stringing in order to understand how the harp was strung and any changes that may have been made to the stringing arrangement.

---

[120] Rimmer, "Talbot's Manuscript," 67. See also Bunting, *Ancient Music of Ireland*, 23. The tuning Bunting describes is for a high-headed Irish harp, however. Notably, the surviving fragments of the Cloyne (a.k.a. Dalway), a low-headed Irish harp dated 1621, include a second rank of seven tuning pins, suggesting that it may have been partially chromatic. For a discussion of this see Michael Billinge and Bonnie Shaljean, "The Dalway or Fitzgerald Harp (1621)," *Early Music* 15, no. 2 (1987): 175 – 187. For a discussion of the unison strings see Simon Chadwick, "Sister Strings, or na Comhluighe," last modified, February, 2014, http://www.earlygaelicharp.info/tradition/sisters.htm.
[121] Bunting, *Ancient Music of Ireland,* 23, and Bunting, *MS 29*, 81, 150, 156.
[122] Rimmer, "Morphology," 44. Rimmer's term is derived from the name *cinnard cruit* (meaning 'high-headed harp') used by the 18th-century Irish harpers. Bunting, *Ancient Music of Ireland*, 20.

The frame of the Lamont harp

Number and arrangement of strings

The frame of the Lamont harp poses some interesting problems with regard to reconstruction of its stringing. In addition to some severe damage and movement of the members there are questions regarding the tuning pins, such as how many were originally on the neck, how many were in use at different stages of the instrument's working life, and which string holes they were strung to in the soundbox. This harp has 32 string holes in its soundbox but only 31 holes for tuning pins in the cheekbands on its neck. A 32^{nd} hole for a tuning pin is located below the cheekbands at the bass end of the neck, directly underneath the position for the 31^{st} tuning pin, as shown in figure 2.1.

Figure 2.1: *detail of the left side of the neck of the Lamont harp. A single tuning pin hole is located below the cheekband at the bass end (arrowed). This tuning pin hole and the one directly above it in the cheekband are located under the sleeve of the end cap, which also covers the ends of the cheekbands on both sides of the neck. Photograph: Maripat Goodwin*

This tuning-pin hole appears to be a later addition to the neck. A plausible explanation is that the neck and cheekbands had been shortened, resulting in the loss of the 32nd tuning-pin hole at the end. This "lost" hole would have then been relocated below the cheekbands, under the 31st hole. This explanation is supported by the crude alteration that had been made to the sleeve of the metal end cap to make it fit the end of the neck, as shown in figure 2.2.

Figure 2.2: *a view of the Lamont harp end cap showing the section of the sleeve that has been cut and bent back to fit the end of the neck (arrowed). Photograph: Maripat Goodwin*

Direct examination of the end of the neck could answer the questions about the 32nd tuning pin hole, however this is hidden from view by the end cap, which is nailed to the neck and not removable without risking damage to both the neck and the cap. It is, however, possible to see under the end cap in the tomograms from the CT scans. Three tomograms of the end of the neck are shown in figure 2.3, below. Although interference from the metal obscures some of the detail, it is possible to see the hidden ends of the cheekbands as well as the cross sections of the tuning pin holes.

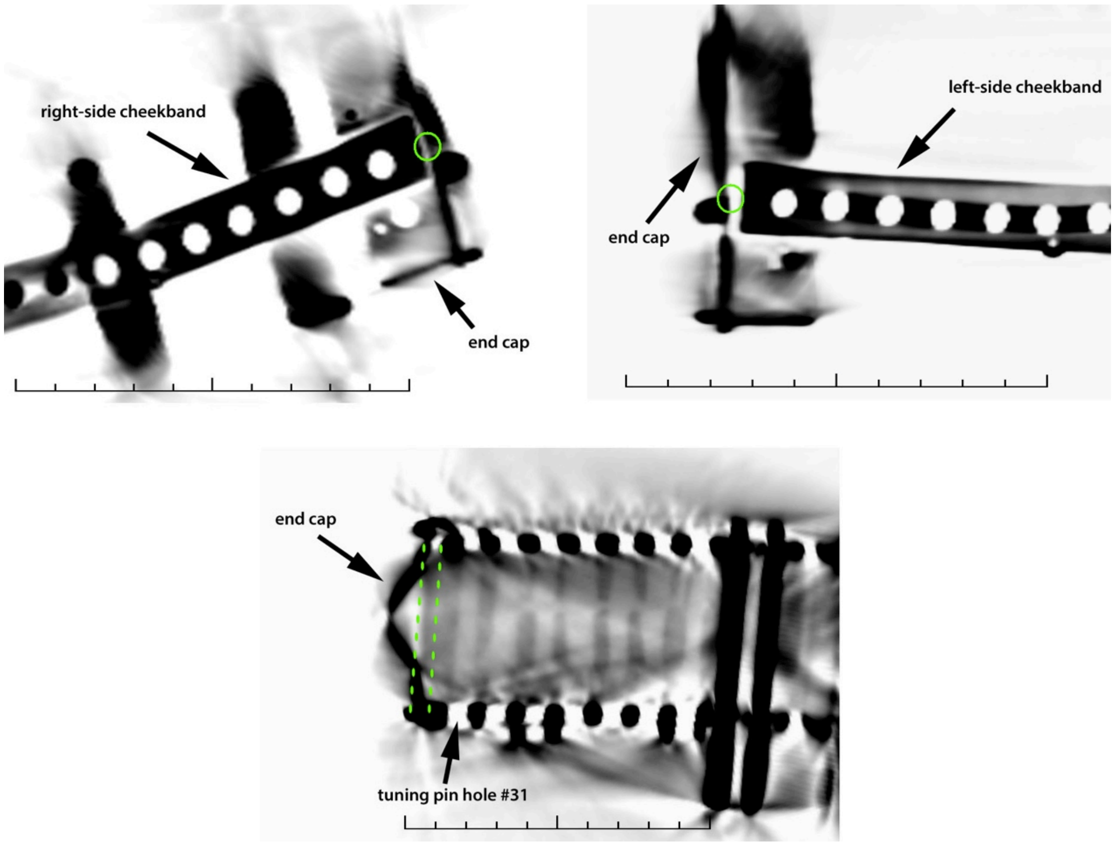


Figure 2.3: *tomograms of the end of the Lamont harp neck. Clockwise from top left: cross sections of the right side cheekband, of the left side cheekband, and across the neck through the tuning pin holes. The ends of the cheekbands, which are under the sleeve of the end cap, are visible in the upper two tomograms. All but two of the tuning pins were removed for this scan. The unoccupied tuning pin holes appear as white circles in the cheekbands. In the lower tomogram, these tuning pin holes appear as lighter grey bands through the neck, while the wood between them appears as darker grey bands. The two remaining tuning pins are visible on the right-hand side in this tomogram. The position that would be occupied by a 32nd tuning pin hole in the cheekbands is indicated by the green circles in the upper two tomograms and by the green dashed lines in the lower tomogram. The scale is 1 tick : 1 cm.*

Given the spacing of the tuning pin holes, if the cheekbands had originally included a 32nd hole, part of this hole should still be present and visible at the end of the neck. The position this hole would occupy is indicated in figure 2.3. For the left-hand cheekband, a 32nd tuning pin hole would have been located just at the edge of the current end of the band. It is not possible to tell from this cheekband if a 32nd hole has been cut away. On the right-hand cheekband, however, the tuning pin holes are larger, so the gap between them is narrower. A 32nd tuning pin hole (if it were present) would overlap the end of the cheekband and should therefore still be visible as a small cut-out at the end of the band, as indicated in the upper left tomogram in figure 2.3. There is no corresponding cut-out at the end of this cheekband, however, suggesting that it has not been shortened.[123] The overlap is not large, though, 2 – 3 mm at most. The cross section through the neck shown in the lower tomogram in figure 2.3 is more convincing. In this cross-section it is evident that the distance from the last hole to the end of the neck is noticeably larger than the space between the tuning-pin holes. Although not shown here, the cheekbands also end a few millimetres short of the end of the neck. Based on the spacing of the tuning-pin holes, part of a 32nd hole would still be visible as a channel in the wood at the end of the neck. Examination of the cross section through the neck as shown in figure 2.3, and of additional cross sections parallel to the neck end, have shown that no channel is present in this location. The conclusion is that the neck of the Lamont harp was originally made for 31 tuning pins, not 32.

Although the neck was made for 31 tuning pins, the soundbox of this harp has 32 string holes. The location of the 32nd string hole on the string band can be seen in the right hand photograph in figure 2.4. The spacing of this string hole with respect to the others suggests that it is part of the original layout and was not added at a later date.

---

[123] This is also discussed in Loomis et al., "Lamont and Queen Mary Harps," 121.

Figure 2.4: *detail of the soundbox of the Lamont harp showing the treble (left) and bass (right) ends of the string band. The bottom most string hole in the bass is #32. The spacing with respect to the other string holes suggests that it was not added at a later date. Photographs: Maripat Goodwin*

If there were originally 31 tuning-pin holes on the neck and 32 string holes on the soundbox, which tuning pin was strung to which string hole, and why doesn't the number of tuning pins in the neck match the number of string holes in the soundbox?[124] Clues to a possible explanation may be found in the stringing marks in the interior of the soundbox. Originally observed by Hobrough (1979), they consist of numerous linear indentations around the string holes, as shown in figure 2.5.[125]

[124] The Lamont is not the only surviving Irish harp for which the number of tuning pin holes does not match the number of string holes. The Downhill harp has 30 tuning pin holes in its cheekbands and 32 string holes in its soundbox. See Armstrong, *Irish and Highland Harps*, 89.

[125] Tim Hobrough, "Notes on European Harps," *FOMHRI Quarterly,* 14 (1979): 49; and *Tim Hobrough to R. B. K. Stevenson, Keeper, National Museum of Antiquities of Scotland,* 23 January, 1979, letter, National Museums Scotland, *H. LT2 archive*. The author would like to thank Simon Chadwick for pointing out the *FOMHRI* reference.

Figure 2.5: *the interior of the Lamont harp soundbox (top) and detail (bottom) showing marks around the string holes. The red box in the upper photo indicates the area shown in detail in the lower photo. The size, shape, location, and distribution of the marks are consistent with their having been made by string toggles and wires pressing against the wood.*

The size, shape, location, and distribution of the marks around the string holes are consistent with their having been made by string toggles and wires pressing against the wood.[126] For comparison, similar marks present around some of the string holes in the author's harp, built by Guy Flockhart after the Lamont, are shown in figure 2.6. The marks observed in the Flockhart harp were made by the string toggles.

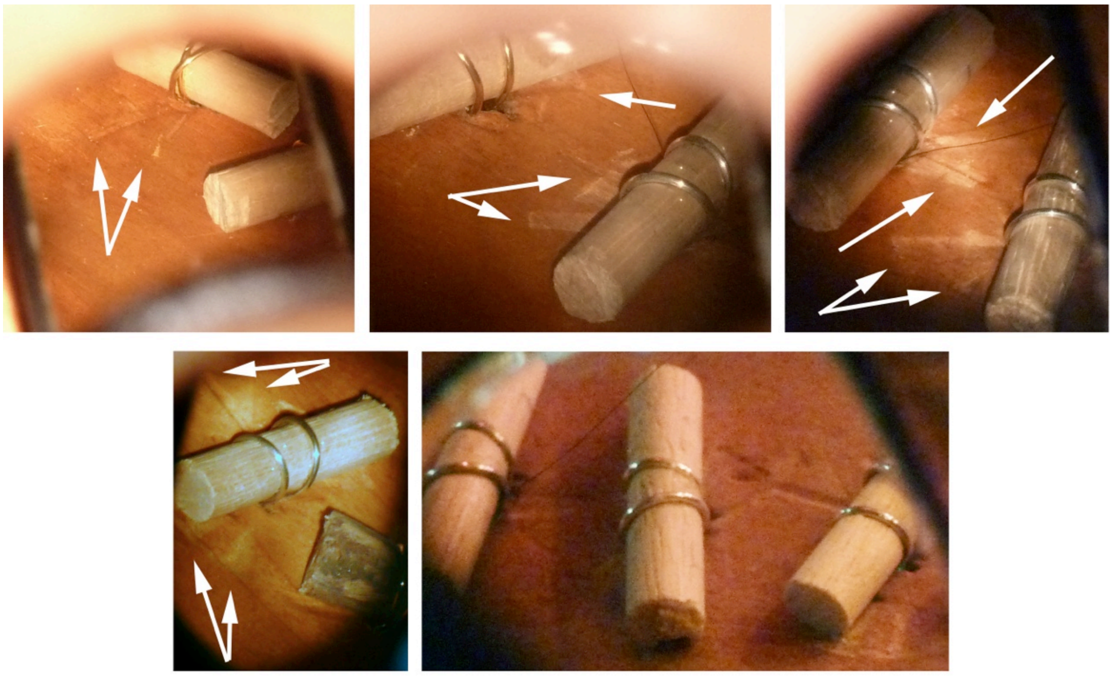


Figure 2.6: *toggles and toggle marks (arrowed) around the string holes in the harp built by Guy Flockhart in 1996, after the Lamont. The string holes shown are (clockwise from top left): #19, #20 – 21, #21 – 22, #23, and # 21 – 23. The photographs were taken with an inspection mirror inserted into a soundhole.*

Each time a string is brought up to tension, the toggle presses against the wood, often leaving an impression.[127] With the string under tension the toggle will stay in place and not rotate or shift until the string is loosened again. Each mark in the wood,

---

[126] Loomis, "Structural Breaks and Repairs," 88. Loomis et al., "Lamont and Queen Mary Harps,"117.

[127] The form of the toggle may affect the impression it leaves in the wood. In the case of the Flockhart harp, most of the current toggles are made from round wooden dowel, but its original toggles were hand-whittled bits of wood (part of one of these is visible in the lower left photo in figure 2.6). These were irregular in profile, and may have left impressions in the wood more readily. A thin metal toggle would also more readily leave an impression.

therefore, effectively represents a string replacement. For the Flockhart harp, the handful of observed toggle marks is consistent with the number of times these strings have been replaced. This harp was 17 years old at the time the photographs in figure 2.6 were taken. The strings at holes #19 – 23 have been replaced 2 – 3 times by the author, over a 7-year period, and may have been replaced a comparable number of times by the harp's original owner over the previous 10 years. The number of toggle marks around these string holes can be compared to the marks visible around string holes #18 – 20 in the Lamont harp soundbox, as shown in the photograph in figure 2.7.

Figure 2.7: *Toggle marks around string holes #20 – 18 (l. – r.) in the soundbox of the Lamont harp.*

At the string holes shown in figure 2.7 numerous toggle marks are present to the point of saturation.[128] This is the case for nearly all of the string holes, although the number of toggle marks tapers off slightly towards both ends of the string band. The

[128] The toggle marks can be used to estimate the number of years the harp was in use. This is discussed in Part II of this dissertation.

exceptions are the string holes at each end of the string band: holes #1 and #32. The string holes were extensively examined under magnification. String hole #32 was found to be devoid of any signs of use, in contrast to all of the other string holes, which have marks from the string toggles as well as indentations, scratches, and some verdigris stains from the wire strings. String hole #1 was found to have only minimal signs of use in the form of a small number of string indentations at the edge of the hole and a few light scratches radiating from the hole. One toggle mark was also found at this hole. This is in contrast to string hole #2, which has significantly more signs of use in the form of numerous toggle marks, scratches, and wire indentations. The comparative differences can be seen in the photographs of the string holes in figure 2.8 and figure 2.9. A close-up of string hole #1 in figure 2.10 shows the signs of use visible at this hole.

Figure 2.8: *String holes #32, 31, and 30 (l. - r.) in the soundbox of the Lamont harp. There are numerous toggle and string marks around holes #31 and 30, but no marks around hole #32. Examination under magnification did not reveal any marks or scratches in or around string hole #32, in contrast to the two adjacent holes.*

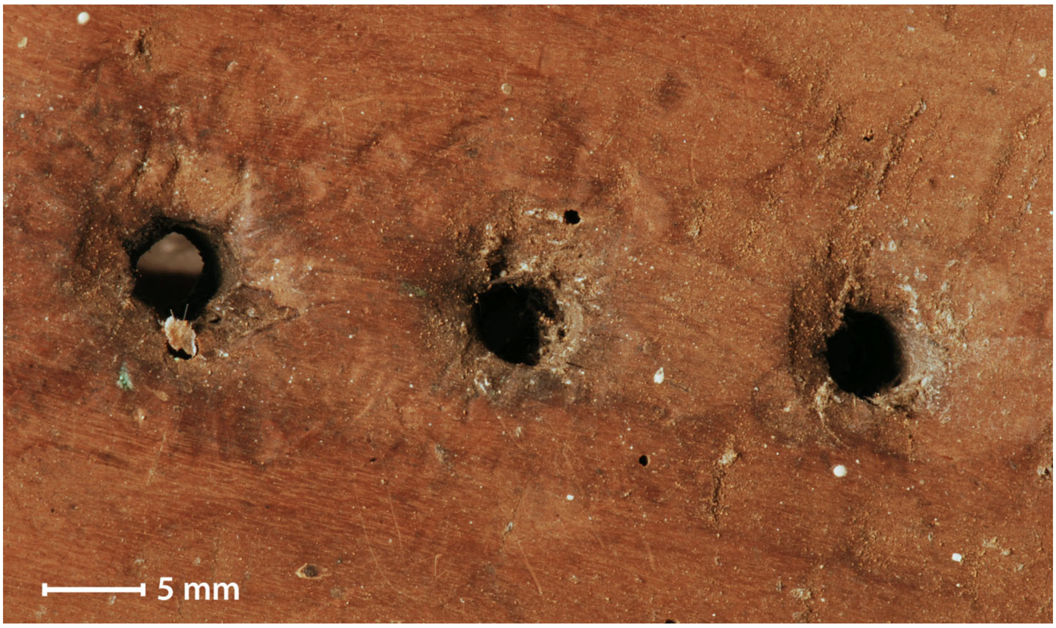


Figure 2.9: *String holes #3, 2, and 1 in the soundbox of the Lamont harp. The lighting in this photograph is less optimal than for the photograph in figure 2.8, however numerous toggle marks are visible around string holes #2 and #3, as well as a few verdigris stains, and a number of fine scratches radiating from the holes. In contrast, string hole #1 has minimal signs of use.*

Figure 2.10: *close-up of string hole #1 in the soundbox of the Lamont harp, showing fine scratches radiating from the hole, string indentations at the hole edge, and a toggle mark (arrowed). The location of the toggle mark is indicated by the top arrow. The string hole is approximately 5 mm in diameter. The treble end of the soundbox is toward the right.*

The absence of marks at the #32 string hole is an indication that this hole was left unused, and the comparatively small number of marks at string hole #1 is an indication that this hole was minimally used. This suggests some possible stringing solutions when considered in conjunction with the evidence on the neck. The harp may have been originally strung with 31 strings, starting from tuning pin #1 and string hole #1, leaving string hole #32 unused. When Armstrong examined this harp, however, he noted that the large crack in the neck passes through the position of the first and second tuning pins, and commented that the first and probably the second tuning pin positions would not have been usable after the crack formed (see figures 2.13 and 2.15, below).[129] Examination of the inside of the neck on the CT scans shows that the first and second tuning pin holes have indeed been compromised by the crack to the point of being unusable, with the #1 hole most extensively damaged. Repairs associated with this crack suggest that the harp continued to be used after the crack formed.[130] Based on this and the evidence of the toggle marks, it is possible that the #1 tuning pin hole ceased to be usable relatively early in the working life of the instrument. Taking this into consideration, one solution for the stringing is for the top string to be strung directly from string hole #2 to tuning pin #2 and the remaining string positions strung likewise down to string hole #31 which would be strung to tuning pin #31, the last position in the cheek band. This avoids the first tuning pin, and presents a harp with 30 strings, the same number as the Queen Mary harp (including its additional string in the bass), and the Trinity College harp (including its additional string in the bass).[131]

While the solution just described explains how the first tuning pin could be avoided after it became unusable, there is still the question of the purpose of the 32nd tuning pin hole, and the question of the second tuning pin hole, which was also compromised by the neck crack. Both of the first two tuning pin holes can be avoided by stringing from string hole #2 to tuning pin #3, and continuing likewise to string

[129] Armstrong, *Irish and Highland Harps*, 164.
[130] For a discussion of the neck crack and repairs see Loomis, "Structural Breaks and Repairs," 28 – 34, and Loomis, et al., 121.
[131] Paul Dooley, "Reconstructing the Medieval Irish Harp," *The Galpin Society Journal* 67 (2014): 113.

hole #30, strung to tuning pin #31. With the addition of the 32nd tuning pin hole below the cheekband, the bottom string can be strung from the 31st string hole to this additional tuning pin position. Offsetting the stringing in this manner avoids the two unusable tuning pin holes, while allowing the harp to retain 30 strings.

Although a string could have simply been strung directly from the 32nd string hole to the added 32nd tuning pin, with the rest of the stringing following suit up to the third string hole and tuning pin, there is a disadvantage to stringing the harp this way. In addition to the problem of the compromised tuning pin holes, there is the issue of alignment of the tuning pins and string holes. The string tension has caused the neck of this harp to shift in a direction that has moved the cheekband towards the treble relative to the position of the string holes in the soundbox. This has the effect of lowering the angle of the strings to the string band on the soundbox and reducing the string spacing, which could present problems for the player. As will be seen in the reconstruction of the straightened frame, offsetting the stringing as described above (e.g. string hole #2 to tuning pin #3) has the advantage of compensating for the backwards shift of the cheekband.

In the following discussion, the stringing schemes described above are used to determine proposed string lengths for the frame of the harp in its current state, and a reconstructed straightened frame with the distortions due to twisting and shifting of the frame members removed.

String lengths for the Lamont harp

Amongst the surviving Irish harps, the Lamont has probably suffered the most extreme twisting of its frame, as evident in the photographs in figure 2.11.

Figure 2.11: *the Lamont harp viewed from the front, top, and bottom (clockwise, from left), showing the distortion of the frame. Right hand photographs: National Museums Scotland H.LT2 archive.*

To reconstruct the string lengths for this harp with a straight frame, it is important to understand how and why the frame came to be in its current state. The Lamont harp is very old and, as with other old musical instruments, there have been multiple episodes of damage, repair, and modification. These, however, provide clues to the original state of this harp.

As discussed in Loomis (2010) and Loomis et al. (2012), the string tension has caused the frame members to rotate, shift, bend, and crack.[132] The overall distortion to the shape of the frame is complex, but by individually addressing each component of the total movement the geometry of a "straightened" frame can be reconstructed

[132] Loomis, "Structural Breaks and Repairs," 9 – 10; Loomis et al., "Lamont and Queen Mary Harps,"115 – 22.

and string lengths can be calculated for this frame. The directions in which the neck and soundbox have moved are shown in figure 2.12, below. It is the movement and distortion of these two frame members that has affected the relative positions of the tuning pins and string holes, and therefore the string lengths.

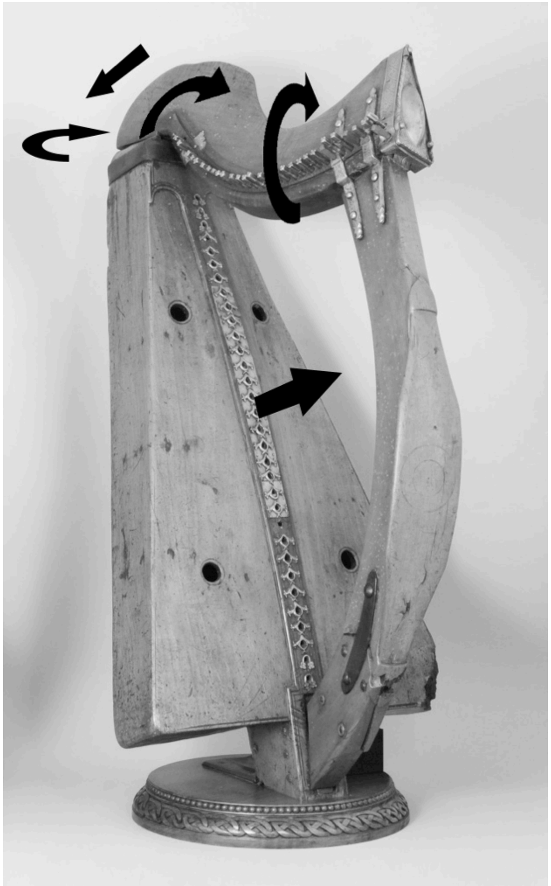


Figure 2.12: *direction of movement of the neck and string band of the Lamont harp. The neck has rotated about its long axis towards the left side of the instrument, and pivoted forwards out of its joint with the soundbox. It has also rotated in this joint towards the left side of the instrument and shifted backwards, towards the back of the soundbox. The soundbox has risen along the string band to form a 'belly'. Photograph: Isabell Wagner; annotations by the author.*

As illustrated in figure 2.12, the neck has rotated about its long axis, pivoted forward (towards the forepillar), rotated sideways in the soundbox joint, and shifted backwards in this joint towards the back of the soundbox. Most of these motions will have altered the string lengths. Although the sideways rotation of the neck in the soundbox joint has caused the top end of the forepillar to pivot dramatically towards the left side of the instrument, this motion has primarily only resulted in the string plane pivoting in the same direction, and has not had a significant effect on the string lengths. The other components of the motion of the neck have, however. These are described in more detail below.

The forward rotation and backwards shift of the neck can be seen more clearly in the cross-sectional tomogram of the neck/soundbox joint shown in figure 2.13. The neck has rotated forwards 5.9°, pivoting against the top end of the soundbox, and has also shifted 10 mm backwards towards the back of the soundbox.[133] This combined motion has reduced the distance between the tuning pins and string holes, and has shifted the cheekbands towards the treble end of the harp relative to the string band. It has also caused the back of the soundbox to be pushed outward by the tenon, which has, in turn, resulted in the tenon being sheared off, necessitating the repairs to both the tenon and the soundbox.[134]

---

[133] A small wooden shim can be seen in between the neck and soundbox, just below and to the left of pivot 1 in Figure 2.13. It has probably been inserted to create some space where the neck would otherwise pinch against the soundbox in its current position.
[134] The damage and repairs to the neck joint are discussed in detail in Loomis, "Structural Breaks and Repairs," 35 – 42. The rotation of the neck towards the left side of the harp has also contributed to the damage to the tenon.

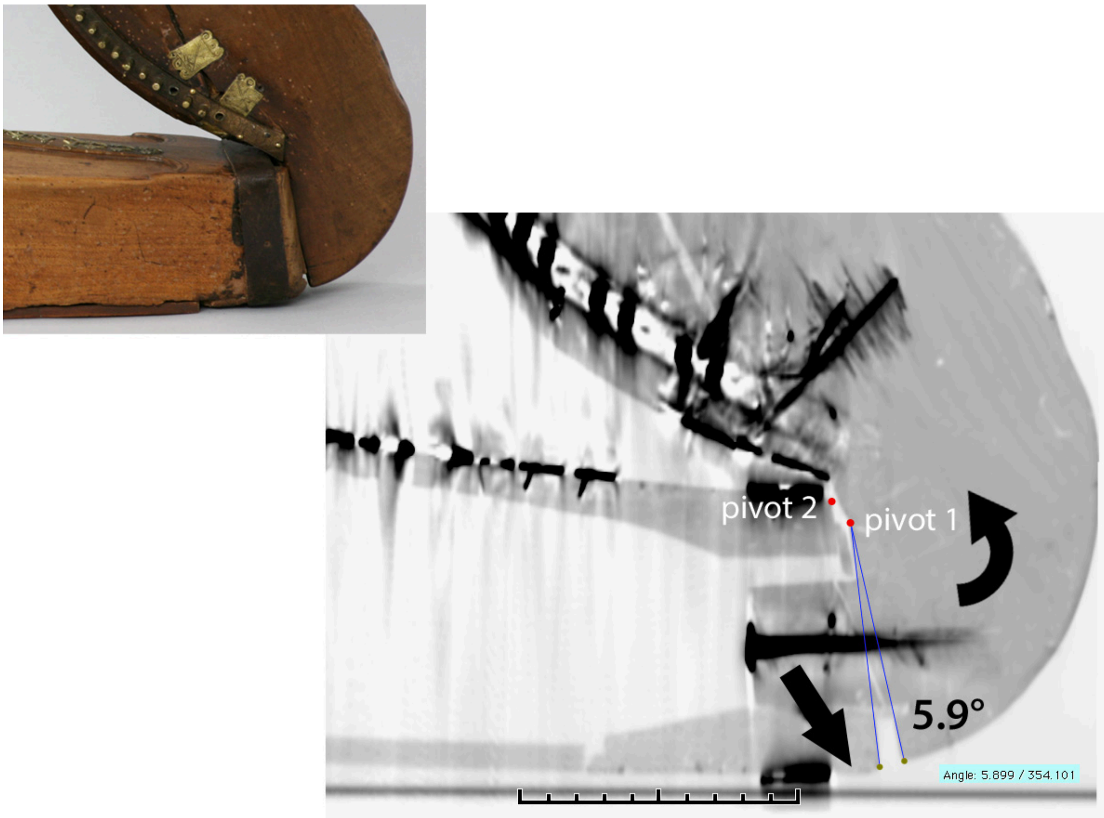


Figure 2.13: *tomogram of the Lamont harp neck/soundbox joint, and photograph of the same area (inset). The points labeled 'pivot 1' and 'pivot 2' were originally adjacent. As a result of the string tension, the neck has shifted backwards and has pushed the back of the soundbox outwards in the direction indicated by the straight arrow. The neck has also pivoted forwards, causing the joint to open by 5.9°, as indicated by the curved arrow. Photograph: Maripat Goodwin. The scale in the tomogram is 1 tick : 1 cm.*

The rotation of the neck around its long axis, towards the left side of the harp has contributed to the change in relative position of the tuning pins and string holes by causing the tuning pins to rotate downwards on the left side of the neck, bringing the string ends of the pins closer to the soundbox. The measured rotation about this axis is 20.5°, as shown in figure 2.14.

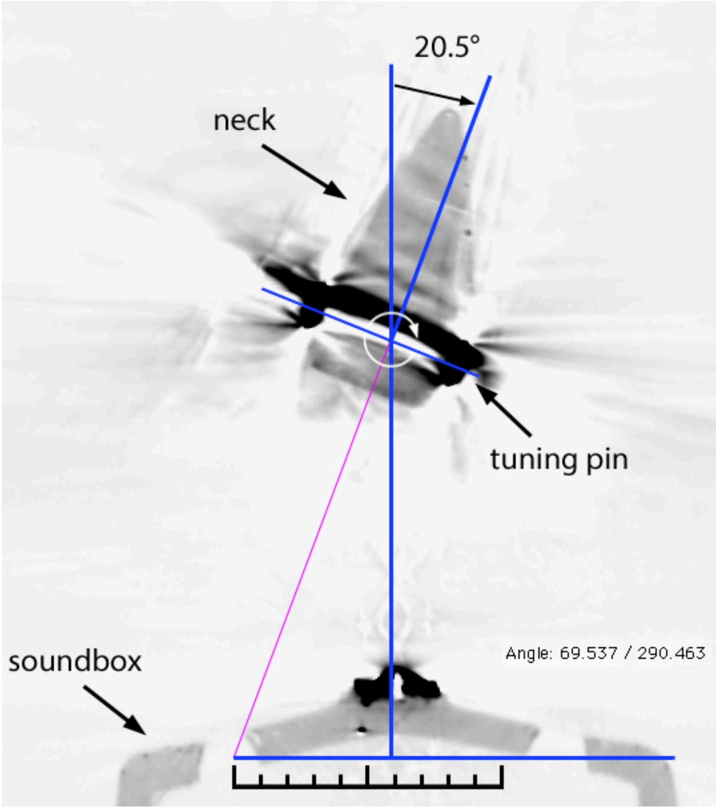


Figure 2.14: *tomographic cross-section of the Lamont harp neck showing the angle of rotation about its long axis. The scale is 1 tick : 1 cm*

The large crack on the left side of the neck has contributed to this rotation by acting as a hinge, with the portion of the neck below the crack, including the tuning pins, having rotated slightly more than the rest of the neck. The crack passes through the first and second tuning-pin holes, rendering them unusable, as discussed above. The remainder of the tuning-pin holes lie below this crack. Nail fragments above the current position of the end of the left-hand cheekband (see figure 2.15) indicate that the end of the cheekband probably had to be re-affixed down and forward as a result of the crack opening up. The presence of more than one nail fragment suggests that the end of the cheekband may have been repositioned more than once. This could have been due to the crack continuing to open up over time, which would agree with the proposed scenario of the first tuning pin hole becoming unusable, followed later by the second tuning pin hole.

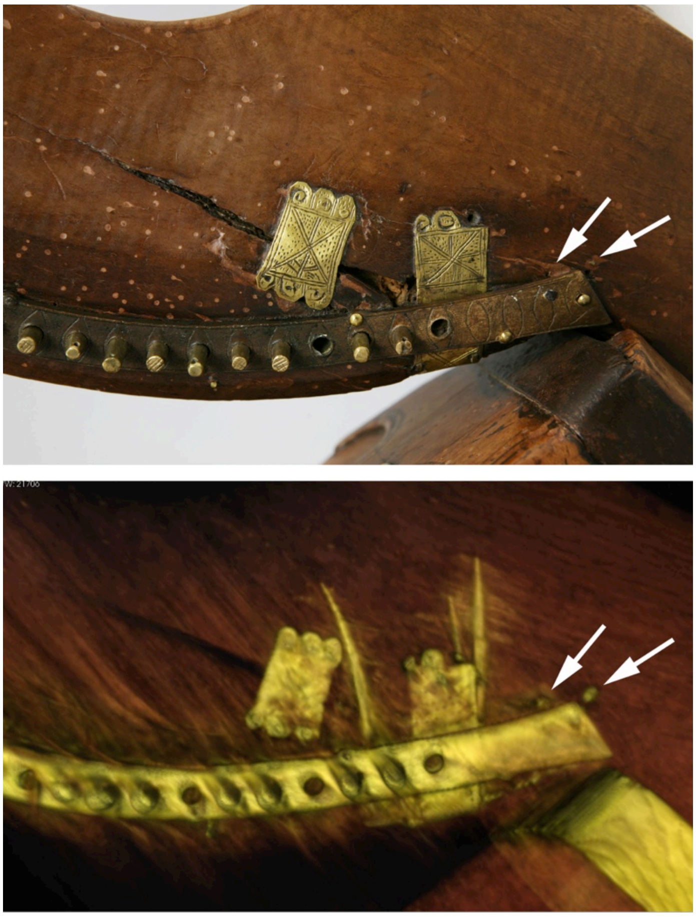


Figure 2.15: *Photograph (top) and tomographic volume rendering (bottom) of a large crack in the neck of the Lamont harp, viewed from the left side of the instrument. The wood is rendered semi-transparent in the tomogram to make embedded metal more visible. Nail fragments near the end of the cheekband (arrowed) suggest that it needed to be re-attached to the neck as the crack opened up. Photograph: Maripat Goodwin.*

In addition to the changes to the shape and orientation of the neck, the string tension has pulled the soundbox front upwards, forming a 'belly', which has moved the string holes up towards the tuning pins. There has long been speculation as to whether the soundbox arch or 'belly' of Irish harps was carved to shape, pulled up by the string tension, or a combination of both of these. It is currently generally accepted that the string tension at least contributes to the shape of the soundbox belly.[135] The evidence for this is discussed in Loomis (2010), and Loomis et al. (2012).[136] The question has

[135] Armstrong, *Irish and Highland Harps*, 56.
[136] Loomis, "Structural Breaks and Repairs," 11 – 12, 46; Loomis et al., "Lamont and Queen Mary Harps," 122 – 23. The author gratefully acknowledges Simon Chadwick for bringing to

remained, however, as to whether the belly is entirely the result of the string tension or whether it was initially carved to shape and then pulled further up by the strings. The answer can be found by examining the string hole cross-sections on tomograms of the soundbox. The holes at the extreme treble and bass ends of the string band, where there is no appreciable belly, have straight sides in cross-section, whereas the string holes nearer the highest point of the belly have sides that are angled towards each other, as shown in the top two tomograms in figure 2.16. The top cross-section in this figure is through string hole #31, which is located near the extreme bass end of the string band, where the front face of the soundbox is nearly flat. The middle cross-section is through string hole #23, which is located on a section of the string band where there is an appreciable belly in the front face of the soundbox.[137] In the cross-section of string hole #31, the walls of the string hole are parallel, whereas in the cross-section of string hole #23 they are angled upwards. This could be due to the tool used to make the hole, but it's unlikely that the builder would have chosen to use a different tool just for the string holes on the belly, so the angling of the sides of the string hole located on the belly must be due to the front of the soundbox being pulled up by the string tension. The question remains as to whether some of the observed belly was carved, however. This can be answered by rotating the two sides of the image of the cross-section of string hole #23 to recreate a 'flat' fronted soundbox. If this string hole was made in a soundbox with a flat front, the two sides of the wall in the 'flattened' cross-section should be parallel. If, however, this string hole was made in a soundbox with a carved belly, the sides of the wall should angle downward. The two sides of the string hole wall in the 'flattened' cross-section (figure 2.16, bottom) are parallel. Just as for string hole #31, this string hole was made through a flat soundbox face. The belly of the Lamont harp is, therefore, entirely the result of the string tension pulling up the wood.

---

her attention the pulled in sides of soundboxes as evidence of the front having been pulled up by the string tension.

[137] These two string holes were also chosen because they had the least amount of interference on the tomograms due to nearby metal parts.

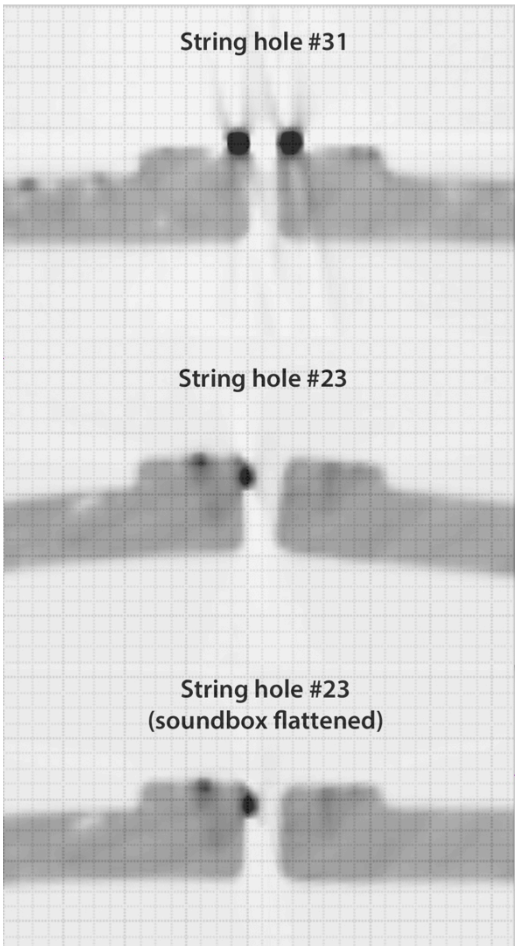


Figure 2.16: *tomographic cross-sections of string holes in the Lamont harp soundbox. Top: string hole #31, located where the front of the soundbox is nearly flat; middle: string hole #23, located on the 'belly' of the soundbox; bottom: string hole #23 with the two 'sides' rotated down to recreate a flat soundbox face. Note the angle of the walls of the string holes. In string hole #31 (top) they are parallel; in #23 (middle) they are angled upwards; in #23 for the 'flattened' soundbox (bottom) they are again parallel, indicating that the face of the soundbox was flat when this hole was made. The grid scale is 1 box : 2.5 mm*

Having established that the Lamont harp soundbox was made with a flat front, this can be taken into account when reconstructing the 'as-built' string lengths for this harp by making a correction for the shift in position of the string holes due to the rise of the belly. It should be noted, however, that for present day wire strung harps constructed in the manner of the historical instruments, the belly develops over a fairly short time period (several months). The belly of the Lamont harp soundbox will have probably developed over a similarly short time period, so this should be taken into account when considering the actual working string lengths for the harp.

The discussion that follows derives proposed string lengths for the Lamont harp in its current state (which represents a 'late' working state), its 'as built' state, and an 'early' working state with a developed soundbox belly. This was accomplished by measuring the current positions of the tuning pins and string holes on the tomograms and utilizing trigonometry and geometry to derive string lengths for a 'straightened' frame with the neck and soundbox restored to their estimated 'as built' configuration.

Reconstruction of string lengths for the frame in its current state

This reconstruction begins by determining the string lengths for the frame of the harp with the frame members in their current positions. Although the frame has suffered significant twisting and damage to its members, there is evidence that it was used in this state during at least part of its working life.[138]

The string lengths for the harp in its current state can be calculated from the CT scan data by measuring the (x, y, z) coordinates of each tuning pin and string hole at the point of contact of the string and applying the distance formula to calculate the distance from string hole to tuning pin:

$$d(P_1, P_2) = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2} \ .$$

With this formula, the coordinates can be used to derive string lengths for any tuning-pin to string hole combination. This has the advantage of making it possible to easily explore any number of different stringing arrangements. As discussed above, there is some ambiguity as to which string hole was strung to which tuning-pin for this harp, and it is probable that different stringing arrangements were used at different times during the working life of the instrument. The string lengths for two

[138] Loomis, "Structural Breaks and Repairs," 24 – 25.

possible stringing schemes described earlier have been calculated: (1) direct stringing, starting from string hole #2 (i.e. string hole #2 – pin #2 : string hole #31 – pin #31); and (2) offset stringing (i.e. string hole #2 – pin #3 : string hole #31 – pin #32). Due to the crack in the neck, however, it is unlikely that a string would have been strung to tuning pin #2 late in the instrument's working life. The string length for that position is included in the direct stringing scheme for the purpose of comparison to the string lengths for the offset stringing scheme. The calculated string lengths for both stringing arrangements are given in table 2.1 on page 91, and a measured diagram of the harp frame in its current state with the offset stringing scheme is shown in figure 2.19.

Reconstruction of string lengths for the 'straightened' frame

As discussed above, string lengths for a 'straightened' frame can be determined by correcting for the relative movement of the tuning pins and string holes that has occurred due to the shifting and bending of the frame members. This can be done by applying some basic rules of geometry and trigonometry to the current positions of the tuning-pins and string holes to derive their positions for a 'straightened' frame, with the neck and soundbox restored to their estimated 'as built' configuration. The method used is described in detail in appendix A, and is briefly summarized here. The 'straight frame' string lengths were determined in three steps. First, the string lengths were adjusted for the forward tilt and backwards shift of the neck such that revised string lengths were derived for the harp with the neck tenon completely seated in the joint with the soundbox. Next, the string lengths were adjusted for the rotation of the neck around its long axis, resulting in string lengths for the harp with the neck upright and the tuning pins parallel to the front face of the soundbox. Lastly, the string lengths were adjusted for the rise of the soundbox belly to derive string lengths for a soundbox with a flat front. The revised (x, y, z) coordinates of the tuning pins and string holes at the points of contact of the strings were also derived from the revised geometry of the frame. The string lengths derived are for the 'straight' stringing scheme (i.e. from string hole #1 - tuning pin #1, to string hole #31

– tuning pin #31), for the frame with and without a soundbox belly. These are given in table 2.1, along with the string lengths for the frame in its current state. Diagrams of the straightened harp frame with the direct stringing scheme are shown in figures 2.20 and 2.21.

The diagrams in figures 2.19 – 2.21 were generated by plotting the coordinates of the tuning pins and string holes and overlaying a tomographic cross-section of the harp, which is shown just in outline for clarity. For the reconstruction of the straightened frame, a separate cross-section taken through the neck (aligned with its center-line) was overlaid on the plotted tuning pin positions. With the neck oriented upright and positioned in its joint with the soundbox, the positions of the pins and of the left-hand cheekband on this cross-section agree with the plotted positions to within the precision of the plotting program. This demonstrates that the values derived analytically for the tuning pin and string hole positions, and for the string lengths, are realistic for this reconstruction of the straightened frame.

Figure 2.19 shows the harp frame in its current state, with 30 strings. These are shown strung starting from string hole #2 – pin #3 down to string hole #31 – pin #32, which is the most plausible stringing scheme for the harp frame in this state, given the evidence discussed earlier. Figure 2.20 shows the harp frame with the neck upright and repositioned, but with the soundbox belly retained. The frame is shown with 31 strings, strung from string hole #1 to tuning pin #1 down to string hole #31 to tuning pin #31. Note that tuning pin #32 is not included in this diagram, as it was likely a later addition. Figure 2.21 shows the frame with the neck repositioned as in figure 2.20, but with the soundbox belly flattened. For this diagram, the positions of the string holes were re-plotted using the coordinates that were derived for a flat fronted soundbox. The harp frame is shown with 31 strings, strung in the same manner as the frame depicted in figure 2.20. The outline of the forepillar in figures 2.20 and 2.21, shown as a dashed line, is speculative and is only included for the purpose of showing the complete frame.

An additional change was made to the reconstruction of the straight frame as depicted in figures 2.20 and 2.21. This has to do with the orientation of the foot of the harp, which does not affect the string lengths in any significant way, but does relate to the 'as built' shape of the soundbox. In its current state, the foot of the soundbox slopes backwards (towards the back of the soundbox). This was observed by Armstrong (1904).[139] At the time he remarked that the angle of the foot follows the slope of the soundbox belly and wondered if it had been carved to this shape. Figure 2.17 shows three tomographic cross-sections of the bass end of the soundbox. The tilt of the foot towards the back of the instrument can be seen in the top two cross-sections. The top one is taken through the centerline of the soundbox and runs through the string holes. The holes nearest the foot (arrowed, at the bass end of the instrument) are angled in the direction of the tilt of the foot, and judging from the rest of the string holes and the shape of the soundbox front, the soundbox itself appears to be arched along its long axis. The lengthwise arch seen in the cross-sections in figure 2.17 appears to involve the entire length of the soundbox, including the foot, which as a consequence is tilted backwards. The foot was not made with this tilt. The evidence for this can be seen in the middle cross-section, which shows the wood grain pattern mirroring the backwards tilt of the foot. The bottom cross-section in figure 2.17 is taken just to one side of the foot, and shows the bottom wall of the soundbox, which is tilted by 6° from the vertical (relative to the back of the box) at this location. This is the same degree of tilt as the neck in the soundbox joint. The pivoting forward of the neck out of that joint has caused it to press down on the forepillar, which in turn has pressed down on the foot at the joint with the soundbox. This, in combination with the strings pulling the front of the soundbox upwards along the string band (which has caused the soundbox to arch along its long axis), has resulted in the observed tilt of the foot. In its 'as built' state, the foot of the soundbox would have been in line with the long axis of the box. Rotating it back by 6° re-aligns it with this axis, and this is how it is shown in the two diagrams illustrating the straightened harp frame.

---

[139] Armstrong, *Irish and Highland Harps*, 159.

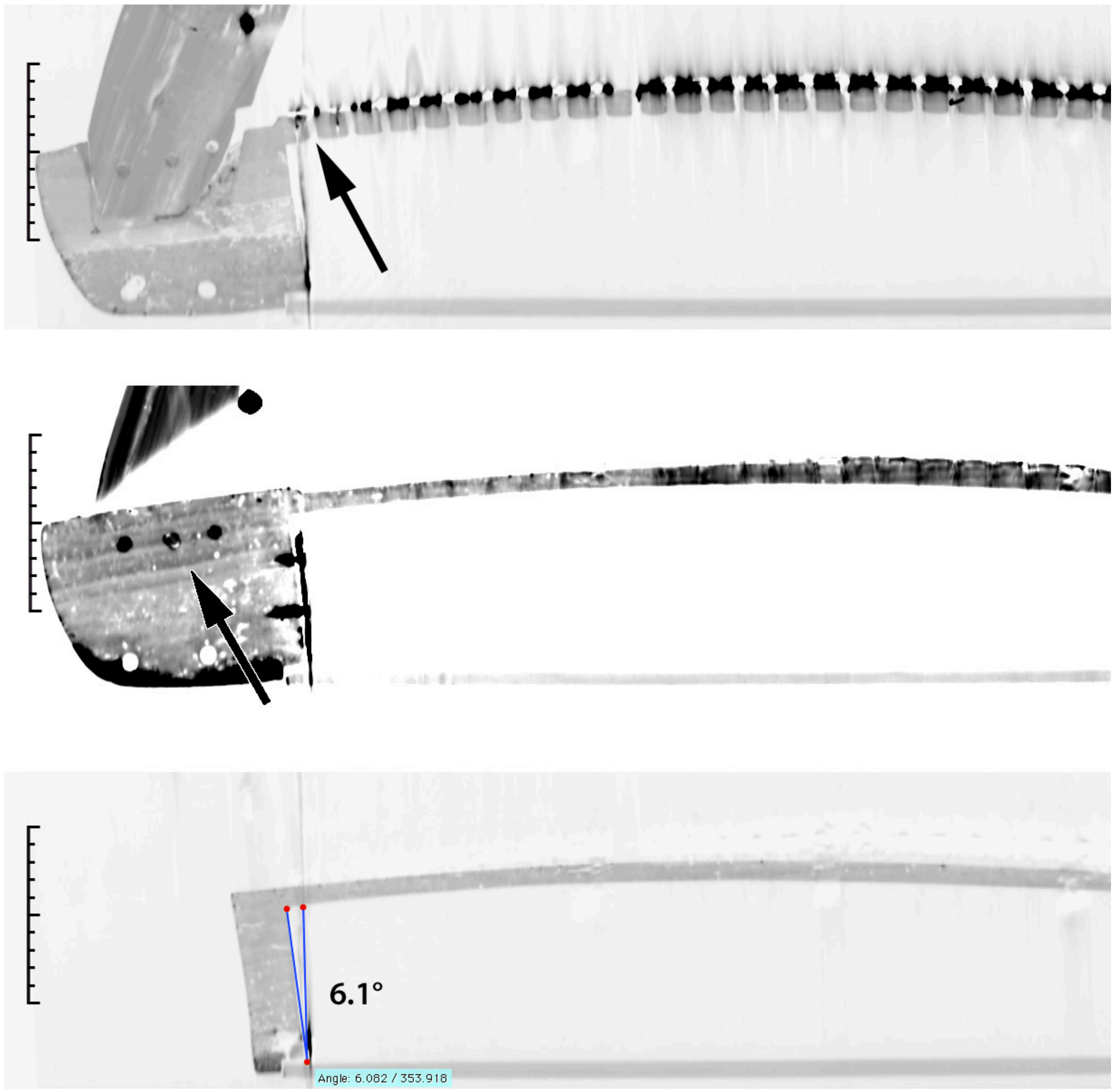


Figure 2.17: *tomographic cross-sections of the Lamont harp soundbox showing the backwards tilt of the foot. The top cross-section passes through the string band. The string holes nearest the foot (arrowed) are angled in the direction of the tilt of the foot. The middle cross section shows the wood grain pattern in the foot (arrowed), which follows the tilt of the foot. The bottom cross-section is located just to the right of the foot, and shows the tilt of the bottom end of the soundbox at this location.*

The backwards tilt of the wall of the soundbox, shown in the bottom cross-section in figure 2.17, can also be seen in the cross-section of the soundbox in figure 2.18. This cross-section, located just above the back cover and back wall of the soundbox, shows the distortion the tilt of the foot has caused at the bass end of the box. The back of the soundbox has been pushed several millimetres in the direction of the treble end of the instrument. This shift becomes noticeable at the treble end of the back of the soundbox when the neck is restored to its original position in the soundbox joint. With the shift, the back of the soundbox would overlap the back of the neck by several millimetres at the treble end of the box. In the diagrams of the straightened frame in figures 2.20 and 2.21, the back of the soundbox is shown terminating at the base of the neck.

A final adjustment to the shape of the soundbox has to do with the neck tenon having pushed the back of the box outwards, as discussed earlier. This is evident from the current position of the tenon as shown in figure 2.13 and from the outline of the back of the soundbox shown in figure 2.19. For the straightened frame in figures 2.20 and 2.21 the back of the box has been drawn as a straight line from the bass end of the box, above the foot, to the base of the neck at the soundbox joint.

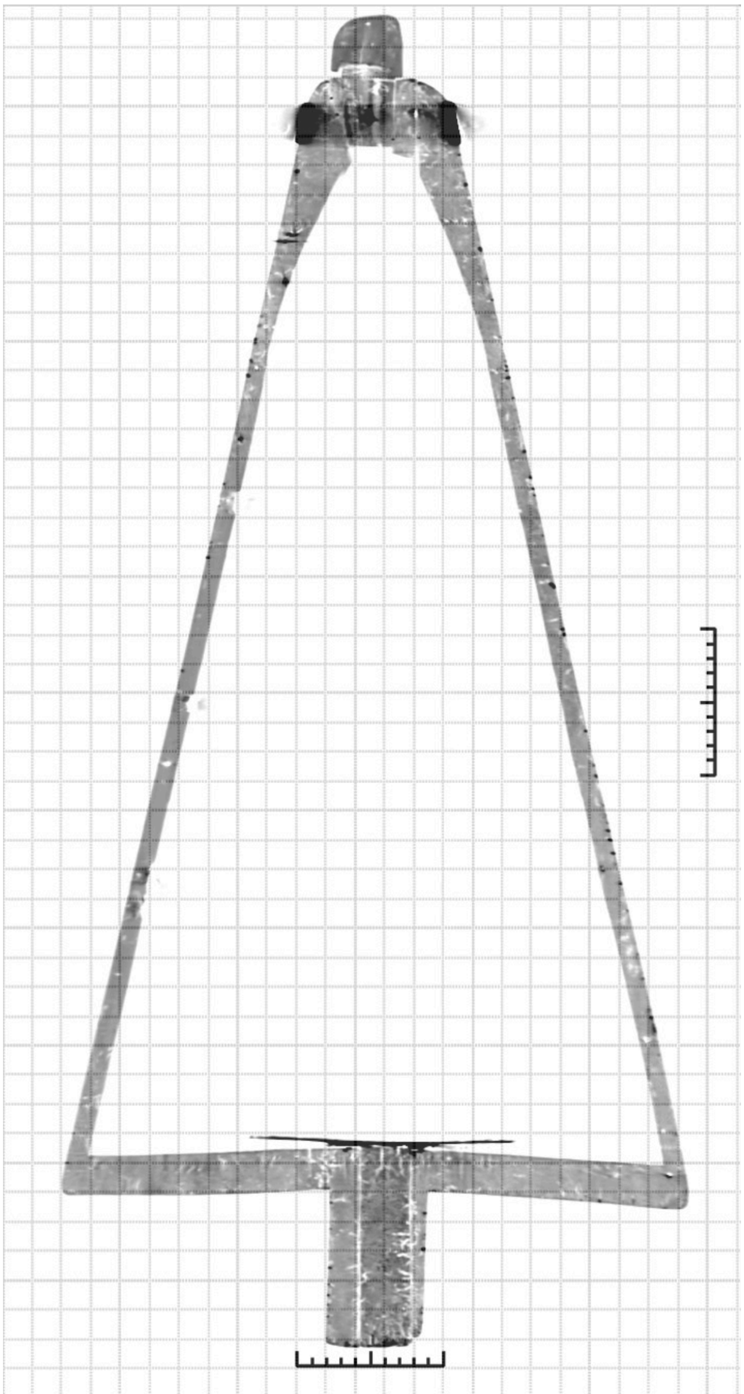
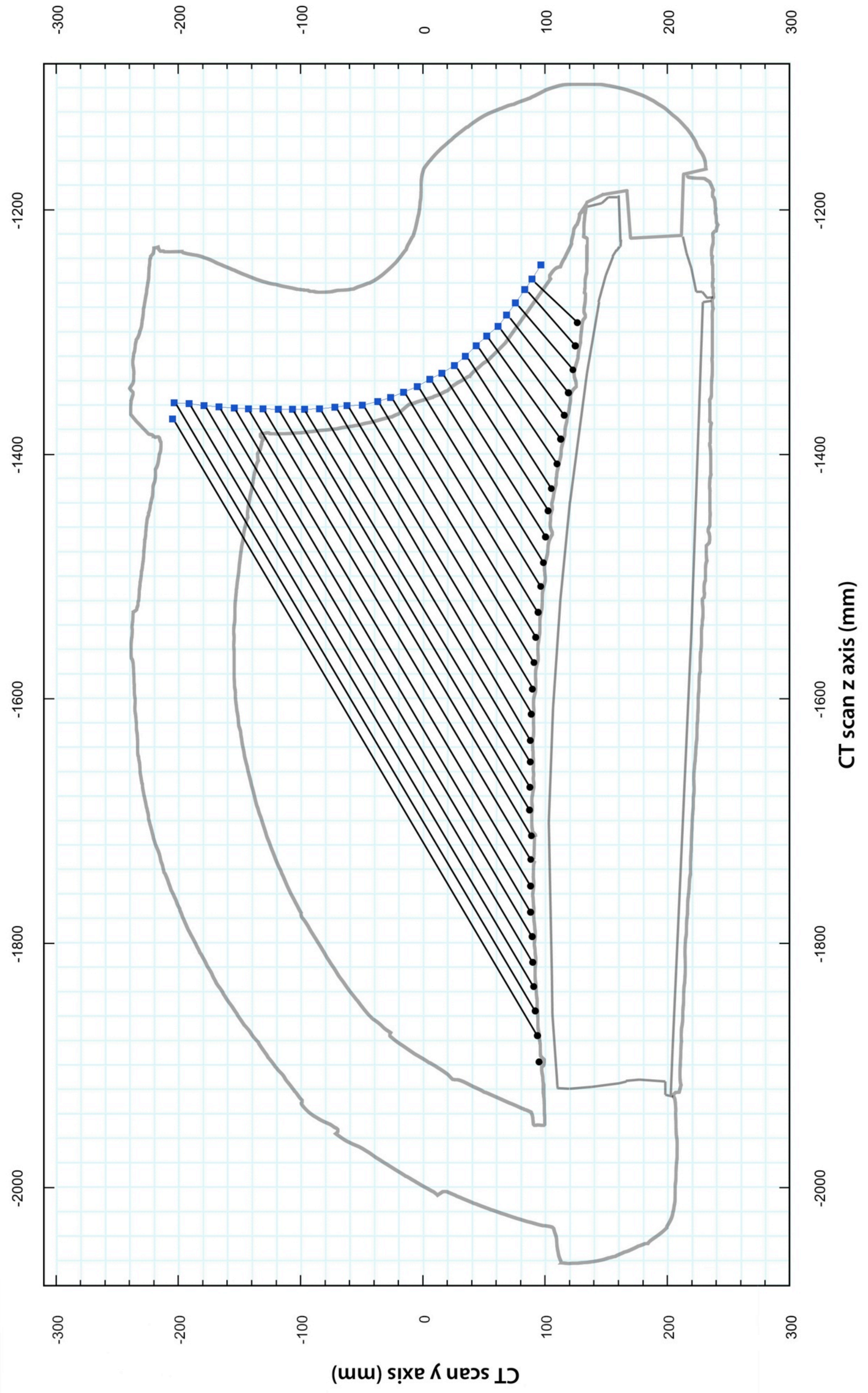


Figure 2.18: *tomographic cross-section of the Lamont harp soundbox. This cross-section is located 2 cm above the back of the box, so does not show the back cover and back wall of the soundbox. The 'upwards' bend in the bass end of the box can be seen against the overlaid grid lines. Grid 1 box : 2 cm; scale 1 tick : 1 cm.*

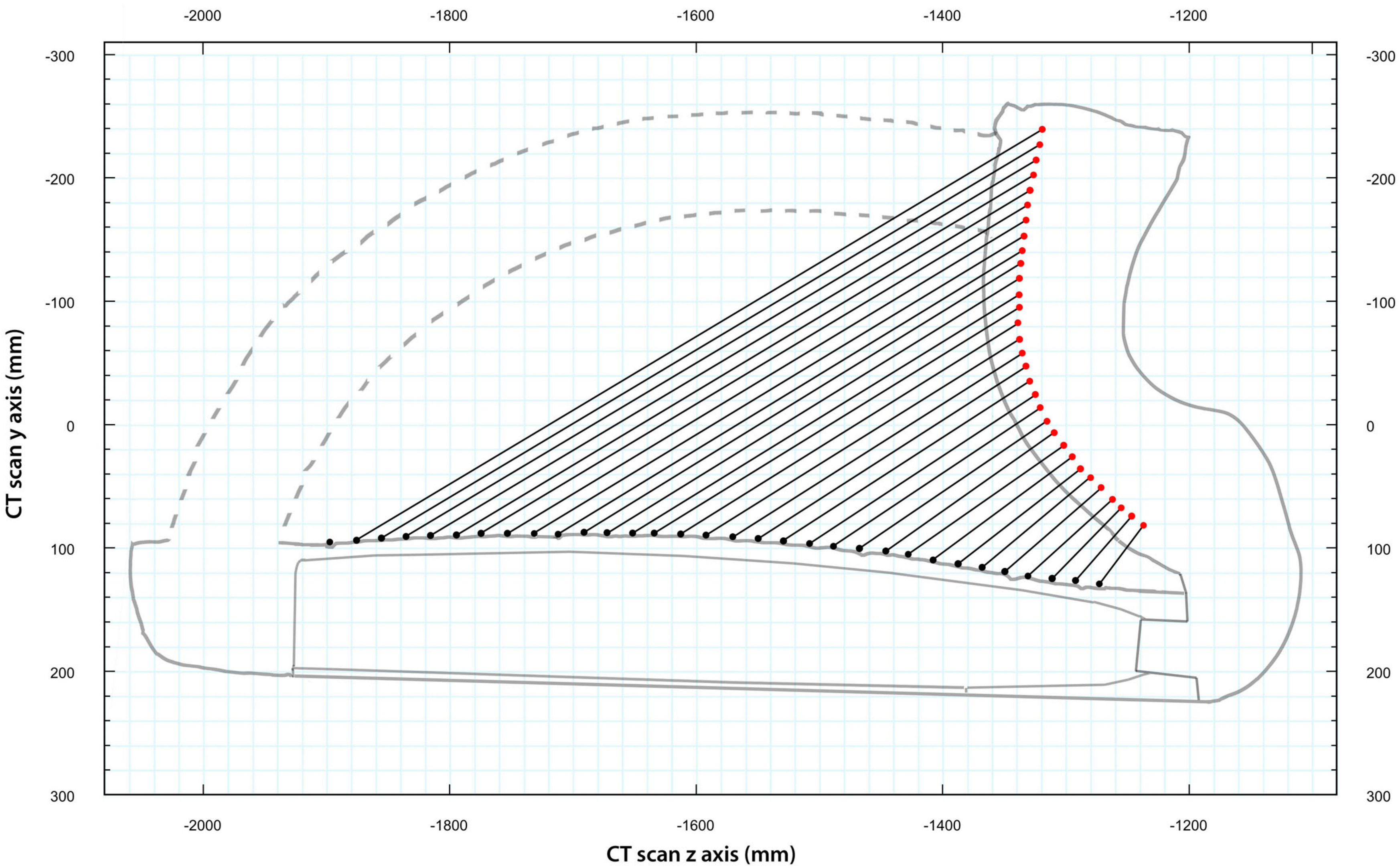
It is important to note that, as a consequence of the design of the instrument, **the strings do not lie in a plane**, even for the straightened frame. The diagrams of the harp frame in figures 2.19 – 2.21 depict the strings as projected onto a plane. Therefore, the string lengths are foreshortened as depicted in the diagrams**,** particularly at the treble end of the instrument. **Measurements of string length should not be taken off the diagrams**. For the actual calculated string lengths, see table 2.1. Also note that **the points plotted at the ends of the strings are the points of contact only. They are not the centre points of the tuning pin holes and string holes.**

Figure 2.19 (overleaf): *the frame of the Lamont harp in its current state. This outline has been taken from a tomogram, and shows the shape of the frame and the strings as projected onto a plane. Because the neck and forepillar actually project out of the plane, towards the viewer, they appear foreshortened. The black circles and blue squares are the points of contact of the strings at the string shoes and tuning pins, respectively, plotted from the measured coordinates taken from the CT data. The frame is shown strung with 30 strings, starting with string hole #2 – tuning pin #3, in the treble. String holes #1 and #32 are shown unstrung. Scale: 1 box : 2 cm.*



CT scan z axis (mm)
CT scan y axis (mm)
-1200
-1400
-1600
-1800
-2000
-300
-200
-100
0
100
200
300

Figure 2.20 (overleaf): *the frame of the Lamont harp, corrected for the rotation and shift of the neck. The black circles are the points of contact of the strings at the string shoes, plotted from the measured coordinates taken from the CT data. The red circles are the calculated points of contact of the strings at the tuning pins, corrected for the repositioning of the neck. The outline of the neck has been taken from a tomographic cross-section through its centre. This has been positioned with the neck tenon completely seated in the soundbox joint. The back of the soundbox has been redrawn to remove the bulge at the treble end (compare with figure 2.19). This bulge appears to have been caused by the rotation and backwards shift of the neck, which has caused the tenon to push the back of the soundbox outwards. The frame is shown strung with 31 strings, starting with string hole #1 – tuning pin #1, in the treble. As for figure 2.19, string hole #32 is shown unstrung. Tuning pin #32 is not shown, as it appears to be a later addition. The outline of the forepillar, shown as a dashed line, is speculative and is only included to show the complete frame. Scale: 1 box : 2 cm.*



-2000
-1800
-1600
-1400
-1200
-300
-200
-100
0
100
200
300
CT scan y axis (mm)
CT scan z axis (mm)

Figure 2.21 (overleaf): *the frame of the Lamont harp, corrected for the rotation and shift of the neck, and the rise of the soundbox belly. The black circles are the points of contact of the strings at the string shoes, plotted from the calculated positions for a flat fronted soundbox. The remainder of the diagram is the same as shown in figure 2.20. Scale: 1 box : 2 cm.*

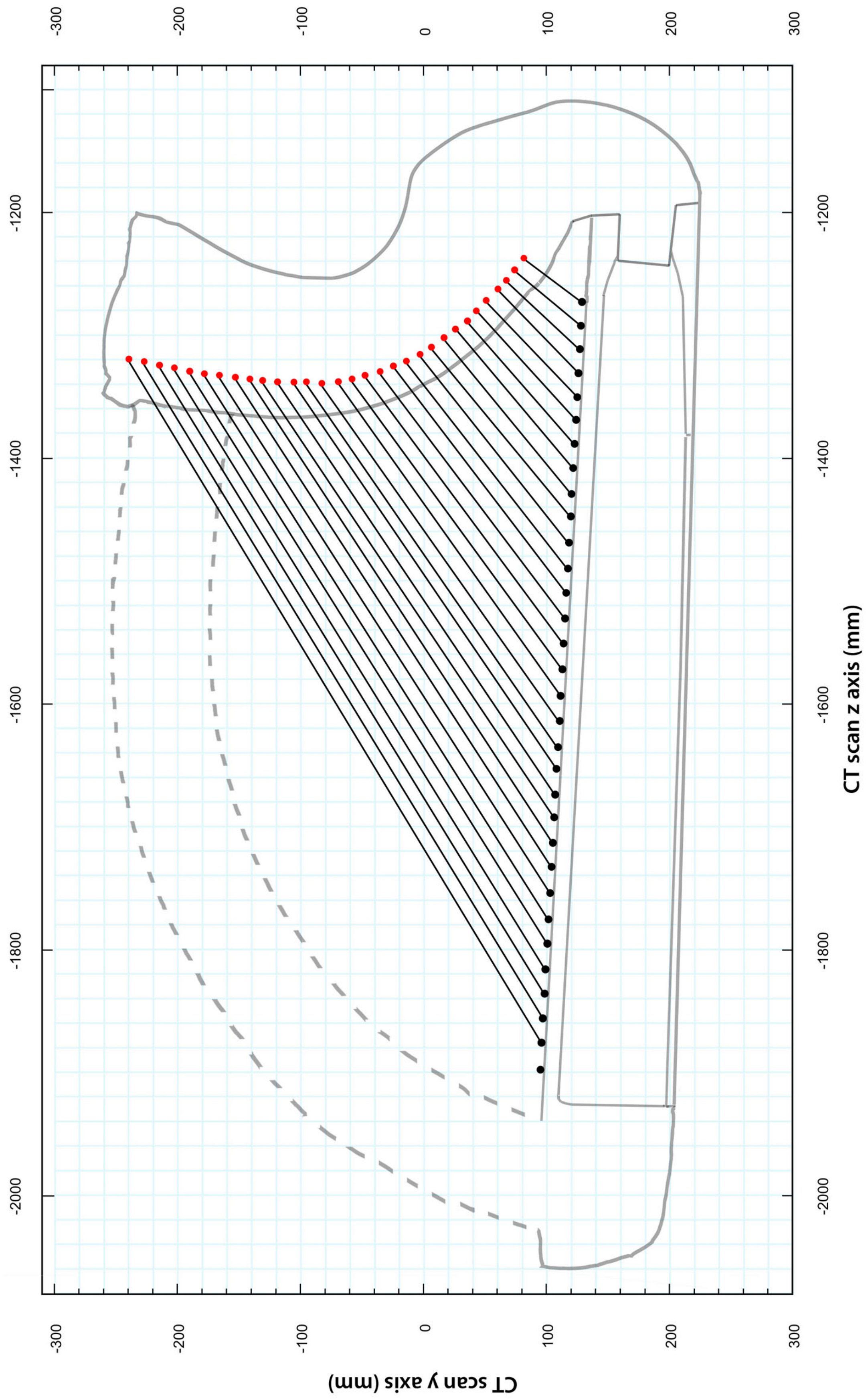

CT scan z axis (mm)
CT scan y axis (mm)
-1200
-1400
-1600
-1800
-2000
-300
-200
-100
0
100
200
300

Table 2.1.

Lamont harp string lengths

	offset stringing		direct stringing			
string #	**hole – pin**	**current frame (mm)**	**hole – pin**	**current frame (mm)**	**straight frame (mm)**	**straight frame no belly (mm)**
1	2 – 3	57	1 – 1	(53)	67	67
2	3 – 4	66	2 – 2	(61)	76	77
3	4 – 5	77	3 – 3	70	85	87
4	5 – 6	86	4 – 4	81	97	99
5	6 – 7	96	5 – 5	90	108	111
6	7 – 8	108	6 – 6	99	118	123
7	8 – 9	121	7 – 7	110	129	135
8	9 – 10	133	8 – 8	123	143	151
9	10 – 11	145	9 – 9	135	157	166
10	11 – 12	162	10 – 10	147	170	180
11	12 – 13	180	11 – 11	162	186	197
12	13 – 14	196	12 – 12	179	204	215
13	14 – 15	215	13 – 13	195	222	233
14	15 – 16	233	14 – 14	213	240	252
15	16 – 17	253	15 – 15	231	260	272
16	17 – 18	275	16 – 16	250	280	293
17	18 – 19	298	17 – 17	271	302	314
18	19 – 20	321	18 – 18	292	324	337
19	20 – 21	341	19 – 19	317	350	362
20	21 – 22	365	20 – 20	335	370	381
21	22 – 23	386	21 – 21	359	395	405
22	23 – 24	411	22 – 22	381	417	428
23	24 – 25	435	23 – 23	405	442	451
24	25 – 26	459	24 – 24	428	466	475
25	26 – 27	485	25 – 25	453	493	500
26	27 – 28	510	26 – 26	478	518	526
27	28 – 29	535	27 – 27	502	544	550
28	29 – 30	561	28 – 28	528	571	576
29	30 – 31	586	29 – 29	553	597	601
30	31 – 32	594	30 – 30	579	623	626
31	–	–	31 – 31	603	649	651

Note: the uncertainty in the string lengths is +/- 1 mm for both the measured and reconstructed string lengths. This, however, just represents uncertainty in measurements taken from the tomograms.

Stringing regimes for the Lamont harp

The states of the harp frame discussed in detail above present a picture of the instrument in the early, middle, and late stages of its working life. As also discussed, the string lengths and the arrangement of the stringing would have changed as a result of the changes to the shape of the frame and the damage to the tuning-pin holes. This section discusses the string scaling of the instrument in these different states and proposes some possible solutions for the stringing regimes.

The Lamont harp string lengths given in table 2.1 are plotted together in figure 2.22, showing the comparative differences between them for the different states of the harp frame.

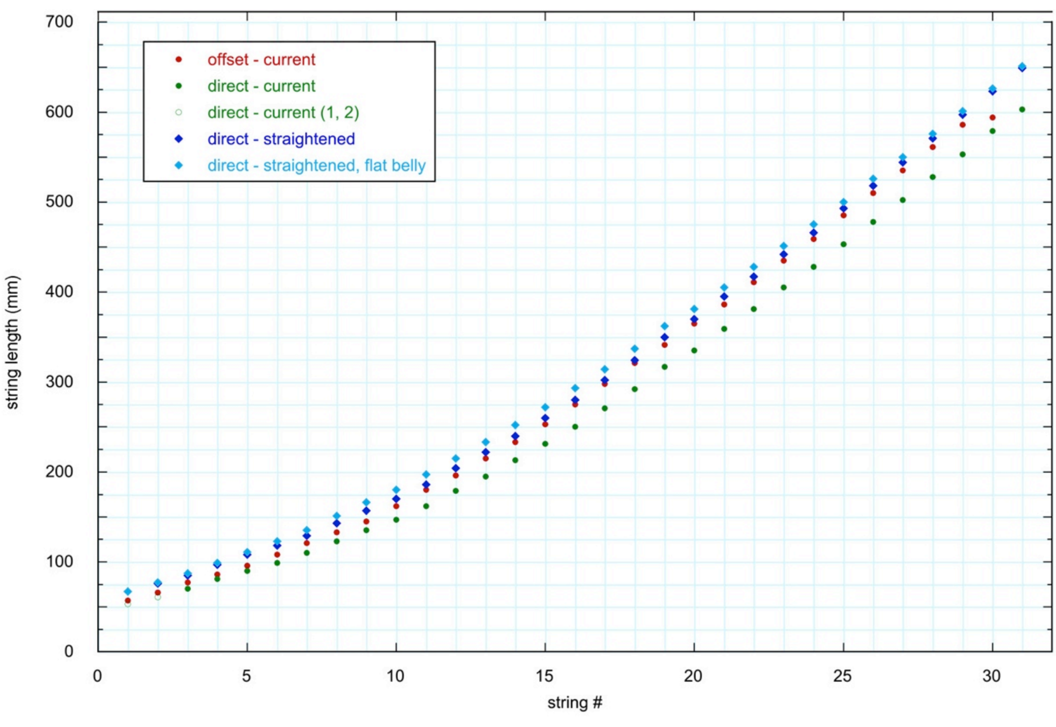


Figure 2.22: *string length versus string number for the Lamont harp. The stringing schemes shown are for the frame in its current state (offset stringing (red), and direct stringing (green)), and the straightened frame with direct stringing (with developed soundbox belly (dark blue), and with a flat soundbox (light blue)). The first two points of the plot of the direct stringing for the frame in its current state are shown as open circles, as it would not be possible to string to the #1 and #2 tuning-pins due to the damage to the neck.*

The graph in figure 2.22 illustrates the effect the twisting of the frame has had on the string lengths. The frame in its current state, with direct hole to pin stringing, has the shortest string lengths overall. The lowest string in the bass is nearly 50 mm shorter than the same string for the reconstruction of the straight frame. This is a difference of 7% of the total length of the string, and although the difference in length is comparatively smaller towards the treble end of the harp, as a percentage of the total length it increases to about 15% in the midrange of the instrument, and up to 20% in the treble. For the frame in its current state, the offset stringing described earlier appears to be a better option. The effect on the string lengths of offsetting the stringing (starting in the treble with string hole #2 strung to tuning pin #3) can be seen in the graph. The advantage of this stringing scheme is evident in that the string lengths are much closer to those for the straightened frame. With this scheme the difference in length as compared to the reconstructed straight frame is reduced to 2.5% in the bass, about 7.5% in the mid-range, and 15% in the treble. The exception is the bottom string. Strung from hole #31 to the added 32nd tuning-pin, this string is comparatively short. This is a consequence of the placement of the 32nd tuning pin below the cheekbands. Stringing to this additional tuning pin, however, makes up for the loss of one of the top two tuning pin holes. As noted earlier, another advantage of this offset stringing scheme is that it compensates for the reduction of the angle of the strings to the soundboard caused by the shift in position of the neck. Note that all of this is accomplished without changing the frame; only the manner in which it is strung has been changed. This stringing scheme, if used, would have been a resourceful solution to the issues caused by the shifting of the frame members and the loss of the top two tuning pin positions.[140]

The reconstruction of the straightened frame has the longest string lengths overall. These are plotted in figure 2.22 with and without the soundbox belly. The effect of the belly on the string lengths in the mid-range of the compass is apparent. This does raise the pitch of the instrument slightly. As discussed below, however, the change is

[140]Ann and Charlie Heymann have suggested that offset stringing may have been employed historically on some Irish harps to change the overall string lengths, particularly in instances where the number of string holes differs from the number of tuning-pin holes. The idea for using an offset stringing scheme on the Lamont harp frame originates from this concept.

small because the highest stressed strings are in the treble, where the difference in string length due to the belly is less than it is in the mid-range.

In order to see the scaling of the instrument, the string lengths are plotted logarithmically in the graph in figure 2.23. Pythagorean scaling would generate a straight line in this plot. The decreasing 'slope' towards the bass indicates the short scaling at this end of the compass, as would be expected. Note that the scaling is different for the different stringing schemes. The effect this has on the overall pitch of the instrument is discussed below along with some possible solutions for the pitch of this harp for each of the states of the frame.

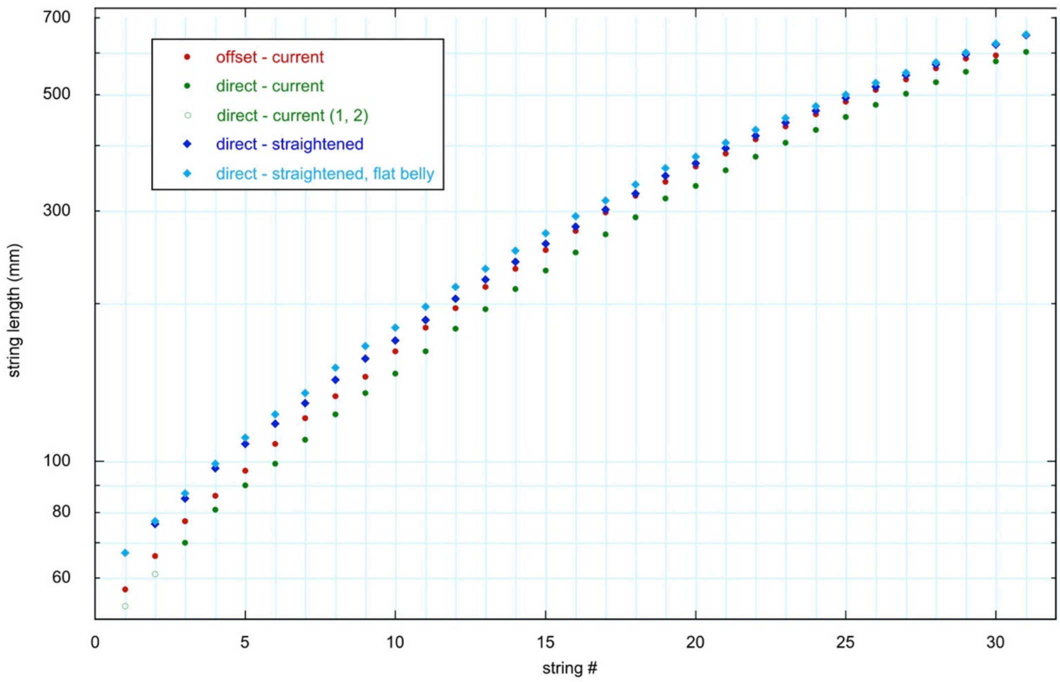


Figure 2.23: *string length versus string number for the Lamont harp, plotted on a logarithmic scale to show the scaling. A decreasing slope towards the bass indicates a 'short scaling' in this region of the compass (i.e. the string lengths are shorter than for Pythagorean scaling).*

The designated pitch of the instrument (i.e. the pitch of the note A above Middle C) depends on the assignment of note names to the strings as well as the string scaling. The note names are not known for this harp, however. The earliest information on the compass of Irish harps comes from Vincenzo Galilei (1581), Michael Praetorius (1619), and James Talbot (late 17th century).[141] Writing at the end of the 18th century, as mentioned earlier, Edward Bunting also provides the tuning for the Downhill harp, which was constructed in 1702.[142] The information these writers provide is summarized in table 2.2, below.

Table 2.2.
Some early historical references to number of strings and compass

Author	Date of writing	Date of harp	# of strings	lowest note	highest note	# of octaves	position of unison strings
Galilei	1581	–	58 (Italian harp)	C	d‴	4 (+1 note)	–
Praetorius	1619	–	43	C	e‴	4 (+2 notes)	–
Talbot	circa 1695	–	36 also 40, 43	GG	g‴	5	middle of compass "C (if not g)"
Bunting	1792 ff., 1840	1702 'Downhill'	30	C	d‴	4 (+1 note)	19, 20 g

The information from Galilei is actually for the Italian double harp. Galilei draws a comparison between this type of harp and information he has for an Irish harp, however, stating that the arrangement of stringing for the Irish harp is the same as the Italian harp, and proceeds to describe a 58-string Italian double harp with a compass of "four octaves plus one tone", from C to d‴.[143] It isn't clear from his text what notes were assigned to the strings of Irish harps, for which he only states, "the strings

[141] Galilei, *Ancient and Modern Music*, 358; Praetorius, *Syntagma musicum II*, 54; Rimmer, "James Talbot's Manuscript," 66 – 67.
[142] Bunting, *Ancient Music of Ireland*, 23. See also, Edward Bunting, *MS 29*, manuscript, Queen's University Belfast Library, Special Collections, *Bunting Manuscript Collection*, folio 77 r., 156.
[143] Galilei, *Ancient and Modern Music*, 357 – 58.

number fifty-four, fifty-six, or as many as sixty".[144] Praetorius describes a 43-string Irish harp with a compass of four octaves plus two notes, from C to e‴.[145] Talbot describes a 36-string Irish harp with a compass of five octaves, from GG to g‴.[146] He also notes that Irish harps can have 40 – 43 strings, adding that, "some lately made in England have 35 strings."[147] According to Bunting's notes, the harp played by Denis O'Hampsey (later known as the 'Downhill harp') was strung with 30 strings, from C to d‴, with a compass of four octaves plus one note.[148] His diagram of the gamut of the harp in staff notation indicates the position of the unison strings at g below c′.

The information from these writers may, or may not, be applicable to the Lamont harp. The harps referred to are not all from the same time period as each other, and it is possible that none is contemporary with the construction of the Lamont harp. The number of strings is also significantly different than the number on the Lamont, with the exception of the Downhill harp. The Downhill, however, is of the later 'high-headed' form of the instrument. As such, it has a somewhat different construction and longer scaling in the bass as compared to the Lamont harp. The Irish harps Galilei and Praetorius refer to are notably different from the Lamont in that they appear to be chromatic, not diatonic, instruments (the note names Praetorius lists for the compass of the Irish harp includes chromatics, and the number of strings quoted by Galilei is too large for a diatonic scale of the given compass).[149] The harps these two writers refer to can, however, be compared to the Cloyne, an Irish harp constructed in 1621, which was designed for 52 strings, with seven in a second, possibly chromatic, rank.[150]

An additional issue is the question of the accuracy of the historical information, in particular the information from Galilei and Praetorius. It is apparent that Talbot and

---

144 ibid.
145 Praetorius, *Syntagma musicum II*, 54.
146 Rimmer, "James Talbot's Manuscript," 66 – 67.
147 ibid., 67.
148 Bunting *MS 29*, f. 74 v. (numbered 153). Denis O'Hampsey's name is Anglicized by Bunting as "Dennis Hempson".
149 Galilei, *Ancient and Modern Music*, 358; Praetorius, *Syntagma musicum II*, 54.
150 Billinge and Shaljean, "Dalway or Fitzgerald Harp," 176.

Bunting examined Irish harps first hand. Galilei, however, appears to have acquired his information on the Irish harp second hand and, although he states that the stringing arrangement is the same as for the Italian harp, he does not elaborate on this point so it is not clear how closely or in what manner the stringing of the Irish harp actually corresponds to that of the Italian harp. Praetorius provides a complete list of notes for the strings of the Irish harp, but the order of the chromatics he includes is curious, raising the question as to whether or not all of his information is correct.[151]

With the understanding that the information provided by these writers may not be entirely accurate or applicable, in the absence of better information it is used here as a starting point for assigning notes to the strings of the Lamont harp. The resulting solutions for the stringing regimes presented here are, as a consequence, only provisional.

Galilei, Praetorius, and Bunting agree on C as the lowest note of the instrument, so C is chosen here, initially, as the lowest note for the stringing regimes derived for the Lamont harp. The octave to which this C belongs will be evident from the string lengths. A stringing regime starting on F is also presented (the justification for this, and its relationship to the stringing from C will be described).

It is evident from the scaling of the Lamont harp that the tuning is essentially diatonic, however the possibility of the presence of unison strings, and of a gap in the bass tuning should also be considered. Historical information on the stringing of Irish harps does indicate the presence of a pair of strings tuned to a unison located near, or somewhat below, the middle of the range of these instruments. Although Galilei and Praetorius do not mention unison strings for the Irish harp, they are specifically noted by Bunting and Talbot as well as other writers.[152] This pair of strings was usually referred to as "ne cawlee" (with variant spellings) or as "the sisters".[153] A survey of

[151] Praetorius, *Syntagma musicum II*, 54.
[152] Chadwick, "Sister Strings."
[153] ibid. "Ne cawlee" is a phonetic English spelling of the Irish and Scottish Gaelic term. The translation from Irish of this term is not fully clear. In Bunting (1840) it is spelled as *caomhluighe* but also as *combh luighe*, and translated as 'lying together' and 'equally

the historical evidence for its inclusion and location in the gamut of Irish harps is discussed in Chadwick (2009).[154] The presence of this pair of strings is noted in 17th – 19th-century texts, with a possible early reference dating to the 14th century as well as a possible 12th-century reference, although this last is somewhat uncertain.[155] Possible additional evidence is contained in the tunings diagramed in the "Robert ap Huw" manuscript (BL MS Add. 14905), which include a tuning for the Welsh single rank harp labeled *y lleddf gywair y gwyddil* ("the Irishman's re-tuning"), that includes two pairs of unison strings in each octave.[156]

For the Downhill harp, Bunting places the pair of 'ne cawlee' strings at the g below c′. Talbot places them at the "middle" of the harp. Referring to them as a "Wolf", he states,

> "The Instrument tun'd gradually from the highest Treble to the middle insert then a Unison those two call'd a Wolf the rest arrived gradually thus supposing that in 36 strings the 1st is ggg the last ΓΓ which includes 5 octaves the Wolf shall be C (if not g)."[157]

Of the unison strings, Bunting shows in his manuscript notes that the strings from the upper unison to the treble end of the instrument were intended to be played by the left hand, and the strings from the lower unison to the bass end of the instrument by the right hand.[158] He also writes that the unison string pair "nearly divided the instrument into bass and treble."[159] Judging from Bunting's observations, this pair of strings can be thought of as dividing the instrument into a bass and a treble voice,

---

stretched', respectively. The Irish word *comhluigh* is equivalent to "co-lie" in English, and *comhluí* translates as 'lying together'. The same term is translated as "the companions" in John Bell's notes taken down from the harper Patrick Byrne. This may derive from *na céilí* which means 'the companions' in both Irish and Scottish Gaelic. See Bunting, *Ancient Music of Ireland*, 21, 32; Henry George Farmer, "Some Notes on the Irish Harp," *Music & Letters*, 24, no. 2 (1943): 102.

[154] Chadwick, "Sister Strings."

[155] ibid.

[156] Henry Lewis, ed. *Musica: B. M. Additional MS. 14905* (Cardiff: University of Wales Press Board, 1936), 108 – 09; Robert Evans, "Robert ap Huw's Harp Tunings", *Welsh Music History*, 3 (1999): 337. The 'Robert ap Huw' manuscript (BL Addl. 14905) dates to the early 17th century, but appears to have been copied from earlier manuscripts.

[157] Rimmer, "James Talbot's Manuscript" 67.

[158] Bunting *MS 29*, f 38v. (numbered 81).

[159] Bunting, *Ancient Music of Ireland*, 21.

where the highest note of the bass voice is tuned to the same pitch as the lowest note of the treble voice. Based on the historical information, a pair of unison strings is therefore included in the tuning proposed here for the Lamont harp.

Bunting also noted the presence of a gap in the bass tuning, stating that, "the Irish harp had no string for F sharp, between E and G in the bass."[160] This gap is included in the scale he diagrams for the Downhill harp. The gap, as described by Bunting, occurred at E/F in the bass, whereby the string directly below G could be tuned to either E or F, depending on the tuning of the rest of the instrument. According to Bunting's description, when the F-strings on the harp were tuned to F-sharp, this string would be tuned to E, whereas when the F-strings were tuned to F-natural, this string would be tuned up to F-natural.[161] Bunting further notes that when tuned to E, this string was referred to as *tead leagtha,* meaning the "fallen string" (*leagtha* = knocked, thrown, or put down), and when tuned to F-natural it was referred to as *tead leaguidh* the "falling string" (possibly *leagaidh* ≈ of putting down).[162] So, for the tuning with F-sharps, the first four bass strings were tuned to C, D, E, G, and for the tuning with F-naturals, these strings were tuned to C, D, F, G. It is not known if the earlier Irish harps had a similar gap in the bass. As a comparison, however, the repertory of the Robert ap Huw manuscript, which happens to also have C as its lowest note, has no E in the bass.[163] So, the implied first four notes of the bass scale in this case are also C, D, F, G. The tuning scheme proposed here for the Lamont harp includes the gap in the bass, as described by Bunting for the Downhill harp, with the understanding that this is only one possible solution. The solutions for the scaling and pitch, discussed below, would be the same for the instrument if both the unison string and the gap in the bass were omitted. The inclusion of the unison string

---

160 Bunting, *Ancient Music of Ireland*, 23.
161 ibid.
162 Colm Ó Baoill notes that the genitive of *leag* is *leagtha* in Irish, but is *leagaidh* in Scottish Gaelic. Colm Ó Baoill, "Tead leagaidh - Falling string Tead leagtha - The string fallen" ed. Simon Chadwick, 2002, last modified 2008, http://www.earlygaelicharp.info/Irish_Terms/22.htm. Dennis O'Hampsey was from Magilligan in Co. Derry, on the north coast of Ireland, so perhaps this form of the word was in his dialect.
163 Sally Harper, *Music in Welsh Culture Before 1650: A Study of the Principle Sources* (Aldershot: Ashgate, 2007), 144.

shifts the note names down towards the bass by one string, and the inclusion of the gap in the bass shifts the note names up towards the treble by one string. So, in terms of the compass of the instrument, these two alterations to the diatonic scale cancel each other out.

A proposed tuning scheme for the Lamont harp for both the 'as built' and current states of the frame is shown in table 2.3. Note that the stringing used for the current frame is the offset stringing described earlier. The string lengths from table 2.1 are reproduced here for reference. As noted earlier, the string lengths for the current frame are actual measurements taken from the frame of the harp, whereas the string lengths for the straightened frame are reconstructions.

Table 2.3.

Proposed compasses for the Lamont harp, from c in the bass

	straightened frame (no belly) direct stringing		current frame offset stringing	
string #	length (mm)	note	length (mm)	note
1	67	e''''	57	d''''
2	77	d''''	66	c''''
3	87	c''''	77	b'''
4	99	b'''	86	a'''
5	111	a'''	96	g'''
6	123	g'''	108	f♯'''/f'''
7	135	f♯'''/f'''	121	e'''
8	151	e'''	133	d'''
9	166	d'''	145	c'''
10	180	c'''	162	b''
11	197	b''	180	a''
12	215	a''	196	g''
13	233	g''	215	f♯''/f''
14	252	f♯''/f''	233	e''
15	272	e''	253	d''
16	293	d''	275	c''
17	314	c''	298	b'
18	337	b'	321	a'
19	362	a'	341	g'
20	381	g'	365	g'
21	405	g'	386	f♯'/f'
22	428	f♯'/f'	411	e'
23	451	e'	435	d'
24	475	d'	459	c'
25	500	c'	485	b
26	526	b	510	a
27	550	a	535	g
28	576	g	561	e/f
29	601	e/f	586	d
30	626	d	594	c
31	651	c	-	-

For the straightened frame, the compass of the instrument is 4 octaves plus 2 notes, from c to e'''', with the pair of unison strings located at strings #20 and #21, and for the current frame the compass is c to d''''.

The overall pitch of the instrument for this proposed compass depends on the length of the highest stressed strings. These were identified by scaling the string lengths to the equivalent length of the string designated as c''. The scaled lengths for these proposed compasses for the straightened frame and the current frame are shown in figure 2.24.

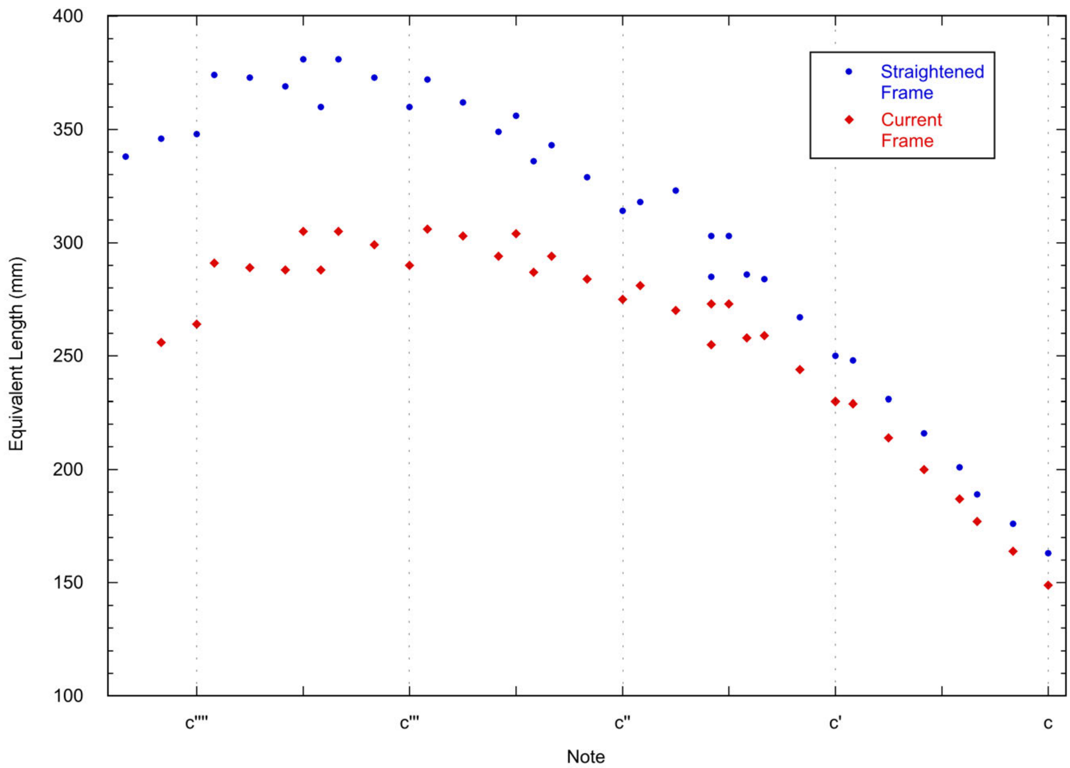


Figure 2.24: *stress curves for the stringing of the Lamont harp, based on a proposed compass of c - e'''' for the straightened frame and c - d'''' for the frame in its current state (see table 2.3). The string lengths have been scaled to the equivalent length of the c'' string for each version of the frame. The equivalent string lengths are represented as blue dots for the straightened frame and as red diamonds for the current frame. The highest stressed strings are identified as those with the longest equivalent length.*

For the straightened frame, the scaling for this compass is 381 +/- 3 mm, based on the equivalent length of the highest stressed strings. For the frame in its current state, with offset stringing, the scaling for the proposed compass is 306 mm +/- 2 mm.[164]

Assuming a yellow brass scaling of 270 mm for c″ at A440, this places the pitch of the instrument at around 310 – 314 Hz for the straightened frame, and at around 386 – 391 Hz for the current frame.[165] These may be considered as optimal pitch for the instrument with this proposed compass and stringing material.[166]

These solutions for the pitch of the instrument, particularly for the straightened frame, which is a reconstruction of the instrument 'as built', are quite low, but are plausible when considered in the context of what is currently known about historical pitches. Haynes (2002) discusses the pitch systems known as "Organ-pitch" and "Quire-pitch", which were in use in the 16th and 17th centuries. These two systems are related by a transposition of a 5th up the scale (or a 4th down). In "Organ-pitch", the bottom note of the organ is a C, and this is understood to have been the lowest note of the compass used when the organist was performing solo. When accompanying a choir, however, the note names were shifted so that the bottom C was renamed F, effectively transposing the pitch of the organ to what is referred to as "Quire-pitch".[167] Haynes quotes Nathanial Tomkins (writing in 1665) describing the "10-foot" pipe of the Worcester Cathedral organ as "double F fa ut of the quire pitch & according to Guido Aretines scale (or as some term it double C fa ut according to y[e]

---

[164] The uncertainty is based on an uncertainty of +/- 1 mm in the string length, carried through the calculation for scaling the length to c″.
[165] This result is determined from the relation for change in pitch for a given change in string length: $[log(l_1/l_2)] \times k = \Delta\, cents$, where $k \;=\; 1/\left[log\left(\sqrt[100]{\sqrt[12]{2}}\right)\right]$, and $f_1/f_2 \;= l_2/l_1$, where *f* and *l* are the frequencies and string lengths. For the scaling of yellow brass, see Murray Campbell, Clive Greated, and Arnold Myers, *Musical Instruments: History, Technology, & Performance of Instruments of Western Music* (Oxford: Oxford University Press, 2004), 308.
[166] This pitch assumes the wire is tuned a whole tone below its snapping pitch. The instrument could be pitched lower, probably by as much as a whole tone, and still retain a useable quality of tone, however if pitched more than a semitone higher there is a risk of snapping the highest stressed strings.
[167] Bruce Haynes, *A History of Performing Pitch: The Story of* "*A*" (Oxford: The Scarecrow Press, 2002), 88 – 89. See also Darryl Martin, "The English Virginal," (PhD diss., University of Edinburgh), 72.

keys & musiks)".[168] Based on measurements of surviving unaltered English organ pipes, Haynes places "Quire-pitch" in England at about A473 and "Organ-pitch" at about A317 (or A634, an octave higher, depending on octave assignment).[169] There are also surviving instruments pitched at multiples of a semitone below "Organ-pitch" or "Quire-pitch", specifically 1, 2, and 3 semitones lower. Martin (2003) has established that 17th-century English virginals were constructed for Quire pitch, and for the intervals of 1, 2, and 3 semitones below, with the instruments constructed at "Quire-pitch" predominating.[170] With regard to the absolute pitch of "Quire-pitch", he notes that A474 (essentially the same pitch that Haynes gives) was most common in the 17th century (based on Gwynn, 1985).[171]

At 310 – 314 Hz, the pitch derived for the straightened frame of the Lamont harp, with a compass starting on C as the lowest note, happens to be close to Haynes's "Organ-pitch" of 317 Hz. If the note names are shifted to start on F, in the manner of the transposing organs, the scaling of the harp converts to 252 – 256 mm, which translates as a pitch of 464 – 471 Hz, corresponding closely with "Quire-pitch" as described above. This also coincides with a common pitch standard in use in Europe in the late 16th and early 17th centuries, referred to as *mezzo punto* or *cornet-ton*.[172] According to Haynes, this was the "normal" pitch for Venetian woodwinds, which were exported throughout Europe and in wide use in the 16th and 17th centuries.[173] Based on surviving cornets, this pitch averaged around 466 Hz, with slightly more than half of these instruments falling within the range of 460 – 471 Hz.[174]

The pitch for the harp in its current state (for the proposed compass, starting on C in the bass), 386 – 391 Hz, should not be expected to agree with any particular pitch standard, as it is a consequence of damage to the harp frame. The frame of the

---

[168] Haynes, *Performing Pitch*, 88.
[169] ibid., 88 – 89.
[170] The other pitches are multiples of a semitone below this pitch (1, 2, and 3 semitones) in concurrence with the pitch groupings for organs of this period. Martin, "The English Virginal," 75.
[171] ibid.
[172] Haynes, *Performing Pitch*, 58 – 60, and 78 – 79.
[173] ibid., 97.
[174] ibid., 60.

Lamont harp would have been in this state late in its working life, probably from sometime in the 17th century until the death of John Robertson of Lude in 1731.

The C and F bass tuning schemes for the Lamont harp are shown together in table 2.4. Note that for the C bass scheme the unison strings are placed at g′, whereas for the F bass scheme the same strings occur at c′. This could provide a possible explanation for Talbot's remark that the unison strings "shall be C (if not g)."[175]

[175] Rimmer, "James Talbot's Manuscript," 67.

Table 2.4.

Proposed compasses for the Lamont harp
from c and F in the bass
(**reconstructed string lengths for the straightened frame with no soundbox belly**)

string #	**length (mm)**	**note (A – 6)**	**note (A + 1)**
1	67	e''''	a'''
2	77	d''''	g'''
3	87	c''''	f'''
4	99	b'''	e'''
5	111	a'''	d'''
6	123	g'''	c'''
7	135	f♯'''/f'''	b''/b♭''
8	151	e'''	a''
9	166	d'''	g''
10	180	c'''	f''
11	197	b''	e''
12	215	a''	d''
13	233	g''	c''
14	252	f♯''/f''	b'/b♭'
15	272	e''	a'
16	293	d''	g'
17	314	c''	f'
18	337	b'	e'
19	362	a'	d'
20	381	g'	c'
21	405	g'	c'
22	428	f♯'/f'	b/b♭
23	451	e'	a
24	475	d'	g
25	500	c'	f
26	526	b	e
27	550	a	d
28	576	g	c
29	601	e/f	A/B♭
30	626	d	G
31	651	c	F

Note: A – 6 is pitched six semitones below A440; A + 1 is pitched one semitone above A440.

The string lengths for the notes in the F bass tuning scheme are plotted in the graph in figure 2.25.[176] The scaling for yellow brass and red brass (adjusted to A467, the midpoint of the range A464 – 471 Hz) is indicated by the dashed lines.[177] The points at which the string lengths intersect the scaling for these string materials indicates where metal transitions may take place in the stringing. For this tuning scheme, the transition from yellow brass to red brass could take place at the unison strings, a convenient point given that it marks the division between the treble and bass voices of the instrument. The longer of the two unison strings would have to be strung with yellow brass, however, and the b/b-flat string directly below this would be in danger of snapping if tuned up to b-natural. It would be safer in this instance to make the transition a string lower, or to lower the pitch of the instrument by a semitone, which would place it at about A440. This could be accomplished by simply omitting the gap in the bass.

As is typical of low-headed Irish harps, the scaling is quite short in the bass, and the tone of the lowest three or four strings might be improved by the use of a denser stringing material than red brass. As discussed earlier, the use of precious metal stringing in the bass has been theorized, and there is some historical evidence that points to the possible use of silver strings on some of these harps.[178] Whether silver strings were ever used on this harp is unknown.

---

[176] Strings that have two possible tunings (i.e. the A/B-flat string in the bass, and the b/b-flat strings in the other octaves) are represented by pairs of points connected by a horizontal line.
[177] Scaling for yellow brass from Campbell, Greated, and Myers, *Musical Instruments*, 308. Scaled from 270 mm for c '' at A440. Scaling for red brass from Grant O'Brien, *Ruckers: A Harpsichord and Virginal Building Tradition* (Cambridge: Cambridge University Press, 2008), 61. Scaled from 211 mm for c'' at A415; silver scaling estimated by the author, based on silver wire hand drawn by Daniel Tokar, scaled from 167 mm for c'' at A440.
[178] Heymann and Heymann, "Strings of Gold." Barbieri, "Gold- and Silver-Stringed Musical Instruments," 147.

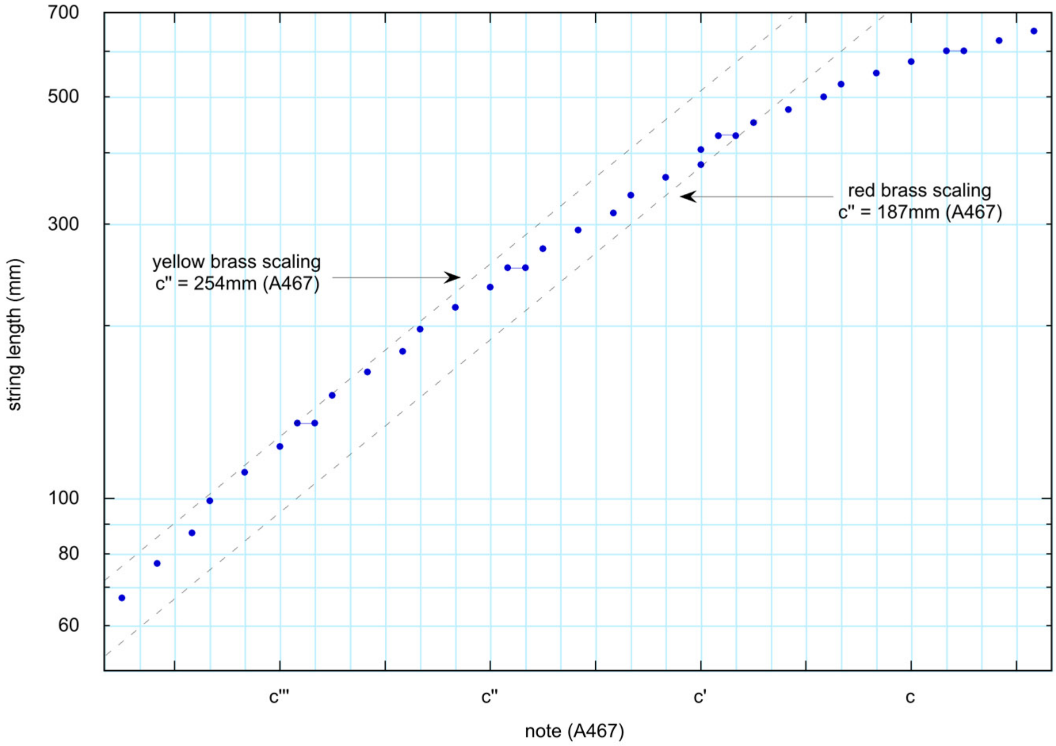


Figure 2.25: *scaling of the Lamont harp for the straightened frame with no soundbox belly for the compass from F in the bass. Strings that have two possible tunings are represented as pairs of points connected by a line. For this scaling, the instrument is pitched at A467. The dashed lines indicate the scaling for yellow brass and red brass (as labeled), adjusted to the pitch of A467. In order to avoid snapping, strings need to be shorter than the scaled length for the chosen material (i.e. they should lie below the dashed lines indicated on the graph).*

With the exception of the wire fragment found in string hole #14, string gauges for the Lamont harp are currently not known. It may be possible to measure string gauges from the wire impressions left in the wood around the string holes (and possibly on the string shoes). By measuring the width and depth of an impression, the gauge of the wire that made it can be calculated from the following formula, which is derived from the theorem for intersecting chords on a circle:

$$D = \frac{\left(\frac{w}{2}\right)^2 + d^2}{d} \; ,$$

where 'w' is the width of the impression, 'd' is the depth, and 'D' is the diameter (or gauge) of the wire. This would require very precise measurements, but may be possible with a high-resolution laser scan.

Using the information derived for string length, pitch, density, and diameter, the tension can be calculated for the string associated with the wire fragment in string hole #14 (which corresponds to string #13 for both the direct and offset stringing discussed above), using the formula

$$T = \frac{f^2 l^2 \rho \pi D^2}{g} ,$$

where 'f' is pitch in hertz, 'l' is string length in meters, 'ρ' is density in kg/m^3, 'D' is diameter in meters, 'g' is the acceleration of gravity in m/s^2, and 'T' is tension in kgf. The measured values for the density and diameter are 8550 kg/m^3 and 6.9x10^{-4} m, respectively (see Chapter 1). For the 'straightened' frame, the reconstructed length of string #13 is 0.233 +/- 0.001 m, the note assigned to this string for the proposed compass starting at F in the bass is c″. With the harp pitched in the range of A464 – 471 Hz, the pitch of this string would be 552 – 560 Hz. The tension on this string would therefore, be 21.9 +/- 0.5 kgf. For the current frame (with offset stringing), the measured length of string #13 is 0.215 +/- 0.001 m, the note is f#″/f″, with the harp pitched in the range of A386 – 391 Hz, so the pitch of this string would be 613 – 621 Hz, for f″ and 649 – 658 Hz for f#″. In this instance the tension on this string would range from 22.9 +/- 0.5 kgf to 25.8 +/- 0.5 kgf.

It is interesting to compare these values to current stringing practices for some modern instruments modeled after the Lamont harp, as summarized in table 2.5, below.[179] A Trinity College harp replica is also included for comparison.

[179] The author would like to thank Simon Chadwick for supplying the stringing specifications for harps B and C.

Table 2.5.

Comparison of derived string tension for the Lamont wire fragment to comparable strings on some harps modeled after the historical instruments

harp	**string #**	**note**	**f (Hz)**	**length (m)**	**gauge (m)**	**density (kg/m^3)**	**tension (kgf)**
Lamont 'straightened, no soundbox belly'	13	c″ A464 – 471	552-560	0.233	6.9E-04	8550	21.9 +/- 0.5
Lamont 'current'	13	f♯″ f″ A386 – 391	649-658 613-621	0.215	6.9E-04	8550	25.8 22.9 +/- 0.5
harp A, after the Lamont (1996 - 2006 stringing)	13	c″ A440	523	0.245 (1996)	7.0E-04	8536	22.0
harp A, after the Lamont (current stringing)	13	c″ A392	466	0.230 (2008)	5.6E-04	8536	9.85
harp B, after the Lamont	12	b″ A440	493	0.228	6.0E-04	8536	12.6
harp C, after the Trinity College harp	12	b″ A440	493	0.225	5.6E-04	8536	10.6

The first two rows in table 2.5 contain the data for the actual Lamont harp, for both the reconstruction of the straightened frame and for the frame in its current state. As discussed, the tension is derived from the proposed pitch of the string corresponding to the string-hole in which the fragment was located, using the density and diameter of the fragment, from Chapter 1. The comparable strings on the modern replicas are 30% zinc yellow brass wire. Note that the string tension derived for the Lamont harp is double the tension of the comparable strings on the modern replicas. The one exception is the tension derived from the earlier stringing regime for Lamont replica A, which had a pitch and gauge similar to the actual Lamont. This harp, which currently belongs to the author, is an interesting example, as the frame shows clear signs of twisting in the same manner as the original Lamont harp. In particular, the neck has also rotated and shifted backwards towards the back of the soundbox. The damage that this caused to the soundbox necessitated the addition of a metal band in the same location as a similar band at the top end of the soundbox of the Lamont harp. Considering the degree of observed motion of the neck in the soundbox joint of this replica, it is probable that the tenon also has a crack in it, again similar to the actual Lamont harp. After 2006, the author lowered the tension on this instrument by reducing the overall string gauges.[180]

The information in table 2.5 suggests that string tensions for the Lamont harp may have been much higher, at least at some point during its working life, than current practice on instruments modeled after this and other surviving low-headed Irish harps. Given the considerable damage to the frame, which can be directly linked to string tension, it is possible, however, that the Lamont harp may not have been originally intended to be strung at the tension indicated by the wire fragment. There is some interesting related evidence to consider with regard to this, not only for this harp, but also for other low-headed Irish harps.

As mentioned above, the Lamont harp has an iron band around the top of the soundbox that appears to have been added at some point to reinforce and prevent further damage to that part of the box as a result of the string tension causing the neck to rotate forwards, forcing its tenon against the back of the soundbox. It also has a pair of brass straps reinforcing the joint between the neck and forepillar against the pull of the strings towards the left side of the harp. These straps may also be a later addition, as discussed below.

The Lamont harp is not unique in having these reinforcements on its frame. Other low-headed Irish harps were equipped with similar bands and straps. As shown in figure 2.26, the Irish harp depicted in the *Syntagma Musicum* of Praetorius has straps

[180] This was done out of some concern for the frame and concern over the effect of the higher tension on the acoustics. The overall pitch of the instrument was later reduced to accommodate repositioning the unison strings within the constraints of the current stringing.

across the neck/forepillar joint, and appears to have also had a band around the top end of the soundbox, similar to the reinforcements on the Lamont harp.[181]

Figure 2.26: *a photograph of the Lamont harp (left) compared with the engraving of an Irish harp in the Syntagma musicum of Praetorius.*[182] *Both harps have straps across the neck/forepillar joint, and both have a strap around the top end of the soundbox where it joins with the neck (arrowed).* Photograph (left): Isabelle Wagner.

The Ballinderry harp fragments include a strap intended to be affixed across the neck/forepillar joint, and both the Queen Mary harp and the Cloyne fragments show signs of having had straps across this joint, as shown in figure 2.27.[183]

[181] Praetorius, *Syntagma musicum*, 54.

[182] Praetorius, *Syntagma musicum*, detail of plate XVIII, 2. "Irlendisch harff mit Messinges Saiten." Praetorius's engraving appears to be flipped left - right with respect to the normal orientation of these harps.

[183] The 'Cloyne' (a.k.a. 'Dalway') harp, National Museum of Ireland, DF: 1886.2. The 'Ballinderry' harp fragments, National Museum of Ireland, WK.372. Armstrong, *Irish and Highland Harps*, see Plate facing 62. The wooden frame for the Ballinderry harp fragments is a modern reconstruction. The author gratefully acknowledges Simon Chadwick for suggesting the nail marks indicated on the Queen Mary harp may have been associated with straps across the joint.

Figure 2.27: *photographs of the area of the neck/forepillar joint of four low-headed Irish harps. Clockwise from top left: the Lamont, the Ballinderry, the Cloyne, and the Queen Mary.*[184] *The Lamont harp and Ballinderry fragments both have straps across the joint, and the Queen Mary and Cloyne show evidence of having had straps in the same location (arrowed).*

Prior to its conservation in 1961, the Trinity College harp had an iron band around the treble end of the soundbox at the neck joint, the same location as the band on the Lamont harp.[185] This can be seen in photographs of the harp pre-dating the conservation work, and it is referred to in the conservation report.[186] Early 19th-

[184] Photographs: (top left) Maripat Goodwin; (top right) Armstrong, *Irish and Highland Harps*, detail of plate facing 62, "Brass mountings for a harp found at Ballinderry, King's County. Right side"; (lower left) Karen Loomis; (lower right) Karen Loomis, used with the kind permission of the National Museum of Ireland.
[185] British Museum conservation Report, "15th c. Irish harp formerly known as the Brian Boru harp & now known as the TCD harp," file 2231 (Department of Conservation and Scientific Research) 7, 9 – 10. See also, Dooley, "Medieval Irish Harp," 119 – 20.
[186] ibid.

century depictions of this harp show it with a pair of straps across the joint between the neck and forepillar in addition to the band.[187] The band and straps can be seen in an engraving of the harp published in Rees's *Cyclopædia*.[188] A detail of this engraving is shown in figure 2.28, which also shows a photograph, dated 1898, in which the metal band can be seen on the soundbox at the neck joint.[189]

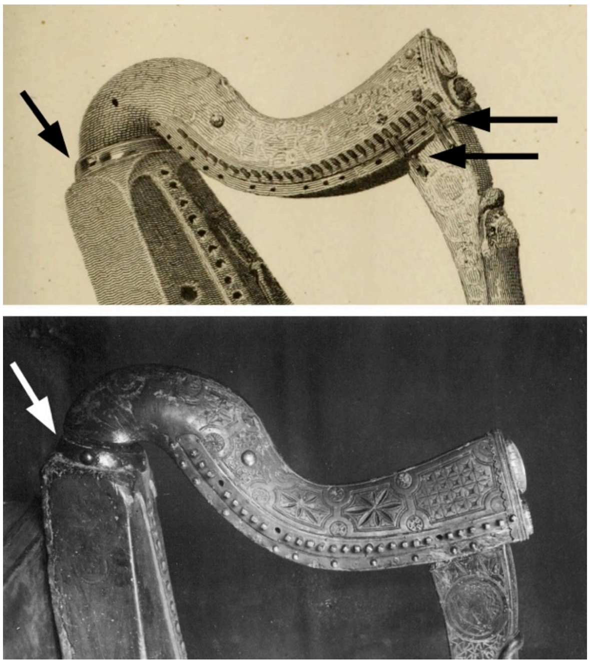


Figure 2.28: *(top) detail of an engraving of the Trinity College harp dated 1808, depicting the instrument with a band around the treble end of the soundbox at the neck joint, and a pair of straps across the neck/forepillar joint (arrowed); and (bottom) detail of a photograph dated 1898, showing the band around the treble end of the soundbox (arrowed).*[190]

---

[187] Simon Chadwick, "The Trinity College Harp: Damage," last modified August, 2014, http://www.earlygaelicharp.info/harps/trinitydamage.htm.
[188] Abraham Rees, *The Cyclopædia, or Universal Dictionary of Arts, Sciences, and Literature, Vol. III: Plates* (London: Longman, Hurst, Rees, Orme, & Brown, 1820), Plate X. The author gratefully acknowledges Simon Chadwick for bringing this engraving to her attention.
[189] Benjamin Stone, photograph of the Trinity College harp, dated 1898, *Sir Benjamin Stone Collection* (Birmingham: Birmingham Central Library, Archives & Heritage), box 302, print 38. Reproduced with the permission of the Library of Birmingham. The author gratefully acknowledges Simon Chadwick for bringing this photograph to her attention.
[190] ibid. Arrows added by the author. At the time of Stone's photograph, the harp did not have straps across the neck/forepillar joint. Under magnification, scratches in the wood of the neck are visible in the photograph at the locations of the straps indicated in the engraving.

For some of the surviving harps, these reinforcements appear to be later additions to the frame of the instrument. The nail fragments across the neck/forepillar joint on the Queen Mary harp cross the decorative work in a manner that suggests they were not part of the original construction of the harp, and the engraving of the 'Brian Boru' harp similarly shows the straps covering the decorative work on the forepillar of that harp, also suggesting they were a later addition. This may not be the case for the strap for the neck/forepillar joint of the Ballinderry harp fragments, however. In this instance, it looks like it could be part of the original construction of that harp, based on the similarity of the decorative work to that on the cheekbands. It's not clear if the straps indicated by the marks on the neck of the Cloyne harp were part of the original construction of that harp or added later, although their location does coincide with two natural gaps in the inscription on the neck.[191] Although it isn't possible tell if the straps and the band in the Praetorius engraving were original to the construction of the harp depicted, their inclusion suggests they may have been typical for Irish harps at the time.

Judging from the gap that has opened up at the back of the forepillar/neck joint on the Lamont harp, the forepillar had already been compressed by the string tension when the straps were placed across that joint, so they are a later addition to the harp. As discussed earlier, the band around the top of the Lamont harp soundbox appears to have been added after the box began to develop cracks at that end, so it is also not part of the original design.

It possible that it was necessary to add these reinforcements to the frame as the joinery shifted under normal use. It is, however, also possible that the harps that had these reinforcements added to them, e.g. the Queen Mary, Trinity College, and Lamont, were intended for a string tension that did not require metal reinforcement of the joint between the neck and forepillar, or of the mortise at the neck joint with the soundbox. If so, this could be an indication that stringing practices changed over

[191] These observations are based on the author's examination of the Cloyne harp fragments in September 2012.

the lifetimes of these harps towards significantly higher tension than that for which their frames were originally constructed. For the Lamont harp, it is possible that the string fragment, the added reinforcing straps, and some of the damage to the frame, date to a period of increased string tension for this instrument. As discussed earlier, the composition of the wire fragment is consistent with brass available in the British Isles in the 17th century. While an earlier or later date for the wire cannot be ruled out, it may point to the 17th century as a period during which this harp was strung to a higher tension than that for which it was originally constructed. It would be worth further investigation to try to determine if this is indeed the case, not only for this harp, but for the others as well.

The frame of the Queen Mary harp

Number and arrangement of strings

Before discussing the frame of the Queen Mary harp, and subsequently the string lengths, it is necessary to understand the stringing arrangement. As was the case for the Lamont harp, this can be understood through examination of the tuning-pin holes in the neck and the string holes in the soundbox.

The stringing arrangement for the frame of the Queen Mary harp appears to have been more straightforward than that encountered on the Lamont harp. On the neck of the Queen Mary harp there are 29 holes for tuning pins in the cheekbands plus an additional hole located below the cheekbands, which is slightly larger than the other tuning pin holes. Given its location and mismatched size, this 30th hole appears to be a later addition.[192] In the soundbox, there are 29 holes in the string band. There is also an iron loop at the bass end of the soundbox, which appears to have been added to

[192] Armstrong, *Irish and the Highland Harps*, 171.

accommodate an additional string.[193] The 30th tuning-pin hole and the iron loop are shown in figure 2.29.

Figure 2.29: *left side view of the Queen Mary harp indicating the location of the tuning pin hole below the cheekbands, and the iron loop at the bass end of the string band (arrowed, top photo). The loop and tuning pin hole are shown in close-up in the lower left and lower right photographs, respectively. Photograph (lower right): Isabell Wagner.*

The tuning pin for the additional hole, now missing, is noted by Armstrong as being of a different style compared to the other tuning pins on this harp. He describes it as being made of iron, with a thicker, shorter shaft, a slotted string end, and a square

[193] ibid. 177. A string could have been attached to the soundbox by being strung through the 29th string hole and then through the loop. This allows the string to have good acoustic coupling with the soundbox. This method has been employed by Simon Chadwick on his Queen Mary replica, as suggested to him by Ann Heymann.

drive head, which he observed was "much worn".[194] The ends of this pin are shown in the archival photographs in figure 2.30.

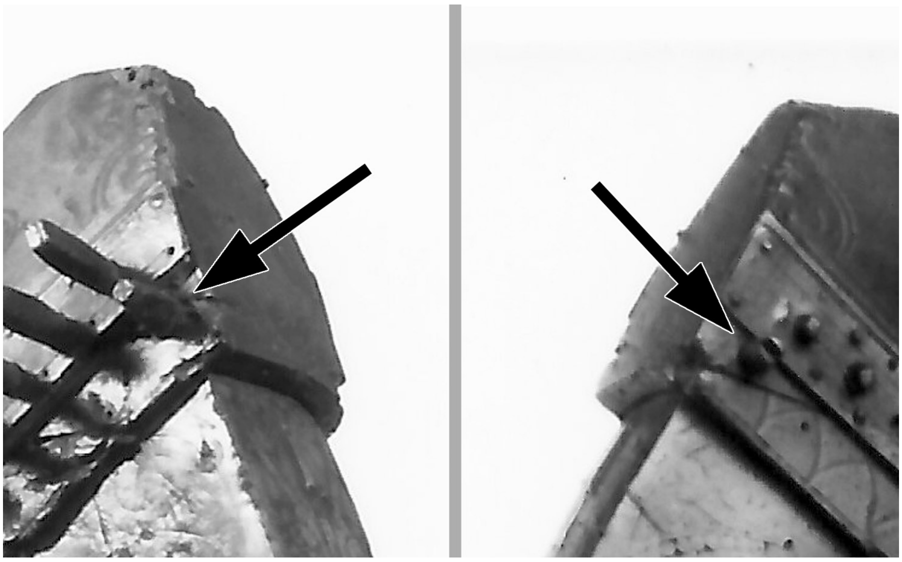


Figure 2.30: *details of archival photographs of the Queen Mary harp showing the ends of the tuning pin in the hole added to the neck for a 30th string. The photograph on the left shows the drive end of the pin, and the photograph on the right shows the string end (undated photographs, National Museums Scotland H.LT1 archive; arrows added by the author).*

With regard to the position of the iron loop in the soundbox, it is evident from its position inside the recess for the mortise in the joint for the forepillar that it was added after the forepillar had shifted in this joint, as can be seen in figure 2.31. Due to the string tension, the forepillar has compressed, causing its tenon to lift up out of the joint at the end facing the string band. The string tension has also caused it to shift forwards in the mortise towards the foot of the harp. This has created the gap in which the loop has been placed.

194 ibid., 171.

Figure 2.31: *a photograph of the iron loop at the bass end of the soundbox of the Queen Mary harp. It is located beyond the end of the string band inside the recess for the mortise at the forepillar joint. The recess has been exposed due to the forepillar shifting in the joint as a result of the string tension.*

The loop, which is actually a staple, was hammered in at an angle to the front of the soundbox. It was not hammered in vertically and bent forward, therefore it could have been added with the forepillar in place. Its shape and orientation in the wood can be seen in the composite image in figure 2.32.

Figure 2.32: *(left) composite image of a photograph and tomogram of the base end of the Queen Mary harp soundbox showing the orientation of the iron loop in the wood. The loop, which is actually a staple, has been hammered in at an angle to the front of the soundbox. The shape of the loop is shown in cross-section in the inset (right). Scale 1 tick : 1 cm.*

Upon examination of the inside of the soundbox of the Queen Mary harp, numerous indentations and scratches, as well as some verdigris stains, were observed around the string holes. These are similar to the markings observed inside the soundbox of the Lamont harp, and as already discussed for that harp, they are consistent with their having been made by string toggles and wire strings. Figure 2.33 shows the marks around the string holes as they appear from the interior of the soundbox of the Queen Mary harp.

Figure 2.33: *The interior of the Queen Mary harp soundbox, showing marks around the string holes. The size, shape, location, and distribution of the marks are consistent with their having been made by string toggles and wires pressing against the wood. The string holes shown are 7 – 12 (top) and 12 – 16 (bottom). Photograph: (bottom) Isabell Wagner.*

Figure 2.34 shows the marks around string holes #1 and #29. Toggle marks and verdigris stains were observed around both, although they were fewer in number than around the string holes in the middle of the compass.[195]

[195] This was the case for both the Lamont and Queen Mary harps. The string holes in the middle 3/4 of the compass were surrounded by the most marks. This is likely a direct indication of the relative number of string replacements at these locations, and therefore may also be an indication of which strings were most used.

Figure 2.34: *string holes #1 (top) and #29 (bottom) as viewed from the inside of the Queen Mary harp soundbox. Signs of use in the form of verdigris stains and indentations are visible around both string holes (arrowed). Photographs: (top) Karen Loomis, (bottom) Isabell Wagner.*

It is evident from the observed marks that all 29 string holes were used. Although tomograms of the neck show evidence of internal damage to some of the tuning pin holes, none are damaged to the extent of not being useable. It does not, therefore, appear that the tuning pin hole below the cheekbands was added to take the place of another, as appears to be the case for the Lamont harp. The iron loop at the bass end of the string band indicates the addition of a string to the full complement, so this harp therefore appears to have been originally constructed for 29 strings, with one added later to bring the total number up to 30. This concurs with Armstrong's assessment upon examination of the harp, and with the generally accepted opinion on the stringing of this instrument.[196] Upon examination of the CT scans and of the harp itself, nothing was observed that suggests otherwise. The analysis of the stringing therefore assumes this was the case.

String lengths for the Queen Mary harp

The Queen Mary harp frame has distorted as a result of the string tension acting on it, although the twisting and damage is not as severe as it is for the Lamont harp. The geometry of the frame has changed enough to have affected the string lengths, however, so the process of reconstructing the 'as-built' shape of the frame in order to determine the original string lengths is undertaken here for the Queen Mary harp using the same method described for the Lamont harp.

As discussed in the introductory section on the construction of this harp, the frame is made of three members joined by mortise and tenon. Much of the distortion to its shape is due to shifting at these joints, and additional distortion is due to twisting or bending of the frame members themselves. Although not obvious upon casual observation, the shifting and twisting of the frame members of the Queen Mary harp is evident upon close inspection. As discussed for the Lamont harp, it is the movement and distortion of the neck and the soundbox that have affected the relative positions of the tuning pins and string holes, and therefore the string lengths. This analysis therefore focuses on the motion of these two frame members. The directions in which they have moved are illustrated in Figure 2.35, below.

[196] Armstrong, *Irish and the Highland Harps*, 171.

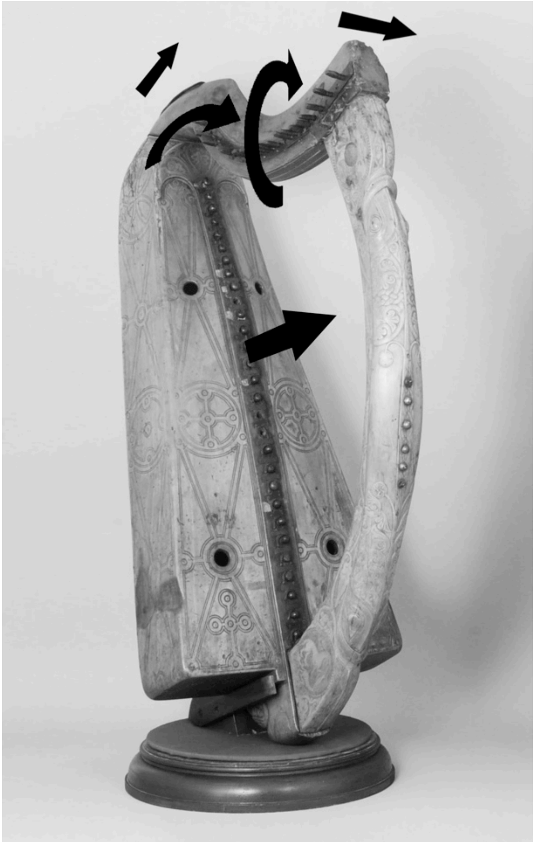


Figure 2.35: *direction of movement of the neck and string band of the Queen Mary harp. The neck has twisted about its long axis towards the left side of the instrument, and pivoted forwards out of its joint with the soundbox. It has also shifted upwards slightly out of this joint. The end of the neck over the forepillar has turned towards the left side of the harp, and the soundbox has risen along the string band. Photograph: Isabell Wagner; annotations by the author.*

The neck of the Queen Mary harp has pivoted forwards slightly out of its joint with the soundbox. It has also shifted upwards a few millimetres out of this joint. Figure 2.36 shows a tomographic cross-section in which the movement of the neck in the joint is indicated.

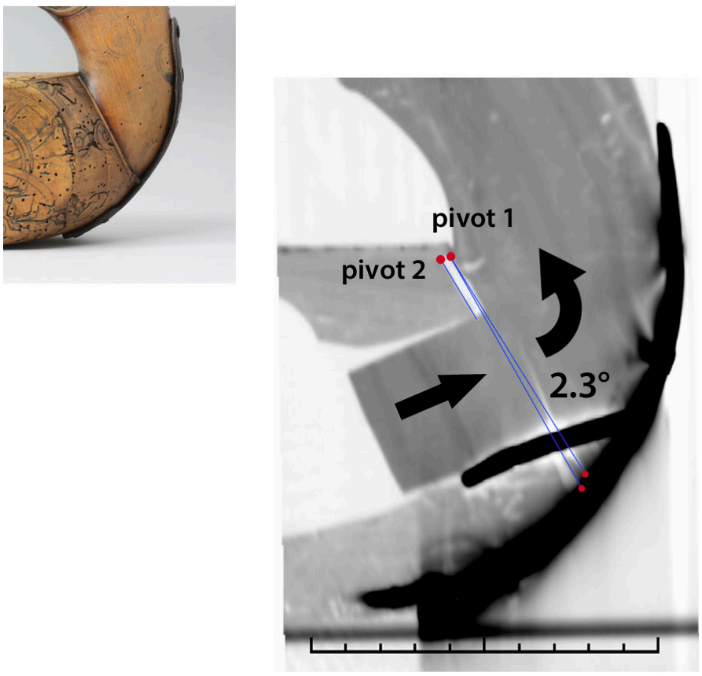


Figure 2.36: tomogram of the Queen Mary harp neck/soundbox joint, and photograph of the same area (inset). The points labeled 'pivot 1' and 'pivot 2' were originally adjacent. As a result of the string tension, the neck has shifted upwards out of the joint by 2 mm in the direction indicated by the straight arrow. The neck has also pivoted forwards, causing the joint to open by 2.3°, as indicated by the curved arrow and the angle lines. The scale in the tomogram is 1 tick : 1 cm.

As shown in figure 2.36, the neck of the Queen Mary harp has pivoted forward by 2.3°, and has shifted upward out of the joint by 2 mm, in the direction indicated by the straight arrow in the figure. Figure 2.36 can be compared to figure 2.13 for the Lamont harp. The necks of both harps have pivoted forward and shifted upward out of the joint, however the neck of the Lamont harp has also shifted backward forcing the tenon into the back of the soundbox, causing significant damage to the box and the tenon. The difference in behaviour of this joint in the Queen Mary harp is due in part to the iron strap across the back of the joint, which would have stopped the neck pivoting forward.[197] The location of this strap across the joint is shown in the

[197] The Lamont harp also had a metal strap across the neck-soundbox joint, similar to the strap on the Queen Mary harp. This was noticed by Michael Billinge on an early 20th-century archival photograph of the harp (Keith Sanger, personal communication, 14 April, 2013). Unfortunately, the strap was removed at some point during the 20th century, so it is not possible to make a direct comparison of it to the one presently on the Queen Mary harp.

photograph in figure 2.37. Based on its placement over worn decorative work, it was evidently added after the harp had been in use for some time. It was also apparently added after the neck had already pivoted forward in the joint, as its placement would have prevented further motion.

Figure 2.37: *two views of the iron strap across the neck/soundbox joint of the Queen Mary harp. Its placement over decorative work that is worn (arrowed) indicates that the harp was in use for some time before it was added.*

Although the strap may have prevented some damage of the sort observed in the same joint on the Lamont harp, some of the observed difference in damage may be due to the difference in construction of this joint on the two harps. This is illustrated in the diagrams shown in figure 2.38.

Given the observed damage to the joint, the strap would have been added after the Lamont neck tenon had already pushed the back of the soundbox outwards.

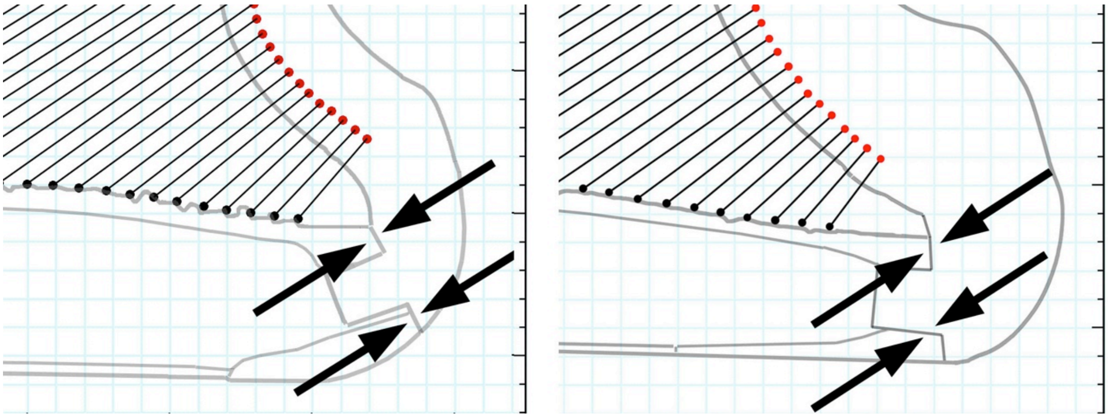


Figure 2.38: *diagrams of the neck/soundbox joint of the Queen Mary harp (left) and the Lamont harp (right). Both joints are shown in their original state, not their current state. The arrows indicate the direction of force of the neck on the soundbox, and vice-versa. Both harps are drawn to the same scale. Scale: 1 tick : 2 cm.*

The differences between the two joints are apparent when viewed in cross-section. Both are shown as they would have been originally, with the tenons seated, and the joints reconstructed to their pre-damaged state.[198] The neck-soundbox joint on the Queen Mary harp has an angled mortise, whereas the same joint on the Lamont harp has an in-line mortise, aligned with the long axis of the soundbox. The arrows on the diagram indicate the approximate direction of force of the neck pushing down on the soundbox, and of the opposite force of the soundbox pushing up on the neck, assuming the forepillar is sufficiently rigid to withstand the force on it at the bass end of the neck. The direction of force is aligned with the angle of the majority of the strings, with a slight adjustment to account for the change in angle of the treble strings (which also contribute less to the total force). Note that on the Queen Mary harp the shoulders of the mortise are angled such that the force is nearly perpendicular to the face of the shoulder on the soundbox and the neck, whereas on the Lamont harp it is at an angle to it. Note also that on the Queen Mary harp the force is roughly parallel to the sides of the tenon, so there is minimal torque on the tenon in this configuration. On the Lamont harp, however, the force is at an angle to the tenon. Consequently, even before the neck began to pivot forward the tenon was

[198] This is particularly relevant to the Lamont harp, as its mortise has been enlarged by the tenon pushing the back of the soundbox outwards, so the soundbox of that harp was originally narrower at this location than it is currently.

already at some risk of shearing off, as it is cut across the wood grain and therefore vulnerable to a force applied to its side. Additionally, because the force of the neck pushing down on the soundbox is not perpendicular to the mortise shoulders on the Lamont harp, a component of the force is directed into the back wall of the mortise. This could have contributed to the damage to the back of the soundbox of this harp even before the neck had begun to pivot forward. This is not the case for the joint on the Queen Mary harp, where the force is not directed into the back wall of the mortise; it is directed onto the shoulder.

On both harps, however, the neck began to pivot out of the joint as a consequence of the forepillar compressing, and this has caused both neck tenons to push into the back of the soundbox. As already discussed, this motion has damaged the soundbox of the Lamont harp and necessitated the addition of the metal strap around the top of the soundbox. On the Queen Mary harp, however, the mortise has a significantly thicker wall on the side that faces the back of the soundbox, which would have strengthened the back of the soundbox. There was still the risk of shearing off the tenon of the Queen Mary harp (which is also cut across the grain), and the tenons of both harps have cracked, although the damage to the Lamont harp tenon is greater.

Although this joint is damaged on both harps, there is considerably less damage overall to the joint on the Queen Mary harp, and while there are other factors that may have contributed to the greater degree of damage to the Lamont harp joint (perhaps higher string tension), as a consequence of its construction, the neck-soundbox joint of the Queen Mary harp appears to be stronger than the same joint on the Lamont harp.

Regarding other movement of the neck, in addition to pivoting forward out of the soundbox joint, it has rotated along its long axis towards the left side of the harp. This has caused the neck/soundbox joint to open up on the right side of the harp, and at some point prior to the addition of the iron strap a wooden wedge was inserted into the gap in the joint on this side of the harp.[199] Some parts of the neck have rotated more than others, however. The degree of twisting is greatest at the treble end of the neck, where it is 8°, and gradually decreases to about 2.6° at pin #22, then increases again, rising to between 4° and 6° for the last three pins. This indicates that for a period of time the neck was being held more rigidly upright at the forepillar than at the soundbox, resulting in the greater twist at the soundbox end. This would have occurred before the iron strap was added across the neck-soundbox joint. After the addition of the strap, the neck would have been held more rigidly in place at the soundbox and any additional twisting would have occurred at the forepillar end. This would have been exacerbated by internal cracks at the bass end of the neck, which have caused it to turn sideways towards the left side of the harp. This can be seen in the photograph in figure 2.39, which shows the alignment of the tuning pins as viewed from above the neck. The orientation of the pins shifts abruptly at tuning pin hole #25 (at the location of the third tuning pin from the top in this photograph), which is just to the bass side of a metal patch that covers a break in the right-hand cheekband.[200] The cheekband on the opposite side is slightly bowed out, and has been carefully cut and spliced at tuning pin hole #19.[201]

[199] Armstrong, *Irish and the Highland Harps*, 179.
[200] The cheekband break is shown and discussed in detail in Loomis "Structural Breaks and Repairs," 59 – 62, and Loomis et al. "Lamont and Queen Mary Harps," 125 – 26.
[201] Armstrong, *Irish and Highland Harps*, 178.

Figure 2.39: *the bass end of the Queen Mary harp neck, viewed from above, showing the alignment of the tuning pins (and therefore the tuning pin holes). Red lines have been superimposed to highlight their orientation. The gaps are due to missing tuning pins. The uppermost tuning pin hole in this photograph is #29. Note that the alignment of the pins shifts at the third from the top, #25, which is located just to the bass side of a metal patch that covers a break in the right-hand cheekband. On the opposite side of the neck, the cheekband is visibly bowed out.*

Internally, the neck has several cracks at the bass end, aligned along the wood grain, one of which passes through tuning-pin hole #25, as shown in figure 2.40, below.[202]

[202] Loomis et al. "Lamont and Queen Mary Harps," 126.

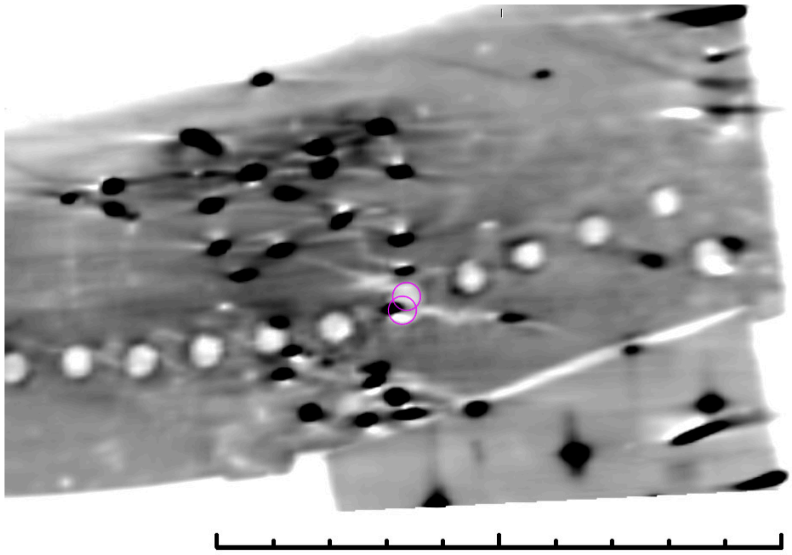


Figure 2.40: *tomogram of the bass end of the neck of the Queen Mary harp showing the tuning pin holes. This cross-section, located a few millimetres inside the neck on the right-hand side, shows a sudden shift in the line of tuning pin holes occurring at a crack that passes through hole #25 (outlined in pink). The position of this hole has shifted by 2.9 mm where the crack has opened up on the right hand side of the neck. The scale is 1 tick : 1 cm.*

These cracks, which appear to be the result of the bass end of the neck being forced down onto the forepillar (as discussed in Loomis (2010)) have allowed the end of the neck to turn towards the left side of the harp, resulting in the observed shift in alignment of the tuning pin holes, as well as the damage to both cheekbands.[203]

The final change in shape of the frame to be addressed is the rise of the belly of the soundbox. The front of the soundbox has been pulled up by the string tension. As discussed in Loomis (2010) and Loomis et al. (2012), this is evident from the observed 'pulling in' of the sides of the soundbox as the front has risen.[204] Earlier in this dissertation, the question of whether the front of the soundbox was originally flat was addressed for the Lamont harp by examining the cross-sections of the string holes. The same method is used here to try to answer this question for the Queen Mary harp.

[203] Loomis, "Structural Breaks and Repairs," 61 – 64.
[204] Loomis, "Structural Breaks and Repairs," 46. Loomis et al. "Lamont and Queen Mary Harps," 122 – 23. The author gratefully acknowledges Simon Chadwick for pointing out that pulled in soundbox sides are evidence of a belly that has been pulled up by the string tension.

Figure 2.41 shows cross-sections of two string holes in the soundbox of the Queen Mary harp: #28, near the bass end, where there is no appreciable belly, and #14 which is located on the belly. These two string holes were chosen because they provided the clearest views of the sides of the string hole and of the string band. Unfortunately, the wooden peg inserted in string hole #28 (and most of the other string holes) makes it difficult to see the sides of the hole. There is, at least, a clear view of the string band, which is flat, along with the front of the soundbox. The sides of string hole #28 are either parallel or angled slightly outward. The sides of string hole #14 are clearly angled outward, and the string band is either flat or curved slightly upwards. If the harp was carved with a flat soundbox front, then rotating the two halves of the cross-section at string hole #14 down to 'flatten' the front of the box (as was done for the cross-sections of the Lamont harp soundbox) should recreate a string hole and string band that resembles the cross-section of hole #28. This has been done for string hole #14 in the 3rd cross-section from the top in figure 2.41. Note that the sides of the string hole are now angled inward, and the string band is angled in on itself. This does not resemble the cross-section of string hole #28. In the bottom cross-section in figure 2.41, the two halves of the cross-section have been rotated down just enough to flatten the string band. Note that the sides of string hole #14 are now parallel, but the front of the soundbox is not flat. This suggests that the soundbox of the Queen Mary harp may not have been made flat, but instead may have been carved with a belly that has subsequently been pulled up further by the string tension, such that the current belly is the result of both string tension and carving.

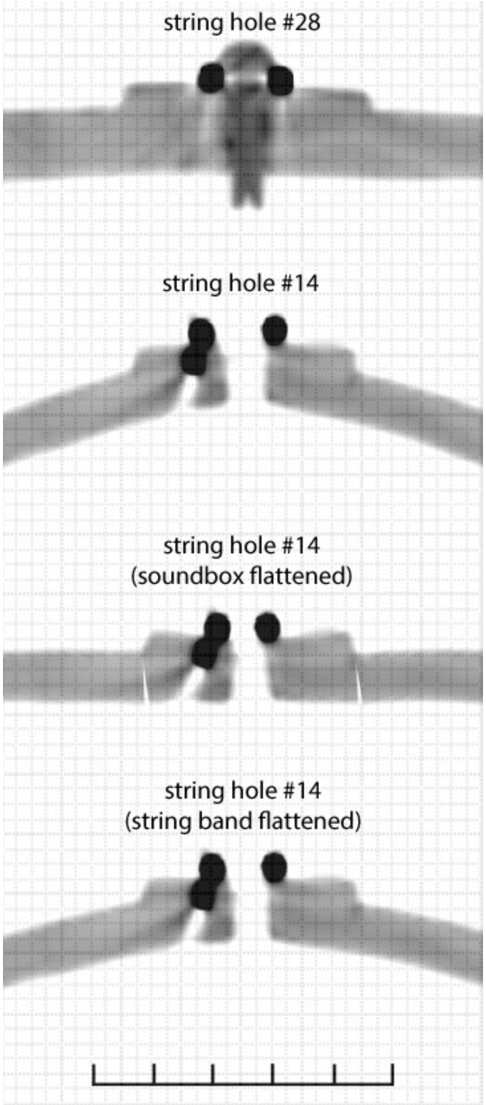


Figure 2.41: *tomographic cross-sections of string holes in the Queen Mary harp soundbox. Top: string hole #28, located where the front of the soundbox is nearly flat; 2nd from top: string hole #14, located on the 'belly' of the soundbox; 3rd from top: string hole #14 with the front of the soundbox 'flattened'; and bottom: string hole #14 with the string band 'flattened'. Note the angle of the walls of the string holes and the front face of the string band. In string hole #28 (top) the sides of the string hole are either parallel or angled outward, and the string band is flat. In #14 (2nd from top) they are angled outward. In #14 for the 'flattened' soundbox (3rd from top) the sides of the string hole are angled inward and the string band is not flat, it is angled downward. In #14 for the 'flattened' string band (bottom), the sides of the string hole are parallel, and the front of the soundbox has a belly. Scale: 1 tick : 1 cm; grid scale 1 box : 2.5 mm.*

There are other possible interpretations of these string hole cross-sections. Tapered wooden pegs, like the one in hole #28, had been inserted into all of the string holes in the early 19th century, and could have altered the profile of the holes. If a peg had less taper than the string hole into which it was inserted it would push the sides of the hole outward. This could explain the sides of the hole consequently angling inward in the 'flattened' cross-section shown in figure 2.41. This doesn't explain the observed profile of the string band, though. At string hole #28, which is not on the belly, the interior and exterior surfaces of the string band are parallel. This is not the case at string hole #14, which is on the belly. Another possibility is that the string toggles have compressed the wood around the string hole to the extent that the inside surface of the string band has been effectively 'pushed up' and is no longer parallel to the outside surface. If this were the case, then it would also be observed on the string hole in the bass, were the string tension is higher and the angle of the string is nearly the same, but it isn't. Furthermore, this effect is it not observed at all on the Lamont harp.

Although the string hole cross-sections suggest the soundbox was not constructed with a flat front, in the event that this interpretation is incorrect, the reconstruction of the 'as-built' string lengths and the string scaling analysis includes solutions for the harp both with and without a belly. It was not possible to estimate the height of the presumed carved belly, so the current belly is used, with the understanding that it would have been lower than this prior to the string tension pulling up the front of the soundbox.

The following section presents the string lengths for the Queen Mary harp frame in its current state, including the 30th string, as well as for a straightened frame with 29 strings and a flat fronted soundbox, and a straightened frame with 29 strings and a belly (although this is the current full height belly). All of the derived string lengths assume direct string hole to tuning pin stringing.

Current and reconstructed string lengths

The method used to calculate the current and reconstructed string lengths for the Queen Mary harp is the same as that used for the frame of the Lamont harp (see Appendix A). The string lengths were derived from the current coordinates of the string holes (and iron string loop) and the tuning pins at the point of contact of each string, as well as the positions of the 'pivot points' and 2.3° forward tilt of the neck (as shown in figure 2.36), and the twist of the neck along its long axis. These quantities were measured in three dimensions on one of the CT scans of the harp. Since the tuning-pins were not in the harp when it was scanned, the tuning-pin positions were measured just outside the cheekband on the leading edge of the tuning-pin hole. This is closer to the string band than a string would be wound in practice, particularly at the extreme treble end of the compass, but provided consistent measurements. This does, however, result in a slight shortening of the calculated string lengths for the top few strings.

In order to take into account the twist in the neck, its sideways rotation was measured at each tuning pin hole. The calculated string lengths for the three versions of the frame are given in table 2.6, and diagrams of the harp frame in its current state and with a reconstructed straightened frame are shown in figures 2.42 – 2.44.

The diagrams of the Queen Mary harp frame in figures 2.42 – 2.44 depict the strings as projected onto a plane. The string lengths are therefore depicted foreshortened, particularly at the treble end of the instrument. **Measurements of string length should not be taken off the diagrams.** For the calculated string lengths, see table 2.6. Also note that **the points plotted at the ends of the strings are the points of contact only. They are not the centre points of the tuning pin holes and string holes.**

Figure 2.42 (overleaf): *the frame of the Queen Mary harp in its current state. This outline is based on a tomogram of the harp, and shows the strings and frame as projected onto a plane. The outline of the interior of the soundbox and the neck-soundbox joint are also shown. The black circles and blue squares are the points of contact of the strings at the string shoes and tuning pins, respectively, plotted from the measured coordinates taken from the CT data. The frame is shown with 30 strings, strung directly from string hole to corresponding tuning pin. The 30th string is strung from the iron loop as discussed above. Scale: 1 box : 2 cm.*

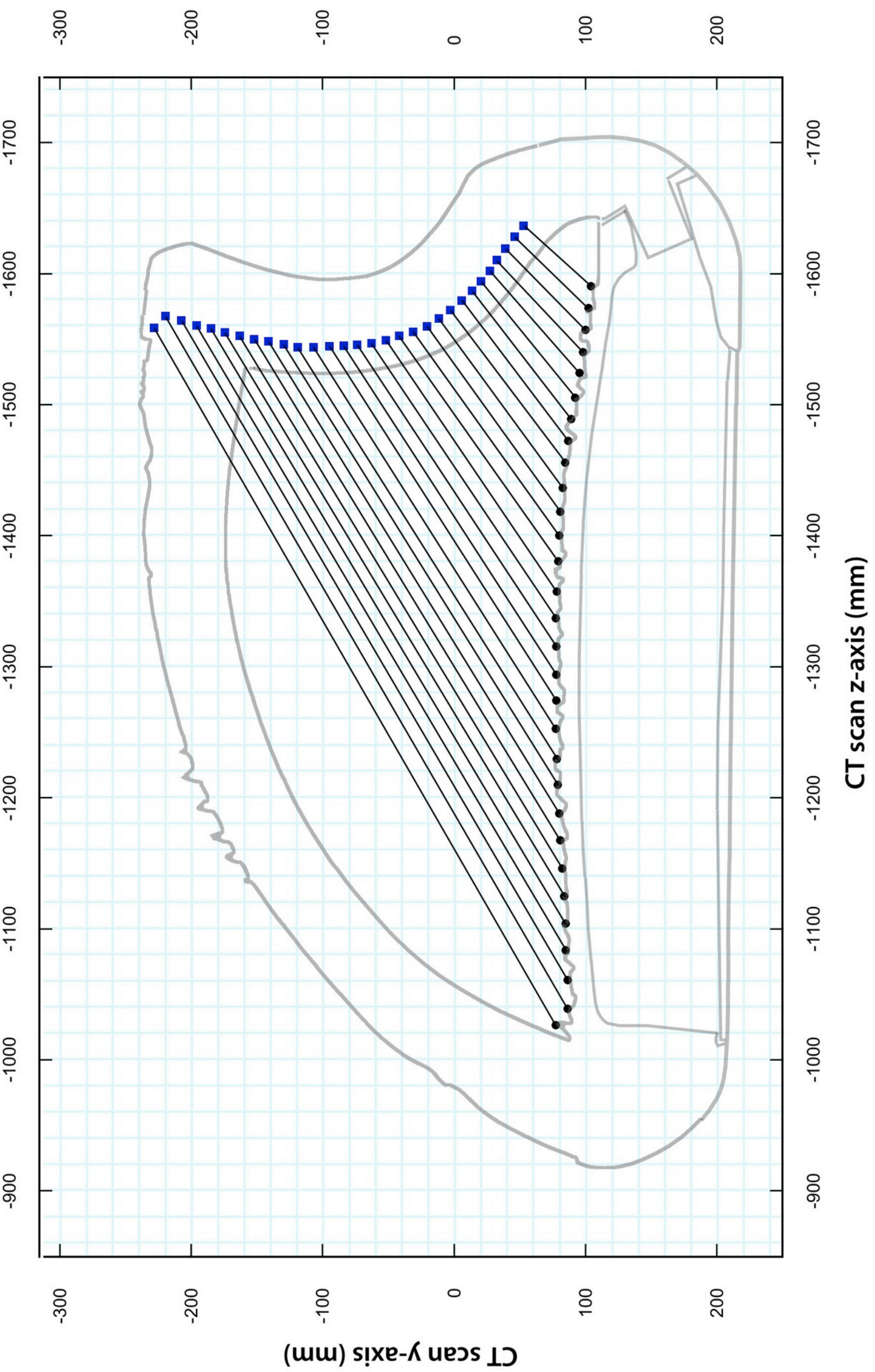

CT scan z-axis (mm)
CT scan y-axis (mm)

Figure 2.43 (overleaf): *the frame of the Queen Mary harp, corrected for the rotation, twisting, and shift of the neck. The black circles are the points of contact of the strings at the string shoes, plotted from the measured coordinates taken from the CT data. The red circles are the calculated points of contact of the strings at the tuning pins, corrected for the repositioning of the neck. The outline of the neck has been taken from a tomographic cross-section through its centre, repositioned with the tenon completely seated in the soundbox mortise. The outline of the back of the soundbox at the neck joint has been slightly redrawn to remove the change in shape that will have occurred due to the tenon pushing against it as the neck rotated forwards. A gap between the back of the tenon and the mortise where a metal rod is currently located has been left in, as it is not known if there was originally a gap at this location. The frame is shown with 29 strings, strung directly from string hole to corresponding tuning pin. The 30th tuning pin and the iron loop are not shown, as they were later additions. The outline of the forepillar, shown as a dashed line, is speculative and is only included to show the complete frame. Scale: 1 box : 2 cm.*

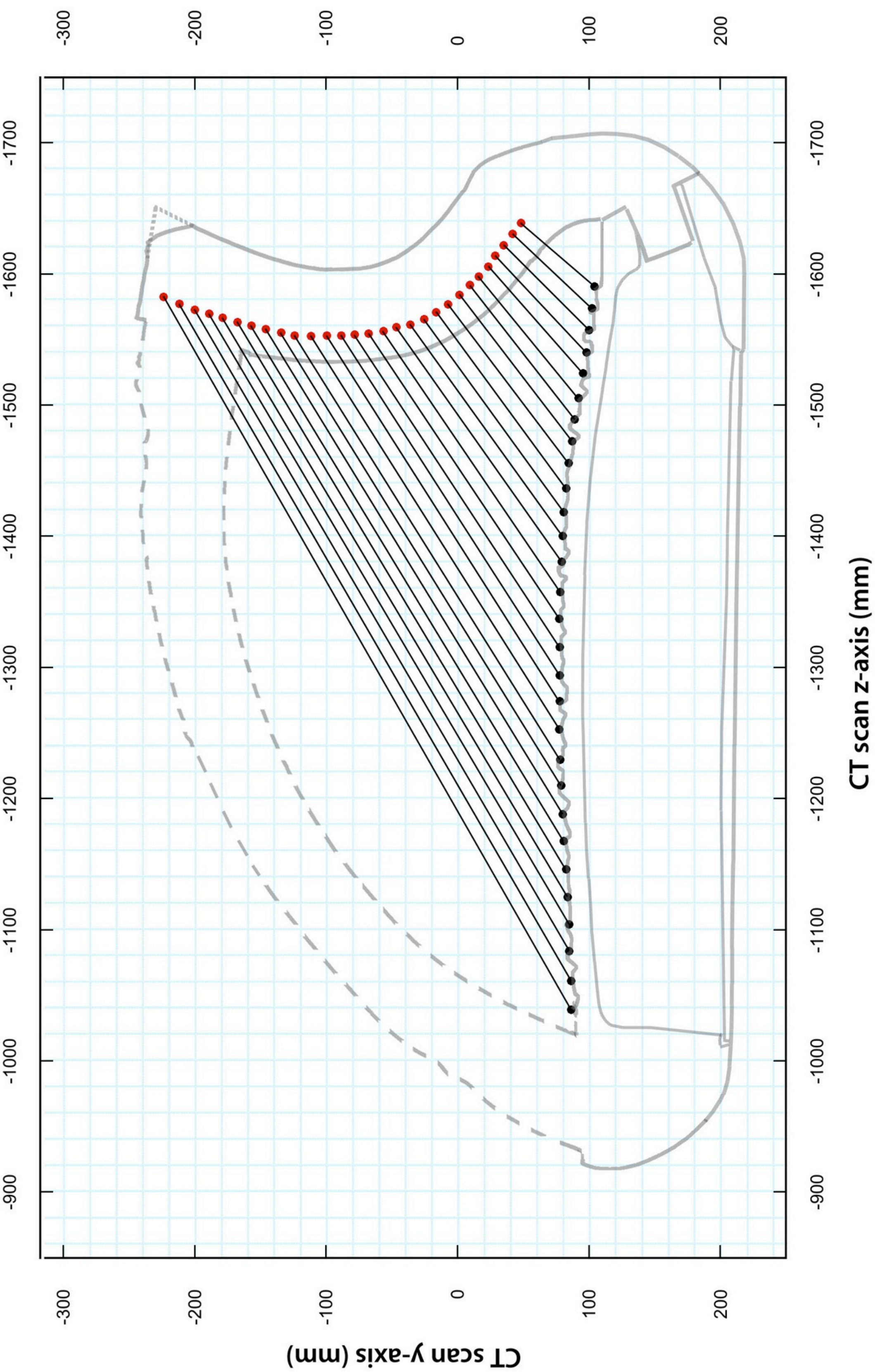

CT scan z-axis (mm)
CT scan y-axis (mm)
-1700
-1600
-1500
-1400
-1300
-1200
-1100
-1000
-900
-300
-200
-100
0
100
200

Figure 2.44 (overleaf): *the frame of the Queen Mary harp, corrected for the motion and distortion of the neck as shown in figure 2.43, and also adjusted to flatten the soundbox belly. The black circles are the points of contact of the strings at the string shoes, plotted from the calculated positions for a flat fronted soundbox. The remainder of the diagram is the same as shown in figure 2.43. Scale: 1 box : 2 cm.*

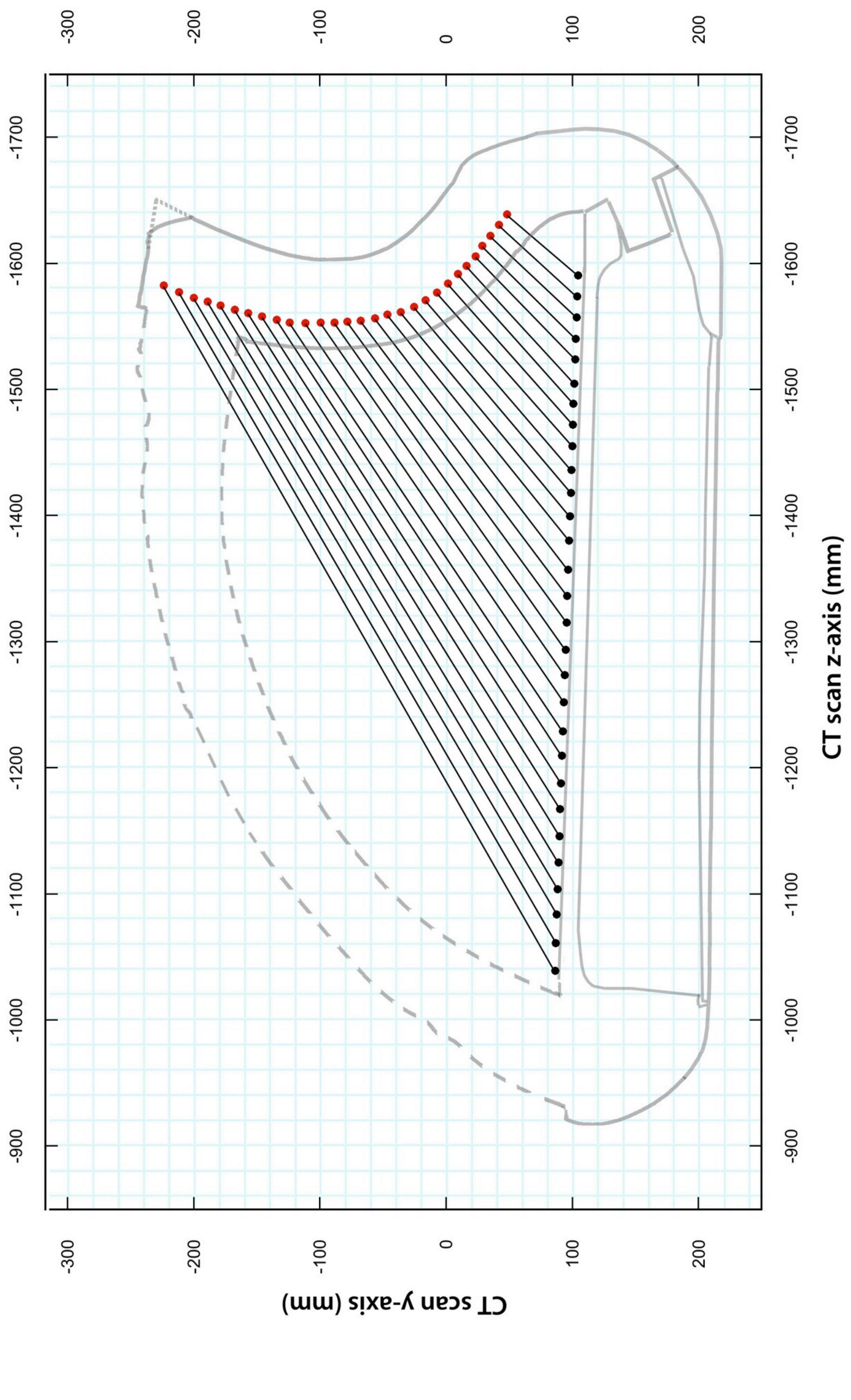

CT scan z-axis (mm)
CT scan y-axis (mm)
-1700
-1600
-1500
-1400
-1300
-1200
-1100
-1000
-900
-300
-200
-100
0
100
200

Table 2.6.

Queen Mary harp string lengths

string #	current frame (mm)	straight frame (mm)	straight frame no belly (mm)
1	74	77	77
2	82	86	88
3	90	95	97
4	99	104	107
5	106	112	115
6	117	122	127
7	126	132	138
8	136	142	150
9	147	154	163
10	161	168	178
11	175	183	193
12	192	200	211
13	212	220	230
14	233	241	252
15	254	262	273
16	277	286	295
17	300	309	318
18	322	331	340
19	346	356	364
20	372	382	389
21	397	407	413
22	424	434	439
23	449	460	464
24	476	487	490
25	503	514	516
26	530	541	542
27	555	567	567
28	584	597	596
29	613	626	626
loop - 30	615	(628)	(628)

Note: the uncertainty in the string lengths is +/- 1, based on the measurement uncertainty carried through the calculations.

Stringing regimes for the Queen Mary harp

The versions of the Queen Mary harp frame presented above represent the harp as it may have been when it was built, and later in its working life. Although it did not suffer the extreme damage and twisting of the Lamont harp frame, it has distorted enough from its original shape to alter the string lengths. This section discusses the string scaling of the Queen Mary harp for the current and straightened states of the frame, based on the reconstructed and measured string lengths, respectively.

The string lengths derived for the straightened harp frame with no belly, and with a full height belly, and for the frame in its current state are shown plotted together in figure 2.45 for comparison.

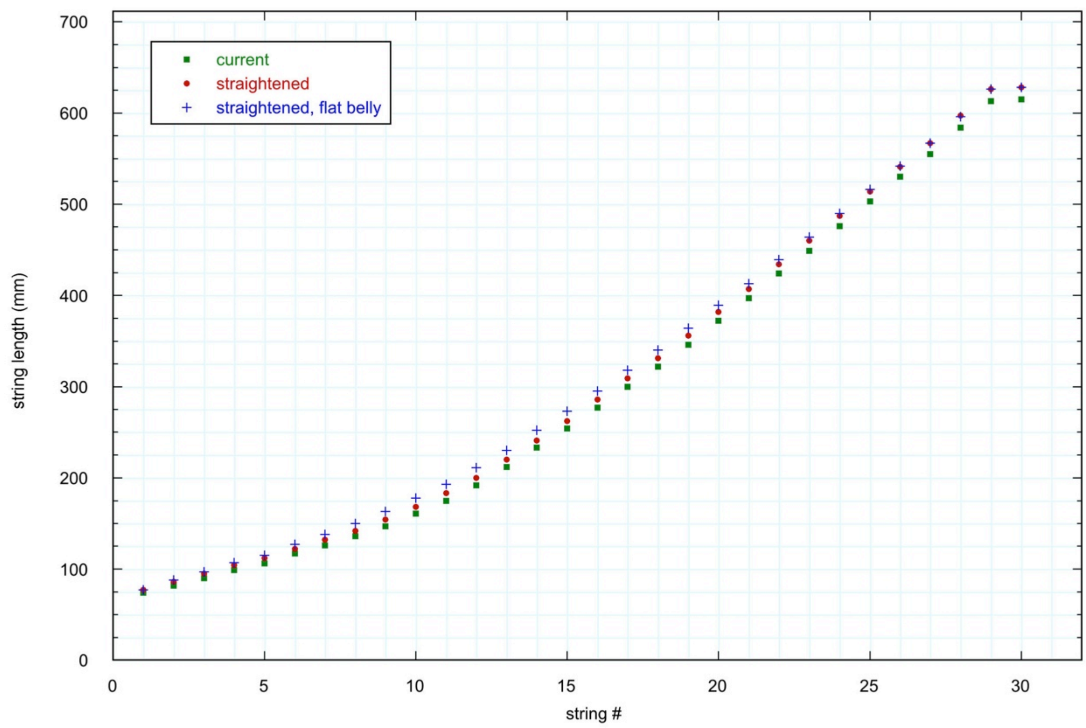


Figure 2.45: *string length versus string number for the Queen Mary harp. The string lengths shown are for the frame in its current state (green squares), the straightened frame with a fully developed soundbox belly (red circles), and the straightened frame with no soundbox belly (blue crosses). All of the string lengths shown are for direct string hole to tuning pin stringing.*

For the frame in its current state, the string lengths fall increasingly short of the straightened frame string lengths towards the bass end of the harp. If the straightened frame is representative of the harp 'as built', string #29 has shortened by an estimated 13 mm from its original length. This represents a change of 2% of the total length of the string. At the treble end of the instrument, string #1 has shortened by an estimated 4 mm (representing a change of 5% of the total length). Not surprisingly, the difference between the current string lengths and those derived for the straightened frame is significantly less than it is for the Lamont harp.

It is worth comparing the current and reconstructed string lengths for both the Queen Mary and Lamont harps to see where they are similar and where they diverge. These are plotted together on the graphs in figures 2.46 and 2.47. Their relative differences are pertinent to the discussion of possible solutions for the compass and pitch of the Queen Mary harp.

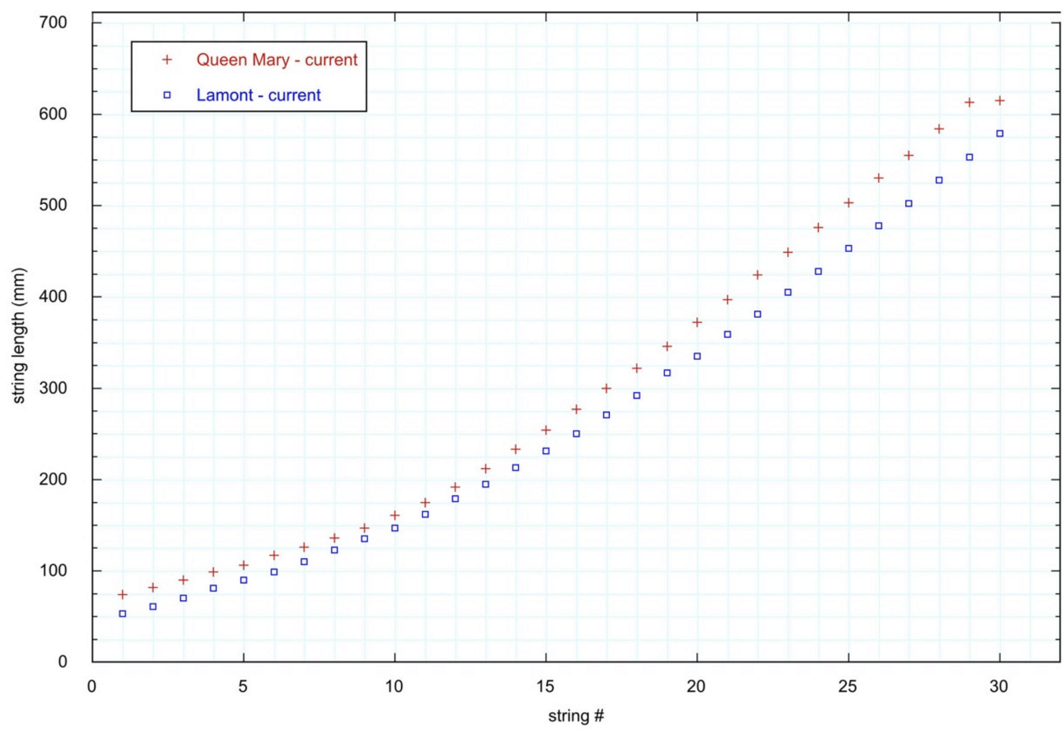


Figure 2.46: *comparison of string lengths for the Queen Mary and Lamont harp frames in their current state. Both sets of string lengths are for direct string hole to tuning-pin stringing. Note that the string lengths at the treble and bass ends of the compass are proportionately longer for the Queen Mary harp.*

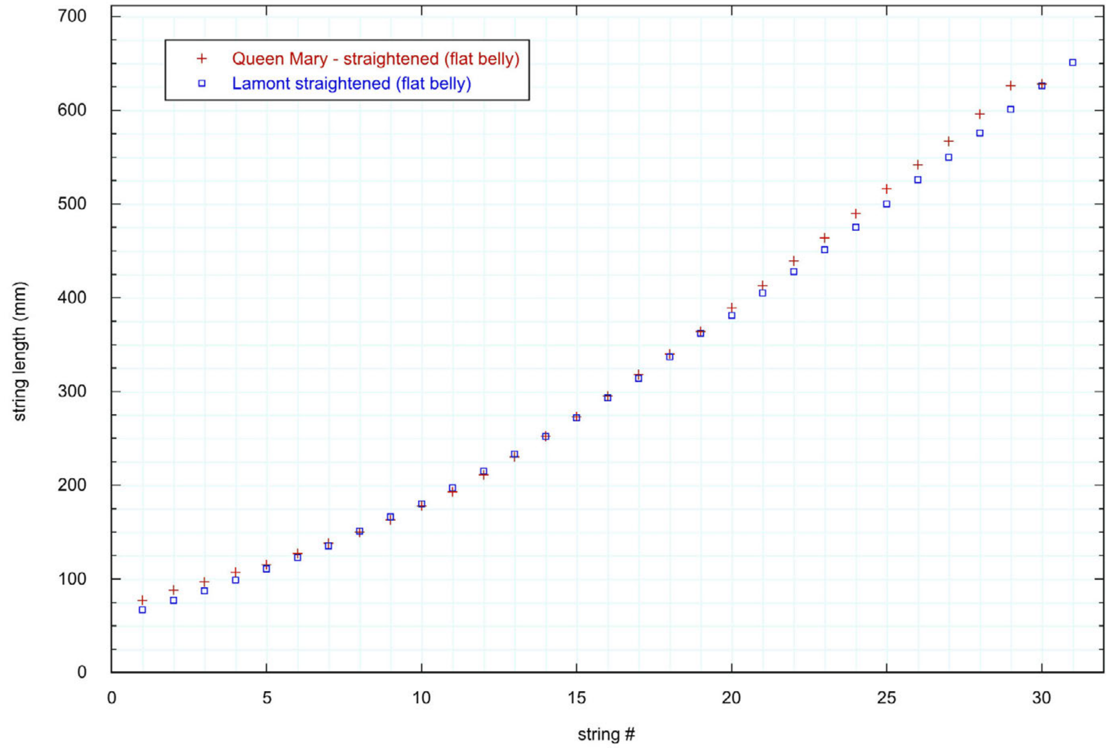


Figure 2.47: *comparison of reconstructed string lengths for the straightened Queen Mary and Lamont harp frames, with no soundbox belly. As for figure 2.46, both sets of string lengths are for direct string hole to tuning pin stringing. Note that the string lengths for both harps are nearly the same in the mid-range of the compass, but the Queen Mary harp string lengths are longer in the treble and the bass.*

The string lengths plotted in figures 2.46 and 2.47 are for direct string hole to tuning pin stringing for both harps, so that a direct comparison can be made. Figure 2.46 shows the current string lengths, and figure 2.47 shows the reconstructed string lengths for the straightened 'as-built' frames. Although the two harp frames are noticeably different in overall size (the Lamont is generally regarded as a 'bigger' harp than the Queen Mary), their string lengths are similar. Actually, the Queen Mary harp currently has entirely longer string lengths than the Lamont harp, due to the extreme distortion of the frame of the latter harp. For the straightened frames the string lengths for the two harps are nearly the same for much of the compass. What is notable, however, is that the string lengths for the Queen Mary harp are proportionately longer in the treble and bass than those for the Lamont harp. This is the case for both the current and the reconstructed 'straightened' frame string lengths, so this difference is not likely to be simply due to underestimating the reconstructed

Lamont harp string lengths. As will be apparent in the discussion that follows, the strings in the treble of the Queen Mary harp are disproportionately long in terms of the scaling of the compass, and this has implications for possible solutions for the stringing and pitch of this harp.

Figure 2.48 shows the string lengths for the Queen Mary harp plotted logarithmically to show the overall scaling of the instrument. As discussed for the Lamont harp, the decreasing 'slope' towards the bass indicates short scaling at that end of the compass. The effect of the belly on string length is also apparent in the mid-treble portion of the compass.

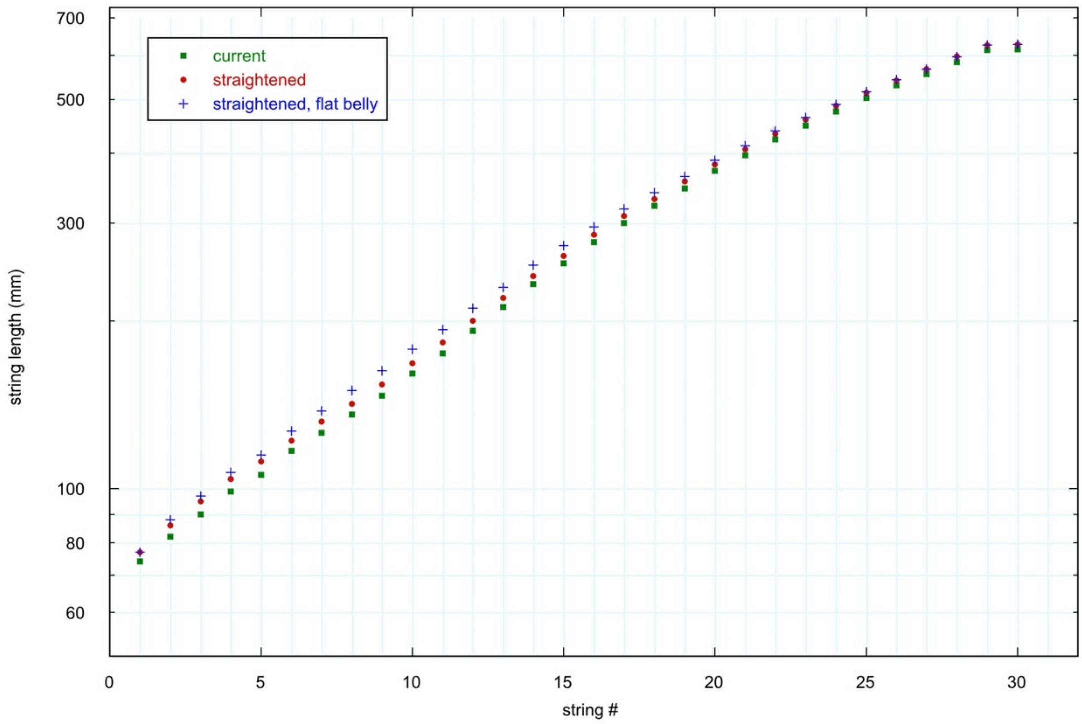


Figure 2.48: *string length versus string number for the Queen Mary harp, plotted on a logarithmic scale. The string lengths plotted are the same as in figure 2.45. This plot shows the expected short scaling in the bass.*

Possible solutions for the compass and pitch of this harp can be explored by scaling the string lengths and identifying the highest stressed string, as discussed for the Lamont harp. Although there are identifying letters, apparently cut out of printed text, pasted onto the soundbox next to several of the strings, these may date to the post-historical restringing of the harp in the early 19th century, and are discussed separately in relation to that.[205] As discussed in detail for the Lamont harp, historical information on the compass of these instruments is limited and there are numerous possibilities. A number of these are explored for the Queen Mary harp. Examining the scaling of this harp has also raised an interesting point, as discussed below.

Using the same method as for the Lamont harp, solutions for the pitch were explored by assigning a proposed compass to the strings and scaling the lengths to determine the pitch based on the highest stressed strings. This was done for a number of possible compasses. Figure 2.49 shows a sample set of stress curves for a diatonic tuning from c in the bass to c‴ in the treble, scaled to c″. These have been calculated for the harp frame in its current state, the straightened frame with a fully developed soundbox belly, and the straightened frame with no soundbox belly. For the two versions of the straightened frame the compass includes a pair of unison strings (at g′) and a gap in the bass (at e / f), as discussed for the Lamont harp. For the frame in its current state, the compass is purely diatonic with no gap and no unison strings (the reason for this choice is discussed later in this section).

[205] For a discussion of the letters pasted onto the soundbox, see also Simon Chadwick, "The Queen Mary Harp: Inscriptions," last modified March, 2014, http://www.earlygaelicharp.info/harps/QMinscription.htm.

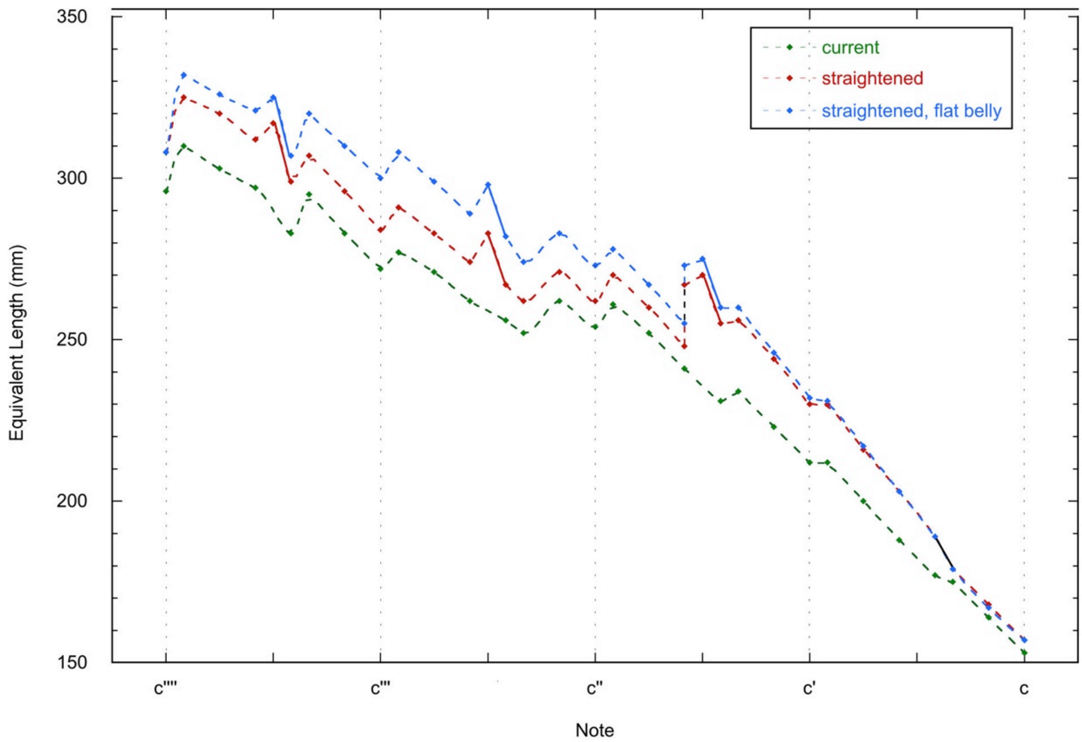


Figure 2.49: *stress curves for the stringing of the Queen Mary harp, based on a proposed compass of c – c'''', with 29 strings, scaled to c''. The three curves shown are for the frame in its current state (green), the 'straightened' frame with a fully developed soundbox belly (red), and the 'straightened' frame with a flat soundbox belly (blue). For clarity, the data points belonging to each are connected by dashed lines. For the two versions of the 'straightened' frame, the compass shown includes a pair of unison strings at g', and a gap at e/f in the bass. The equivalent lengths of re-tunable strings are connected by a solid line. For this stringing, these occur at e/f in the bass, and at f/f# for the rest of the compass. The compass shown for the current frame is purely diatonic, with no gap in the bass, no unison strings, and no re-tunable strings.*

The shape of the stress curves, which is a function of the scaling and is therefore essentially the same regardless of choice of compass, can be compared to the stress curves shown in figure 2.24 for the Lamont harp. The curve for the Lamont harp falls off towards the treble, past the mid-point of the compass, whereas the stress curves for the Queen Mary harp continue to rise almost to the top string. This means the highest stressed strings of the Queen Mary harp are at the extreme treble end of the compass. The instrument cannot be pitched higher than the snapping pitch of these strings, and the implication of this is that using a stringing material of the same strength for both the treble and the mid-range of the compass would result in the strings in the middle of the compass being tuned below their optimal pitch. The stringing marks on the inside of the soundbox suggest the strings in the middle of the compass received a lot of use, historically, as would be expected, so it seems unlikely that they would be strung sub-optimally. It is therefore possible that the Queen Mary harp was intended to be strung with stronger strings in the treble than in the mid-range of the compass. This is discussed further below.

While it is beyond the scope of this dissertation to explore all plausible compasses for this harp, solutions for the pitch of the instrument were calculated for compasses beginning on c and F in the bass (with their variants). This also includes compasses starting on G in the bass for the harp with 29-strings, as that is equivalent to a 30-string compass starting on F. Compasses were considered for the instrument with either 29 or 30 strings, for the string lengths derived for the straightened frame, both with and without a soundbox belly. The calculated values for the pitch of the instrument are for yellow brass stringing with a scale length of 270 mm for c″ at an instrumental pitch of A440 Hz. These solutions can be found in table A.1 in Appendix B.

Considering first the solutions that assume no change to a stronger stringing material for the treble, in several cases the resulting instrumental pitch was found to be either implausibly low or high, making these compasses less likely to have been used. Haynes (2002) lists very few instruments pitched below A380 Hz or above A500 Hz, so solutions that yield a pitch outside of this range may be considered as unlikely. From the data compiled in table A.1, this eliminates nearly all of the solutions for a compass beginning on F in the bass for the instrument with either 29 or 30 strings. The transpositions from c to F, in the context of "Organ-pitch" and "Quire-pitch" as discussed for the Lamont harp, yielded pitches for the compasses on F that were too high to be plausible. This also means that compasses beginning on G in the bass for the instrument with 29 strings also yielded an instrumental pitch that is implausibly high. The one exception is a compass on F, with 30 strings, that is either purely diatonic, or has unison strings plus the gap in the bass. Assuming yellow brass wire with a scaling of 270 mm for c″ at A440 Hz, the pitch of the instrument with this compass would be between about A480 – 500 Hz, depending on the height of the soundbox belly. If the lengths of the top strings are adjusted for the position of the winding on the tuning pins (as discussed earlier), this pitch could be as low as A 470 – 490 Hz. All except one of the compasses starting on c in the bass result in a pitch that is implausibly low. The one exception is a compass starting on c with 29 strings that includes the pair of unison strings, but no gap in the bass. Stringing with yellow brass with a scaling of 270 mm for c″ at A440 Hz, would yield an instrumental pitch between about A 397 – 408 Hz. These two compasses are summarized in table 2.7 (see below).

The two compasses (29 strings, from c, pitched at A 397 – 408 Hz; and 30 strings on F, pitched at A 481 – 502 Hz) result in plausible pitches for the instrument, and it is interesting to think about the harp with the original 29 strings having a compass from c in the bass, followed later (after the addition of the iron loop) with a 30 string compass from F in the bass. It is possible that these two compasses were indeed used. There is, however, the issue of the scaling of the string lengths in the treble. As discussed earlier, the scaling appears to favour using stronger strings there. On describing the Irish harp, Galilei (1581) remarked that, "they commonly have strings made of brass with some steel in the higher pitches in the manner of the harpsichord [*gravicembalo*]".[206] Table A.1 includes a set of solutions for stringing with iron on the top eight strings in the treble. Other sufficiently strong wire could be used in place of iron. Based on the string scaling for this harp, the wire used in the treble would need a scale length at least 1.12 – 1.16 times longer than that for the wire used lower down in the compass.[207] There would not be a significant advantage to having more than eight iron strings, also based on the string scaling. Additionally, setting the number at eight conveniently places the stringing change at the top octave of the compass. Putting iron stringing in the treble allows the strings farther down the

[206] Galilei, *Ancient and Modern Music*, 357.

[207] This is calculated as follows: $\frac{S_1}{e.l._1} = \frac{S_2}{e.l._2}$, where S_1, e.l.$_1$, and S_2, e.l.$_2$ are the scale lengths of the wire used and equivalent lengths of the highest stressed strings for each of the two portions of the compass, respectively. At 330 mm, the scale length of iron for c″ at A440 is 1.22 times longer than the scale length of yellow brass at 270 mm for c″ at A440.

compass to be tuned up closer to their optimal pitch, raising the overall pitch of the instrument. Placing iron stringing in the treble results in the instrument being pitched implausibly high for all of the proposed compasses starting on F in the bass, however (as well as those starting on G for the instrument with 29 strings). Most of the compasses starting on c in the bass, which were primarily pitched too low before, though, now result in a plausible range of pitches for the instrument. These are shown in table 2.7, along with the two most plausible solutions discussed above for brass stringing in the treble.

Table 2.7.

Possible compass and pitch for the Queen Mary harp

# of strings	**compass**	**unison strings?**	**stringing**	**instrumental pitch (Hz)**
29 strings	c – b‴	yes	brass	A397 – 408
30 strings	F – g‴	no *or* unison + bass gap	brass	A481 – 502
29 strings	c – c⁗	no *or* unison + bass gap	brass + iron	A383 – 411
29 strings	c – b‴	yes	brass + iron	A430 – 462
30 strings	c – d⁗	yes	brass + iron	A383 – 411

Note: the pitch is derived for yellow brass with a scale length of 270 mm for c" at A 440 Hz, and is based on the scaled length of the highest stressed strings. For the stringing with iron in the treble this is the highest stressed string below the top eight strings in the treble. ***The pitch ranges include the solutions for both flat and bellied soundboxes*** *and also reflect an uncertainty in the un-scaled string lengths of +/- 1 mm. Taking into account the underestimate of string length at the upper end of the treble would result in slightly lower pitch ranges for the harp with brass only stringing.*

As an example, figure 2.50 shows the scaling of the harp with a straightened frame and a fully developed soundbox belly, for the 29-string compass from c in the bass, with unison strings at g′ and no gap in the bass, and with iron stringing in the treble (see table 2.7, second line from bottom). The scale lengths of iron, yellow brass, and red brass wire are plotted on the graph for c″ at A459 Hz (the average of the pitch range for this solution, with a soundbox belly).

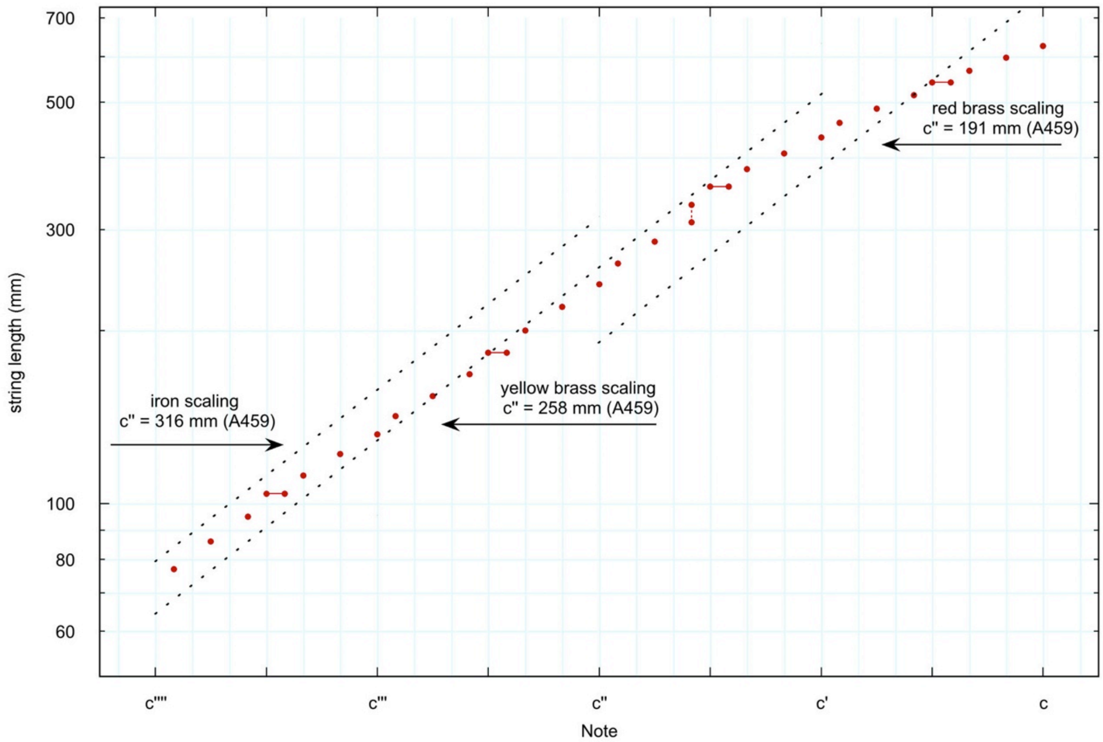


Figure 2.50: *Queen Mary harp string scaling for a proposed compass of 29 strings from c – c'''' with a pair of unison strings at g', and brass stringing with eight iron strings in the treble. The scaling for red brass, yellow brass, and iron at the proposed instrumental pitch of A459 Hz is shown as dotted lines.*[208] *Strings that might be retuned are represented by data points connected by a horizontal bar. For this compass, these are the F – F# strings. A vertical dashed line is shown connecting the data points for the two unison strings. The string lengths are for the straightened frame with a fully developed soundbox belly.*

The string lengths plotted in figure 2.50 indicate possible metal transitions where the data points cross the scaling lines for iron, yellow brass, and red brass. The transition from iron to yellow brass could occur at a‴ (string #9), and from yellow brass to red

[208] The scale lengths for yellow brass and iron are based on scalings of 270 mm and 330 mm for c″ at A440 Hz from Campbell, Myers, and Greated, *Musical Instruments*, 308. The scale length for red brass is based on a scaling of 211 mm for c″ at A415 Hz from O'Brien *Ruckers*, 61.

brass at g (string #25). This would result in the instrument being strung in red brass from c to g, in yellow brass from a to a″, and in iron from b″ to b‴. The iron stringing is more than sufficiently strong for the treble strings, as indicated by the position of the plotted string lengths below the line for iron scaling, however the actual lengths for these strings may be 2 – 3 mm longer. Nevertheless, as discussed earlier, a stringing material that is not as strong as iron (with the scale length used here) would also suffice. A significant point illustrated by figure 2.50 is that with this stringing there is no requirement for precious metal strings in the bass of this harp.

There are a number of possible solutions for the historical compass and pitch of the Queen Mary harp, some of which have been presented here. It is not possible with the available information to single out one solution that is most likely to have been what was originally used. We do know from Gunn (1807) that this harp was restrung in brass in the early 19th century for exhibition performances by the harpist John (or Joseph) Elouis.[209] As mentioned earlier in this section, there are several letters pasted onto the string band of the Queen Mary harp, adjacent the string holes. These letters, which appear to be for the purpose of labelling the strings with notes of the scale, are shown in the photographs in figure 2.51.

[209] Keith Sanger, "John Elouis," WireStrungharp.com, accessed 29 April, 2014, http://www.wirestrungharp.com/harps/harpers/elouis/elouis_john.html#_ednref2.

Figure 2.51: *letters pasted onto the string band of the Queen Mary harp. The letters, which appear to have been cut out of printed text, label six strings with notes of the scale. The letters are oriented on the soundbox so that they appear right side up to the player looking down onto them.*[210] *A photograph of each letter is shown on the right, in the order that they appear on the harp. The photographs have been rotated to orient the letters right side up (note the direction of the string shoes). Photograph (left): Isabell Wagner.*

The letters, cut out of printed text, read from bass to treble: C, C, G, B, c, (c). The letter at the top end of the scale has been partially eaten away by insect damage and is not legible, but may be a lower-case c. Gunn (1807) mentions the harp first being restrung in brass and then later gut, and discusses the compass chosen for the stringing as follows:

> The shortest string, or highest note, of Queen Mary's Harp, we found to be the upper C, or highest note of the modern piano forte, with additional keys; and proceeding by the descending scale, it has exactly a compass of four complete octaves, terminating in C, the

[210] Chadwick, "The Queen Mary Harp: Inscriptions."

> notation of which, in our music, is placed on the second space of the bass stave.[211]

This compass matches the positions of the letters pasted onto the string band. It is likely that it did not include unison strings or a gap in the bass. Although Gunn was aware of Edward Bunting's work, and quotes from his 1796 volume, Bunting's discussion of the scale of the Irish harp with unison strings and bass gap was not published until 1840, so it would not have occurred to Gunn, Elouis, or Wood to include these modifications to the scale.[212]

It appears from Gunn's account that this description refers to the gut stringing, however this compass could also work for brass stringing with string lengths for the frame in its current state. Using the same method discussed for the string lengths derived for the 'straightened' versions of the harp frame, the instrumental pitch can be determined by scaling the string lengths and identifying the highest stressed strings. If they had strung the harp entirely in brass through the treble, the instrument would have to be pitched about a whole tone below A440 Hz (at around 380 – 388 Hz, for yellow brass with a scaling of 270 mm at c″), and the strings in the middle of the compass would be below their optimal pitch.

As discussed in Chapter 1, a fragment of iron wire was found embedded in the end of one of the wooden string-hole pegs. As also discussed, these pegs most likely date to the early 19th-century restringing of the harp, and were either supplied by Wood or Elouis. Since Wood was in charge of the stringing and tuning of instruments manufactured by Muir, Wood, and Co., including pedal harps, he is a likely source, and it is very possible that the iron wire fragment is evidence that iron stringing was used in the treble when the harp was re-strung in brass. It is interesting to note that, although Gunn doesn't mention iron, he quotes from the same passage in Galilei that mentions iron stringing, so he would have been aware of Galilei's remark about iron strings in the treble. If Wood and Gunn had strung the harp with iron in the treble, the pitch of the instrument would rise to about A426 – 430 Hz (using yellow brass,

---

[211] Gunn, *Historical Inquiry*, 22.
[212] Bunting, *Ancient Music of Ireland*, 23.

scaled as before). This happens to be close to the prevailing pitches in London, Vienna, and Paris at the time (A430 – 440 Hz), which might have encouraged them to settle upon this particular compass.[213]

Comparison with the Trinity College harp

It is worth comparing the reconstructed string lengths for the straightened frames of the Lamont and Queen Mary harps to the string lengths for the Trinity College harp. As for the Queen Mary and Lamont harps, the frame the Trinity College harp has distorted over time, altering the string lengths. Paul Dooley has undertaken the task of reconstructing the dimensions of the Trinity College harp with a straightened frame.[214] Thanks to this work, it is possible to make a direct comparison of the reconstructed string lengths for the Queen Mary and Lamont harps to Dooley's reconstructed string lengths for the Trinity College harp.[215] It is of particular interest to compare the Trinity College and Queen Mary harps, due to their similarity.[216]

Figure 2.52 shows the string lengths of the three harps plotted together. The lengths are for direct string shoe to tuning pin stringing for all three harps. For the Lamont and Queen Mary harps, these are the reconstructed lengths for the straightened frame with their current soundbox bellies. For the Trinity College harp, these are the reconstructed string lengths published in Dooley (2014), for that harp with a straightened frame and an adjusted soundbox belly with a height of 12.7 mm.[217] The current bellies of the Queen Mary and Lamont harps have maximum heights of 18 and 22 mm, respectively, as calculated from measurements taken from the CT scans.

---

213 Haynes, *History of Performing Pitch*, 329 – 30, 333.
214 Paul Dooley, "Medieval Irish Harp," 107 – 42.
215 ibid., 124.
216 Compare, for example, the photograph of the Trinity College harp in Dooley, "Medieval Irish Harp," 48 to the photograph of the Queen Mary harp in figure 2.51. See also Armstrong *Irish and Highland Harps*, 55 – 62, and 168 – 83.
217 Dooley, "Medieval Irish Harp,"124.

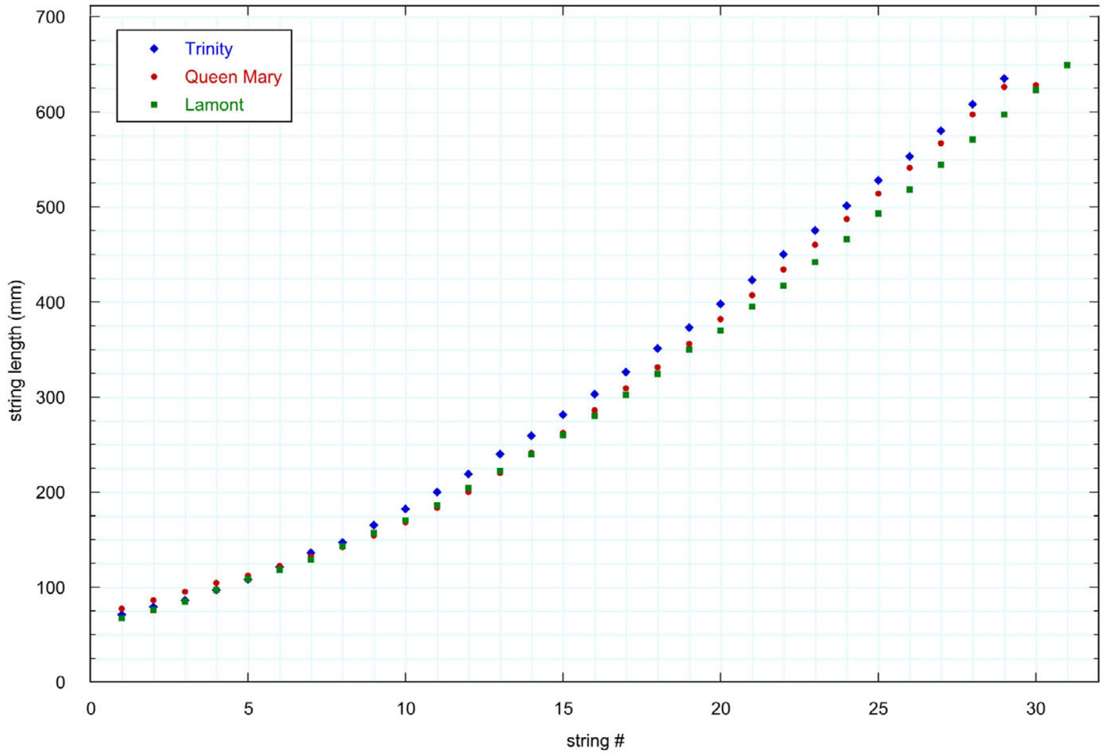


Figure 2.52: *a comparison of reconstructed string lengths for the Trinity College, Queen Mary, and Lamont harps with straightened frames. The string lengths for the Trinity College harp are from Dooley (2014).*[218]

Aside from the treble end of the compass, where the string lengths of the Queen Mary harp are comparatively long, the reconstructed string lengths for this harp fall short of those for the Trinity College harp by as much as 20 mm in the middle of the compass. Part of the difference in length is due to the different soundbox belly heights. Even taking this into consideration, however, the string lengths for the Queen Mary harp would still be shorter than those for the Trinity College harp in this part of the compass. As a comparison, if the Trinity College harp had a compass from c – b‴ (with unison strings) and stringing as discussed above for the Queen Mary harp (although without iron in the treble), it would have a pitch of about A418 – 423 Hz (assuming a measurement uncertainty of +/- 1 mm for the string lengths).[219] The Queen Mary harp, with its current soundbox belly, (and with iron in the treble) would have a pitch of A 455 – 462 Hz. This is a difference of about 1½ semitones. If

[218] Dooley, "Medieval Irish Harp," 124.
[219] This is for yellow brass stringing with a scaling of 270 mm at c″ (A440).

the difference in height of the soundbox bellies is taken into account, the difference in pitch between the two harps would be 1 semitone.

In comparing the string lengths of the Lamont harp to the Trinity College harp, the string lengths of the Lamont fall increasingly short if each is compared starting from the first string in the treble, as plotted in figure 2.52. If the string lengths are compared starting from string #2 for the Lamont harp instead (shifting the Lamont harp string lengths up by one), the lengths for these two harps are, in fact, very similar, as shown in figure 2.53, below.

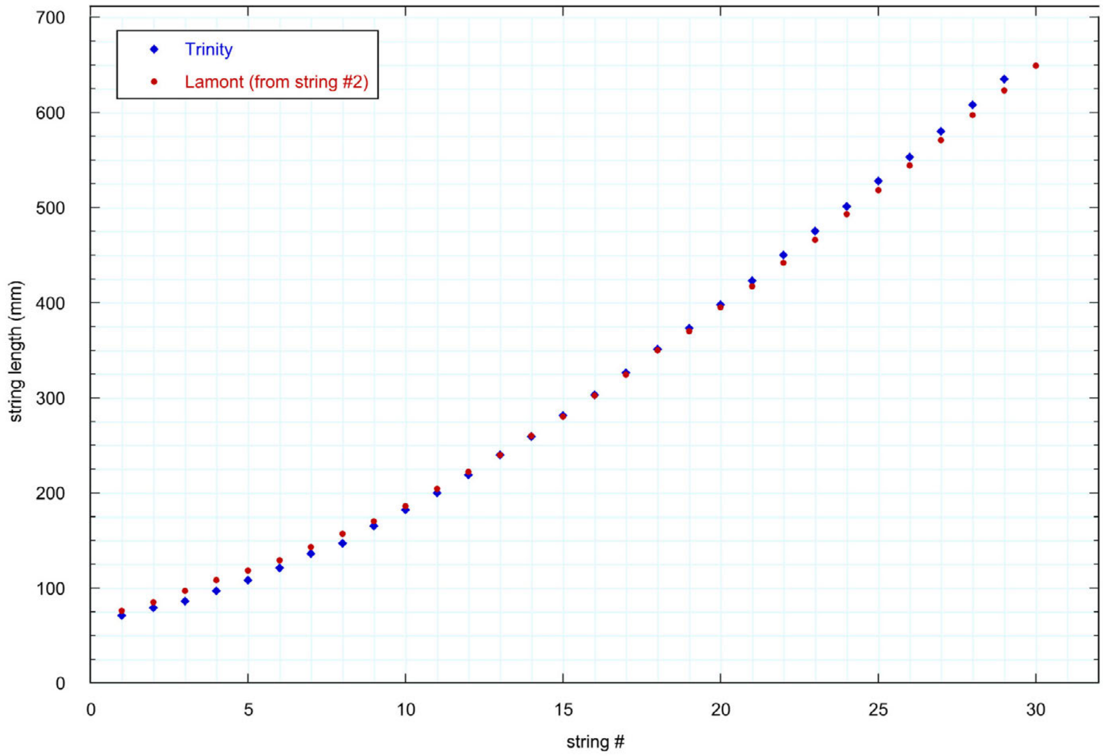


Figure 2.53: *comparison of reconstructed string lengths for the Lamont and Trinity College harps with 'straightened' frames with soundbox bellies, from string #2 on the Lamont harp and string #1 on the Trinity College harp. Note the close correspondence in string lengths. Trinity College harp string lengths from Dooley (2014).*[220]

[220] Dooley, "Medieval Irish Harp," 124.

It is difficult at this point to say if the observed differences in reconstructed string lengths are entirely due to actual differences in construction between these three harps, or if they are due in part to the different approaches to reconstructing the string lengths for the straightened frames. It should also be reiterated that there is currently not enough information to provide definitive answers for the historical compass and pitch of the Queen Mary and Lamont harps. The solutions discussed above are only possibilities, or to quote Lewis Morris's marginalia in the "Robert ap Huw" manuscript, "These modern notes are only my guesses."[221]

Summary

The primary focus of Part I of this dissertation has been the stringing of these two harps. Although it is not possible to definitively identify the specific compass (or compasses) used historically without further information, the reconstructed string lengths made it possible to examine some plausible solutions. The analysis also raises the interesting possibility that the Queen Mary harp might have been scaled for stronger wire for the top strings in the treble, and that this wire could have been iron. Instrument builders will perhaps find the reconstructed string lengths useful, particularly for the Lamont harp, whose severely distorted frame has hindered efforts to build instruments modelled on this harp. Although the lengths derived for the straightened frames are provisional, this analysis of the motion of the frame members may lead to further refinements. It is hoped that instrument builders will also look beyond the string lengths to a deeper understanding and appreciation of the underlying craftsmanship in the construction of these two harps.

The examination of the stringing began with a discussion of the wire fragments discovered in each of the harps. Two fragments (one in each harp) were identified as brass, while a third very small fragment in the Queen Mary harp was identified as iron. Both fragments in the Queen Mary harp were identified as likely dating to the

[221] Lewis Morris, marginalia in, BL Addl. 14905, Lewis, ed., *Musica*, 35. By plainly distinguishing his interpretation from fact, Morris has probably made one of his more important contributions to the manuscript.

restringing in the early 19th century. The fragment in the Lamont harp was identified as possibly dating to the 17th century, although this estimate is open to interpretation given variations in historical brass composition. Analysis of its composition and measurement of the gauge were combined with the reconstructed string length for the straightened frame to calculate the string tension for a plausible solution for the compass and tuning. The relatively high string tension that was found has informed a discussion of the reinforcing straps across the neck-forepillar joint of the Lamont harp, and signs of similar straps on other Irish harps, as possibly being evidence of a change in stringing practice towards higher tension.

As part of the process of determining the string lengths, the stringing arrangements for each harp were deduced based on examination of marks at the string holes, evidence of damage and/or modifications to the instruments, and examination of the tomograms. For the Queen Mary harp, it was confirmed that all of the string holes were used, at least at some point, during the working life of that instrument. For the Lamont harp, it was determined that 31 of the 32 string holes in had been used, with the last string hole in the bass remaining unused. The stringing arrangement for the Lamont harp was determined to have likely changed over time in response to damage to the instrument, starting with a direct string hole to tuning pin arrangement of 31 strings, then a change to an offset arrangement of 30 strings, starting in the treble with string hole #2 strung to tuning-pin #3, with the final string in the bass strung to a tuning pin added to the neck below the cheekbands.

In the course of determining the string lengths, the effect of the string tension on the shape and relative positions of the neck and soundbox of both harps was studied. Additionally, for the Lamont harp, it was established from examination of the tomograms that the belly is entirely due to the string tension pulling up a soundbox that originally had a flat front. The backwards tilt of the foot of this harp was found to also be due to bending of the wood in response to the string tension, rather than a construction feature. It was determined, on the other hand, that the soundbox of the Queen Mary harp may not have been made with a flat front, and that its belly may actually be due to a combination of carving and the effect of string tension. The motion and twisting of the neck of each harp was quantified. Twisting and damage to the neck of the Queen Mary harp was determined to have resulted from repair work that had altered the flexibility of the neck-soundbox joint. The behaviour of the neck tenon in the soundbox joint was discussed for both harps, and the effect it has had on the treble end of the soundbox was determined. Notably, the Queen Mary harp was found to have a more robust design in terms of its ability to minimize damage to the soundbox mortise and neck tenon.

Part II of this dissertation further examines the construction these two harps in order to establish their construction history. This will, it is hoped, provide a deeper understanding, not only of the craftsmanship of these harps, but also of the way in which they were used, as well as providing important clues to their dates of construction.