

The Technological Development of the Bow and the Crossbow in the Later Middle Ages

Ph.D. Thesis

by
Stuart Gorman

Trinity College Dublin
2016

I declare that this thesis has not been submitted as an exercise for a degree at this or any other university and it is entirely my own work.

I agree to deposit this thesis in the University's open access institutional repository or allow the library to do so on my behalf, subject to Irish Copyright Legislation and Trinity College Library conditions of use and acknowledgement.

Summary

This thesis explores the complexity of the design and development of the bow and the crossbow in the Later Middle Ages. The data used in this study were primarily archaeological, supplemented by some textual and artistic evidence. Information on over two hundred bows and crossbows was collected for the analysis in this study. The methodology of this work was primarily comparative: bows and crossbows were compared to each other across and within centuries and regions, to chart how the weapons developed over time.

The main thrust of this thesis was to argue for a more complex understanding of the bow and the crossbow. Historians have generally not engaged with the complex mechanics involved in the operation of a bow or crossbow. An understanding of these mechanics offers valuable insight into why these weapons were designed the way they were, as well as highlighting what aspects of these weapons were truly significant. For example, longbow discussions have generally focused on the length of the weapon, but thickness was actually a more important factor in determining how powerful, and therefore deadly, a longbow was.

This thesis includes information on longbows from as early as prehistory and as late as the *Mary Rose*. These data were used both to show that length was not the most important factor in longbow design – the prehistoric bows were very long but would have been comparably weak – and to show that powerful longbows were made in the High Middle Ages, but were still weaker than the *Mary Rose* longbows. This thesis also challenges the idea that depictions of the longbow in medieval art could be used to reliably provide specific insight into the weapon's design or development, but could provide information on other aspects, such as how bows and crossbows were handled.

The study of the medieval crossbow focused on surviving examples from the fourteenth through to the sixteenth centuries. No clear narrative for the weapon's development could be found; instead, crossbows developed into an increasingly complex variety of weapons as the Middle Ages became the early modern period. There was some standardisation to the weapon's design in the fifteenth century, both in composite and steel crossbows, but, while the composite lathe barely changed in the sixteenth century, the steel crossbow diversified into a range of different styles of crossbows, all of which came in different sizes and shapes. There should be a typology to describe the diversity of these crossbows, in order to allow historians to talk about the weapon in a more specific and meaningful way.

In conclusion, this thesis has advocated for greater complexity and detail in the study of the bow and crossbow. The simplification of these weapons has led to much misunderstanding about their performance and use in medieval armies. Craftsmen, soldiers, and commanders all played a role in determining what kinds of weapons were used at a given time or place, and understanding the reasons for the variety of these weapons available during the Later Middle Ages could provide new and significant insight into medieval and early modern warfare.

Table of Contents

List of Illustrations	5
Acknowledgements	7
Introduction	8
1. The Mechanics of Archery	36
2. The Development of the Longbow	64
3. The Bow in Medieval Art	92
4. Crossbow Data and Methodology	133
5. The Development and Design of the Late Medieval Crossbow	146
6. Medieval Crossbow Spanning Devices	191
7. Comparing Bows and Crossbows	213
Conclusion	240
Appendix I: Crossbows	254
Appendix II: Spanning Devices	307
Appendix III: Glossary	328
Bibliography	330

Illustrations

1. Illustration 1: Compass Bows vs. Target Bows	42
2. Illustration 2: Bow Shape	44
3. Illustration 3: Composite Lathe Cross-Section	48
4. Illustration 4: Arrow Yaw Diagram	50
5. Graph 5: <i>Mary Rose</i> Bow Length	68
6. Graph 6: Prehistoric Bow Length	74
7. Graph 7: Iron-Age Danish Bow Length	76
8. Graph 8: Irish Bow Width/Thickness Comparison	79
9. Graph 9: Bow Length Comparison	82
10. Graph 10: <i>Mary Rose</i> Limb Width/Thickness	86
11. Graph 11: Bow Width at Grip	86
12. Graph 12: Bow Width at Limb	87
13. Graph 13: Bow Thickness at Grip	88
14. Graph 14: Bow Thickness at Limb	88
15. Plate 15: Cod. Bibl. Fol. 23, f. 021r	122
16. Plate 16: <i>Bayeux Tapestry</i> Scene 51	122
17. Plate 17: <i>Bayeux Tapestry</i> Scene 55-6	122
18. Plate 18: MS. Royal. 2, B vi. f. 10	123
19. Plate 19: British Library, Royal 2 B VII, f. 151v	123
20. Plate 20: British Library, Royal 2 B VII, f. 146	123
21. Plate 21: British Library, Royal 2 B VII, f. 162v	124
22. Plate 22: Legend of St Ursula: Return to Basel, Franz Wallraf Cologne	124
23. Plate 23: Bibliothèque Nationale de France, MS fr. 616, f. 11v	124
24. Plate 24: Martyrdom of St. Sebastian, SGS Munich	125
25. Plate 25: British Library, Add MS 47682, f. 40	125
26. Plate 26: Bibliothèque Nationale de France, Fr 2643, f. 165v	126
27. Plate 27: Bibliothèque Nationale de France, Fr. 2680, f. 208	126
28. Plate 28: Hans Memling Martyrdom of St Sebastian	127
29. Plate 29: Meister der Heligen Sippe d.J. Martyrdom of St Sebastian	127
30. Plate 30: Albrecht Durer Martyrdom of St Sebastian	128
31. Plate 31: <i>Képes Krónika</i> , f. 146	128
32. Plate 32: British Library, Add MS 42130, f. 56	129
33. Plate 33: British Library, Add MS 42130, f. 147v	129
34. Plate 34: Pierpont Morgan Library, Ms M. 638, f. 42	129
35. Plate 35: Pierpont Morgan Library, Ms M. 638, f. 32	130
36. Plate 36: Bodleian Library, MS Bodley 264, f. 51v	130
37. Plate 37: Hans Holbein the Elder, Martyrdom of St. Sebastian	131
38. Plate 38: Pietro Perugino, Martyrdom of St. Sebastian	131
39. Plate 39: Piero de Pollaiuolo, Martyrdom of St. Sebastian	132
40. Graph 40: Fifteenth-Century Composite Lathe Lengths	151
41. Graph 41: Fifteenth-Century Composite Tiller Lengths	153
42. Graph 42: Fifteenth-Century Composite Lathe/Tiller Comparison	154
43. Graph 43: Fifteenth-Century Composite Weight	156
44. Graph 44: Fifteenth-Century Steel Lathe Length	157

45. Graph 45: Fifteenth-Century Steel Tiller Length	159
46. Graph 46: Fifteenth-Century Steel Tiller/Lathe Comparison	159
47. Illustration 47: Bern W1982	161
48. Graph 48: Heavy-Steel Crossbow Tiller/Lathe Comparison	162
49. Illustration 49: Bern W1982 Close-Up	164
50. Graph 50: Sixteenth-Century Composite String Length	166
51. Graph 51: Sixteenth-Century Composite Total Length	167
52. Graph 52: Sixteenth Century Composite Tiller/Lathe Length Comparison	168
53. Graph 53: Sixteenth-Century Steel String Length	170
54. Graph 54: Sixteenth-Century Steel Lathe Length	171
55. Graph 55: Sixteenth-Century Steel Lathe Length Comparison	171
56. Graph 56: Sixteenth-Century Steel Tiller Length Comparison	173
57. Graph 57: Sixteenth-Century Steel Lathe/Tiller Length Comparison	174
58. Graph 58: Sixteenth-Century Steel Lathe/Total Length Comparison	175
59. Graph 59: Sixteenth-Century Steel Crossbow Weight	176
60. Graph 60: Crossbow Weight Comparison	177
61. Graph 61: Composite Lathe Width/Thickness Center	180
62. Graph 62: Composite Lathe Width/Thickness Outside	180
63. Figure 63: Crossbow Lathe Dimensions Diagram	181
64. Graph 64: Composite Lathe Center Thickness vs Outer Width Comparison	182
65. Graph 65: Steel Lathe Width/Thickness Center	182
66. Graph 66: Steel Lathe Width/Thickness Outside	183
67. Graph 67: Lathe to Lock Distance	185
68. Illustration 68: Grandson B199	187
69. Graph 69: Spanish Crossbow Length	188
70. Graph 70: Spanish Crossbow Weight	189
71. Illustration 71: Bern <i>Cranequins</i>	195
72. Illustration 72: Goats-Foot Lever Diagram	196
73. Illustration 73: Grandson B2	197
74. Graph 74: <i>Cranequin</i> Bar Length	200
75. Graph 75: <i>Cranequin</i> Section Thickness/Width Comparison	201
76. Graph 76: <i>Cranequin</i> Weight	203

Acknowledgments

My interest in medieval history, and weaponry in particular, stretches back well into my youth and probably owes more to the works of one J.R.R. Tolkien than it does to actual history. I finally got my exposure to the real thing when I came to Trinity College Dublin in 2007 as a fresh faced undergraduate. At that time, I could not have guessed that my interest in the history of the Middle Ages would eventually result in me engaging in the long and detailed study laid out here. I particularly could not have predicted that it would have led to me traveling to an isolated village in the Swiss alps to examine crossbows in a medieval castle. Throughout this experience and the exciting opportunities it provided me, my parents, Michael and Margaret, have patiently supported me and for that I am eternally thankful. I would also like to thank the Trinity History department for awarding me a grant from the Grace Lawless Lee fund, which enabled the aforementioned trip to Switzerland to study crossbows in person.

Many thanks are due to my supervisor, Prof. Terry Barry, who helped to guide and structure my vague vision of a research project and helped me to produce a polished final product from what started as a general interest and a lot of enthusiasm for the subject. I must also thank my partner Emily Neenan who patiently proof-read my entire thesis twice in the final months before submission (despite having little interest in the subject!) as well as producing several of the illustrations used in the final work. Her tolerance and help were invaluable in the final push to finish this thesis.

I would like to thank all the museum curators and administrators who responded to my many inquiries for information on their crossbows and collections. In particular, I would like to thank Ian Ashdown and Jürg Meier of Grandson Castle; Quirinus Reichen of the Bernisches Historisches Museum; Christoph Lichtin of Historisches Museum Luzern; and Donald LaRocca of the Metropolitan Museum of Art.

Introduction

The Battle of Crecy (1346) contained in its opening hours one of the most famous duels between the two dominant ranged weapons of the Middle Ages. The Genoese crossbowmen fared poorly against the English longbowmen and much scholarly thought has been devoted to explaining this result.¹ This work is focused on the weapons used by these two groups of soldiers and on how scholars have understood and discussed these weapons. Both of these weapons saw widespread use across Europe in the Middle Ages and played an important role in both contemporary warfare and hunting, but scholarship in general has not devoted the attention to them that they warrant. Historians' and archaeologists' understanding of the function and design of these two weapons has, when design is even considered, been simplistic at best and misguided at worst. On those occasions when a detailed study of the weapons has been undertaken it is usually based on a small sample size that is presumed to stand in for the technology in general. The following chapters will outline the case for why the current understanding of both the bow and the crossbow is too simplistic, and specific ways in which this could be improved.

The first chapter of this thesis covers the essential characteristics of the mechanics of archery. The chapter explains how a general understanding of physics is necessary to the accurate study of the design and operation of both bows and crossbows. Before any of the analysis of the archaeological data that makes up much of this work is possible, it is first necessary to outline the physical principles that govern those weapons. This chapter also discusses much of the experimental archery that has been conducted over the last half century and considers both the merits and flaws of these experiments. The second chapter analyses the archaeological record of the longbow from prehistory to the sinking of the *Mary Rose* in 1545. The earliest bows were used to establish a basic context and foundation for the technology, to show that bows the length of an adult human were present in Europe during prehistoric times. Next, early and high medieval longbows were examined to show the similarities and differences between the *Mary Rose* bows and those from previous centuries. The next chapter covers the use of

¹ For examples see:

Hereford B. George, "The Archer's at Crecy", *The English Historical Review* 10:40 (1895). pp. 733-738.

Russell Mitchell, "The Longbow-Crossbow Shootout at Crecy (1346): Has the 'Rate of Fire Commonplace' Been Overrated?" in *The Hundred Years War (Part II) Different Vistas* ed. L.J. Andrew Villalon and Donald J. Kagay (Leiden, 2008). pp. 233-57.

J.E. Morris, "The Archers at Crecy", *The English Historical Review* 12:47 (1897). pp. 427-436.

Jim Bradbury, *The Medieval Archer*, (1985, repr. Woodbridge 2011). pp. 105-9.

contemporary medieval art as a supplement for the lack of surviving medieval longbows. This chapter discusses the flaws of interpreting medieval art literally as well as a brief discussion of the composite bow in art and what that can tell historians about how depictions of the longbow should be viewed. The next three chapters cover the crossbow and the devices used to assist archers in spanning it. The first of these chapters, chapter four, outlines the archaeological record of the crossbow from the thirteenth to mid-sixteenth century. It also discusses the methodology of this thesis: the use of a wide selection of data to determine what general trends existed in crossbow design over the course of the Later Middle Ages. The fifth chapter contains the detailed analysis of the crossbow data collected for this work. This chapter focuses primarily on composite and steel crossbows due to the dearth of surviving wooden crossbows. Crossbows from the fourteenth through to the sixteenth century are discussed with the wide selection of data used to try to determine what, if any, standardization there was to crossbow design at this time. The dimensions and weight of crossbows are discussed within the context of their century of origin, type, and region of manufacture. Crossbows are compared across time period and type to try to determine how the crossbow developed over time as well as possible design features that might have been shared across steel and composite crossbows. The sixth chapter focuses on crossbow spanning devices. The general history of these devices is considered, alongside analysis of the archaeological record for the same devices, to try to chart their development over time. The role of medieval art in showing historians how these devices were used is also discussed. The final chapter compares the development and use of the longbow and the crossbow during the Later Middle Ages. Each weapon's role in battle and siege is examined as well as their relative power, and the difficulty in training soldiers to use them. This final chapter situates the overall discussion within broader debates of medieval warfare, in addition to considering how these two weapons related to each other at the time of their most widespread military use.

This thesis argues that the bow and crossbow are weapons of greater complexity than their treatment in scholarly works would suggest. Despite its name, the longbow's most important feature is not its length, but rather its girth: width and thickness. This thesis uses data on surviving longbows to show that bows of a length equal to a fully grown adult have existed since prehistory but bows with similar dimensions to those on the *Mary Rose* were likely first adopted sometime during the High Middle Ages. Similarly, while the word 'crossbow' describes a collection of weapons that share a core

trait - that they have a lathe which is attached to a tiller - for many crossbows that is their only similarity to each other. The size and shape of the component parts of crossbows from across the Middle Ages varied significantly. This level of variation has received only limited scholarly attention. In this thesis, data collected on over one hundred crossbows was used to document the level of variation in the weapon. The purpose of this study is to show that the crossbow should not be treated as a single weapon type, but rather a broad category of weapons. Crossbows could be used for many purposes and individual crossbows were designed to match their intended use. Before making any broad statements about the effectiveness or use of the medieval crossbow, historians should first be expected to qualify what they mean by their use of the label “crossbow”. The way historians think and write about the crossbow is in need of a change to better fit with the complexity of the weapon. While much of the body of this work is dedicated to documenting and demonstrating crossbow diversity, traditional areas of debate and comparison in the study of bows and crossbows have also been covered. This discussion is to show how a more detailed understanding of these weapons complicates the debates around them.

Before the analysis and examination, it is necessary to understand what the state of scholarship is and where this work is situated in that broader scholarship. What follows is not a complete dissection of everything ever written on either the longbow or the crossbow. Both weapons, but particularly so the longbow, have long been a favourite topic for popular and amateur historians, resulting in a literature that is too large to cover in this thesis. Instead, the following discussion will highlight key works while simultaneously outlining how the historical narrative of both the longbow and crossbow has developed and changed over the past century. In some cases, a single book has been chosen as representative of a broader view or trend in the historiography. One difficulty that should be noted about historical works from around the turn of the twentieth century is that while the authors clearly consulted primary sources when they were writing, the standards of referencing were not nearly as high as they are now. This lack of high quality references makes tracking down the primary sources that these authors referenced quite difficult and sometimes nearly impossible.

Scholarship from the Turn of the Twentieth Century

The overall narrative of the development of medieval archery has changed little since Charles Oman wrote his seminal work on medieval warfare in the late nineteenth century. His account was Anglocentric with a special focus on the Hundred Years War. It

argued that archery reached its zenith during the fourteenth and fifteenth centuries, especially in the armies of England. The tactical revolution that made archery so successful was massed archers wielding the famous English longbow. The introduction of this tactic of massed archery, at least in an English context, was attributed by Oman to the reign of Edward I (r.1272-1307) and his successors. In contrast to the English, the armies of the continent, especially the French, primarily used the crossbow. The longbow remained the dominant weapon of English armies up to the reign of the Tudors (1485-1603) when it was eventually replaced by gunpowder weapons.² This core narrative has lasted through many subsequent historical debates but the specifics of how and why these tactics came into use has been hotly debated. The most contested topics have been: when the longbow was introduced into English armies; the actual specifics of the longbow as a weapon; the relative strengths of the crossbow compared to the longbow; to what extent victories and defeats can be attributed to the weapons used by the combatants; and whether these weapons had an impact beyond just the battles they were used in. Accounts of the history of the longbow are necessarily Anglocentric since England was the only kingdom to make widespread use of the weapon.³ In comparison, crossbows are usually viewed through a much broader lens and have a significantly larger body of non-English books dedicated to them. Accounts of the history of the crossbow and the longbow were initially handled in the same work. Charles Oman, J.E. Morris, and Ralph Payne-Gallwey included discussions of both weapons in their works, all of them written around the turn of the twentieth century. Since then, however, the two weapons have been discussed mostly separately. When both are included in a work one of them is clearly favored over the other. Historians like Robert Hardy and Jim Bradbury only mentioned crossbows in comparison to bows and Josef Alm's work on crossbows contained no detailed discussion of bows or longbows. As a result of this split in the historiography, this discussion will begin chronologically before focusing first on the development of scholarship on the longbow, followed by the same treatment for the crossbow.

Charles Oman was in many ways the father of medieval military history. While historians' understanding of medieval warfare has developed significantly in the time since he published his last book his influence remains unparalleled. When writing about archery Oman considered the crossbow, or arbalest as he chose to call it, as obviously the

² Charles Oman, *The Art of War in the Middle Ages*, (Oxford, 1885). pp. 96-101

³ Ralph Payne-Gallwey, *The Crossbow: Its Military and Sporting History, Construction and Use*, (1903, repr. London, 1995). pp. 3-5

inferior of the longbow. His bias showed when he argued that the longbow could not have existed during the reigns of Henry II (r. 1154-1189) or Richard I (r. 1189-1199) because they both preferred the crossbow, something he thought no monarch would do had the longbow existed.⁴ No bows were present in Henry II's assize of arms of 1181, and Richard I made his fondness for the crossbow well known both on his Crusade and upon his return to England.⁵ As a result of this, Oman concluded that the short bow must have been dominant in England up until around the reign of Henry III (r. 1216-1272) when bows began to replace crossbows in English warfare.⁶ Oman was somewhat vague as to what he thought the origin of the longbow was in his original 1885 publication. He acknowledged that there existed some evidence to support a Welsh origin of the longbow but argued there was also evidence which suggested alternative origins. He argued that the longbow saw greater use in Northern England than in regions close to Wales, which to him suggested that the two weapons came from separate geographic regions. Oman did not dwell much on this debate, however. He devoted only a single paragraph to it, and spent half of that paragraph discussing how the crossbow remained in favour above the longbow up to the 1280s. He credited to Edward I (r. 1272-1307) with the rise of the longbow and primarily used evidence from the Scottish wars (1296-1328, 1332-1357) to support this case.⁷ Oman was clearly more interested in the longbow tactics of the Hundred Years War (1337-1453) than the origin of the weapon and so devoted more time to that topic. In his 1898 book, an updated and extended work based on his 1885 paper, Oman expanded his argument to include a more thorough discussion of the arguments for the Welsh origin of the longbow. However, he still remained skeptical of the Welsh origin and cited the first reference of the English use of the longbow as belonging to a band of raiders in Sussex in 1216.⁸ As far as Oman was concerned, however, the landmark moment in the history of archery was Henry III's *Assize of Arms* in 1252 which required all men holding between 40 and 100 shillings worth of land to serve with a sword, bow and arrows, and a knife.⁹ That was the beginning of the rise of the English

⁴ Charles Oman, *A History of the Art of War: The Middle Ages from the Fourth to the Fourteenth Century*, (London, 1898). pp. 558-9.

⁵ *Select Charters and Other Illustrations of English Constitutional History From the Earliest Times to the Reign of King Edward the First* ed. William Stubbs and H.W.C. Davis, 9th ed. (1870, London, 1913). pp. 181-4.

David Bachrach, "Origins of the Crossbow Industry in England", *Journal of Medieval Military History*, 2 (2004). pp. 79-80.

⁶ *Ibid.* pp. 559-61.

⁷ Charles Oman, *The Art of War in the Middle Ages*, pp. 96-101

⁸ Charles Oman, *A History of the Art of War*, pp. 559-60.

⁹ *Select Charters and Other Illustrations of English Constitutional History From the Earliest Times to the Reign of King Edward the First* ed. William Stubbs and H.W.C. Davis, pp.362-5.

bowman as the dominant force in medieval archery. According to Oman, the longbow played a major role in the English victories of the Hundred Years War, especially since it was superior to the French crossbow. He considered it to be one of the two most important tactics of the Middle Ages (the other being the close formation of Swiss pikemen).¹⁰

J.E. Morris was a contemporary of Oman and while he was best known for his work on Edward I's conquest of Wales, which was the definitive work on the subject for many years, he also wrote on other matters of military history.¹¹ Morris was one of the greatest supporters of the theory of the Welsh origin of the English longbow. Most of his discussion of archery was included in his *Welsh Wars of Edward I*, which was published in 1901. Morris' first mention of archery in his book was in a discussion of the Battle of Hastings (1066). While attributing Norman victory to a combination of skilled archery and cavalry tactics he described the Norman bow as: "... the weak short bow [...] the string was pulled only to the chest, and the arrow, except in close quarters, was shot high into the air, a high trajectory in itself a confession of weakness."¹² Morris gave no reference for the source he was basing this argument off of but the most likely candidate is the *Bayeux Tapestry*. The *Bayeux Tapestry* contains four Norman foot archers, one horse archer, and one Anglo-Saxon foot archer in the central narrative. In addition to those six archers there at least a dozen archers in the margins. The Norman foot archers were all depicted wielding short bows and drawing the arrows only to their chest.¹³ Given that this is one of the most famous sources relating to the Battle of Hastings and it shows exactly the type of archery Morris thought was used at the time it seems likely that it greatly influenced his opinion. Morris contrasted the Norman archers of Hastings with the Welsh archers described by Gerald of Wales in his twelfth century *Tour of Wales*.¹⁴ Morris entirely believed Gerald's account of the Welsh archers especially his description of how powerful their bows were. He assumed that the Welsh bows that Gerald wrote about in the twelfth century were the same as those used by English archers during the Hundred Years War. Having decided upon this origin of the English longbow,

Robert Hardy and Matthew Strickland, *The Great Warbow: From Hastings to the Mary Rose*, (2005, repr. Thrupp, 2011). pp. 150-2.

¹⁰ Charles Oman, *The Art of War in the Middle Ages*, pp. 96-101

¹¹ For example see:

J.E. Morris, "The Archers at Crecy", *The English Historical Review* 12:47 (1897). pp. 427-36.

¹² J.E. Morris, *The Welsh Wars of Edward I*, (1901, repr. Stroud, 1996). p. 26

¹³ For further discussion see Chapter 2.

For images from the Bayeux Tapestry see Plates 16 and 17.

¹⁴ Giraldus Cambrensis, *The Itinerary and Description of Wales*, trans. Richard Colt Hoare, (1809; repr. London, 1908). pp. 49-50

i.e. that it was clearly absent from the Norman invasion in the eleventh century but present in Wales in the twelfth, Morris then had to provide a narrative explaining how the bow entered England from Wales. The key point of his debate was whether the longbow was introduced before or after Edward I's Conquest of Wales. Morris began by discussing what he argued was the most immediate use of Welsh archers under English control: the invasion of Ireland. Here, again, he used Gerald as his evidence, this time for Welsh archers in Strongbow's army in 1167.¹⁵ There are several references to archers in Gerald's *Expugnatio Hibernica* but only one reference to Welsh archers. These archers were part of the retinue of Raymond Fitzgerald who held land in Wales. Part of his retinue for the Irish invasion was described as: "... three hundred bowmen, the best in Wales".¹⁶ Morris at least seemed to acknowledge that the Irish invasion hardly represented a mass adoption of Welsh archery, and later in his work cited the presence of quite a few archers in the assize of arms of Henry III, as well as the presence of archers in the campaigns of the baronial revolts, as proof that archery existed in the English military before the Welsh conquest. However, he did not suggest that use of the longbow was widespread in England before the 1270s. Instead, he argued that there was some archery in English armies but a rapid growth of bow use and the adoption of more advanced bows from the Welsh took place during and after the Welsh conquest. Rather than arguing that the technology was taken from the conquered Welsh, though, Morris instead believed that Welsh soldiers were brought into Edward's armies as allies, and from them the knowledge of the longbow spread to the English until it became the standard bow of the English archer.¹⁷ The Welsh bows did not represent the pinnacle of bow development for Morris, however; instead the bow continued to develop, along with the skill of the English archer, until the fourteenth century. His argument was that to shoot a very powerful bow required great skill, and it took time for archers to develop that skill. When the use of the longbow first moved to England from Wales, the weapons would have been quite weak, since the English archers would have still been too familiar with the weaker short bow of Hastings. Morris speculated that the longbow would have grown in strength with the skill of the archers until the fourteenth century, when it reached its peak. After that point it declined until it was eventually replaced by gunpowder weaponry in the sixteenth century. In his account of medieval English

¹⁵ J.E. Morris, *The Welsh Wars of Edward I*, pp. 26-34, 87-94, 99-104.

¹⁶ Giraldus Cambrensis, *Expugnatio Hibernica*, trans. Thomas Forester, (London, 1905). p. 258

¹⁷ J.E. Morris, *The Welsh Wars of Edward I*, pp. 26-34, 87-94, 99-104.

warfare, perfection in nearly every area was reached under Edward III (r. 1327-1377).¹⁸

Morris' opinion on the crossbow was that it was a medieval equivalent to the musket. Both were 'point and shoot' weapons the use of which could be easily taught to soldiers, who then wielded them effectively in battle. His view assumed that crossbowmen were professional soldiers who were taught basic drills to load and fire their weapons. In contrasting the crossbow and the longbow, he likened the longbow to the rifle, since both the rifle and the longbow had superior range and accuracy over their contemporary counterparts, but required greater skill to use which delayed their initial adoption. Edward I's accounts from the Welsh conquest included many references to crossbows and crossbowmen and Morris acknowledged this. Morris mentioned crossbows in the context of the conquest of Wales, but was clearly not as interested in the weapon as he was in the longbow. His discussions of the crossbow were not as frequent and often framed in the context of its eventual replacement by the longbow in the following century. If one were to summarize Morris' outlook it would be that he viewed everything from the context of the fourteenth century. When he discussed archery he was primarily concerned with explaining how the dominance of the longbow in the fourteenth century came about rather than examining the weapons in the context of the twelfth century. This coloured his treatment of both the longbow and the crossbow. In his eyes, the crossbow was a weapon that was soon to be eclipsed by the longbow; he was careful to document the rise of the longbow and seemed to only mention the crossbow at all because it played such a large part in Edward's wars. This is not to say that Morris was entirely biased against the crossbow. He did not argue that the crossbow was a useless weapon, he simply saw it as a weapon on the decline. In essence he saw the crossbow as a weapon that needed to be replaced by the longbow in the same way the longbow was replaced by gunpowder weapons. Both were fine weapons, but they were rendered obsolete by new advances in weapons technology.¹⁹

Ralph Payne-Gallwey's *The Crossbow*, first published in 1903, covered the history of the crossbow from the Middle Ages through the Early Modern Period. He used a handful of surviving crossbows as his primary evidence, most of them in private collections, and established a broad narrative for the history of the crossbow. He divided his argument across two main topics: the extent of the crossbow's use in armies across Europe, and the changes that crossbows underwent during the same time period. His

¹⁸ Ibid. pp. 26-34, 87-94, 99-104.

¹⁹ Ibid. pp. 97-102.

book began with Roman siege weaponry, specifically the ballista and scorpion. To Payne-Gallwey, they were the predecessors of crossbows, and the ancient weapon most similar to them. His reference for Roman crossbows was a mention of the weapon by Vegetius (c.300-400), although he provides no specific edition or page reference, but he admitted there was scant evidence of widespread crossbow use by the Romans. Instead, the real narrative of the crossbow begins in the tenth century when crossbows first began to appear in medieval textual sources. From there the evidence for the existence and use of the crossbow in Europe was pretty overwhelming. England in particular made quite substantial use of the crossbow up until the reign of Henry III when, Payne-Gallwey noted, the longbow replaced it nearly entirely. By the time of Henry V's Agincourt campaign (1415), only a hundred crossbowmen were to be found among the 30,000 soldiers sent to France. On the continent, however, the crossbow remained the dominant ranged weapon. The crossbow was such a major weapon for continental armies that crossbowmen were seen as elite troops and, according to Payne-Gallwey, even granted knighthoods in Spain. The use of the crossbow in Europe only declined in the late fifteenth century with the introduction of reliable gunpowder weapons as an alternative.²⁰

Payne-Gallwey's narrative for the changes crossbow technology underwent was entirely linear. The oldest crossbows were simple and made of wood. These bows would initially have been spanned by hand. Sometime during the first three Crusades (1099-1189), however, the composite crossbow was introduced to Europe likely via Muslim craftsmen. He noted the presence of a 'Peter the Saracen' having been employed to make crossbows in England at the start of the thirteenth century.²¹ Payne-Gallwey provided no specific year as the point when the steel crossbow was first used, but assigned it to sometime during the fourteenth century. The steel crossbow, in Payne-Gallwey's eyes, was the perfection of the crossbow.²² When comparing the bow to the crossbow, Payne-Gallwey subscribed to the idea of the short bow having been used before the introduction of the longbow in the thirteenth century. In his opinion, the short bow was probably of equal power to the wooden and composite crossbows of the time, while the longbow was superior to all but the steel crossbows of the fourteenth century. His discussion of wooden and composite crossbows was quite brief and not particularly detailed. Much of his work was dedicated to the description and analysis of a handful of specific steel crossbows which he had access to. He provided numerous pictures and drawings of these

²⁰ Ralph Payne-Gallwey, *The Crossbow*, pp. 31-7.

²¹ *Ibid.* pp. 62-3.

²² *Ibid.* pp. 90-1.

weapons as well as a detailed analysis of them. Most of these crossbows were from either the Later Middle Ages or the Early Modern Period, and so his conclusions about earlier crossbows were not backed up by much evidence. This could be blamed in no small part on the lack of evidence relating to early crossbows available to Payne-Gallwey at the time of his writing. He also went into impressive detail on the various methods of spanning different types of crossbows. His description of spanning techniques connected different methods of spanning crossbows with different types of crossbow lathe. Wooden crossbows were spanned by hand; composite crossbows required the aid of a belt hook or other piece of machinery that provided enhanced leverage to the archer but still used human power to span the bow; and steel crossbows were spanned using complex machinery like the windlass or *cranequin*.²³ As far as Payne-Gallwey was concerned the more complex the spanning machinery the better, since this indicated that the weapon was extremely powerful. Payne-Gallwey's book was well written and very thorough when it comes to the subjects it covered but the limitations on what he had access to shows when reading it in a modern context. His use of textual and archaeological sources should be lauded, however, and it is understandable why his book has remained the most widely accessible book on the crossbow.²⁴

The Longbow

The 1960s saw the publication of several important works on archery. Donald Featherstone's *The Bowmen of England* was published in 1967 and, while it was primarily focused on the story of England's archers, he dedicated several of its pages to the longbow as a weapon. Featherstone's book represents one of the earliest works of popular history on the longbow, and as such represents a significant development in the history of England's most famous weapon. Featherstone was a dedicated wargames enthusiast and his interest in medieval warfare inspired him to publish a book on the subject.²⁵ *The Bowmen of England* offers little in the way of change from the narratives of Oman and Morris and so did not cause a major shift in the historiography of the longbow.

Ewart Oakeshott's *The Archaeology of Weaponry* was published a few years before Featherstone's book. While Oakeshott was primarily concerned with melee

²³ Ibid. pp. 62-5, 90-1.

²⁴ Ralph Payne-Gallwey, *The Crossbow*, pp. 3-10, 31-37, 43-53, 57-65, 73-91, 121-125.

²⁵ Jon Peterson, *Playing At the World: A History of Simulating Wars, People and Fantastic Adventures from Chess to Role Playing Games*, (San Diego, 2012). pp. 298-300.

weaponry, especially swords, his brief discussion of the longbow does provide a useful example of a line of argument that has remained quite popular. Oakeshott noticed that the transition from mail to plate armour occurred around the same time as the English switch from the crossbow to the longbow.²⁶ Seeing these two elements as related, Oakeshott posited that the introduction of a longbow capable of penetrating chain mail - again citing Gerald of Wales as a source of the longbows effectiveness - forced soldiers to find a new type of protection. Claude Blair's work on European armour, still the one of the best overall surveys on the subject, enhanced this theory by providing the context of when plate armour began to appear in medieval Europe. This new element to the history of the longbow contributed significantly to the view that the longbow was the dominant weapon of the Later Middle Ages.²⁷

The next major work on the history of the longbow, which was one of the most widespread books fully dedicated to the subject, was written by Robert Hardy and published in 1978. Hardy's book was a very thorough, if not particularly academic, discussion of the history of the longbow. Hardy did not completely accept the idea that the *Bayeux Tapestry* showed only short bows, and suggested that some of the bows, particularly those wielded by the figures in the margins, could have been longbows.²⁸ Hardy argued that bows, whether long or short, were used by the Normans up through the twelfth century, while the rest of Europe used the crossbow. While Richard I had a preference for the crossbow, he was probably an exception rather than the rule. For example, King Stephen (r. 1135-1154) had brought archers to Yorkshire to fight against the Scots at the Battle of Standard (1138). Hardy also pointed out, perhaps inspired by Morris, that Richard de Clare's title of Strongbow indicated a Norman link with powerful bows.²⁹ However, Hardy did not provide detailed references, so it is hard to know what sources he was using to support these arguments. At the same time as he supported the Norman use of the bow Hardy used Gerald of Wales as evidence for the existence of a powerful Welsh longbow during the twelfth century. Hardy argued for a sort of marriage of technologies between the Welsh and Norman archers. The Normans introduced yew to the Welsh, who had the skills required to make powerful longbows but were working

²⁶ Oakeshott actually points his readers to Claude Blair's then quite recent book on medieval armour for a more in depth discussion of the development of plate armour. See:

R. Ewart Oakeshott, *The Archaeology of Weapons: Arms and Armour from Prehistory to the Age of Chivalry*, (1960, repr. London, 1996). p. 283.

Claude Blair, *European Armour circa 1066 to circa 1700* (London, 1958). pp. 53-76.

²⁷ R. Ewart Oakeshott, *The Archaeology of Weapons*, pp. 282-300.

²⁸ See Plates 16 and 17.

²⁹ Robert Hardy, *The Longbow: A Social and Military History*, 3rd ed. (1978, Fort Worth, 1993). pp. 35-8.

with inferior wood. This resulted in the yew longbow of the Hundred Years War. His evidence for this combining of technologies was that Gerald explicitly mentioned that the Welsh bows were not made of yew. He said that they were made with elm instead.³⁰ To Hardy, this observation indicated that Gerald was aware of yew as a material for making bows and, more importantly, was surprised that the Welsh did not use it. Once Hardy explained his account of the origin of the English longbow he did not differ greatly from Oman or Morris on the longbow's role in English warfare. In his account, Edward I introduced the longbow to wider use in English armies and it saw its peak use on the fields of France during the Hundred Years War.³¹ Hardy's work romanticized the role of the archer and the longbow, and that view certainly coloured his discussion of the weapon. For example, Hardy mentioned Henry V's birth in Monmouth as a sign of his ties to the Welsh origin of the weapon that would make him famous.³² His lack of reference notes and a scant page and a half long bibliography makes his book a problematic historical source. He does have the distinction of being one of the first authors to have discussed the bows found on the *Mary Rose*. The ship was discovered close to the time of the publication of the first edition of his book, and so many of the details relating to the *Mary Rose* bows were included in later editions. His close involvement with the recovery and preservation of the *Mary Rose* bows makes his account nearly unique and quite reliable. If there is a criticism to be leveled at his treatment of this important find, it is that he overemphasized how they support his arguments and his theories about the longbow, and played down alternative interpretations of what the bows might show about medieval English archery.³³ Hardy's book was also the first major work on the longbow to mention the earlier neolithic longbows found across Europe. He even included a very brief mention of the late Iron-Age and early medieval longbows found in Denmark.³⁴ Hardy argued that while these represented an earlier stage in the development of the longbow, the technology was likely lost during the Middle Ages and rediscovered later. He argued that the Welsh, being from the fringes of medieval society, probably retained the old ways of longbow archery through the dark ages and from there it was reintroduced to England.³⁵

Jim Bradbury was the first major historian to break from the Welsh origin of the

³⁰ Geraldus Cambrensis, *The Itinerary and Description of Wales*, pp. 49-50

³¹ Robert Hardy, *The Longbow*, pp. 41-7.

³² Ibid. p. 42.

³³ Ibid. pp. 37-8.

³⁴ Ibid. p. 21

³⁵ Ibid. pp. 30-40.

longbow narrative entirely. In his book *The Medieval Archer* (1985) he rejected both the Welsh origin of the longbow and the idea that the wooden short bow had ever existed as an alternative to the longbow. Bradbury rejected the idea of the Anglo-Saxon short bow in two ways: he dismissed the idea that the wooden short bow existed in Europe and argued that even if it had, there would be no significance to its existence. Bradbury argued that the only short bow that existed, in Europe or elsewhere, was the composite bow.³⁶ On the topic of the Battle of Hastings - and specifically the *Bayeux Tapestry* - he pointed out that there were multiple errors in the depiction of the archers, the most prominent being that most of them were holding their arrows incorrectly, which suggested that the artists were not entirely familiar with their subjects, or perhaps not concerned with accurate depictions of them.³⁷ Bradbury's second assertion against the idea of the short bow was that there is no significant difference between a short bow made of a single piece of wood and a longbow made the same way. He questioned the significance of length as an important feature of the longbow. He argued that the very idea of the short and long bow being unique technologies is incorrect. Bradbury also briefly made reference to finds of medieval longbows from Denmark and Ireland that showed the technology had existed before the twelfth century, but, unlike Hardy, did not believe that this technology fell out of popular use everywhere but the fringes of European society. Bradbury instead suggested that a large wooden bow was used throughout Europe for the entirety of the Middle Ages, and while there were likely some differences between the longbow of fourteenth-century England and tenth-century Ireland they would not have been sufficient for the latter to be considered a completely new technology. By rejecting the idea of the short bow, he did a lot to challenge the belief that the longbow was introduced as a new technology in the thirteenth century. Bradbury also rejected the term "longbow" preferring instead to use "ordinary wooden bow" since the former term put too much emphasis on the idea that length was the most important element of the bow's design.³⁸ Bradbury had relatively little to say on Gerald of Wales as a source for the Welsh origin of the longbow. He argued that there was evidence to doubt that longbows from the High Middle Ages differed greatly from those of the Hundred Years War. He was more interested in rejecting the arguments of Morris than with specifically contradicting Gerald, which is understandable given that Gerald's account was not inherently problematic. How Gerald's work has been used as evidence

³⁶ Jim Bradbury, *The Medieval Archer*, pp. 12-16

³⁷ *Ibid.* pp. 33-8.

³⁸ *Ibid.* p. 14.

was the problem, not what he wrote.³⁹

Kelly DeVries has not written a lengthy treatment of the longbow itself, but he has made a very important contribution to the debate on the effect the longbow had on medieval warfare. DeVries has written on many subjects of medieval military history, including the history of gunpowder weaponry and medieval battles, but has from time to time ventured into the area of the history of the longbow. His primary contribution has been to argue against technological determinism in the history of the longbow and to suggest that it was a less powerful weapon than has at times been argued. DeVries has written extensively on the history of infantry warfare and of how it came to be the dominant form of warfare during the Later Middle Ages. A key part of the rise of infantry warfare was the rise of massed archery, especially when it came to the English. This trend had been noticed as far back as Oman, but DeVries produced a very in-depth analysis of the trend through the extensive use of chronicle sources.⁴⁰ In his most influential article on the longbow, which also covered technological determinism more generally, DeVries rejected both the idea that the longbow had caused the onset of plate armour, and that the longbow's deadly power was the cause of England's victories during and around the Hundred Years War. He argued that many historians had overstated the power of the longbow and misused chronicle sources to support their arguments. According to DeVries, most chronicle accounts were much more muted in their descriptions of the carnage inflicted by the longbow than they have been represented as having been by the majority of medieval military historians. For every chronicler who described the brutal aftermath of a battle, there was one who described the longbow as not particularly effective. DeVries supposed that if all accounts of medieval battles were examined the trend would indicate that while at times the longbow was devastating, most of the time it was not. He argued that instead of being a weapon primarily designed to kill, the longbow was a weapon used as part of a broader strategy. Even if an arrow from a longbow did not kill its target, it could still be effective. For example, continuous longbow fire could break up enemy formations and damage morale. DeVries' argument was that these tactical uses of the longbow helped enable the English to guarantee that they fought from a strong defensive position, by forcing their enemies to abandon their positions and attack. Arrow fire could also ensure that the enemy was disorganised when

³⁹ Ibid. pp. 15-6, 71-5.

⁴⁰ For example see:

DeVries, Kelly, *Infantry Warfare in the Early Fourteenth century: Discipline, Tactics, and Technology* (Woodbridge, 1996).

it reached the English lines by injuring or distracting the charging soldiers. These elements managed to reliably enable English victory. In DeVries' view the longbow was an important part of English tactics during the Later Middle Ages but its primary purpose was as a support weapon that helped guarantee the success of the broader English strategy of clever defensive positioning and fighting on terrain that suited them.⁴¹

Robert Hardy and Matthew Strickland's joint work *The Great Warbow: from Hastings to the Mary Rose* is the most impressive and thorough account of the history of the longbow yet written. Its account spans the entire latter half of the Middle Ages. The opening chapter outlined the rediscovery of the *Mary Rose*, and included an excellent section from Robert Hardy detailing the excavation and preservation of the longbows based on his firsthand experience.⁴² The controversial part of the book appeared early on in the second chapter, called "The Myth of the Short Bow", when Matthew Strickland outlined his argument for rejecting the thesis that before the thirteenth century medieval Europeans used a small, underwhelming wooden bow drawn only to the chest. He then argued that not only was the longbow used in early and high medieval warfare, but also that those earlier longbows were nearly identical to the bows found in the wreck of the *Mary Rose*.⁴³ While the idea of the short bow, sometimes called the Saxon Short Bow, has not been widely accepted by academics in recent years, there has been little agreement on what kind of bow, if any, was used in early and high medieval warfare.⁴⁴ More often than not, historians were happy to simply either ignore the longbow's history before the reign of Edward I, or else to assume the weapon was weaker, or in the hands of inferior soldiers, or largely unknown to contemporaries. Strickland's argument challenged much of the accumulated scholarship on the innovations and tactics of later medieval England. In the middle of *The Great Warbow*, Strickland justified his argument that the true innovation in English tactics was the use of massed archery along with the proper deployment of those archers for battle. This idea is not in and of itself necessarily unique - Michael Prestwich was at least slightly inclined towards a similar argument⁴⁵ - but Strickland did an impressive amount of research into battles from the eleventh through sixteenth centuries to show how these tactics progressed, meaning he had ample

⁴¹ DeVries, Kelly, "Catapults Are Not Atomic Bombs: Towards a Redefinition of 'Effectiveness' in Premodern Military Technology," *War in History* 4:4 (1997). pp. 460-470.

⁴² Robert Hardy and Matthew Strickland, *The Great Warbow*, pp. 3-33

⁴³ *Ibid.* pp. 34-43.

⁴⁴ *Ibid.* pp. 35-6.

Jim Bradbury, *The Medieval Archer*, pp. 14-6.

⁴⁵ Michael Prestwich, *Armies and Warfare in the Middle Ages: The English Experience* (1996, repr. Hong Kong, 2006). pp. 319-23.

evidence to support his claims. That all having been said, the work was not perfect. While nearly every battle of any significance in Britain and France, as well as some in neighboring regions, between 1000 and 1600 was discussed by the authors, there was little to no analysis of siege warfare during this period. This means that while *The Great Warbow* presented a very impressive picture of the longbow and its role in medieval battles, it was only covering one aspect of medieval warfare.⁴⁶ However, given that Strickland and Hardy had already written a rather lengthy book it is perhaps understandable that they were unable to give sieges the same treatment they gave battles.⁴⁷

The arguments of Oman and Morris are not without their modern advocates. Clifford Rogers has pushed against the recent trend towards reinterpretation in several recent articles. The first of these was a direct rebuttal of Kelly DeVries' argument, Rogers even included DeVries' name in the article title. The article was essentially a collection of medieval accounts describing the deadly power of the longbow which Rogers argued was sufficiently convincing evidence to disprove DeVries' argument. The difficulty with this was that DeVries did not say that no contemporary sources said the longbow was deadly, instead he argued that they were not a significant majority. While Rogers compiled an impressive range of sources he did not provide any analysis showing how often accounts like these appeared, compared to accounts that either did not emphasize the longbow's power, or that stated that the longbow had little to no effect. Rogers agreed with DeVries that the longbow had more to contribute to the battle than just its killing power and that it was not the sole reason England was successful in its late medieval wars, but he strongly disagreed with DeVries on the subject of how powerful the longbow was.⁴⁸

Rogers' second article took aim at another trend in recent longbow historiography. In this article he rejected Bradbury, Hardy, and Strickland's argument that the short bow never existed and that the longbow was the same throughout the Middle Ages. He argued for a return to the idea that the longbow of the fourteenth century was a fundamentally new and significant weapon. Semantics played a key role in his new argument. Rogers defined the longbow in terms that excluded any examples that were not almost identical to those from the *Mary Rose*. He used a handful of fourteenth-

⁴⁶ Bernard S. Bachrach, "Medieval Siege Warfare: A Reconnaissance", *The Journal of Military History* 58:1 (1994). pp. 119-23.

⁴⁷ Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 61-68, 84-96, 149-162.

⁴⁸ Clifford Rogers, "The Efficacy of the English Longbow: A Reply to Kelly DeVries", *War In History* 5:2 (1998). pp. 233-42.

century texts that included the term 'longbowe' to argue that contemporaries used a term to distinguish between the new "longbowe" and the shorter bows from preceding centuries. This new kind of bow, he argued, was the *Mary Rose* style longbow which was, according to Rogers, unknown in previous centuries. Rogers also disagreed with the idea that a five foot tall bow could be a longbow. He essentially used his preference for specific meanings of the word to define the longbow as a unique weapon from the short bow, which, he argued, existed because it is shown in contemporary art. In the place of the longbow, he provided his new classifications of the "medium bow" and the "near-longbow" which bridged the gap between short bow and longbow.⁴⁹ Rogers did make an effort to prove that the longbow of the Later Middle Ages was significantly more powerful than the bows of the High Middle Ages, to provide an alternative to his semantic argument for why these weapons were distinct from each other. These arguments, however, relied on suppositions. Few chronicles contain descriptions of the equipment of their subjects in any great detail, and so when a source mentions the arrows slaying, or not slaying, the enemies of its protagonist historians have to assume certain standards of weaponry and armour at that battle. Rogers placed significant faith in the reliability of chroniclers and artists from the twelfth and thirteenth centuries.⁵⁰ He made many of the same assumptions that he criticized Hardy and Strickland for making. For example, Rogers disputed the use of surviving high medieval bows to argue that the longbow existed throughout the Middle Ages. Excluding a confusing tangent he took to discuss nineteenth-century bows from the Great Plains of America, most of his argument focused on the bows excavated from Waterford, Ireland.⁵¹ Rogers accurately pointed out that the bows excavated from Waterford are much smaller than those found on the *Mary Rose* but at the same time he completely ignored the earlier bow from Balinderry Crannog that is almost the same length as the median average bow from the *Mary Rose*.⁵² Rogers' article represented an argument supporting a return to earlier historical ideas. He supported Morris' account of the history of the longbow over more recent

⁴⁹ Clifford J. Rogers, "The development of the longbow in late medieval England and 'technological determinism'", *Journal of Medieval History*, 37 (2011). pp. 322-6, 336-40.

⁵⁰ Ibid. pp. 332-5.

⁵¹ Clifford J. Rogers, "The development of the longbow in late medieval England and 'technological determinism'", pp. 332-4.

⁵² H. O'Neill Hencken, Gwyneth Harrington, H. L. Movius, Jr., A. W. Stelfox and Geraldine Roche, "Ballinderry Crannog No. 1," *Proceedings of the Royal Irish Academy. Section C: Archaeology, Celtic Studies, History, Linguistics, Literature* 43 (1935 – 1937). pp. 133, 139.

Bartlett, Clive, Chris Boyton, Steve Jackson, Adam Jackson, Douglas McElvogue, Alexzandra Hildred and Keith Watson, "The Longbow Assemblage" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). pp. 2:596-9.

arguments and attempts to change the focus of the debate in a way that would support his arguments, especially when it came to redefining the modern terminology used in the discussion.⁵³

The Crossbow

In 1947, Josef Alm published a broad survey of European crossbows. This monograph was just over a hundred pages long and originally published in Swedish. It was not translated into English until 1994 when the Royal Armouries included it in their monograph series.⁵⁴ His book covered crossbows from the tenth to the sixteenth century with a focus on the later centuries. Despite being a much smaller work than Payne-Gallwey's, Alm's book went into more specific detail on how crossbows were built. He spent almost no time discussing the general history of archery and instead focused on several areas in great detail, at the cost of the more general approach that Payne-Gallwey took. Alm also included far fewer images in his book. He devoted no time to discussing famous battles or comparing crossbows to longbows. Instead his book was entirely focused on the technical elements of the crossbow. In this regard, his work was superior to Payne-Gallwey's. His examination of composite crossbows was much more thorough and includes a breakdown of the methods used to make composite crossbow lathes. His coverage of wooden crossbows was severely limited by the lack of surviving examples and he substituted modern African crossbows to show what he expected early medieval European crossbows to be like.⁵⁵ Alm also included an in-depth discussions of how crossbow trigger mechanisms changed over the course of the Middle Ages, in part based on earlier work by Rudolf Wegeli. For the majority of the text, however, Alm did not disagree with Payne-Gallwey. He dated composite bows to the twelfth century and steel bows to the fourteenth century. He did not praise steel crossbows to nearly the extent that Payne-Gallwey did and instead argued that certain builds of composite materials could easily be just as powerful as a steel lathe.⁵⁶ His narrative of the spanning devices used with crossbows agreed almost entirely in the order of their invention with Payne-Gallwey. His one big disagreement was his assertion that the *krihake* was likely an invention of the Later Middle Ages. Payne-Gallwey placed it in the twelfth century while

⁵³ Clifford J. Rogers, "The development of the longbow in late medieval England and 'technological determinism'", pp. 322-7, 332-6, 340-1.

⁵⁴ Josef Alm, *European Crossbows: A Survey*, trans. H. Bartlett Wells, ed. G.M. Wilson, (1994, repr. Dorchester, 1998). pp. 2-5.

⁵⁵ *Ibid.* pp. 11-3.

⁵⁶ *Ibid.* p. 38.

Alm argued that despite its simplicity of design there was no evidence of its existence before the fourteenth century.⁵⁷ Alm assigned spanning devices to crossbows based on the power of the crossbow rather than on the type of crossbow. He also made an interesting geographical distinction between the windlass and the *cranequin*. He referred to the windlass as the English windlass but treated it as having been a device of western European archers, not just the English. The *cranequin*, on the other hand, was a German device used in the eastern parts of Christendom.⁵⁸ Alm's book did not drastically alter the narrative history of medieval crossbows but did offer more detail than any work done before it, despite its short length, and is still the most detailed general work on subject. If Alm's work had a major problem it is that, due to his personal circumstances, he had to draw primarily from Swedish and German crossbows for his study with only a few from further abroad than that. As an example, his chapter on Western European crossbows after 1500 was only 5 pages long, while his chapter on Nordic crossbows from that same time was 23 pages long.⁵⁹ This gave his work a noticeably Central European bias in its discussion of the design of crossbows.

A few years before the translation of Josef Alm's book into English was completed the Society for Archer-Antiquaries published a book on the crossbow based on research conducted by W.F. Paterson. The book was published in memory of Paterson's death and was titled: *A Guide to the Crossbow*. Paterson was a prominent amateur archer historian who wrote articles for the Society's journal, including several reports on the *Mary Rose* as it was being excavated.⁶⁰ His most famous work was probably *Saracen Archery*, a translation of a medieval Muslim manuscript on the practice of archery which he completed in cooperation with J.D. Lathan. *A Guide to the Crossbow* was a compilation of notes Paterson had written on the crossbow throughout the course of his life as his research wandered into that area.⁶¹ Since it was a collection of notes the information contained in this work was a bit scattered and did not provide a clear narrative of the history of the crossbow. While it did not provide an overarching narrative it did include new information on the crossbow. For example, Paterson went into even more depth than Alm in his research of trigger mechanisms for crossbows. He engaged in relatively little discussion about the steel crossbow and instead most of his notes, when

⁵⁷ Ibid. p. 41.

⁵⁸ Ibid. pp. 39-40.

⁵⁹ Ibid. pp. 64-8, 69-92.

⁶⁰ For example see: W.F. Paterson, "Mary Rose'- a Preliminary Report", *Journal of the Society of Archer-Antiquaries* 23 (1980). pp. 29-34.

⁶¹ W.F. Paterson, *A Guide to the Crossbow*, (Oldland, 1990). pp. 7-12.

they were concerned with crossbow lathes, were focused on wooden and composite crossbows. Also, he went into the greatest depth of any book on the subject on of wooden crossbow lathes. He included a reference to an actual surviving wooden lathe, the Berkhamsted Bow, as well as an examination of yew as it pertained to crossbow lathes. While Alm's book had a detailed account of composite lathes, Paterson's included more cross-sections of lathes as well as several surviving examples that Alm had not included. While not a revolutionary work in the field, the individual sections of Paterson's book were all very informative and represent a useful contribution to the study of the crossbow.⁶²

The most recent book written on the crossbow was Dirk Breiding's *A Deadly Art: European Crossbows, 1250-1850*, which was published in early 2014. Breiding was formerly a curator at the Metropolitan Museum of Art [Met] and *A Deadly Art* was primarily a showcase for the crossbows in the Met's collection rather than an overview of the weapon in general.⁶³ Each of the chapters started with a few pages of introduction to the technology of that time period before moving on to a detailed discussion of the crossbows in the Met collection from that time. For example, the first chapter on steel crossbows had five pages of introduction to the invention and spread of steel crossbows in Europe while the remaining thirty pages of the chapter contained detailed examinations of specific steel crossbows in the Met's collection.⁶⁴ The book focused more on modern crossbows than medieval ones. Each crossbow received at least two pages of analysis, and some received significantly more. Breiding included most but not every crossbow owned by the Met. He focused on the outstanding or unique examples, he picked crossbows with beautiful artistic elements over crossbows with little decoration.⁶⁵ Breiding's most valuable contribution to the discussion of late medieval crossbows was in his detailed study of Spanish crossbow design and its differences from Central European crossbow design. Spanish crossbows were a subject that Alm largely neglected, likely due to the geographical distance between him and Spain, and Breiding really emphasised how different these weapons were to those made elsewhere in Europe. Spanish crossbows, and Breiding's opinions on them, will be discussed in more detail later in this thesis.⁶⁶

⁶² Ibid. pp. 29-30, 38-52, 65-77.

⁶³ Dirk Breiding, *A Deadly Art: European Crossbows, 1250-1850* (New York, 2014). pp. vi-vii.

⁶⁴ Ibid. pp. 30-4 and pp. 35-65.

⁶⁵ For example, MET 29.16.14 and MET 14.25.1575a, both composite crossbows, were not included in the book.

⁶⁶ See Chapter 5.

There are several important works on the history of the crossbow that have not been translated into English. One of the earliest, important German books on the crossbow was Egon Harmuth's *Die Armbrust*. Harmuth's book, first published in 1975, is a translation and revised edition of Ralph Payne-Gallwey's *The Crossbow*. Harmuth made extensive updates and changes to Payne-Gallwey's original book. He continued the history of the crossbow into the early twentieth century, past Payne-Gallwey's original finishing date.⁶⁷ Payne-Gallwey had originally included several sections comparing the crossbow to the longbow and early firearms, as well as a long section on classical siege weaponry.⁶⁸ Harmuth removed all of these from his text and instead focused entirely on the crossbow. He also re-structured the book into fewer chapters, each covering a more general topic. Payne Gallwey's work was divided into four sections with fifty-four sub-sections spread across those parts.⁶⁹ Harmuth excised the entire fourth section and its four sub-sections and re-divided his book into three parts with only thirty-six sub-sections in total. Harmuth also added a section on the mechanics of the crossbow.⁷⁰ While Payne-Gallwey's original used exclusively hand drawn reproductions of crossbows and images, Harmuth added images of actual medieval artwork and photographs of contemporary crossbows. Many, but not all, of Payne-Gallwey's original images were retained in Harmuth's edition.⁷¹ The most notable additions were images of the cross section of a composite lathe, and several graphs which described where the power of a steel crossbow lathe came from.⁷² The greatest addition to the work overall, which will be discussed in greater detail in Chapter One, was his examination of the mechanics of the steel crossbow. He went into greater depth on the efficiency and function of the crossbow than anyone else had before or since.⁷³ Harmuth's work was not ground breaking but he did bring a much needed update to a classic book on the history of the crossbow, and simultaneously added several very important and new insights into the mechanics of the steel crossbow lathe.

Holger Richter's *Die Horgenarmbrust* (2006) was the most thorough and detailed study of the composite crossbow yet written. Totalling just under 200 pages, the book

Dirk Breiding, *A Deadly Art*, pp. 30-1, 37-8.

Josf Alm, *European Crossbows*, pp.64-8.

⁶⁷ Egon Harmuth, *Die Armbrust*, (Graz, 1975). pp. 152-4.

⁶⁸ Ralph Payne-Gallwey, *The Crossbow*, pp.40-53, 249-320.

⁶⁹ *Ibid.* pp. ix-xii.

⁷⁰ Egon Harmuth, *Die Armbrust*, pp. 9-10.

⁷¹ For example: Egon Harmuth, *Die Armbrust*, pp. 36-7, 138-40.

⁷² *Ibid.* p. 94.

⁷³ *Ibid.* pp. 125-36.

See also, Chapter 1.

included 28 composite crossbows in its analysis of the technology. Much of the book was devoted to the examination and discussion of specific composite crossbow lathes. The illustrations and images included in this analysis contained an unprecedented level of detail. Richter included images and illustrations showing the internal structure of many composite crossbows' cores, which provided a valuable insight into the design and construction of these weapons. To Richter, the composite crossbow represented a complex and sophisticated technology of war. He argued for an Islamic origin to the technology and saw its eventual replacement by the steel crossbow in the sixteenth century as the result of the composite lathes' complexity of manufacture. The composite lathe could not compete with the easier to build, and cheaper, steel lathes.⁷⁴ The book was not limited to just archaeological analysis. Richter also discussed textual sources, and wrote a general history of the composite crossbow.⁷⁵ Richter focused on the composite crossbow's design and the methods used to manufacture it. His book did not revolutionize historians' understanding of the crossbow or its development but he did add a new level of depth to the study of the composite crossbow. If there was a flaw in Richter's work, it was that he drew his archaeological evidence primarily from Central European museums, most of them based in Germany, Switzerland, or Austria, and neglected evidence from elsewhere. However, most of the surviving composite crossbows are from this part of Europe so it is no surprise that it forms the majority of Richter's evidence.

While he did not write a single, comprehensive history of the crossbow, Jens Sensfelder made several important contributions to the study of the crossbow. Sensfelder has written several articles on specific crossbows or spanning devices but his greatest contributions have come from the detailed museum catalogues he has compiled. His most impressive work is his unpublished catalogue of Grandson Castle which spans several hundred pages across three large binders. Each crossbow in Grandson Castle, of which there are over a hundred, has received at least two pages of description and discussion as well as a photograph. While this work is Sensfelder's most impressive achievement the fact that it was not published and can only be consulted by visiting the village of Grandson in western Switzerland has limited its impact on the study of crossbows. His *Crossbows in the Royal Netherlands Army Museum* was a much more accessible work and was made to the same rigorous standards as the Grandson catalogue.

⁷⁴ Holger Richter, *Die Horgenarmbrust*, (Ludwigshafen, 2006). pp. 9-19, 170.

⁷⁵ *Ibid.* pp.119-36.

While the Grandson catalogue was entirely in German, *Crossbows in the Royal Netherlands Army Museum* was published in English, German, and Dutch, making it much more approachable. The book included an introduction to the crossbow and a very general history which does not alter the already dominant narrative. What is very useful about this work is the level of detail Sensfelder put into his analysis. The crossbows he examined were measured in over a dozen different ways and he even included a discussion of the type of wood used in the tillers, something that almost no other work mentioned.⁷⁶ The unique contribution that made this book stand out was the metallurgical analysis of a steel crossbow lathe.⁷⁷ Performing this kind of analysis required the destruction of the lathe so it is unlikely that a museum would allow it, meaning Sensfelder's work is unique in containing this type of study. Sensfelder's analysis and conclusions will be discussed in greater detail in Chapter One but the presence of this alone is sufficient reason for his work to be included in any discussion of the steel crossbow. In general, Sensfelder's catalogues contained far more detail than any other published work on the crossbow and his level of detail represents a standard that should be expected from all subsequent publications that include information on surviving crossbows.

Jan Kruczek wrote a history of the crossbow and crossbowmakers which was published by the Pszczyna Castle Museum in 2013. He had previously written a detailed catalog of crossbows held in Pszczyna Castle Museum, most of which are from the early modern period. Both books are in Polish, a language that this author unfortunately has no practical familiarity with. Retrieving data from the catalog was fairly straightforward, however, since it required only the translation of a few sentences and a handful of terms. The bibliography of Kruczek's longer work makes for interesting reading.⁷⁸ While it showed the existence of an extensive German and Polish scholarship on the crossbow he primarily drew from articles from the 1970s and 1980s. His choices are confusing, for example, he referenced several articles by Egon Harmuth but not *Die Armbrust*. He also made no reference to Holger Richter's *Die Horgenarmbrust* and only one reference to an article by Jens Sensfelder. There were a few English language references in his bibliography but not Payne-Gallwey or Josef Alm, either in translation or in Swedish.

⁷⁶ See Jens Sensfelder, *Crossbows in the Royal Netherlands Army Museum*, (Delft, 2007). p. 154 for an example of the measurements taken for every crossbow.

Ibid. pp. 355-360 for tiller analysis.

⁷⁷ Ibid. pp.361-7.

⁷⁸ Jan Kruczek, *Kusze I Ich Twórcy*, (Pszczyna, 2013). pp. 173-180.

The only reference to Paterson was to a small book on crossbows in the Simon Collection, which is an archery collection in Manchester. This latter book is so esoteric it does not even have a WorldCat page. Many of Kruczek's references were from around the turn of the twentieth century. The bibliography suggests that while Kruczek had many sources to draw on few of them were written in the last decade, which might explain why he decided to write this book. The book was a little over 150 pages long, about half of which were devoted to pre-modern history. The book has an impressive selection of pictures and illustrations which makes even skimming the book remarkably informative. It is easy to follow the general periods of time and crossbows each section is covering. From all appearances he wrote a fairly broad, general history of the crossbow and his chapter divisions suggest that his narrative did not differ greatly from that used by Alm or Harmuth. His archaeological evidence seems to draw on well-known Western European examples in addition to some from across Poland.⁷⁹ Still, it is unfortunate that language difficulties, and a lack of time to overcome them, have limited the time spent studying this work meaning it is difficult to know if it contains some more specific arguments where it shifts from the established narrative.

In the last few decades several historians have published insightful articles on more specific topics relating to crossbow use in medieval Europe. Some of the most interesting articles were written by David Bachrach. Bachrach used the *Close Rolls* and *Pipe Rolls* of the kings of England, especially those of Henry III and Edward I, to examine the spread of the use of the crossbow in the medieval English army. While many of these sources were previously referenced by Payne-Gallwey, Bachrach's articles went into much greater depth than anyone had before. These accounts frequently made a distinction between three types of crossbows (*ballista* in Latin): one-foot, two-feet, and *ad turnum*. The label *ad turnum* is usually left in its original Latin due to difficulties with exactly how it should be translated. *Ballista ad turnum* is only one of several different labels applied to this type of crossbow in medieval Latin texts.⁸⁰ These three categories had been noted by historians before and many theories were made on what exactly the terms meant. The general consensus seems to be that the one-foot and two-foot

⁷⁹ For example, Jan Kruczek, *Kusze I Ich Twórcy*, p. 52 contains detailed images of a crossbow from Cologne which is also discussed in detail in the following two works:

Egon Harmuth, "Concerning the One-Foot Crossbow of the High Gothic", *Journal of the Society of Archer-Antiquaries* 28 (1985). pp. 9-10

Holger Richter, *Die Horgenarmbrust*, (Ludwigshafen, 2006). pp. 26-31.

⁸⁰ Josef Alm, for example, used *ballista de torno* instead of *ballista ad turnum*. Josef Alm, *European Crossbows*, p. 22.

crossbows were named based on the number of feet placed into the stirrup mounted on the crossbow when spanning the weapon.⁸¹ These definitions are slightly problematic, which Bachrach pointed out, since no known examples of crossbows with stirrups designed for two feet survive. This suggests that the one-foot/two-foot distinction could be indicative of a different element of crossbow design. *Ad turnum*, on the other hand, likely refers to a sort of winch system like a windlass or a *cranequin*. Bachrach offered a convincing argument for the history of the *ballista ad turnum*. He examined documents that specifically mention either *ballista ad turnum* or else devices that sounded similar to try to distinguish between references to a windlass spanned crossbow as opposed to references to a large siege ballista. Based on this evidence, he argued that the *ballista ad turnum* was in wide use during the reign of Henry III and was probably introduced to England sometime before then. Mardi ibn Ali al-Tarsusi wrote a military manual for Saladin (1138-1193) that mentioned a crossbow spanned with a winch and Bachrach theorised that Richard I encountered this weapon and brought the idea back with him after the Third Crusade (1189-92).⁸² To support his evidence, he pointed to the presence of Peter the Saracen, a crossbow builder, in King John's *Pipe Roll*. He argued that since Peter was paid fifty percent more than the next highest paid crossbow maker and twice as much as the majority working in the same area he was probably held in high regard by the crown, perhaps as a result of having unique knowledge of crossbow technology. Peter was not the only Muslim employed by King John either, as the *Pipe Rolls* also include a reference to another crossbow maker, Benedict the Moor.⁸³

In addition to his discussion of crossbow manufacturing in medieval England, Bachrach analysed mentions of crossbows in *Pipe*, *Close*, and *Liberate Rolls* to try to get an idea of the number and types of crossbows used in England during the High Middle Ages. His conclusion is that one-foot crossbows were by far the most frequently used while the other two types were increasingly rare, with *ballista ad turnum* being the rarest. He also noted, where possible, the materials of the crossbows and based on this somewhat limited evidence he found that one-foot crossbows were by far more likely to be made of wood while two-foot and *ad turnum* crossbows were more likely to be made

⁸¹ David Bachrach, "Crossbows for the King: The Crossbow During the Reign of John and Henry III of England", *Technology and Culture* 45:1 (2004). pp. 109-13.

Josef Alm, *European Crossbows*, p. 22.

⁸² David Bachrach, "Crossbows for the King: The Crossbow During the Reign of John and Henry III of England", pp. 113-7.

Anne-Marie Eddé, *Saladin*, trans. Jane Marie Todd, (Cambridge, 2011). pp. 281-2.

W.F. Paterson, *A Guide to the Crossbow*, pp. 34-5.

⁸³ David Bachrach, "Origins of the Crossbow Industry in England", pp. 80-8.

of composite materials.⁸⁴ Based on this evidence as well as the higher proportion of one-foot crossbows mentioned in the rolls he concluded that they were the weakest and cheapest crossbows while the others were likely more powerful and restricted to use by elite troops.⁸⁵ Crossbow material is so rarely mentioned, however, that these conclusions should be accepted with some reservations. The most interesting part of Bachrach's research, however, came when he compared the reign of Henry III with that of Edward I. When the numbers of crossbows were compared it showed that Henry III had many more two-foot and *ad turnum* crossbows while Edward I had much larger numbers of one-foot crossbows. He theorized that this was because Henry III primarily used his crossbows for garrisons while Edward I took his into battle against the Welsh. This theory is reasonably well supported by the *Pipe Rolls* which show a large increase in the number of one-foot crossbows purchased by the crown leading up to the Welsh Wars (1277-83). This is especially interesting since it shows that Edward I, who is often considered the father of the English longbow, primarily used the crossbow for at least the first half of his reign. Still, Bachrach presented a challenge to Morris and Oman's narrative that the longbow was adopted by the English around the time of Henry III's 1252 *Assize of Arms* since Edward could clearly be shown to have used the crossbow as a major component of his armies several decades later.⁸⁶

While the longbow eclipsed the crossbow in England after the reign of Edward I, it did not replace it entirely. Paul Holmer made a useful, if narrow, contribution to the study of English crossbows in the Later Middle Ages when he examined an audit conducted by William Ross, Master of the King's Ordinance and Controller of the Ordinance for Edward IV's invasion of France (1475). Several documents survive that relate to this audit and Holmer classified them into two areas: expenditures Ross was responsible for, and war materials stored in Calais. The expenditures showed that England was still in the habit of buying crossbows. William Ross bought over a hundred crossbows between the years 1473 and 1483. These crossbows were not exclusively made of steel, in several cases they were made of wood. The continued use of the wooden crossbow so late into the fifteenth century is particularly interesting since according to Payne-Gallwey's narrative it should have been rendered obsolete by then.

⁸⁴ David Bachrach, "Crossbows for the King: The Crossbow During the Reign of John and Henry III of England", pp. 109-11.

⁸⁵ *Ibid.* p. 119.

⁸⁶ David Bachrach, "Crossbows for the King, Part II: The Crossbow During the Reign of Edward I of England (1272-1307)," *Technology and Culture* 47:1 (2006). 84-90.

The steel and wooden bows even had comparable costs. Concerning the garrison at Calais, there were a substantial number of crossbows kept there; William Ross's audit indicates nearly two hundred in 1481. There was also a garrison of crossbowmen, forty in total, who were not part of a particular retinue and were paid more per day than the standard archer. This evidence, along with information from other sources, such as the *Calendar of Inquisitions Miscellaneous*, indicated to Holmer that at this time the English used the crossbow primarily as a siege weapon, to be assigned to garrisons they expected to have to defend against an overwhelming threat. The crossbow did not completely disappear from English warfare, but it did become a niche weapon with only a few specific uses. While Holmer's research is valuable, it only really covers the reign of Edward IV (r. 1461-1470, 1471-1483) and without further research it cannot be assumed that other fifteenth-century English monarchs had the same policies.⁸⁷

An important subject that this thesis has not covered is the study of the soldiers who wielded these weapons. Several scholarly works dedicated to analysing the medieval archer have already been written. Bradbury's *The Medieval Archer* remains an insightful discussion of both English archers and, to a lesser extent, continental crossbowmen. While his book primarily covered their role in medieval warfare Bradbury also spent time discussing the importance of the legend of Robin Hood as a representation of the yeoman archer as well as briefly discussing the archer's role in society.⁸⁸ What update this work needed was provided by Strickland and Hardy's *The Great Warbow*, which shows how the English archer transitioned from being a common soldier in the High Middle Ages to a semi-professional yeoman by the end of the Hundred Years War. Strickland also included several pages discussing the adoption of the longbow by non-English armies, and the way those societies tried to adapt to the necessary training and supply required to maintain a force of skilled archers. Recent scholarship has provided historians with invaluable insights into the lives and minds of these soldiers but understanding of the weapons they wielded has not progressed to the same degree.

The works discussed in this introduction do not represent the totality of books or articles written on medieval archery. Covering every single work would cover too many pages to be a practical endeavor. Instead these works have been chosen to represent highlights of major developments in historians' understanding of the bow and the

⁸⁷ Paul L. Holmer, 'The Military Crossbow in Yorkist England', *Journal of the Society of Archer-Antiquaries*, 22 (1979), pp. 11-14

⁸⁸ Jim Bradbury, *The Medieval Archer*, pp. 58-70, 159-80.

crossbow. This has included older works which have had lasting influence on modern historical debate, as well as detailed studies of certain aspects of these technologies that go into a greater level of detail than any of their predecessors. While the longbow has primarily been the subject of English language histories the crossbow has a much broader historiography, in which English language books are in the minority. This work has taken archaeological information on the longbow and the crossbow, and attempted to construct a coherent picture of the design of these weapons, and how it may have changed over the course of the later middle ages.

The study and practice of archery have terminology that is unique to them, and can at times be archaic and confusing to anyone not familiar with the subject. For this reason a glossary has been included in the appendix III of this thesis and any reader new to the study of archery may wish to start there before moving on to the rest of this work.

Chapter One

The Mechanics of Archery

The arguments laid out in the following chapters rely upon first establishing a basic understanding of the mechanics of archery. Since physics remains constant regardless of time period, a modern understanding of the mechanics of archery can inform historians about the performance and design of bows from the past. For the purposes of this chapter, the bow and the crossbow are treated as functionally identical technologies, since both operate according to the same core mechanics. The crossbow, or more specifically the *lathe*, is essentially a compact, powerful bow. Understanding the principles governing a bow's performance and, more importantly, how that relates to different types of bow design, can help historians better understand why the weapons examined later in this thesis were designed the way they were. A basic grounding in the mechanics of these two weapon systems will inform much of the discussion in the following chapters, and presents an ideal introduction to the study of medieval archery. This chapter will cover the basic physical forces of archery, and how those forces would have affected, and been affected by, the different materials used to make bows. Modern tests by historians that try to approximate medieval weaponry will also be covered. It will conclude with a discussion of why this information is important to the study of medieval archery.

The physics involved in the ballistics of a bow are far too complicated to be discussed in complete detail in this thesis.⁸⁹ Instead, this chapter will explore the general outline of how a bow works and what forces act on it as it is fired, but with little to no recourse to the raw numbers and calculations involved in the aforesaid operations. First, however, a brief explanation of the essential terms associated with bows is necessary. The back of the bow is the part of the bow that, when the bow is held ready to fire, faces away from the archer, while the belly is the side that faces the archer. A bow can generally be divided into three main parts: the upper limb, the lower limb and the grip. The limbs of a bow are generally slightly asymmetrical, with the upper limb being slightly longer than the lower limb. The final parts of the bow it is important to mention here are the nocks. The nocks are the points of the bow at which the string is attached.⁹⁰

⁸⁹ Mark Denny, *Their Arrows Will Darken the Sun: A Guide to the Evolution and Science of Ballistics*, (Baltimore, 2011). pp. 7-15

⁹⁰ Tim Baker, "Bow Design and Performance" in *The Traditional Bowyers Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). p. 1:57.

How Bows Work

The simplest type of bow, and therefore the best one to start with, was the wooden self bow. A self bow was a bow made of a single piece of wood. A self bow got its power from a combination of the compression of the belly of the bow and the extension of the back of the bow. These two forces combined to store potential energy in the bow as the string was drawn back. The further the bow was drawn, the greater the energy stored.⁹¹ When the string was released, it transferred this stored energy to the arrow as the bow's limbs returned to their original position. An interesting element to note here is that if a bow was dry fired, that is, drawn and released without an arrow, the result was often great damage being done to the bow due to the sudden transfer of kinetic energy into the limbs of the bow.⁹² The primary factors in determining the power of a bow were the bow's shape and size. A bow derived much of its power from its thickness. This is because when a bow was drawn the wood compressed and extended across the thickness of the bow. Increasing a bow's thickness greatly increased its capacity for storing potential energy, but also increased the risk of breaking. A section of bow can only tolerate so much stress before either splintering or breaking. Increasing the width of a bow could have helped mitigate this problem since it spread the force of the draw out across a wider area, so no one area bore too much of the strain. However, this would have increased the weight of the bow, since it necessarily involved using more wood, and an increase in weight would have had a negative impact on the efficiency of the bow.⁹³

Before discussing more of the specifics of bow design it is necessary to establish how the power of a bow was determined and affected by its design. An important signifier of the power of a bow was the draw weight, for both bows and crossbows. Draw weight refers to the amount of force required to pull the bow back to a specific distance. It is usually represented by the unit of pounds at a given distance. For example, a longbow might be described as having had a draw weight of 150 lbs at 30 in. The amount of force generated by a bow was increased by drawing it further but the effort required to draw the bow increased the further the bow was drawn. Elements of a bow's design, especially its length, can limit the distance it could have been drawn without damaging the bow.⁹⁴ The easiest way to determine a given weapon's draw weight is to connect a force gauge to a winch which draws the bow or crossbow back to a measured

⁹¹ Ibid. pp. 1:96-103.

⁹² Ibid. pp. 1:43-45.

⁹³ Ibid. pp. 1:65-74.

⁹⁴ Ibid. pp.1: 46, 68-73.

distance. However, due to the risk of breaking a very valuable artefact, this can rarely be done with any medieval weapons. Even in cases when it has been done, as with a selection of the *Mary Rose* bows, damage or decay of the weapon can result in these tests not accurately reflecting the weapon's original power.⁹⁵ In the specific example of the *Mary Rose*, the bows were waterlogged for so long that they had lost a lot of their rigidity and so were much easier to draw than they would have been when they were made.⁹⁶ Since drawing the weapons is rarely an option, the draw weight must be estimated through other means. Usually this is done by using the exact dimensions of the bow or crossbow and calculating an estimate of the amount of force necessary to draw the weapon. For the *Mary Rose* bows, careful measurements were taken of all of the surviving bows which were then entered into computational software to model the forces required to bend the bows.⁹⁷ A replica bow was built, which could have its draw weight measured directly. This gave a likely figure for the draw weight of a historical bow of the same dimensions, and was also used to test the accuracy of the computational models method.⁹⁸ Most finds have not been as rich in evidence as the *Mary Rose* and have been reliant entirely on estimates based on bow dimensions. These are usually rife with complications, as in some cases the entire bow hasn't survived. Draw distances for a longbow are generally assumed to have been between 28 and 30 in.⁹⁹ Estimates of draw distance are based on a few factors, including the length of the bow, the length of surviving arrows, and in some cases textual evidence describing the length of contemporary arrows.¹⁰⁰ These are all necessarily 'best guess' estimates rather than hard fact. The lengths assumed for the draw weight can have a substantial impact on the final estimated draw weight, as a difference of even a few extra in of draw can have a significant impact on the overall force required to draw a bow.¹⁰¹

Calculating the draw weight of a crossbow also relies on examining the

⁹⁵ Matthew Strickland and Robert Hardy, *The Great Warbow: From Hastings to the Mary Rose*, (2005, repr. Somerset, 2011). pp. 13-5.

⁹⁶ Robert Hardy, J. Levy, P. Pratt, Roy King, S. Stanley, B.W. Kooi, D. Adams, and A. Crowley, "Assessment of the Working Capabilities of the Longbows" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). p. 2:627.

⁹⁷ Ibid. pp. 627-9.

⁹⁸ Matthew Strickland and Robert Hardy, *The Great Warbow*, pp.15-8.

Robert Hardy, J. Levy, P. Pratt, Roy King, S. Stanley, B.W. Kooi, D. Adams, and A. Crowley, "Assessment of the Working Capabilities of the Longbows", p. 627.

⁹⁹ Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 12-3, 17-8.

¹⁰⁰ Arthur G. Credland, "The Medieval War Arrow", *Journal of the Society of Archer-Antiquaries* 25 (1982). pp. 28-33.

¹⁰¹ Tim Baker, "Bow Design and Performance", pp. 1:45-53.

dimensions of the lathe and estimating the draw weight based on those measurements, but there are a few key differences. If the lathe is still attached to its tiller then the draw distance does not have to be estimated since the weapon can only be drawn a fixed distance. However, many lathes have been mistakenly attached to different tillers than their original at some point in the past, so it is important to determine whether the current tiller is authentic or not.¹⁰² In cases where the lathe either is not attached to a tiller, or the tiller is not its original, the draw distance has to be estimated. Depending on the shape of a composite lathe, it may be necessary to estimate its draw distance regardless of its tiller. When the glue binding the composite materials has dried, the lathe becomes rigid, and if it has done so while un-strung then the draw distance becomes harder to estimate. The distance between the lathe and the nut can be determined in this case, but only some of that distance actually would have added force to the bolt when the weapon was fired. The weapon can only impart force onto the projectile up to the resting point of the string, so any distance between the string and the lathe is effectively 'lost'. Estimates can be more problematic with crossbows since the draw distance for medieval crossbows was quite short, almost always under one foot (300mm), meaning that each individual inch (25.4mm) had more of an impact on the total draw weight.

There has been considerably less work done on estimating the draw weight of crossbows than there has been for longbows. For the few surviving yew crossbow lathes, the estimates have followed similar principles to those of the yew longbows.¹⁰³ When it comes to composite and steel crossbows, estimates become more difficult as the physics has not been studied in as much depth. Some steel crossbows have survived in a sufficiently good condition that they could probably be spanned with a winch, and their draw weights could be determined at a number of draw distances. This generally has not been done, however, due to fears of damaging the steel lathes. Ralph Payne-Gallwey tested the strength of one of the Steel Lathes in his collection and found it to have been over one thousand pounds (454 kg) of draw weight at an unspecified distance.¹⁰⁴ As a point of comparison, the average *Mary Rose* longbow likely had a draw weight between 100 and 130 lbs. (45-59 kg) at 30 in (76 cm).¹⁰⁵ However, this lathe also weighed

¹⁰² Egon Harmuth, "Concerning the One-Foot Crossbow of the High Gothic", *Journal of the Society of Archer-Antiquaries*, 28 (1985). p. 11.

¹⁰³ Robert C. Brown, "Observations on the Berkhamstead Bow," *Journal of the Society of Archer-Antiquaries* 10 (1967). pp. 12-17.

¹⁰⁴ Ralph Payne-Gallwey, *The Crossbow: Its Military and Sporting History, Construction and Use*, (1903, repr. London, 1995). p. 14.

¹⁰⁵ Clive Bartlett, Chris Boyton, Steve Jackson, Adam Jackson, Douglas McElvogue, Alexzandra Hildred and Keith Watson, "The Longbow Assemblage" in *Weapons of Warre: The Armaments of the Mary*

approximately eighteen pounds (over 8 kg), and would have been even heavier with its tiller intact, and so definitely represents an extreme end of possible crossbow power.¹⁰⁶ In contrast, recent analysis of an early modern steel target crossbow by Jens Sensfelder suggested a draw weight of approximately 440 lbs (200 kg).¹⁰⁷

Draw weight is not the only factor to consider when discussing the power of bows and crossbows. The efficiency of the weapon is equally important. The energy stored in a bow when it was drawn did not completely transfer to the arrow when it was fired. Some energy was lost in the mechanics of firing the bow. While a bow can, at least theoretically, be an almost one hundred percent efficient system, this was never true in practice.¹⁰⁸ Energy was spent returning the limbs of the bow back to their original position, as well as in the vibrations of the string after firing. There was also some energy lost due to the space between the bow string and the grip on the bow. This gap still stored energy but since the string did not move past its original resting position, none of that energy was transferred to the arrow. **Illustration 1** shows this principle. The distance ‘d’ was the draw length that transferred energy to the arrow while the distance ‘s’ was the ‘lost’ space. Longer limbs were heavier and used up more energy when they were released, but they were also often capable of storing more energy when drawn. The general trend with longbows was that a larger bow was more powerful but less efficient. That means that the gain in power by increasing the size of a bow was mitigated by the loss in efficiency. It was possible for a smaller, less powerful bow to shoot an arrow faster and with greater force than a heavier, more powerful bow if the difference in their efficiency was large enough. Effective tillering – which was the technique of shaving wood off of the bow to reduce its weight, and ensure that it bent smoothly and evenly when drawn – could have significantly increased the efficiency of a bow. This was, however, a very time consuming and skill-intensive process, and improper tillering could render a bow useless. From an efficiency perspective, the limbs of a bow should have become thinner the further from the grip they were. This was to prevent the ends of the bow being too heavy, since extra weight near the nocks greatly decreased the efficiency of the bow.¹⁰⁹ The tips of the bow limbs moved farthest from their original position when

Rose, ed. Alexandra Hildred, *Archaeology of the Mary Rose 3*, 2 vols. (Portsmouth, 2011). pp. 2:616-7.

¹⁰⁶ Alan Williams, *The Knight and the Blast Furnace: a history of the metallurgy of armour in the Middle Ages & the early modern period*, (Leiden, 2003). pp. 919-20.

¹⁰⁷ Jens Sensfelder, *Crossbows in the Royal Netherlands Army Museum*, (Delft, 2007). p. 363.

¹⁰⁸ Mark Denny, *Their Arrows Will Darken the Sun*, pp. 7-15

¹⁰⁹ Tim Baker, “Bow Design and Performance”, pp. 65-7.

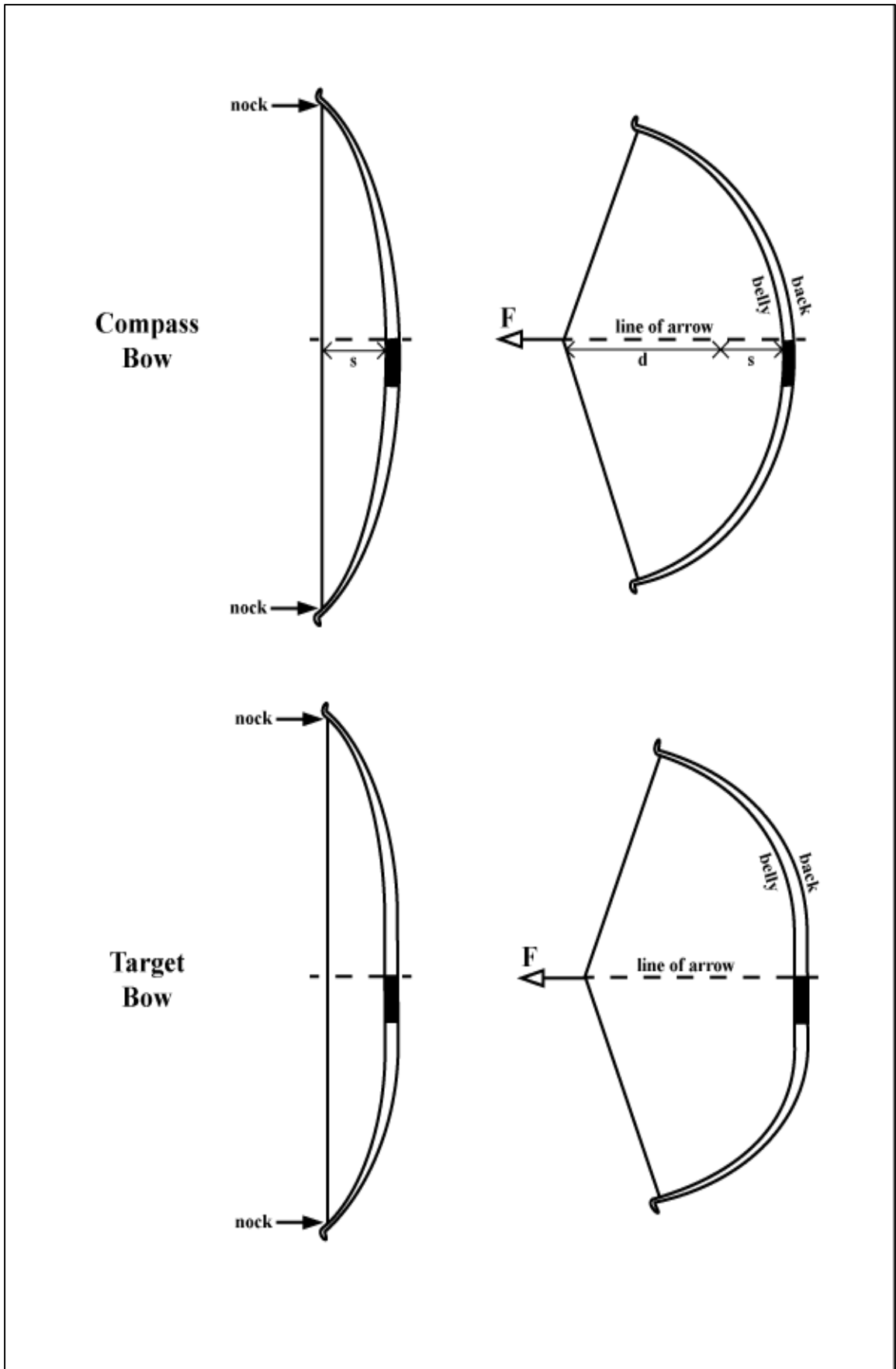


Illustration 1: Compass bow vs. Target Bow, Figure by Emily Neenan, commissioned by author

the bow was drawn, and so used the most energy as they returned to their resting position. Crossbows were, generally speaking, very small, heavily built bows. They were very powerful but also were often very inefficient. W.F. Paterson tested a crossbow he had access to and determined that its efficiency was around 40%, meaning less than half of the power of the crossbow was transferred to the bolt.¹¹⁰ It is very difficult to estimate the exact efficiency of a medieval bow or crossbow, however, for similar reasons as with estimating the draw weight. The only way to reliably calculate the efficiency is to determine the draw weight of the weapon in question and then fire several shots from the weapon and accurately measure the speed of the projectiles fired. That would allow the amount of energy transferred to the projectile after it was released to be calculated, and the loss from the original draw weight could be determined. However, given how few medieval weapons are in a condition to still be fired – let alone the difficulty with getting permission to actually fire any of them – this is not a feasible practice. Efficiency can be estimated to some extent by studying the weapons and looking at their shape, much like with estimating draw weights. Heavier limbs are often a good indication that a weapon was less efficient, for example. Calculating the efficiency of replica weapons can also give an indication of how efficient the original weapons were.¹¹¹

Building a bow that had a high draw weight and an optimal efficiency of energy transfer is no simple matter. There were several different designs for bows that appear to have been dominant in Western Europe. For raw power, the ideal shape of a bow was approximately, but not completely, circular. This is generally referred to as the D-shape since its cross-section resembled a capital letter D. Most of the girth of the bow was curved but one side of the bow was mostly flat. There were many variations on this design which were more or less circular, as well as variations in which side - the back or the belly - was the flat side of the D. The other common bow shape was the diamond shape. This type of bow was flat on both the belly and the back with limbs that were approximately diamond shaped. The limbs flared out from the grip, reached their widest point near the grip, and then narrowed slowly as they approach the nocks. This design spread out the force of drawing the bow over a much wider area, and so greatly reduced the risk of the wood breaking when the bow was drawn, but these limbs had to be relatively thin to work and so a diamond shape bow was usually weaker than a D-shape

¹¹⁰ W.F. Paterson, *A Guide to the Crossbow*, (Oldland, 1990). pp. 31-2.

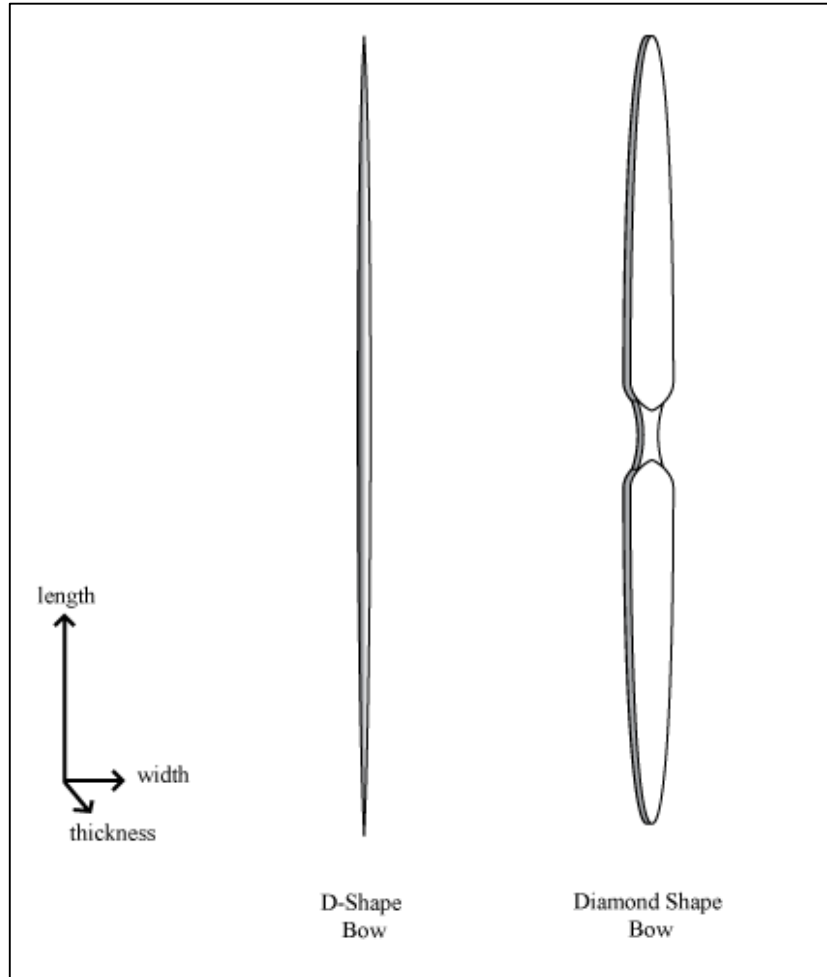
¹¹¹ Mark Denny, "Bow and Catapult Internal Dynamics", pp. 372-6.

Brian Cotterell and Johan Kamminga, *Mechanics of Pre-Industrial Design* (Cambridge, 1990). pp. 181-5.
Tim Baker, "Bow Design and Performance", pp. 1:44-9, 69-74.

bow.¹¹² See **Illustration 2** for an example of the different profiles of the diamond and D-shape bows.

The contribution of length to the power of a bow was largely due to increasing the distance that the bow can be drawn. A short wooden bow could only be drawn back a short distance before the limbs would begin to break. A longer bow's arms could be drawn back further without risk of breakage.¹¹³

Depending on how the longbow was carved, it could have had one of two different types of grip section and the chosen type of grip could have had a significant impact on the bow's performance. A compass bow was a bow that used its entire length when it was drawn. The entire bow, including the grip, bent when the string was pulled back, which meant that



every part of the bow stores energy. This

Illustration 2: Bow Shape, Figure by Emily Neenan, commissioned by author

could cause a loss in accuracy as the grip was likely to shake when the bow is fired which could throw off the archer's aim at the moment of release. Effective tillering could mitigate this problem, but was difficult to do. The alternative to a compass bow was a

¹¹² Ibid. pp. 1:66-71.

Paul Comstock, "Other Bow Woods" in *The Traditional Bowyer's Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). pp. 1:149-55.

¹¹³ Tim Baker, "Bow Design and Performance", pp. 1:46-74.

Mark Denny, "Bow and Catapult Internal Dynamics", *European Journal of Physics* 24 (2003). pp. 367-72; 377-8.

Jim Hamm "Tillering" in *The Traditional Bowyers Bible*, ed. Jim Hamm, 4 vols. (Guilford, 1992). pp. 1:257-86.

target bow. A target bow had a separate grip section that was often thicker than the rest of the bow. This grip did not bend at all when the bow was drawn. Target bows were often easier to fire and more accurate. Bows used in target archery usually had grip sections. The *Mary Rose* war bows were all compass bows.¹¹⁴

The Effect of Material on Bow Performance

Certain types of wood could only be used to make bows with certain profiles. These limited design options in turn dictated the maximum force that a bow could achieve. Modern bowyers working on self bows have experimented extensively with different materials and written on the different properties of the different woods.¹¹⁵ This discussion will be limited to yew and elm wood because those were the two most frequently used in ancient and medieval bows.¹¹⁶ Yew was the ideal wood for building bows because of the different properties of its sapwood and heartwood. The sapwood of yew is very elastic while the heartwood is very strong and rigid. This means that a bow made of heartwood with a layer of sapwood along the back would have had greater elasticity on the back than one that did not. Since the back of a bow stores energy by stretching, that greater elasticity allowed for greater power. The heartwood in turn was remarkably resistant to compression and as a result had a high capability for storing potential energy. These properties also allowed for yew bows to be built much thicker than bows of other wood, as the sapwood helped to prevent splintering and breakage when the bow was drawn, while the heartwood stored an impressive amount of energy as the bow was drawn.¹¹⁷ Elm, however, was not as sturdy a material and an elm bow could not have been built in the same shape as a yew bow. Elm bows must be built with wide limbs or else they are liable to break. Elm bows were often built in the diamond shape. This means that elm bows were generally unable to match the power of yew bows. The primary advantage of elm was the ease with which a bow could be made from it. Firstly, elm did not have to be left to dry out as long as yew did. Trees have a high water content

¹¹⁴ Tim Baker, "Bow Design and Performance", pp. 1:74-6.

Paul Bourke and David Whetham, "A report of the Defense Academy warbow trials Part I Summer 2005", *Arms and Armour* 4:1 (2007). pp. 54-6.

¹¹⁵ Tim Baker, "Bow Design and Performance", pp. 1:104-7.

¹¹⁶ J.G.D. Clarke, "Neolithic Bows from Somerset, England, and the Prehistory of Archery in North-western Europe", *The Proceedings of the Prehistoric Society* 29:3 (1963). pp. 89-95.

Paul Comstock, "Ancient European Bows" in *The Traditional Bowyer's Bible*, ed. Jim Hamm, 4 vols. (Fort Worth, 1992). pp. 2:86-96.

Andrew Halpin, "Archery Material" in *Late and Viking Age Medieval Waterford: Excavations 1986-92*, ed. M.F. Hurley, O.M.B. Scully, and S.W.J. McCutcheon (Waterford, 1997). pp. 546-52.

¹¹⁷ Tim Baker, "Bow Design and Performance", pp. 1:68-73.

while alive and this moisture remained in freshly cut wood. Moisture was problematic when making a bow since wood with a high water content was much more likely to take a set. Set was when a bow became bent even when it was not strung. This curve no longer stored nearly as much energy when the bow was drawn and the maximum force of the bow was significantly reduced as a result.¹¹⁸ Yew had to be left to dry out for many months before it could be crafted into a bow. The bowyer could use heat to dry the yew out; this was risky but could be effective with the right tools. Elm, on the other hand, dries out quickly, and in fact was best used sooner rather than later for if it was left out for several months it would likely have rotted.¹¹⁹ Also, an elm bow was able to reach sufficient power for hunting or shooting unarmoured targets. It was only unable to reach the massive heights of power of the yew longbow, which was only really necessary for war. The fact that most elm bows that survive were from prehistoric times or the Early Middle Ages is probably no surprise given that no sophisticated techniques were required to make these bows. Yew bows could be made as either grip bows or compass bows but elm bows almost always have to have a grip section.

Composite bows were made with multiple materials and this meant there were significant changes to how the bow works. The techniques used with composite materials differed substantially depending on if they were used in hand bows or crossbow lathes. All composite bows shared the same general design with only minor variations, but composite crossbows came in many different designs and styles. A common composite bow had a core of wood with a layer of horn along the belly. The back of the bow was then covered in sinew, some of which may have stretched around to the belly. When the sinew dried, it pulled the bow forward, giving it a natural resistance when drawn. Most bows also had a protective layer of another material over the sinew to keep it safe from environmental damage.¹²⁰ The sinew was very elastic and stored a large amount of energy when it was stretched as the bow was drawn.¹²¹ The horn along the belly was very resistant to compression, further increasing the amount of energy required to draw the bow. The width of a composite bow often varied depending on the culture that made the bow; this was often but not exclusively because different materials were available to different cultures, such as the specific type of wood or horn.¹²² Composite bows were

¹¹⁸ Tim Baker, "Bow Design and Performance", pp. 1:47-50.

¹¹⁹ Paul Comstock, "Other Wood Bows", pp. 1:149-60, 162-4.

¹²⁰ Matthew Strickland and Robert Hardy, *The Great Warbow*, p. 99.

¹²¹ Jim Hamm, "Sinew Backing", in *The Traditional Bowyers Bible*, ed. Jim Hamm, 4 vols. (Guilford, 1992). pp. 1:213-4, 229-32.

¹²² C.A. Bergman, E. McEwen and R. Miller, "Experimental Archery: Projectile Velocities and

generally shorter than self bows, usually between three and five feet long.

Composite bow arms, also called *siyahs*, had a distinctly curved nature as a result of the sinew pulling them forward: this feature is called recurve. Recurve helped to make composite bows more powerful; storing energy in the bow through the simple act of stringing the bow meant that the bow started at a point of having more energy than a standard wooden bow. Turkish flight archery bows have been known to have had so much recurve that they almost formed a circle when left unstrung. Recurve was not a universal feature in all composite bows, but only composite bows are capable of having recurve.¹²³ Recurve came in several different forms, include static and working recurve, and the exact impact these differences had on the bow's performance is even more complicated than anything capable with a self bow. B.W. Kooi carried out some complex analysis of several replica Asiatic bows, but his results are both too complex for and only tangentially related to this study, so have been left out of this discussion.¹²⁴

The grip of a composite bow did not need to contribute to the working of the bow, and could even be made of different materials than the limbs of the bow. The nocks of a composite bow could also be made of a different material than the rest of the bow. Some composite bows have been found with nocks made of a light wood to reduce the weight on the ends of the bow. This also increased the speed with which the arms return to their original position.¹²⁵

Composite crossbow lathes had more layers of sinew than their bow counterparts, but otherwise the sinew was used in a very similar way. The core of the crossbow lathe, however, was quite different from the core of a composite bow. **Illustration 3** shows a cross section of the core of a composite lathe from the Bernisches Historisches Museum. Some cores had wood at their very centre with two layers of horn on either side of the wood, others had a core of horn with wooden layers around the horn. There were many different ways of laying the wood, depending on if the horn was in discrete blocks, glued together, or in thin, long strips. Some composite crossbows forewent having wood entirely, and others used whale baleen to fulfil a similar purpose.¹²⁶ The core of a composite lathe was always much larger than that of a composite bow. The exact impact

Comparison of Bow Performances”, *Antiquity* 62 (1988). pp. 660-5

¹²³ Tim Baker, “Bow Design and Performance”, pp. 1:48-65.

¹²⁴ B.W. Kooi, “Functioning of the Ears and Set-Back at the Grip of Asiatic Bows”, *Journal of the Society of Archer-Antiquaries* 39 (1996). pp. 73-7.

¹²⁵ Wayne Atex and G. Menes, “The Omnogov Bow”, *Journal of the Society of Archer-Antiquaries* 38 (1995). pp. 73-5

¹²⁶ Josef Alm, *European Crossbows: A Survey*, ed. and trans. G.M. Wilson and H. Bartlett Wells, (1994, repr. Dorchester, 1998). pp. 16-7.

that the various types of composite crossbow lathe design had on weapon performance has not been entirely established. The sheer number of different lathe designs makes undertaking any comprehensive study a daunting task, especially given how difficult it can be to determine what the core of a still intact crossbow lathe looks like without either cutting it open or spending a significant amount of money on advanced imaging equipment.¹²⁷

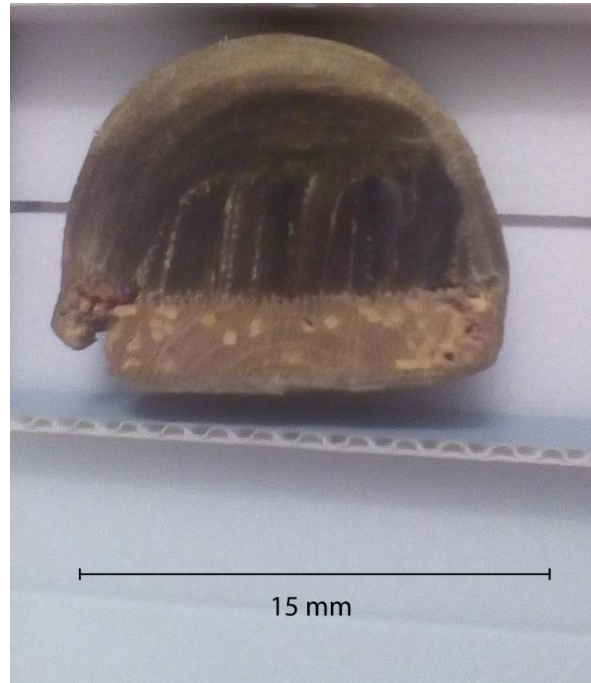


Illustration 3: Cross-section of composite crossbow lathe from Bernisches Historisches Museum, photo by author

The steel crossbow presents the most significant variation from the core mechanics that govern both bows and crossbows. The same processes for generating power apply for all three materials: the steel arms were drawn back and stored potential energy. When the trigger was pulled, the ends of the steel limbs moved forward rapidly and launched the crossbow bolt. The steel crossbow lathe functioned as a spring and followed the same mechanical principles. Due to the more consistent properties of steel, compared to wood and horn, in theory steel lathes should be easier to analyse than other types of crossbow. However, the mathematics involved are still abstruse. Some authors, such as Egon Harmuth and Erhard Franken-Stellamans, have written very impressive pieces on the mathematics behind steel crossbows, but historians are still some way away from being able to implement these ideas in a practical manner.¹²⁸ While the complexity of the mathematics involved is certainly a problem, accessing detailed and accurate descriptions of medieval crossbows has also proved difficult. To take Franken-Stellamans' work as an example; he has shown how the draw distance of a steel lathe can be calculated with what is relatively simple maths (at least compared to other calculations mentioned in this chapter) but this requires at least

¹²⁷ Mark Denny, "Bow and Catapult Internal Dynamics", pp. 377-8.

Arab Archery, trans. Nabih Amin Faris and Robert Potter Elmer (Princeton, 1945). pp. 10-16.

Adam Karpowicz, "Ottoman Bows – An Assessment of Draw Weight, Performance and Tactical Use", *Antiquity*, 81 (2007). pp. 675-683.

Paul E. Klopsteg, *Turkish Archery and the Composite Bow*, (London, 1934). pp. 30-40.

Brian Cotterell and Johan Kamminga, *Mechanics of Pre-Industrial Design*, pp. 185-7.

¹²⁸ Egon Harmuth, *Die Armbrust* (Graz, 1975). pp. 125-36

four measurements from the lathe, only one of which is standard in most museums.¹²⁹

The exact quality of the steel used for crossbow lathes in the Middle Ages is not clear, and there was likely significant variation between lathes. Crossbow lathes definitely have to be made of steel, and not iron. The Royal Netherlands Museum allowed Jens Sensfelder to undertake some metallurgical analysis of a lathe in their possession. This process is very rarely done because it is necessarily destructive to the lathe. Only an unattached lathe of little historical value can realistically be permitted to be destroyed. The lathe was a small steel lathe for a target crossbow and could only be dated to sometime during the sixteenth to eighteenth centuries. Sensfelder found that the lathe was made of several pieces of varying qualities of steel mixed together to create a single pattern welded lathe.¹³⁰

There seemed to be a belief among some medieval warriors that the steel crossbow would become brittle and break if it was used during times of great cold. The Teutonic Order, who mostly campaigned in Eastern Europe during winter, had a noted preference for composite lathes over steel.¹³¹ Arthur Credland, however, noted that in the early modern period several tribes in Nordic Lapland used steel crossbow lathes which to him suggested that this belief was at the very least falsely held, if it was held at all.¹³² Jens Sensfelder found that reducing the temperature of the lathe he was testing to minus fifteen degrees Celsius increased its draw weight by approximately 12%. This increase could easily have been too much for the lathe to take, and could have caused damaging breaks.¹³³ It is possible that this could have been mitigated by making the lathe slightly weaker in the first place, since the increase in power would not cause harmful stress to the lathe. Josef Alm suggested that composite crossbows would experience a similar rise in rigidity in cold weather, so it might be a more general flaw in non-wooden crossbows rather than exclusively a problem with steel crossbows.¹³⁴ More experimentation is necessary for historians to better understand these technologies.

¹²⁹ Erhard Franken-Stellamans, "A Mathematical Method for Determination of the Appropriate Draw Length for a Given Steel Bow", *Journal of the Society of Archer-Antiquaries* 47 (2004). pp. 92-4.

¹³⁰ Jens Sensfelder, *Crossbows in the Royal Netherlands Army Museum*, pp.361-7.

¹³¹ Sven Ekdal, "Horses and Crossbows: Two Important Warfare Advantages of the Teutonic Order in Prussia" in *The Military Orders Volume 2: Welfare And Warfare* ed. Helen Nicholson (Aldershot, 1998). pp. 147-148.

Sven Ekdal, 'Die Armbrust in Deutschordensland Preussen zu Beginn des 15. Jahrhunderts', *Fasciculi Archaeologiae Historicae* 5 (1992). pp. 22-26, 45.

¹³² A. G. Credland, "The Crossbow in the Far North", *Journal of the Society of Archer-Antiquaries*, 26 (1983). pp. 13-14.

¹³³ Jens Sensfelder, *Crossbows in the Royal Netherlands Army Museum*, pp. 365-6.

¹³⁴ Josef Alm, *European Crossbows*, p. 35.

Bolts and Arrows

The physics of an arrow's flight is, if anything, more complicated than the internal mechanics of a bow. The most important elements to determining the flight of an arrow are yaw, fletching, and gravity. Arrow yaw is the side to side motion an arrow undergoes as it flies through the air. When an arrow is fired the string pushes the arrow straight forward but the arrow is not actually pointing straight forward, as the bow is directly in front of the string, see **Illustration 4**. Since the arrow is unable to fire completely straight it must instead curve around the bow's grip before continuing directly forward. This curving, and the residual energy it creates, causes the arrow to sway back and forth as it flies through the air. This motion of the arrow has important, and complicated, implications for the arrows flight and eventual impact with its target.¹³⁵ The fletching on an arrow serves to generate both lift and drag when the arrow is fired. While drag slows the arrow down, lift allows the arrow to fly further as it keeps the arrow in the air longer than would be possible if the arrow had no fletching. This is even more noticeable if the arrow is fired upward in an arc rather than straight ahead at a target. Gravity is the simplest of these forces; however, since the weight of an arrow is not evenly distributed – the arrowhead is much heavier than the arrow nock – gravity's effect on an arrow's flight is more complex than its effect on, for example, a bullet.¹³⁶ With all of these forces at work, calculating the trajectory and force of an arrow is difficult to the point of impracticality. In general, it is much easier to make a replica medieval bow and fire several arrows while measuring their trajectory and force, rather than try to calculate trajectory and force mathematically by accounting for every variable.

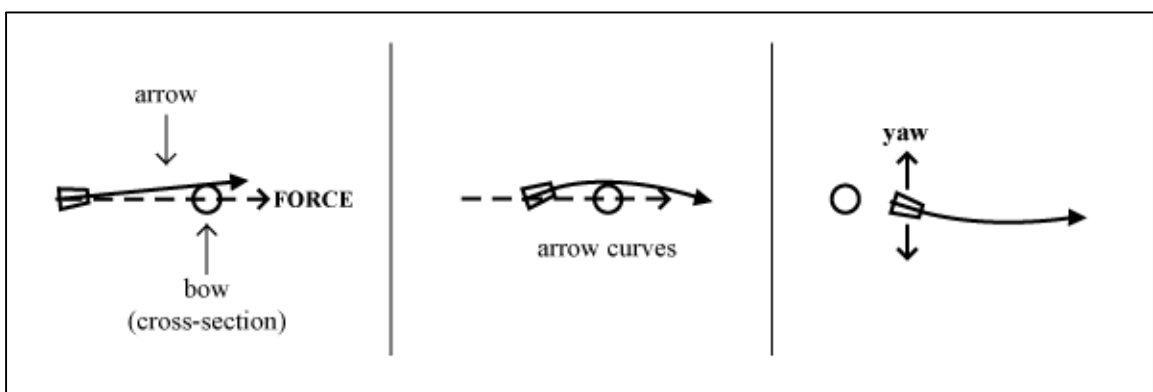


Illustration 4: Arrow Yaw, Figure by Emily Neenan, commissioned by author

¹³⁵ Brian Cotterell and Johan Kamminga, *Mechanics of Pre-Industrial Design*, pp. 187-8.

¹³⁶ Mark Denny, "Bow and Catapult Internal Dynamics", pp. 377-8.

Mark Denny, *Their Arrows Will Darken the Sun*, pp. 7-15

Professor Anna Crowley led an excellent study of arrow flight, published as an appendix in *The Great Warbow*. In her experiment, arrows were fired in an arc and the velocity, ranges, and weights were measured for each of three shots per arrow. The information from those shots was used to fill in several of the variables that would usually have to be calculated mathematically. Several different types of arrow were fired, including arrows made of ash and poplar, arrows with different arrowheads attached to them, and arrows with different weights. While the types of arrows used did not cover every possible eventuality, there was a broad representation of historically likely arrows based on examples that survived in the *Mary Rose*. With these data, she calculated drag and impact energy, as well as the possible effects firing at varying elevations might have had on an arrow's flight. Her calculations showed that longbow arrows typically retain seventy-five and eighty percent of their initial velocity on impact, as well as approximately 60 to 65 percent of their kinetic energy. This study is somewhat limited by the fact that the results should only really be applied to arrows similar to those used in the experiment, but aside from that minor limitation, it is a very useful study of arrow flight.¹³⁷

Crossbow bolts operate under essentially the same mechanics as arrows but with some slight differences. The crossbow lathe is mounted horizontally on the tiller, so any yaw that the crossbow bolt would experience would be up and down rather than side to side. However, since the lathe is mounted beneath the tiller, the bolt actually goes straight forward when firing which, combined with the rigidity of the bolt – which was generally much thicker and more rigid than an arrow – renders yaw largely nonexistent. In many examples, the lathe was often mounted in such a way as to minimize the problem of the string not firing straight ahead, so that the string didn't hit the tiller when fired, which also greatly reduced any possible yaw. Unfortunately, the interest in traditional crossbow shooting is not nearly as widespread as the interest in traditional archery, and there is no major study of traditional crossbow bolts in flight like there exists for arrows.¹³⁸ Crossbow bolt fletching was generally less extensive than arrow fletching, and in some cases medieval bolts may not have had fletching at all. In general, bolts only had two vanes of fletching, one on either side of the bolt, rather than the three that arrows had. Bolt fletching was also made of materials other than feathers. Bolts could have fletching made from parchment, wood, leather or sometimes even copper

¹³⁷ Anna B. Crowley, "Appendix" in *The Great Warbow: From Hastings to the Mary Rose*, by Matthew Strickland and Robert Hardy (2005, repr. Somerset, 2011). pp. 408-414.

¹³⁸ W.F. Paterson, *A Guide to the Crossbow*, pp. 30-4.

alloy.¹³⁹ In any case, the effect of fletching on bolts, especially if there are only two vanes, would be significantly different than for arrows. Without thorough study and many complex calculations it is not completely clear what that exact difference would be.

W.F. Paterson observed that an arrow, or arrow-like projectile, has a practical maximum velocity. Increasing the power of a bow, or crossbow, had diminishing returns on the increase in velocity of the arrow, or bolt. This means that a longbow with double the power of another longbow would not have fired an arrow twice as fast as its weaker counterpart. However, it could have fired a much heavier arrow at that same speed.¹⁴⁰ This is important when it comes to examining arrows and bolts. Crossbows tended to be much more powerful than longbows and bolts much heavier. While a crossbow may not have fired a bolt at a speed any faster than a longbow fires an arrow, the greater mass of the bolt means it will have had more momentum when it hit its target. Some testing, discussed in more detail later in this chapter, has supported Patterson's observations and this concept is important to remember when analysing the results of tests of the power of medieval bows and crossbows.¹⁴¹

Experimental Archery

There have been several modern attempts to test replica medieval weapons to better understand how these weapons would have worked in the past. While no single study is perfect, each of them provides a useful insight into how lethal these weapons were. The greatest problem from the perspective of this thesis is that nearly every one of these tests was an attempt to study the impact of arrows on armoured targets and quite often only a small amount of data was gathered on the performance of the weapons themselves. It would be of much greater interest to this study if the velocity and mass of the arrows and bolts fired for these tests had been recorded, and the efficiency and power of the weapons calculated. Several of these studies will be covered below, including how they were conducted, what information they provided about medieval ranged warfare, and possible problems with their methodology or conclusions.

S.V. Grancsay performed what is probably the first modern test of medieval archery versus medieval armour. His experiment was published as an article in *True, A*

¹³⁹ Thom Richardson, "Ballistic testing of historical weapons", *Royal Armouris Yearbook* 3 (1998). p. 51. Dirk Breiding, *A Deadly Art European Crossbows, 1250-1850* (New York, 2014). pp. 118-22.

¹⁴⁰ W.F. Paterson, *A Guide to the Crossbow*, pp. 30-32.

¹⁴¹ Thom Richardson, "Ballistic testing of historical weapons", p. 51.

Man's Magazine. W.F. Paterson wrote a brief account of Grancsay's experiment which contained the following details. Grancsay's test used a longbow made of osage orange wood and backed with rawhide, and a *cranequin*-spanned crossbow of unspecified materials. The longbow drew 68 lbs (31 kg) at an unspecified distance, while the crossbow drew 740 lbs (336 kg) at an unspecified distance. The test found that these two weapons fired at comparable speeds, with the longbow arrow travelling at 40.37 metres per second (90 mph) and the crossbow bolt travelling at 42.28 metres per second (95 mph). The one problem with this experiment is that the crossbow bolt in question was half of the weight of the arrow, despite the much greater power of the crossbow. It is unlikely that a bolt for a crossbow that drew 740 lbs would be as light as the one used by Grancsay. While a heavier bolt would travel slightly slower than the one used by Grancsay, its momentum on impact would have been much greater.¹⁴²

The next significant test of the longbow versus a medieval plate armour substitute, which became the reference for many of the studies that followed, was conducted by Peter Jones in 1984. His tests used a yew longbow with a draw weight of 30 kg, or approximately 66 lbs, at a distance not specified in the article but assumed to be somewhere in the region of 28 to 30 in. An associate of his fired several different kinds of arrows at iron plates, ranging from 1 mm in thickness to 3 mm in thickness, and measured the ability of the arrows to penetrate the iron. He found that the 1 mm plates were consistently penetrated by the arrows, while the 2 mm plates were more resistant, and the 3 mm plates were impenetrable. The 2 mm plates were sometimes penetrated by the arrows, and Jones concluded that the degree of penetration would have been insufficient to deliver a fatal blow, but likely would have been disabling. In the case of the 1 mm plates, the shot would almost certainly have killed the target, assuming it hit in a vital area. In Jones' article, he put aside only a short paragraph to discuss the tests, so there are few details to work from. Much of the article was concerned with the history of armour and arrows, as well as some discussion of modern projectiles. The armour stand-in was hardly perfect, since it was just a sheet of iron, not steel, and held in place by a clamp with no support along the back. Plate armour would be worn over thick cloth on a person, so it could compress when hit and absorb some of the power of the arrow, which would reduce how much penetration could be achieved. This was hardly a sophisticated representation of plate armour, but Jones also did not seem to intend for it to be one. Jones did his tests before the analysis of the *Mary Rose* bows indicated that the longbow

¹⁴² W.F. Paterson, *A Guide to the Crossbow*. pp. 31-2.

in the Later Middle Ages had a draw weight closer to one hundred pounds (45 kg) draw weight at 30 in (76 cm). The increased power of these bows over those he used means his results cannot be applied to *Mary Rose* type bows. Jones also made no attempt to measure the raw power of the bows he used, so no conclusions could be drawn about the force of the arrow independently.¹⁴³

C.A. Bergman, E. McEwen, and R. Miller did a comparison of the velocities of arrows fired from several types of bows, as well as other projectiles in 1985. The primary reason for their study was to compare the prehistoric spear-thrower, also known as the *atlatl*, with early bows, the technology often assumed to have replaced the spear-thrower in most cultures.¹⁴⁴ They tested several different types of bows, all modern replicas, including a Tartar composite bow from Crimea, an Apache warbow, a Souix self bow, an African self bow, and a medieval yew longbow. They also included a modern crossbow for comparison. They carried out the tests at the Royal Ordnance Small Arms Division in Enfield, which had sophisticated machinery to accurately measure the speed of the projectiles.¹⁴⁵ From their conclusions, it seems they had a system for calculating the impact of the projectiles as well, but no actual impact data were included in the published article. Since the data from the longbow are the only data relevant to this thesis, that is what this paragraph will focus on. The longbow they used was made from two separate pieces of yew, glued together at the grip section to form an overall bow of 1930 mm (76 in) in length with a draw weight of 80 lbs. (36.2 kg) at 32 in (81.3 cm). The authors fired five different types of arrow from the longbow. Each arrow type was fired several times, but the article only included the maximum speed achieved by each arrow type.¹⁴⁶ Unfortunately, the arrow descriptions are vague about their design, but the article does say they were all made of birch wood and fletched radially with three feathers. The slowest arrow was the small broadhead, which weighed 65 g and travelled at a speed of 37 metres per second (83 mph). The fastest arrow was the field arrow, which weighed 50 g and travelled at a speed of 53 metres per second (119 mph). The heaviest arrow fired was the large broadhead, which weighed 90 g and travelled at a speed of 43 metres per second (96 mph). As a point of comparison, the modern crossbow had a draw weight of 40.8 kg (90 lbs) and fired a bolt that only weighed 13 g at a speed

¹⁴³ Peter Jones, "A short history of the attack of armour", *Metallurgist and Materials Technologist*, 16:5 (1984). p. 247-8.

¹⁴⁴ C.A. Bergman, E. McEwen and R. Miller, "Experimental Archery: Projectile Velocities and Comparison of Bow Performances", *Antiquity* 62:237 (1988). pp. 658-60.

¹⁴⁵ *Ibid.* pp. 666-9.

¹⁴⁶ *Ibid.* pp. 662-5

of 62 metres per second (139 mph).¹⁴⁷ It is hard to draw any solid conclusions from these data, especially given the limited information on the arrows. The article says that a bodkin arrow - the most common type of military arrowhead from the Middle Ages - was fired as part of the testing, but the table that contains all of the data makes no mention of it. Instead there are enigmatic arrow descriptions like 'field arrow', 'forked arrowhead', and 'spearhead with flutes'.¹⁴⁸ In the end, the study does provide data on the speed of arrows fired from a replica medieval longbow that could prove a useful point of comparison with other studies. Unfortunately, due to the vagueness of the data table, the experiment is hard to interpret so this study is limited in the benefits it provides to historians' understanding of medieval warfare.

Peter Jones conducted another set of tests in 1992, using a yew bow that drew 70 lbs (32 kg) at 28 in (81.3 cm). This time, he fired several different types of arrows at iron sheets of differing thickness, which were held at one of three different angles. This test was much more thorough than his previous experiment, and included extensive discussion of thickness and metal quality of several surviving pieces of medieval armour, including a discussion of their Vickers hardness ratings. Vickers hardness rating is a scale used to determine the hardness of a metal by measuring how much it deforms when under pressure.¹⁴⁹ The arrows he fired were all of approximately the same weight but had different types of arrow head attached to them. Jones measured the penetration each arrow achieved, as well as the frequency with which the arrows broke on impact. The arrows were fired from ten metres away from the target. His overall conclusion was that when an arrow hit 1 mm thick armour straight on, or at an angle of no more than twenty degrees, significant penetration occurred. At wider angles, penetration almost never happened. Some minor penetration occurred against 2 mm plates when they were hit straight on, but not enough to probably even penetrate the layer of clothing worn underneath plate armour. However, he pointed out that armour this thin was often only in limb sections and other areas where a penetrating hit would not be lethal.¹⁵⁰ He concluded that few arrows would have resulted in fatal penetrations against a knight in full plate armour. However, against other types of armour, arrows were more likely to achieve fatal penetrations. His overall conclusion was that at the start of the Hundred

¹⁴⁷ Ibid. p. 663

¹⁴⁸ Ibid. pp. 662-3

¹⁴⁹ Peter Jones, "Metallography and relative effectiveness of arrowheads and armour", *Materials Characterization* 29 (1992). pp. 111-5.

¹⁵⁰ Ibid. p. 116.

Years War (1337-1453), longbows would have been quite dangerous, but as armour grew more advanced, the ability of the longbow to deliver lethal blows would have decreased substantially. The longbow used in these experiments was weaker than most of the bows found on the *Mary Rose*. Depending on how the *Mary Rose* bows' draw weights are determined, the bow Jones used could be considered equivalent to some of the weaker bows found on the ship.¹⁵¹ The close range of the archer to the targets represented fairly optimal conditions for armour penetration. Once again, Jones was primarily concerned with testing against armour rather than the raw power of the longbow on its own, so the data cannot be applied to the longbow's performance in other situations. Still, his consideration of angle of impact was significant. It can be easy to forget that in the heat of battle, an arrow would rarely hit its target head on, and the angle of impact had a significant impact on the effectiveness of the weapon.¹⁵²

The Defense Academy Warbow Trials, in 2005, were an attempt to update Peter Jones' study to reflect more recent discoveries about the medieval longbow. They made two primary changes to the type of bow used in Jones' test: they increased the draw weight to 140 lbs (64 kg) at 32 in (812 mm), and they changed the type of bow to a compass bow instead the target type bow that Jones had used. The bow used was made of yew, with a backing of hickory to replace the sapwood. This was done for cost reasons, due to the expense of the high quality of yew required to make a yew self bow.¹⁵³ They also changed the method of mounting the target plate, to better replicate the effects of armour being worn on the body. They disagreed with Jones' assessment of the thickness of medieval armour, noting that most of Jones' examples were helmets and not breastplates. Helmets, they argued were often thicker than breastplates, which would have skewed Jones' results. Lastly, they measured the kinetic energy of the arrows as they impacted the plate.¹⁵⁴ They tested against three thicknesses of metal: 1.15 mm, 2 mm, and 3 mm. The 1.15 mm was penetrated by all types of arrowhead, which suggested that armour of that thickness would have been little use against the longbow. However, armour this thin was usually only covering non-vital areas, like thighs and upper arms, so a puncture was unlikely to result in a fatal wound. Their report on the 2 mm thick armour was confusingly written but it seems that, depending on angle, the shorter bodkin arrow

¹⁵¹ Clive Bartlett, Chris Boyton, Steve Jackson, Adam Jackson, Douglas McElvogue, Alexzandra Hildred and Keith Watson, "The Longbow Assemblage", pp. 2:616-7.

¹⁵² Ibid. pp. 115-7.

¹⁵³ Paul Bourke and David Whetham, "A report of the Defense Academy warbow trials Part I Summer 2005", pp. 58-60

¹⁵⁴ Ibid. pp. 54-8.

and the lozenge arrow head achieved penetration but the needle bodkin did not. The best penetration achieved against the 3 mm thick sheet was only partial, even that was not consistently achieved with any arrow. The needle bodkin head, which had proved to be the most effective arrow in Jones' 1992 study, was found to be remarkably ineffective in this study.¹⁵⁵ The reason for this sudden change appeared to be due to the increase in the power of the bow. When the needle bodkin did not hit the plate perfectly perpendicular to it, the tip bent – and often broke – rather than penetrating the plate. It seemed that the increased force on the arrow was too much for the arrowhead to take.¹⁵⁶

The Warbow Trials were not without their detractors, and Kelly DeVries wrote a rather extensive rebuttal to them. The authors of the study made very broad claims about the effectiveness of longbows based on their study, and DeVries pointed out that many of these claims have little basis in either the study or other contemporary evidence. As an example, the authors at one stage suggest that even wounding arrow strikes would likely have proven fatal in the long run, as they would have disabled the soldier in question and he later would have died of his wounds. As a rebuttal, DeVries pointed out that evidence from the excavation at Towton showed that many medieval soldiers suffered serious wounds and recovered from them.¹⁵⁷ In general, DeVries noted, the authors put a lot of emphasis on the blunt force trauma that the arrow would have when it hit its target, without giving enough consideration to the multiple layers of clothing that would have been worn beneath a piece of armour. While examining the actual force an arrow put out is very important, and a factor often neglected in tests, it is important not to overstate the effect this had. DeVries' criticism also showed that the authors were overly reliant on the works of Robert Hardy and Ralph Payne-Gallwey, with little consideration for authors who might have had different opinions. The fact that they used Mark Stretton as their test archer reinforces this idea, since he had previously collaborated with Hardy on medieval longbow draw weights. This does seem to indicate that the authors had a predisposition towards the argument that the English longbow drew at least 140 lbs (64 kg) at 30 in (76 cm). DeVries disputed the weight of the longbow used in the test, since he did not accept the idea that the *Mary Rose* longbows had draw weights this high, although he did not make clear if he objected to all aspects of that assessment, just one of either the weight or

¹⁵⁵ Peter Jones, "Metallography and relative effectiveness of arrowheads and armour", pp. 115-7.

¹⁵⁶ Ibid. pp. 65-8.

¹⁵⁷ Kelly DeVries, David Whetham and Paul Bourke, "Comments", *Arms and Armour* 4:1 (2007). p. 80
Jennifer Coughlan and Malin Holst, "Health Status" in *Blood Red Roses: The Archaeology of a Mass Grave from the Battle of Towton AD 1461* ed. Veronica Fiorato, Anthea Boylston, and Christopher Knüsel, 2nd Ed. (2000, Oxford, 2007). pp. 71-5.

the draw distance.¹⁵⁸ DeVries has in the past argued against the high power assigned to the longbow by Hardy. DeVries has often been critical of the conclusion that the longbow was a consistently deadly weapon –which is an idea the authors of this study supported with their conclusions – so it is not surprising that he rejected the idea that the average longbow in the Middle Ages was as powerful as the one used in the tests.¹⁵⁹ DeVries therefore could hardly be called neutral on this subject, so to some extent his criticism could be seen as simply disagreement. However, in many cases DeVries simply pointed out that the authors of the study used the phrase 'contemporary opinion', or similar expressions, without providing proper context, or justification, for what they thought the 'contemporary opinion' was. In the authors' response to DeVries, it was made pretty clear that they viewed 'contemporary opinion' as the opinions of Robert Hardy and individuals who agree with him, such as Mark Stretton.¹⁶⁰ Their reliance on Payne-Gallwey was less problematic, but it was still not ideal. Payne-Gallwey could hardly be called a controversial author, but his seminal work was first published at the turn of the twentieth century, and while no book since then has completely replaced it, his work should still be referenced with caution. While some of the conclusions of the test were applied too broadly to the scope of history, the actual tests themselves were well conducted and was a valuable contribution to historians' understanding of the longbow. DeVries did dispute the power of the bow used, but beyond that, his major critique of the test was that he felt the authors did not do enough to update Jones' methodology. Since the authors stuck so closely to Jones' original study, most criticisms of how he conducted his study could just as easily be levelled at this one, and DeVries believed that they should have changed more aspects of the original Jones study than they did.¹⁶¹

In 1998, the Royal Armouries published a series of experiments led by Thom Richardson. These tests involved a wide range of weapons from the Middle Ages and earlier. These included: a replica arquebus from The *Mary Rose*; a medieval handgun; three longbows; two crossbows; six types of slings; a spear thrower; and spear thrown by manpower alone. Given the scope of this thesis, only the tests of the longbows and crossbows will be considered in detail here. The weapons were fired an unspecified

¹⁵⁸ Ibid. pp. 76-9.

¹⁵⁹ Kelly DeVries, "Catapults Are Not Atomic Bombs: Towards a Redefinition of 'Effectiveness' in Premodern Military Technology", *War in History* 4:4 (1997). pp. 460-4.

¹⁶⁰ Kelly DeVries, David Whetham and Paul Bourke, "Comments", p. 79

¹⁶¹ Ibid. pp. 75-6.

number of times at a firing range using arrows, or bolts, with different heads with the speed of each projectile measured, and then an average calculated for each type of arrow. One of the crossbows had a steel lathe, while the other had a yew lathe.¹⁶² The testing showed little difference in the speed of the projectiles launched from either the crossbows or the longbows. The yew crossbow had a draw weight of 90 lbs (41 kg) while the steel crossbow had a draw weight of 440 lbs (200 kg). The longbows were all made of yew and drew, in order, 72, 78 and 90 lbs (33, 35, 41 kg), at 28 in (71 cm). For the tests, each bow was drawn to only 27 in (69 cm) before firing. Direct comparisons of the results are complicated by the fact that some weapons did not fire the same types of arrows. The 72 and 90 lbs longbows both fired a bodkin headed arrow with average speeds of 41.65 metres per second (93 mph) and 43.47 metres per second (97 mph) respectively. The steel crossbow fired two different bodkin headed bolts built by different fletchers. These bolts travelled at an average speed of 44.6 metres per second (100 mph) and 43.9 metres per second (98 mph). The bodkin crossbow bolts weighed approximately the same as their arrow counterparts. The steel crossbow fired a square headed bolt that weighed twenty grams more than the bodkin arrows at an average speed of 41.4 metres per second (92 mph). Little information was provided about the bolts fired from the yew crossbow but two kinds of ammunition were tested, with average speeds of 41.65 metres per second (93 mph) for bolts made of poplar, and 36.36 metres per second (81 mph) for bolts made of birch/pine.¹⁶³

All of these weapons were also fired at a 2 mm thick piece of steel, but none of them was able to penetrate the sheet. The primary objective of these experiments was to show the sudden increase in the power of early gunpowder weaponry in comparison to more traditional projectiles and it made this point well since the gunpowder weapons fired their ammunition at a speed that was an order of magnitude higher than either the bows or the crossbows.¹⁶⁴ All of the draw weights for the bows and crossbows used could be argued to have been on the low side of what would have been normal in the Middle Ages. The highest longbow draw weight was about equal to that of a *Mary Rose* longbow, given that the draw weight was measured at 28 in (71 cm), but the bows in the test certainly did not represent the full range of *Mary Rose* bows.¹⁶⁵ The crossbows were

¹⁶² Thom Richardson, "Ballistic testing of historical weapons", pp. 50-1.

¹⁶³ Ibid. p. 51

¹⁶⁴ Ibid. p. 52

¹⁶⁵ Keith Watson, "Estimating Longbow Weights from the Arrow Shaft Data" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). pp. 2:617-18.

both on the lower end of expected power. The Berkhamsted bow, a thirteenth or fourteenth century yew crossbow lathe, has an estimated to draw weight of 150 lbs (68 kg) at between eight and twelve inches (200-300 mm), which is 60 lbs (27 kg) more than the yew crossbow used in this experiment.¹⁶⁶ The steel crossbow is exactly the same power as the lathe examined by Jens Sensfelder discussed earlier in this chapter, but that crossbow was an early modern target crossbow and was likely weaker than a medieval war crossbow would have been.¹⁶⁷ As a result, the numbers for the crossbows should probably be considered a minimum threshold for crossbow power. The longbows were also under-powered, but not by quite as wide a margin. Still, given the vast disparity shown between these weapons and the gunpowder weapons tested, the conclusions drawn from the experiment stand unchallenged.

In contrast to all of the tests of longbows versus plate armour, Russ Mitchell tested a composite bow versus chain mail in 2006. With a specific eye toward the history of the Crusades (1095-1272), Mitchell began with a discussion of textual accounts of arrows versus soldiers clad only in mail. He then performed three different tests using several different composite bows. The draw weight of these bows varied from 45 to 70 lbs (20-32 kg) at an unspecified draw distance but with an average of close to 50 lbs (23 kg). The actual data gathered by Mitchell were quite confusing, something he readily admitted, and there appears to have been substantial difficulty with regards to setting up a proper target for the tests.¹⁶⁸ The layering underneath the suits of chain had substantial impacts on the effectiveness of the arrows which made for some interesting conclusions. Mitchell's overall conclusions were not extensive, since his article was mostly an account of his attempts at these experiments. He did suggest that the type of armour worn underneath the mail was very important, particularly when bodkin arrows were involved. Bodkin arrowheads could pass between the links of chain but could not always penetrate the materials underneath, while broadheads were often better at penetrating the materials underneath but only penetrated the mail by shattering links in the armour. Overall, bodkin arrow types showed greater success against layers of woven material underneath the mail, such as cotton, as opposed to those of a solid material like fleece. The layers of

Robert Hardy, J. Levy, P. Pratt, Roy King, S. Stanley, B.W. Kooi, D. Adams, and A. Crowley, "Assessment of the Working Capabilities of the Longbows", pp. 2:627-32

¹⁶⁶ Robert C. Brown, "Observations on the Berkhamstead Bow", *Journal of the Society of Archer-Antiquaries* 10 (1967). p. 17.

¹⁶⁷ Jens Sensfelder, *Crossbows in the Royal Netherlands Army Museum*, p. 363.

¹⁶⁸ Russ Mitchell, "Archery versus Mail: Experimental Archaeology and the Value of Historical Context", *Journal of Medieval Military History* 4 (2006). pp. 19-22.

fleece spread the force of the arrow impact across a wide area, which often resulted in the arrow bouncing off rather than penetrating the fabric.¹⁶⁹

While not an experiment, the analysis of the draw weights of the *Mary Rose* bows was a very interesting case study in how the power of the longbow has been studied in the past few decades. The official publication of the *Mary Rose* Trust contained two main methods of analysis: modelling based the dimensions of the bows, and conclusions based on the types of arrows found. The modelling studies have been lead primarily by Robert Hardy, but with the actual modelling being done by the mathematician Robert Kooi. Kooi has made elaborate models for measuring the power of a longbow based on its dimensions, and has had his models verified against modern replica longbows to determine their accuracy. His conclusions were therefore quite convincing and his draw weight estimates should be taken seriously. If there are any criticisms to level against his study they would be that he assumed a draw of at least 30 in, without providing the draw weights at 28 in, and that his work did not account for the efficiency of the bows. These are only minor issues, though, and not enough to warrant ignoring his results.¹⁷⁰

The study of the power of the *Mary Rose* bows based on arrow data began with a detailed measurement and examination of all the different types of arrows found on the ship. Most of the arrows were quite similar, but they were made of several different kinds of wood, and had minor differences in dimensions. Keith Watson, the researcher in charge of this project, argued that a given power of longbow required a specific type of arrow. Arrows must have been able to bend around the bow's grip and if an arrow was too rigid to do so it would either break or fail to fly straight. Too much force on the arrow could also have impaired its ability to deflect around the grip, creating an inaccurate or weak shot. Using information from the modern arrow manufacturing industry on the relationship between arrow rigidity and draw weight, Watson worked backwards from his arrow measurements to get draw weight estimates. Several different types of wood were used to make arrows on board the *Mary Rose* and Watson's modelling suggested that the different woods were suited to bows with different draw weights. Poplar, alder, and willow seemed to all be made for bows that drew between 40 and 110 lbs (18-50 kg) at 30 in (76 cm), while birch arrows were for bows drawing over 90 lbs (41 kg) at 30 in

¹⁶⁹ Ibid. pp. 27-8.

¹⁷⁰ Robert Hardy, J. Levy, P. Pratt, Roy King, S. Stanley, B.W. Kooi, D. Adams, and A. Crowley, "Assessment of the Working Capabilities of the Longbows", pp. 627-32.

Clive Bartlett, Chris Boyton, Steve Jackson, Adam Jackson, Douglas McElvogue, Alexzandra Hildred and Keith Watson, "The Longbow Assemblage", 2:615-17.

(76 cm). Watson's evidence was based on only the arrows that survived in good enough condition for detailed analysis, so his data pool did not include the entire arrow assemblage of the *Mary Rose*. Overall, his estimates for the average draw weights of bows from the *Mary Rose* were about 20-35% less than the estimates made by Hardy and Kooi.¹⁷¹ The most interesting, and useful, aspect of Watson's study is that it managed to account for the efficiency of the longbows. Since Watson's calculations were based on the energy that was transmitted to the arrow, his conclusions largely ignored the energy lost in the firing of the longbow. In this way his figures could be reconciled with those of Hardy and Kooi. If the *Mary Rose* bows were between 65% and 80% efficient, than these two draw weight estimates would be essentially identical, they would just be measuring different things.

Alan Williams included a detailed and thorough discussion of medieval and early modern weapons' ability to penetrate armour in his 2003 book *The Knight and the Blast Furnace*. Williams' work was a theoretical experiment based on his extensive understanding and study of medieval armour and metallurgy. By careful study of the design of plate and other metal armours, as well as the physics and chemistry governing their sturdiness, Williams was able to establish approximately how much power a weapon would have to deliver to penetrate a given piece of armour. The power required to penetrate armour varied significantly between the type of weapon and armour in question. No other publishing historian can equal Williams' understanding of metallurgy and its impact on how medieval armour performed. His study provided the best account of all the variables involved in the attack on armour, and how each of those variables impacted the performance of the weapons involved. Williams described how an indirect angle of attack required more energy to cause penetration and how layers under armour increased the total energy necessary to deliver a damaging blow. While primarily concerned with metal armour, Williams also included a brief discussion of leather and cloth armours. The only minor flaw in Williams' discussion is that he drew his figures for the power of the longbow from Jones' study, which used a low estimate of the weapon's possible power. Using Jones' as his source, Williams estimated that an arrow fired from a longbow would have energy of 80 joules when it left the bow. In contrast, Anna Crowley's experiments estimated that on impact a longbow arrow made of ash would

¹⁷¹ Keith Watson, "Estimating Longbow Weights from the Arrow Shaft Data" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). pp. 2:617-8.

have an energy of 80 joules and the initial energy would likely be closer to 120 joules.¹⁷² This latter figure likely represents the upper end of power for longbows, as all the other arrows Crowley tested performed noticeably worse than the arrow made of ash. Williams provided figures – estimates based on his calculations – of what forces would be required to penetrate certain types of armour at various angles and an astute reader could easily substitute Crowley's figures for Jones' and make their own conclusions. Overall Williams' study suggested that, as the Middle Ages progressed, armour became increasingly resistant to penetration by bows and crossbows. While bows were generally capable of breaking the rings on a suit of chain mail, they would not have performed anywhere near as well against a suite of full plate, particularly if it was a late fifteenth century suit of German plate. Williams' offered a detailed image of how the attack on armour likely developed, and in so doing provided an impressive justification for why gunpowder weaponry, with its vastly more powerful projectiles, eventually replaced both the longbow and the crossbow.¹⁷³

This chapter only provided a brief introduction into the mechanics and operations of bows and crossbows, for the purposes of engaging in a more in-depth discussion of the design of those two weapons later in this thesis. The mechanics of archery deserve a more substantial study in their own right, ideally with interdisciplinary help from physicists. With physicists' assistance, the barrier of mathematical complexity can be overcome. Historians only stand to gain from a greater knowledge of the physical workings of bows and crossbows. It will help historians better understand medieval archery, the power of the medieval ranged weapons, and their potential impact in warfare.

¹⁷² Anna Crowley, "Appendix", p. 411.

¹⁷³ Alan Williams, *The Knight and the Blast Furnace: a history of the metallurgy of armour in the Middle Ages & the early modern period*, (Leiden, 2003). pp. 927-49.

Chapter Two

The Development of the Longbow

The longbow was arguably the most iconic weapon of the Hundred Years War (1337-1453). Famous for its contribution to the victories of Crécy (1346), Poitiers (1356), and Agincourt (1415), it had become closely associated with the English by the end of the sixteenth century and much controversy surrounded its official retirement from the armies of England in 1595.¹⁷⁴ Despite being such a popular weapon, not a single medieval English longbow has survived from before the sixteenth century, and no longbows of any kind have survived from the fourteenth or fifteenth centuries. With this dearth of archaeological evidence, it has been difficult for historians to construct a detailed picture of what the longbow would have looked like during the Hundred Years War. Historians have, as a result, turned to textual evidence to construct their narrative of the development of the medieval longbow. This chapter will focus on the available archaeological evidence, and how evidence from surviving longbows, from prehistory to the sixteenth century, can show how the longbow both did and did not change over the centuries.¹⁷⁵

While the myth of the Anglo-Saxon short bow – famously supported by Charles Oman and best defined by J.E. Morris – has fallen out of favour with academic historians, there is still an ongoing debate about the exact details of the performance and design of the high medieval longbow.¹⁷⁶ The *Mary Rose* longbows provided a clear picture of the state of the longbow in the mid-sixteenth century. Whether or not these later longbows were identical to those from centuries before has been the subject of much debate. Matthew Strickland and Robert Hardy were firm in the assertion that the longbow had essentially been unchanged at least as far back as the eleventh century, if not before.¹⁷⁷ In contrast, Clifford Rogers has argued for gradual progression of the weapon. Rogers is one of the few remaining advocates for the short bow thesis. He has argued that, based on artistic evidence, the short bow was likely used in the Early Middle Ages and up to the eleventh century in certain parts of Europe before being replaced by

¹⁷⁴ Gervase Phillips, “Longbow and Hackbutt: Weapons Technology and Technology Transfer in Early Modern England”, *Technology and Culture* 40:3 (1999). pp. 577-80

¹⁷⁵ Robert E. Kaiser, “The Medieval English Longbow: Characteristics and Origin”, *Journal of the Society of Archer-Antiquaries* 23 (1980). pp. 21-2.

W.F. Paterson, “What is a Longbow?”, *Journal of the Society of Archer-Antiquaries* 25 (1982). p. 36

Jim Bradbury, *The Medieval Archer* (Woodbridge, 1985). p. 14-6.

¹⁷⁶ Charles Oman, *The Art of War in the Middle Ages*, (Oxford, 1885). pp. 96-101

Charles Oman, *A History of the Art of War: The Middle Ages from the Fourth to the Fourteenth Century*, (London, 1898). pp. 557-563.

J.E. Morris, *The Welsh Wars of Edward I*, (1901; repr. Stroud, 1996). p. 26

¹⁷⁷ Robert Hardy, *The Longbow A Social and Military History* (Fort Worth, 1978, repr. 1993). pp. 54-6.

Matthew Strickland and Robert Hardy, *The Great Warbow: From Hastings to the Mary Rose*, (2005; repr. Somerset, 2011). pp. 38-43.

an intermediate step between the short bow and longbow. Rogers has named this interstitial bow the medium-long bow.¹⁷⁸ Both Strickland and Rogers have drawn on an extensive variety of sources to support their arguments, including: the handful of surviving bows from medieval Europe, medieval artistic representations of bows, and textual references to both the longbow's dimensions and its effectiveness. The textual evidence has been thoroughly and rather convincingly explored in Robert Hardy and Matthew Strickland's *The Great Warbow*, and there would be little this thesis could add to that analysis. While one could very well disagree with their assessment of the information, it cannot be disputed that they have well and truly laid out most of what there is to be said on the subject. Therefore it is on the matter of interpretation that the debate must focus. A later chapter in this thesis will examine the problems inherent with artistic interpretation.

The Mary Rose Bows

The single largest collection of longbows, and also the source of all of the surviving medieval English longbows, came from the wreck of the *Mary Rose*. The *Mary Rose* was the flagship of Henry VIII's fleet and sank in 1545. It was remarkably well preserved at the bottom of the sea due to a rapid build-up of silt. After a brief rediscovery in the nineteenth century by the Dean brothers, and its subsequent loss again, it was fully exhumed in the late 1970s and early 1980s. There were over one hundred intact bow staves on board.¹⁷⁹ The greatest question in the study of the medieval longbow is: how similar were the *Mary Rose* longbows to the bows from several centuries earlier? To try to answer this question, this study will first start with an examination of the *Mary Rose* longbows and their significant features.

The most important design elements of the *Mary Rose* longbows to consider are: length, width, thickness, draw weight, and the type of wood they were made from. These elements will be used to construct a theoretical 'precursor bow' that, if found, would be a clear indication of a *Mary Rose* style bow from an earlier century since it would have all of the elements that make a *Mary Rose* bow a *Mary Rose* bow. The available data from actual longbows from prehistory to the twelfth century will then be examined and

¹⁷⁸ Clifford Rogers, "The development of the longbow in late medieval England and 'technological determinism'", *Journal of Medieval History*, 37:3 (2011). pp. 322-6.

¹⁷⁹ W.F. Paterson, "A "Mary Rose" Archery Symposium", *Journal of the Society of Archer-Antiquaries* 26 (1983). pp. 49-50

W.F. Paterson, "Mary Rose'- A Second Report", *Journal of the Society of Archer-Antiquaries* 24 (1991). pp. 4-6.

Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 3-10.

compared to the requirements outlined for the precursor bow to determine whether it is fair to assume that *Mary Rose* type bows existed during the High Middle Ages.

All of the bows from the *Mary Rose* were made of yew.¹⁸⁰ This is hardly surprising given that contemporary texts on longbows – including Roger Ascham's *Toxophilus* which was written the same year the *Mary Rose* sank – all argued that a good longbow ought to be made of yew above all other woods.¹⁸¹ Modern bowyers making traditional wooden bows have also shown that yew is one of the best woods from which to make a self bow. All of the *Mary Rose* bows were primarily made of heartwood, but had a layer of sapwood along their backs. This was ideal bow design, as the sapwood's higher elasticity allowed for the construction of a powerful longbow without having to use composite materials. These two design elements set a simple, and generally easy to identify, starting point for examining earlier bows as a point of comparison: for a longbow to be seen as an earlier equivalent of a *Mary Rose* bow it must have been made of yew and must have had a layer of sapwood along its back. Wood type is relatively easy to determine, but in some cases decay can obscure the existence of a sapwood layer.¹⁸²

The average length of the *Mary Rose* bows was 1960 mm. **Graph 5** shows the distribution of the lengths of the *Mary Rose* bows. The gaps in the graph represent bows whose lengths were not included in the data published in *Weapons of Warre*, which was the official *Mary Rose* trust publication. The lengths were relatively uniform with only a handful of outliers on either end of the spectrum. Over half of the bows were between 1900 and 2000 mm long, while only a small proportion were shorter than 1800 mm. The longest bow was 2113 mm long, while the shortest was 1746 mm long. These data suggest that there was a generally standardised size to longbows in England by the mid sixteenth century. It is definitely not a strict standardisation, though, as it was quite rare for two bows to be the exact same length. That there was nearly always some variation between bows was likely the result of the difficulties of working with an organic material

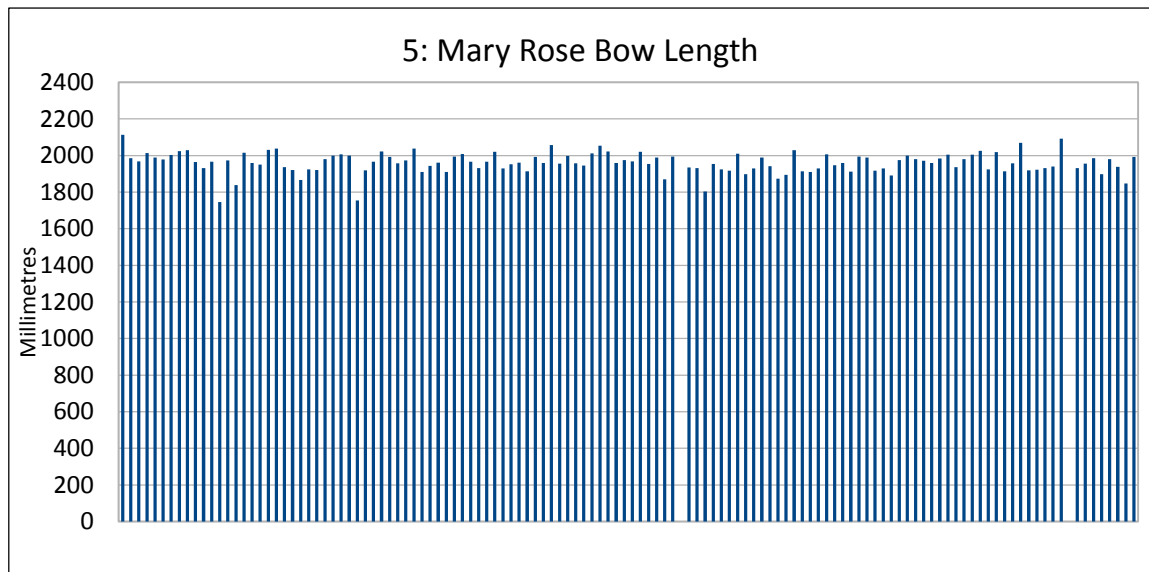
¹⁸⁰ Clive Bartlett, Chris Boyton, Steve Jackson, Adam Jackson, Douglas McElvogue, Alexandra Hildred and Keith Watson, “The Longbow Assemblage” in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). pp. 2:612-5

¹⁸¹ Roger Ascham, *Toxophilus*, ed. Edward Arber (London, 1868). p. 113.
The Art of Archery, ed. Henri Gallace and trans. H. Walrond (London, 1903).

<http://www.archerylibrary.com/books/gallice/docs/chapter01-1.html> [Accessed 11/4/13]

¹⁸² Tim Baker, “Bow Design and Performance”, p.1:71-73, 1:92-5

like wood.¹⁸³



Graph showing lengths of all 126 Mary Rose bows, listed in catalogue order. Data from Clive Bartlett et. al. 2011.

The term 'longbow' has problematic implications that should be explored before moving on to other aspects of longbow design. The word 'longbow' is not particularly descriptive since only means a bow that is long. It does not give an idea of how long a bow must be to be considered a 'longbow'. It is not clear from the word alone what the minimum length required for a bow to be considered a longbow is. A bow that is less than four feet is clearly not long, and one over six feet clearly is, but how to categorise bows that are between four and six feet long is not clear. Jim Bradbury argued against the use of the word longbow for describing the bow used by the English during the Middle Ages and instead used 'ordinary wooden bow'.¹⁸⁴ While there is merit to this argument the term 'ordinary wooden bow' – or 'self bow', which is the more technical term meaning the same thing – is difficult to work seamlessly into sentences. It also does not necessarily make the reader immediately think of the English war bow of the Middle Ages. Clifford Rogers has engaged in a similar form of linguistic argument with his recent support for a classification of the 'medium-length' longbow. He proposed the creation of a new classification of bow, however, and not just a new term for an existing one, and so is a different kind of argument.¹⁸⁵ While the word 'longbow' does not on its

¹⁸³ Clive Bartlett, Chris Boyton, Steve Jackson, Adam Jackson, Douglas McElvogue, Alexzandra Hildred and Keith Watson, "The Longbow Assemblage", pp. 2:596-9.

¹⁸⁴ Jim Bradbury, *The Medieval Archer*; pp. 12-6.

W.F. Paterson, "What is a Longbow?", p. 36

¹⁸⁵ Clifford Rogers, "The development of the longbow in late medieval England and 'technological determinism'", pp. 322-6.

own contain much meaning there is a cultural association between the word and the six foot long yew bow most associated with the English. This cultural association means that, while longbow is a vague term, the word immediately conveys the idea of a large bow made of wood to the reader without the need for further clarification. For this reason, even though it is lacking in precision, this thesis has used the term ‘longbow’ rather than ‘self bow’ or ‘ordinary wooden bow’.

There was some variety to the cross-sections of the *Mary Rose* longbows. These cross-sections differed in degree rather than in shape. Looking at them from a distance, the bows would seem almost identical. It is only on close examination that their differences can be seen. This is an important distinction because, when it comes to bows, general form can be more important than specific detail. There is an expected degree of variation between wooden bows because they must mirror the tree from which they were cut. This means that minor differences between bows are very much to be expected and might reflect more on the individual stave, and the tree it was cut from, than the intent of the bowyer who made it.¹⁸⁶ That is not to say these differences were meaningless, just that they were not necessarily indications of differences in intended design. The general form of the *Mary Rose* bows was a shallow D-shape. This means that one side of the bow, either the back or the belly, was slightly rounded while the other side was flat. The word 'shallow' means that the cross-sections are closer to being circular rather than actually looking exactly like a capital letter D. The *Mary Rose* bows had several minor variations of the basic D-shape. Some were mostly flat on the back and belly but curved slightly on the edges, while others were almost completely round. The bows were not grouped in the wreck or the chests they were stored in based on shape, which suggests that they were not categorised as different classes of bow. While the individual differences in the shapes of the *Mary Rose* bows present an interesting subject for further study, for the purposes of this work it was the general shape that was significant. When looking for a *Mary Rose* precursor bows it is important that they had a D-shape cross-section and were not, for example, diamond shaped.¹⁸⁷

Most of the *Mary Rose* bows had an approximate width to thickness ratio of 1.1:1 at their grip.¹⁸⁸ See **Illustration 2** for clarification on which part of a bow is the width

¹⁸⁶ Tim Baker, “Bow Design and Performance”, pp.1:51, 55-6.

¹⁸⁷ Robert Hardy, “Longbows” in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). pp. 2:589-593

Clive Bartlett, Chris Boyton, Steve Jackson, Adam Jackson, Douglas McElvogue, Alexzandra Hildred and Keith Watson, “The Longbow Assemblage”, pp. 2:600-605

¹⁸⁸ J.G.D. Clarke, “Neolithic Bows from Somerset, England, and the Prehistory of Archery in North-

and which is the thickness.¹⁸⁹ The width and thickness of a bow's limbs were very important as a bow derived much of its power from the thickness of its limbs and much of its durability from its width.¹⁹⁰ The bows were largest at the middle and thinned slightly as they reach the end of the limbs. For the purposes of simplicity and consistency, this study has only looked at the grips and lower limbs of the *Mary Rose* longbows. There were slight differences between the upper and lower limbs, but the differences were minor and could be ascribed to the properties of the wood. The lower limb data set was slightly more complete – several bows had broken upper limbs – and so presented the preferable subject for analysis. Overall, the *Mary Rose* longbows were impressive in their size. The median bow had a grip width of 35.6 mm and a thickness of 33 mm. The smallest grip was 31.2 mm by 21.8 mm, while the largest was 39.8 mm by 36.7 mm. At approximately midway down the limb, 500 mm from the grip, the median bow was 29.6 mm wide and 26.3 mm thick. At the same distance the smallest bow was 24.4 mm by 16.6 mm, and the largest was 35.8 mm by 30.5 mm. The size of the median bow near the tips of the bow, 800 mm from the grip, was 21.2 mm by 20 mm. The smallest bow at the same point was 16.5 mm by 15.5 mm, while the largest was 26.8 mm by 23.6 mm. The bulk of the *Mary Rose* data was clustered closer to the median data point than to the two ends. There was, however, a vast difference between the smallest bow in the data and the bow closest in size to it. The smallest bow differed the most from the general data in its thickness rather than in its width. This shows a certain uniformity of design to the *Mary Rose* bows even if there is significant and noticeable variation between the overall sizes of the bows. The actual sizes involved here, not just the ratios, are important, though, since their size creates a significant point of comparison with other surviving longbows. That particular topic, however, will be discussed later in this chapter.¹⁹¹

One of the most important elements to consider for a theoretical precursor bow is whether it had a comparable draw weight to the *Mary Rose* bows. The methods used for determining the draw weights of the *Mary Rose* bows were already discussed in the previous chapter.¹⁹² This section will instead examine some of the results of those

western Europe”, pp. 86-7.

Matthew Strickland and Robert Hardy, *The Great Warbow*, p. 39.

¹⁸⁹ See Chapter 1.

¹⁹⁰ Tim Baker, “Bow Design and Performance”, p.1:71-73, 1:92-5

¹⁹¹ Clive Bartlett, Chris Boyton, Steve Jackson, Adam Jackson, Douglas McElvogue, Alexandra Hildred and Keith Watson, “The Longbow Assemblage”, pp. 596-9.

¹⁹² See Chapter 1.

studies. Hardy and Kooi's modelling method gave the range of draw weights for the Mary Rose bows as between 110 lbs. (49.9 kg.) and 185 lbs. (83.9 kg.) at 30 in draw (76 cm). A different model by Kooi gave a slightly weaker range of between 65 lbs. (29 kg) and 170 lbs. (77 kg) but did not specify at what draw distance.¹⁹³ The draw weights calculated from the arrow shaft data by Keith Watson showed a very wide range of possible draw weights. Watson's study estimated draw weights between 40 lbs. (18 kg) and 190 lbs. (86 kg). However, these figures represented the absolute extreme ends of the data. Instead, Watson argued, the average draw weight based on arrow data is somewhere between 100 lbs. (45 kg) and 130 lbs. (59 kg).¹⁹⁴ These measurements do not require draw distances - even though Watson did estimate draw distances for his calculations - because they are based on the maximum force the arrows could have sustained without breaking, rather than the force required to draw the bow a certain distance.¹⁹⁵ The available data, along with several replica bows, suggested that the Mary Rose bows had an average draw weight of about 120 lbs, give or take ten to fifteen pounds, (50-60 kg) probably at 28 to 30 in (71-76 cm) draw, with a few notable outliers on either end of the spectrum.¹⁹⁶ There was a noticeable variation in draw weights, however, so a precursor bow could easily be as low as 100 lbs. (45 kg) at 30 in (76 cm) and still fit in with the bows found on the *Mary Rose*.

While no ideal precursor bow appears to have survived to prove whether the *Mary Rose* bows were a perfect representation of the longbow of the Hundred Years War or not, that does not mean there have been no surviving bows from earlier centuries. Bows survived in Western Europe from as early as prehistoric times. While those bows are so old that a clear connection cannot be made between them and the *Mary Rose* bows thousands of years later, they can be used to set a sort of baseline expectation. If prehistoric humans could make these bows with only stone tools, then one would not

¹⁹³ Robert Hardy, J. Levy, P. Pratt, Roy King, S. Stanley, B.W. Kooi, D. Adams, and A. Crowley, "Assessment of the Working Capabilities of the Longbows" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). pp. 627-9

Clive Bartlett, Chris Boyton, Steve Jackson, Adam Jackson, Douglas McElvogue, Alexzandra Hildred and Keith Watson, "The Longbow Assemblage", pp.616-7

¹⁹⁴ Keith Watson, "Estimating Longbow Weights from the Arrow Shaft Data" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). pp. 2:617-18.

¹⁹⁵ Clive Bartlett, Chris Boyton, Steve Jackson, Adam Jackson, Douglas McElvogue, Alexzandra Hildred and Keith Watson, "The Longbow Assemblage", pp. 617-8.

Keith Watson, "Estimating Longbow Weights from the Arrow Shaft Data", pp. 2:617-18.

¹⁹⁶ Robert Hardy, J. Levy, P. Pratt, Roy King, S. Stanley, B.W. Kooi, D. Adams, and A. Crowley, "Assessment of the Working Capabilities of the Longbows", pp. 627-9

expect bows of an inferior quality to have been made a few thousand years later by a society with much more sophisticated tools and better resources. At the very least, historians should have to justify why they thought an inferior bow was present in a later century. More recently, bows have survived from Iron-Age Denmark, the early medieval Low Countries, early medieval Germany, and high medieval Ireland. These bows, both prehistoric and medieval, were found in a variety geographical locations across several centuries, or even millennia. For the purposes of analysis, these weapons, despite some of their differences, will be grouped into three broad categories: prehistoric bows, Iron Age Danish bows, and longbows from Ireland. Bows that do not fit in to any of these categories did not make up a sufficiently large data pool for analysis, but will be discussed briefly on their own.

The Prehistoric Bows

There are at least 24 mostly complete bows, and many more fragments, that have survived from prehistory. These bows were found across the geographic area of several modern countries including: England, Switzerland, Germany, Denmark, and the Netherlands. The oldest discovered bows were fragments found in Stellmoor in Germany and dated to c. 8,000 BC. Sadly these fragments were destroyed during World War II.¹⁹⁷ The oldest surviving bows were from Holmegaard on the island of Zealand, Denmark. They have been dated to between c. 6,000 BC and c. 2,000 BC. Very few surviving prehistoric bows have dates more specific than 'neolithic'. The oldest prehistoric English bow has been dated to c.2690 BC while the youngest prehistoric English bow has been dated to 1320 BC. All of these dates are best estimations in an accurate 100-year window, due to the limitations on the precision of carbon dating. The two Dutch bows have been dated to c.1550 BC and c.2020 BC. Very few of these bows have survived in their entirety, but many have survived as half or as more than half of the original bow which is enough to estimate the size the complete bow originally was with a reasonable degree of accuracy. Smaller fragments have survived in even greater numbers but will not be covered in detail in this work as they cannot be used to get an accurate idea of the properties of the complete bow they came from.¹⁹⁸

Almost all of the prehistoric bows were made from yew. There were two other

¹⁹⁷ Ragnar Insulander, "The Bow from Stellmoor – The Oldest in the World?", *Journal of the Society of Archer-Antiquaries* 42 (1999). p. 78.

¹⁹⁸ J.G.D. Clarke, "Neolithic Bows from Somerset, England, and the Prehistory of Archery in North-western Europe", *The Proceedings of the Prehistoric Society* 29:3 (1963). pp. 89-95.

kinds of wood present, one fragment of pine from Sweden and five elm bows, three from Denmark and one each from Germany and the Netherlands. Even thousands of years ago humans seemed to know that yew was a good wood for bows. Both of the elm bows had very wide limbs and were carved into the diamond shape. One of the English yew bows, known as the Meare Heath bow, had a nearly identical diamond shape to the elm bows but remained quite wide almost all the way to its nocks. Two other yew bows were also made in the diamond shape, but were not quite as wide as the Meare Heath bow, which was over ten millimetres wider than both of them. The yew bows did not have a discernible division between heartwood and sapwood. This could be because they did not have a sapwood layer or it could be that over time the distinction faded away. For now it is probably best to assume that there was no sapwood layer, since there is no evidence of one, but it is worth keeping in mind that it may have existed and just not be visible now.¹⁹⁹

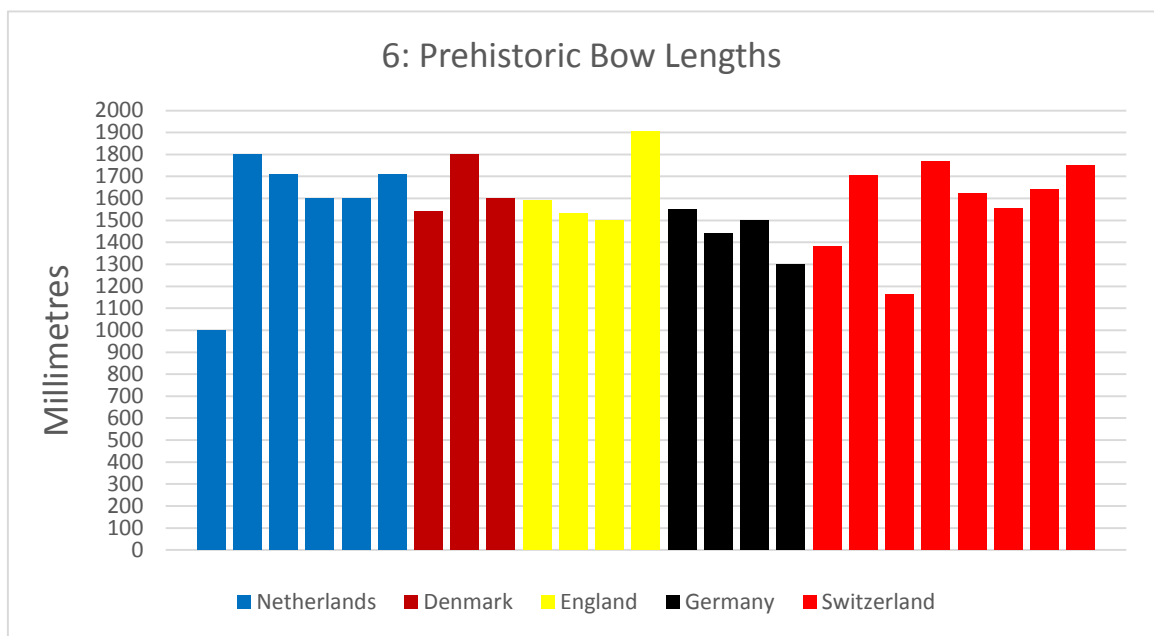
Most of the prehistoric bow lengths used in the following analysis are estimates. Since bows are approximately symmetrical a bow's original length can be accurately estimated so long as around half of the bow has survived. Most bows were a couple of inches longer on the upper limb than the lower limb. In the case of most prehistoric bows, it was largely impossible to determine which limb was the upper. In **Graph 6** the minimum estimated length has been used. A more generous estimate of these lengths could easily add between 50-100 mm to most of these lengths. The median length of the prehistoric bows was 1600 mm. The minimum length was an elm bow from the Netherlands that dates to c.4900 BC and is currently 1000 mm long. It represents an extreme outlier. The longest bow was 1905 mm long. This bow, while it was comparable in length to the *Mary Rose* bows, was definitely not like a precursor bow. This is the Meare Heath bow which had the widest limbs of any of the surviving prehistoric bows despite being made of yew. There does not appear to have been any correlation between the age of a bow and its length, however, the data pool for this was quite small, limited to the five bows that can be accurately dated. One thing to keep in mind when discussing lengths of prehistoric bows is that the average height of a person was different in different time periods and geographical areas. For example, J.G.D. Clarke gave the

¹⁹⁹ Paul Comstock, "Ancient European Bows" in *The Traditional Bowyer's Bible*, ed. Jim Hamm, 4 vols. (Fort Worth, 1992). pp. 2:86-96.

J.G.D. Clarke, "Neolithic Bows from Somerset, England, and the Prehistory of Archery in North-western Europe", pp. 89-95.

J.N. Lanting, B.W. Kooi, W. A. Casparie and R. van Hinte, "Bows from the Netherlands", *Journal of the Society of Archer-Antiquaries* 42 (1999). pp. 7-8.

average height of a man in neolithic England as approximately 1.7 metres (1700 mm) while the average height of a man in neolithic Switzerland was closer to 1.6 metres (1600 mm).²⁰⁰ The dead from the Battle of Towton (1461) were similar in height to the prehistoric English, but the Swiss were significantly shorter.²⁰¹ This should be kept in mind when examining the comparative bow lengths as the height of the archer certainly had a role in determining the how long a bow could have been while still remaining a practical weapon. As a result, some of these shorter prehistoric bows could have been more the result of limitations on the height of the archers using them, rather than a failure



Lengths of prehistoric bows whose total length could either be measured or estimated. Colour sorting indicates region where the bow was found. Data from J.G.D. Clarke 1963, Paul Comstock 1992, and J.N. Lanting et. al. 1999.

The Danish Bows

Hundreds of items worth of archery material and other artifacts have been excavated from bogs across Denmark and northern Germany. The most significant finds have been at Nydam, Vimose, and Illerup Ådal. Most of these items have been dated to

²⁰⁰ J.G.D. Clarke, “Neolithic Bows from Somerset, England, and the Prehistory of Archery in North-western Europe”, p. 68.

²⁰¹ Anthea Boylston, Malin Holst, and Jennifer Coughlan, “Physical Anthropology” in *Blood Red Roses: The Archaeology of a Mass Grave from the Battle of Towton AD 1461* ed. Veronica Fiorato, Anthea Boylston, and Christopher Knüsel, 2nd Ed. (2000, Oxford, 2007). pp. 53-5.

²⁰² Paul Comstock, “Ancient European Bows”, pp. 2:86-96.

J.G.D. Clarke, “Neolithic Bows from Somerset, England, and the Prehistory of Archery in North-western Europe”, pp. 89-95.

J.N. Lanting, B.W. Kooi, W. A. Casparie and R. van Hinte, “Bows from the Netherlands”, *Journal of the Society of Archer-Antiquaries* 42 (1999). pp. 7-8.

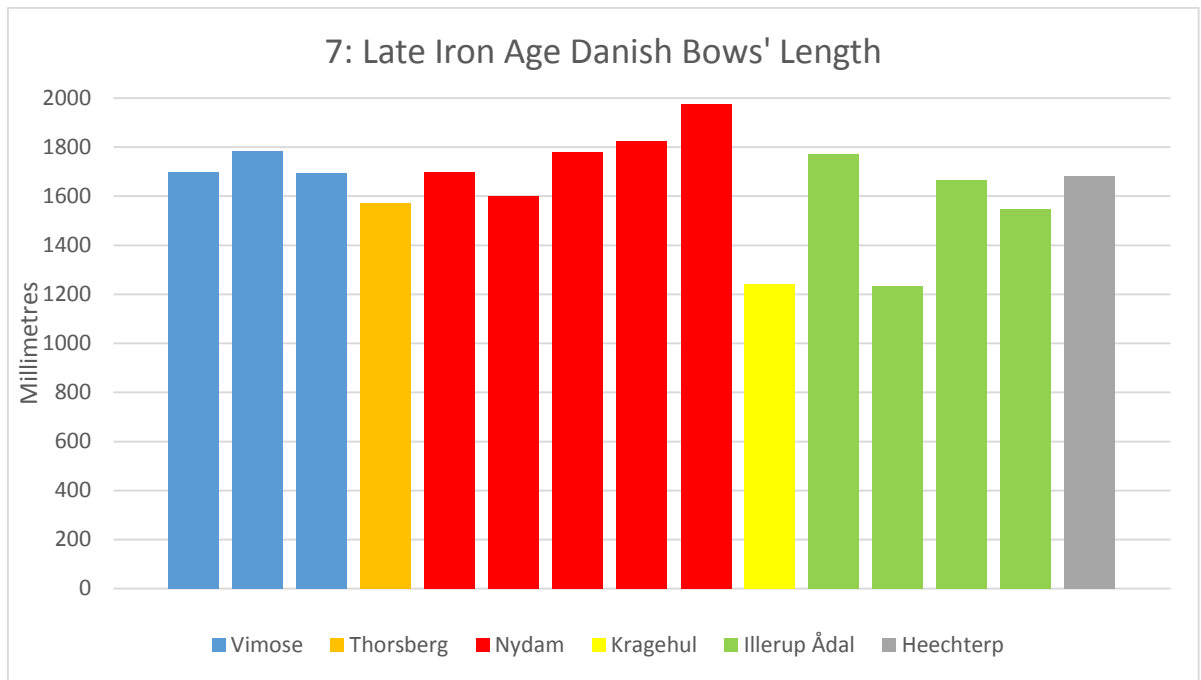
between the second and sixth centuries, but a small fraction are from as late as the eighth century. The sheer number of artifacts that have been found in these bogs is impressive, and include almost 600 items related to Iron-Age archery. Most of these items were arrow shafts, or parts of arrow shafts, but several dozen bows were also recovered. These bows have received little scholarly attention until recently, so the published details on them are limited.²⁰³ The vast majority of these bows were made of yew with a heartwood and sapwood layer. There were a few exceptions to this pattern, including two bows possibly made of pine and hazel, but they were in the minority. In total there were over sixty bows from various bog finds across Denmark, however few of these were complete bows. The data used in this study are a combination of details published by J.G.D. Clarke and analysis by Xenia Pauli Jensen. Clarke published the minimum and maximum lengths of near complete bows from several of major excavations, including Nydam and Vimose. He also included a rough indication of the number of bows found in each bog. Pauli Jensen has published more detailed studies of specific finds, especially Illerup Ådal. **Graph 7** shows a comparison of the lengths of bows found from the various bog sites and, as with the prehistoric bows, these lengths represent minimum estimates.²⁰⁴ The Nydam find – which was also the largest find, including over forty bows in various states – was the only one with a bow that was neither elm nor yew in it. The final bow in the Nydam section on the graph was either made of pine or hazel. Illerup Ådal has the most detailed information available but also only had two near complete longbows, the rest were fragments shorter than 900 mm. The smallest Danish bow was only 1235 mm long, while the longest, which was also a non-yew bow, was an impressive 1975 mm, making it the longest bow studied in this thesis that was not from the *Mary Rose*. The median Danish bow was 1695 mm long. Overall the data had a fairly broad spread, and all but two of the bows were over 1500 mm long. There do not appear to have been any obvious differences between the bows based on which site they were found in; they seem to have been largely interchangeable. The differences that are visible – for example that Nydam bows were slightly longer on average – are not backed up by a sufficient amount of data to be considered conclusive. In general, it seems reasonable to treat the Danish bows as a unified collection when using them for broader comparative analysis.²⁰⁵

²⁰³ Xenia Pauli Jensen, pers. comm. [18/01/13]

²⁰⁴ Xenia Pauli Jensen, “Alliances and Power Structures in Southern Scandinavia during the Roman Iron Age”, *Lund Archaeological Review* 17 (2011), pp. 35-40.

Xenia Pauli Jensen and Lars Christian Nørbach, *Illerup Adal: Die Bogen, Pfeile und Axte 13* (Aarhus, 2009), p. 49

²⁰⁵ Xenia Pauli Jensen and Lars Christian Nørbach, *Illerup Adal*, p. 49



Lengths of Iron-Age Danish bows, colouration indicates which sites contained the surviving bows, data from J.G.D. Clarke 1963, and Xenia Pauli Jensen and Lars Christian Nørbach 2009.

The Irish Bows

Bows, and bow fragments, have been found in Ireland at excavations in: Balinderry Crannóg, Waterford City, Dublin City, and county Cork. Most of the discoveries have been of bow fragments, but at least three complete bows have been found. The bows found in Balinderry Crannóg and Waterford are best suited for this study.²⁰⁶ First, however, something should be said about the other excavations. In Dublin and Cork most of the finds were bow fragments but one complete bow was excavated in Dublin. The full bow was only 678 mm long and has been dated to the first half of the thirteenth century. Andy Halpin has suggested that the bow might have been for hunting or possibly it might have been a child's toy.²⁰⁷ A similar bow, which dates to prehistoric Switzerland, is currently 807 mm long but has been estimated to have originally been

Xenia Pauli Jensen, "Alliances and Power Structures in Southern Scandinavia during the Roman Iron Age", pp. 35-40.

²⁰⁶ H. O'Neill Hencken, Gwyneth Harrington, H. L. Movius, Jr., A. W. Stelfox and Geraldine Roche, "Ballinderry Crannog No. 1", *Proceedings of the Royal Irish Academy. Section C: Archaeology, Celtic Studies, History, Linguistics, Literature* 43 (1935 – 1937). pp. 133, 139.

Andrew Halpin, "Archery Material" in *Late and Viking Age Medieval Waterford: Excavations 1986-92*, ed. M.F. Hurley, O.M.B. Scully, and S.W.J. McCutcheon (Waterford, 1997). pp. 546-52.

Andrew Halpin, "Military Archery in Medieval Ireland: Archaeology and History", *Military Studies in Medieval Europe –Papers of the 'Medieval Europe Brugge 1997' Conference* 11 (1997). pp. 54.

²⁰⁷ Andrew Halpin, "Archery and Warfare in Medieval Ireland: A Historical and Archaeological Study" 2 vols. (Unpublished Ph.D. Thesis, Trinity College Dublin, 1998). pp. 2:6-7

910 mm long. Clarke argued, like Halpin, that this bow was probably a 'toy'.²⁰⁸ Later evidence of archery practice in England has suggested that at that time it was relatively common for children to start practicing with a bow from a very young age.²⁰⁹ It stands to reason, then, that bows must have been made for children. While these bows could theoretically have represented evidence for the long disputed short bow, when compared to the overwhelming evidence of longbows approximately contemporary to when they were made, this explanation seems unlikely. If these two bows, separated by many millennia, do represent bows for children then they are important and near unique finds. With only two bows from two very different periods in time it is impossible to do any more than speculate on their possible uses, however, so they will be left out of the analysis in this chapter.

The Dublin bow fragments were, at most, only 100 mm long. All of the Dublin fragments were made of yew and had a clear sapwood layer, along with a shallow D-shape.²¹⁰ All of the fragments dated from between the eleventh and thirteenth centuries. The bow fragments found in an excavation of Skiddy's Castle and Christ Church in Cork were all less than 100 mm long. None of these fragments were long enough to make an estimate of the bows' original lengths. The Cork fragments were also made of yew, had a heartwood and sapwood layer distinction, and had a shallow D-shape. While these fragments were not usable in the specific analysis for this study, they did suggest that three traits were common among Irish longbows by at least the eleventh century. These traits were: they were made of yew, they had a layer of sapwood over a heartwood belly, and they were carved in a D-shape.²¹¹

The bow found in Balinderry Crannóg has been dated to sometime during the tenth century. The bow was found beneath the floor of one of the residences.²¹² The settlement in general had at least some Viking influence, if it was not actually a Viking settlement, so it is possible this bow was a result of outside influence and not reflective of native Irish archery. The bow had survived almost completely intact with only one of

²⁰⁸ J.G.D. Clarke, "Neolithic Bows from Somerset, England, and the Prehistory of Archery in North-western Europe", p. 95

²⁰⁹ Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 393-4.

²¹⁰ Andrew Halpin, "Archery and Warfare in Medieval Ireland: A Historical and Archaeological Study", pp. 2:6-7.

²¹¹ R.M. Clear, M.F. Hurley and E. Shee Twohig, *Skiddy's Castle and Christ Church, Cork Excavations 1974-77* (Cork, 1997). pp.306-7

²¹² H. O'Neill Hencken, Gwyneth Harrington, H. L. Movius, Jr., A. W. Stelfox and Geraldine Roche, "Ballinderry Crannog No. 1", pp. 133, 139.

Andrew Halpin, "Archery and Warfare in Medieval Ireland: A Historical and Archaeological Study", pp. 2:6-7.

its nocks missing. The surviving bow is 1850 mm long but estimates based on the surviving nock suggest that the full bow was originally 1900 mm long. The bow had a clear layer of sapwood along its back and had a shallow D-shape. At its grip it was 38.1 mm wide by 28.6 mm thick. Unfortunately measurements of the cross-section of its limbs were not readily available, but based on the drawings of it, there was no drastic alteration in size over its length. Instead it thinned gradually from grip to nock.²¹³

During excavations in Waterford City a near-complete bow and several large bow fragments were found. The Waterford bows were all made of yew. Most of the fragments had a layer of sapwood, but the boundary on many of them was very faint. The near-complete bow appeared to have been of uniform construction, but it was not clear whether heartwood or sapwood was used. Heartwood was the more likely of the two, however, as yew heartwood was a much better bow material when used alone, and the sapwood of yew tends to not be thick enough to make an entire bow out of.²¹⁴ It is also possible that the complete bow has simply lost its sapwood distinction. The Waterford bows have been dated to either the late twelfth or early thirteenth centuries.

Unfortunately the Waterford bows had decayed so much that it was quite difficult to accurately estimate their original lengths. Andy Halpin has estimated that the bows were all between 1200 mm and 1500 mm long originally, but beyond that it is difficult to get more specific estimates for them. The longest surviving Waterford bow fragment, which is the near-complete bow, was only 1258 mm long.²¹⁵ While accurate measurements have been made of the widths of the Waterford bows, they are noticeably smaller now than they were originally due to centuries of slow decay. For this reason, it is important to treat their dimensions as representative of minimum possible size. It is much harder to provide a reasonable estimate for how much larger the bows originally were, however, and every millimetre difference is much more significant when it is applied to a bow's thickness rather than to its length. **Graph 8** shows a comparison of the widths and thicknesses of both the Waterford bows and the Balinderry bow. These measurements were all taken at the point where the bow was thickest. If the bow fragment was long enough to include a part of its grip, the measurement was taken for the grip dimensions,

²¹³ H. O'Neill Hencken, Gwyneth Harrington, H. L. Movius, Jr., A. W. Stelfox and Geraldine Roche, "Ballinderry Crannog No. 1", pp. 133, 139.

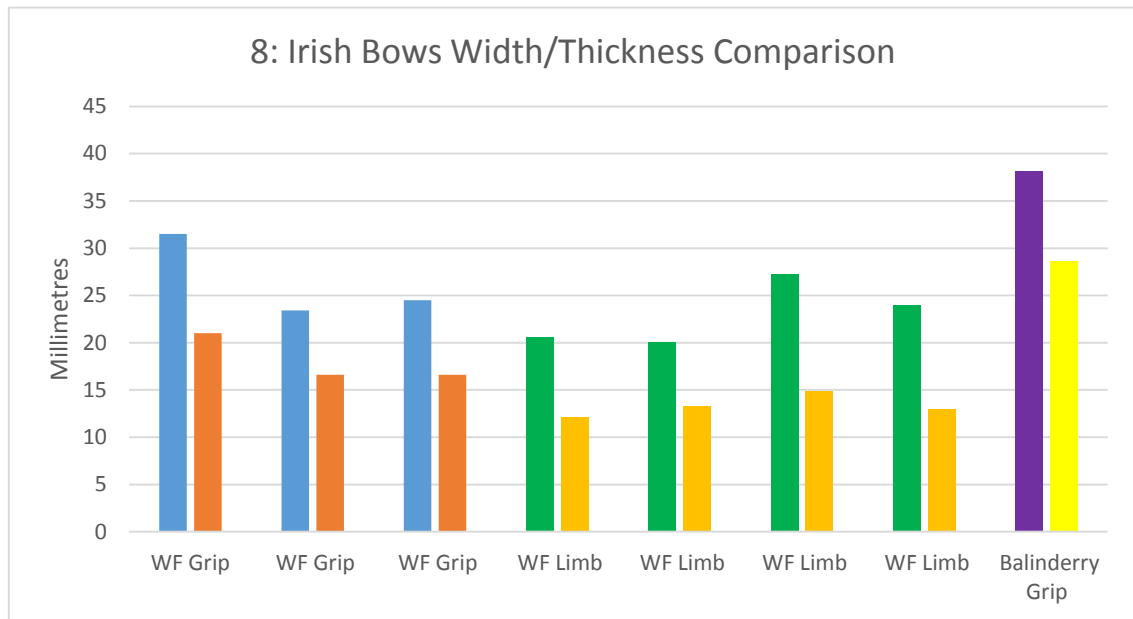
Andrew Halpin, "Military Archery in Medieval Ireland: Archaeology and History", p. 54.

²¹⁴ Ron Hardcastle, "Cutting and Seasoning Wood" in *The Traditional Bowyer's Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000), pp. 1:22-4

²¹⁵ Andrew Halpin, "Archery Material", pp. 546-52.

Andrew Halpin, "Archery and Warfare in Medieval Ireland: A Historical and Archaeological Study", pp. 2:6-7.

while if the fragment was only part of a bow limb then the measurements were treated as limb dimensions. The graph clearly shows that the Balinderry bow was significantly larger than any of the Waterford bows. All of the bows had a fairly significant difference between their widths and thicknesses. On average, there was a difference between the width and thickness of between five and ten millimetres for both the grip dimensions and the limb dimensions. The limb dimensions reflected the same trends seen in the grip



Comparison of the width and thickness of medieval Irish bows. Most Waterford bows were measured on either the limb or the grip, and have been separated into different colour groups to represent this. Data from H. O'Neill Hencken 1935-37, Halpin 1997, Halpin 1998.

dimensions but the raw numbers trended slightly smaller. Overall, though, the differences between the Waterford grips and limbs were minor – one of the limbs was actually wider than two of the grip sections – which is understandable given the varying degrees of decay suffered by the bows, as well as the problem of determining which measurements actually were grips and which were limbs due to the fragmentary state of the bows.²¹⁶

Other Bows

This thesis has tried to gather data from as wide a range as possible, but unfortunately in several cases data have either been unavailable or insufficiently detailed to be of use for the analysis in this chapter. The two most important examples of bows that were not included are the longbow from Hedeby in Denmark, and the Oberflacht

²¹⁶ Andrew Halpin, “Military Archery in Medieval Ireland: Archaeology and History”, pp. 55-8. Andrew Halpin, “Archery Material”, pp. 546-52.

bows of the Alemanni from Wurttemberg in Germany. The Hedeby bow was uncovered in an excavation and has been measured as being 1920 mm long, easily within the range of *Mary Rose* bow lengths, but unfortunately that was all the readily available information on it. The rest of its dimensions were not readily accessible and it was an isolated sample, making it difficult to establish its context. Its most obvious counterpart was the Balinderry Bow, since both were from Viking Age settlements and it was of a comparable length to that bow. Without more information, however, it cannot show anything more than what was already apparent from the Balinderry Bow.²¹⁷ The Oberflacht bows were 8-10 bows excavated in the nineteenth century from a series of graves dated to c. 600 AD. These bows have appeared in several publications but with only minimal information provided. Gad Rausing mentioned that they were all at least 1830 mm long, with most of the bows being approximately 2100 mm – which would be long even for a *Mary Rose* era bow – but provided no more information.²¹⁸ Publications on the original excavations provided some details on the bow shape, but not much more on the dimensions.²¹⁹ The bows appear to have had separate grip sections, similar in style to the much later Victorian target archery bows, meaning their draw weights would have been significantly less than that of a *Mary Rose* longbow. Dr. Veeck has published two books on the Alemanni excavations but much of his work on the subject was not accessible. His second book, which was published in 1931, has so far been difficult to access due to its age. Attempts to contact the *Landesmuseum* of Wurttemberg, where the Alemanni artifacts are currently stored, have proven unsuccessful. The available information on these bows did not suggest that including them in this thesis would have resulted in a radical revision to the arguments that have been laid out here. Their length, combined with the fact that they seem to have had a static grip, generally supports this thesis' argument that earlier medieval longbows were of the same length as the *Mary Rose* bows but not as powerful.

A final group of bows that were not included in the later analysis have survived from the classical and early medieval Low Countries. These bows, found in the modern day Netherlands, did not present a large enough sample to be part of the analysis in this chapter but are still worth considering, even if only in brief. There were three bows in

²¹⁷ Else Roesdahl, *The Vikings*, (London, 1991). p. 143.

²¹⁸ Gad Rausing, *The Bow: Some Notes on Its Origin and Development* (Manchester, 1967). p. 60.
W.M. Wylie, 'The Graves of the Alemanni at Oberflacht in Suabia', *Archaeologia* 36 (1855). pp. 133-8, 145.

²¹⁹ Walther Veeck, *Der Alamannenfriedhof von Oberflacht*, (Stuttgart, 1924). pp. 25, 31-3.

total, one from between c. 50 BC and c. 250 AD, and two from between 700 and 950 AD. The classical era bow is currently 1510 mm in length but was likely c.1600 mm originally. The early medieval bows were originally 1550-1850 mm and 1800-1900 mm, respectively. The early medieval bows were on the long end of the scale for longbows of around that era, and an equivalent length to several bows from the *Mary Rose*. Unfortunately such a small sample of bows does not allow for detailed analysis. Additionally, without information beyond just their lengths, it is hard to say much at all about how they compared to other medieval longbows.²²⁰

Bow Comparison and Analysis

Each of these groups of bows only provided a limited amount of information when considered in isolation. It is through the comparison of these bows that an overall image of the history of the longbow can be created. The following analysis will first consider the broad general design elements of these bows, before moving on to more detailed and specific elements of their size and shape. Due to very limited information on the draw weights of most of the longbows discussed here, it is not possible to do a comparison between the estimated draw weights of the *Mary Rose* bows and earlier bows to try to establish what power disparity, if any, existed between them.

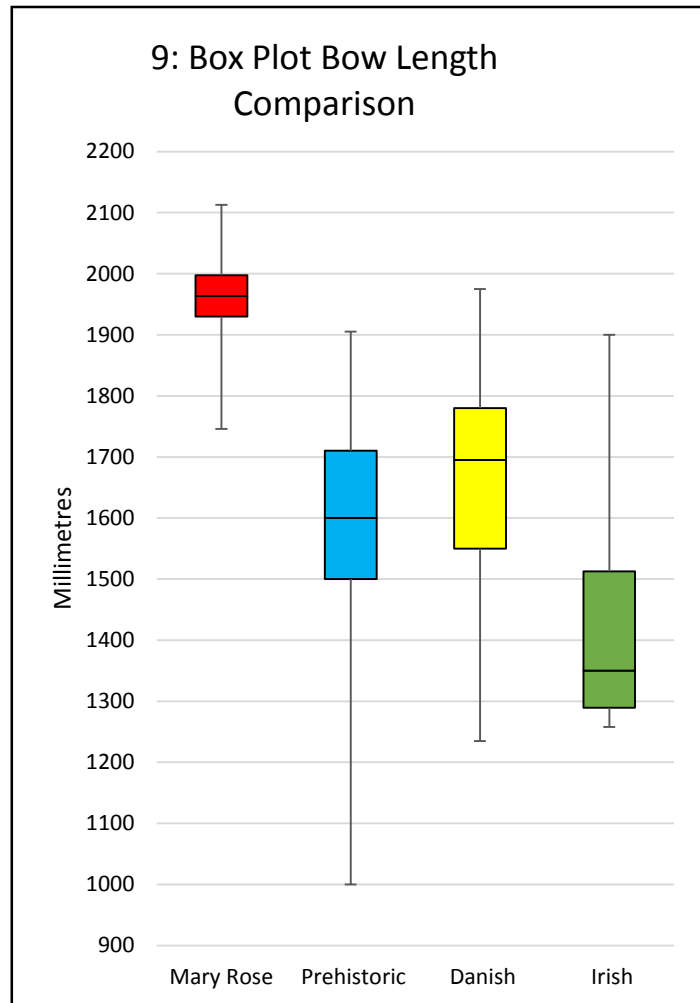
The bow material is the simplest element to compare, since in almost all cases the wood used for surviving longbows was yew. There are a few noteworthy exceptions, such as a bow that was either made of pine or hazel and a handful of elm bows, but by far the majority of bows were made of yew. Given that the majority of the bows were yew, the presence of sapwood on the yew bows is the next important element to consider. The prehistoric bows were all made exclusively of heartwood. In some cases, the sapwood layer could simply now be indistinguishable from the heartwood, due to the ageing of the bows. By the time of the Iron-Age Danish bows, the sapwood layer was already present far more often than not, and in nearly all of the Irish examples there was a layer of sapwood. There was one example of an Irish bow that appeared to have a sapwood layer on the belly instead of the back but it was only a fragment, and the back and belly of the bow were not definitively identifiable. From this, then, it is possible to draw the conclusion that, not only was the yew the primary wood for making longbows, but also a layer of sapwood was a part of longbow design for hundreds of years before

²²⁰ J.N. Lanting, B.W. Kooi, W. A. Casparie and R. van Hinte, "Bows from the Netherlands", pp. 8-9.

the *Mary Rose* bows.²²¹

Comparing the shapes of the *Mary Rose* bows to other surviving bows is more complicated. Unfortunately, for many of the surviving bows, there has been little published information on their shapes. Sometimes shape can be inferred from published details about their cross-sections, but this requires at least some speculation. For example, the limbs of some of the prehistoric bows, such as those of the elm bows and the Meare Heath bow, were all clearly diamond shape. This can be determined based on the fact that these bows had narrow, thick grips and very wide, thin limbs. This shape was ideal for durability but limited on power, and about as different from the *Mary Rose* bows as a bow reasonably could have been. Very little information is available on the exact shape of

the Danish bows. Andy Halpin has made a very close study of the surviving Irish bow fragments and concluded that they are very alike in form to the *Mary Rose* bows.²²² Both



Comparison of bow lengths by bow time/place of origin. Includes 126 Mary Rose bows, 25 prehistoric bows, 20 Danish bows, and 4 Irish bows. Data from Clive Bartlett et al. 2011, J.G.D. Clarke 1963, Xenia Pauli Jensen 2009, Halpin 1998.

²²¹ Andrew Halpin, “Archery and Warfare in Medieval Ireland: A Historical and Archaeological Study”, pp. 2:5-9.

Xenia Pauli Jensen, “Alliances and Power Structures in Southern Scandinavia during the Roman Iron Age”, pp. 35-40.

J.G.D. Clarke, “Neolithic Bows from Somerset, England, and the Prehistory of Archery in North-western Europe”, pp. 64-70, 89-95.

Xenia Pauli Jensen and Lars Christian Nørbaek, *Illerup Adal*, p. 49

²²² J.G.D. Clarke, “Neolithic Bows from Somerset, England, and the Prehistory of Archery in North-western Europe”, pp. 64-70

Clive Bartlett, Chris Boyton, Steve Jackson, Adam Jackson, Douglas McElvogue, Alexandra Hildred and Keith Watson, “The Longbow Assemblage”, pp. 596-9.

Andrew Halpin, “Archery Material”, pp. 546-52.

the Irish bows and the *Mary Rose* bows were made with shallow D-shapes, the ideal shape for making powerful yew longbows.

The comparative lengths of the groups of bows can be seen in **Graph 9**. This is a box-plot graph representing the general spread of the data from each group. Each section of the graph represents a quarter of that data. The sections are divided up like this: the first section is from the bottom of the graph to the bottom of the box, the second section is from the bottom of the box to the line in the box, the third section is from the line in the box to the top of the box, and the final section is from the top of the box to the top of the graph. The data were sorted numerically and then evenly distributed across these sections. For example, the first box plot is the *Mary Rose* data. Each section of the graph contains roughly 30 bows, and the 30 shortest *Mary Rose* bows are in the first section. The line dividing the box in two is the median of the overall data while the box itself contains exactly half of data points in the group. The graph clearly shows that the *Mary Rose* bows were, on average, significantly longer than those from any of the previous eras. No other graph's box is even with the *Mary Rose* box. Only the upper extremes of the Danish bows even reaches level with the *Mary Rose*'s box. On average, the Irish bows are the smallest. This data set warrants special mention, however, since it only consists of four bows, so each section represents one bow. The Waterford bows, since their lengths were only estimated to a range, were entered as one data point each for: the minimum length, the maximum length, and the length of the most complete bow. The prehistoric data contains 25 bows, the Danish includes thirteen bows, and the *Mary Rose* consists of 126 bows. The lower bulk of the Irish data, then, is the Waterford bows while the upper extreme is the Balinderry bow. What this data shows is that, while it was very possible for earlier bows from all eras and locations to reach lengths comparable to that of a *Mary Rose* bow, in general the *Mary Rose* bows were significantly longer than previous bows. It is also worth considering the absolute numbers, however, not just the comparison. None of these bows would be considered particularly short. The lowest median point is from the Irish bows and it is still well over a metre long. The vast majority of the data was over 1500 mm long, in fact, in every case but the Irish bows, 75% of the bows were longer than that. It seems fairly safe to say that, while the *Mary Rose* bows are significantly longer than any surviving bows from previous eras, it would be unfair to label those earlier bows as short-bows.²²³

²²³ Andrew Halpin, "Archery and Warfare in Medieval Ireland: A Historical and Archaeological Study", pp. 5-9.

Xenia Pauli Jensen, "Alliances and Power Structures in Southern Scandinavia during the Roman Iron

Longbows were clearly in existence well before the thirteenth century. However, no direct causal relationship can be drawn between the earlier bows discussed above and the famous English longbow of the Hundred Years War. Clifford Rogers has argued that, while these early and high medieval bows existed, they were not the same as the English longbow and instead should be described as a different type of bow: the medium-long bow, or in some cases the near-longbow. He proposed a technological development of the bow originating with an early medieval short bow, which developed into the medium-length longbow, and finally became the famous English longbow in the thirteenth century.²²⁴ A core part of his argument was based on the Waterford bows which, as the above length data shows, were the shortest of the groups of bows considered in this study. Rogers was not without good reason for picking out these bows, though. The Waterford bows were the closest surviving bows chronologically to the period of the English longbow's adoption as the primary weapon of English armies. They were also geographically closer to the English longbow than any non-prehistoric bows considered here. However, the fact that these represented the smallest medieval bows, combined with the fact that Rogers completely ignored the Balinderry Bow, limits the strength of his argument. Particularly problematic was the argument for a short bow developing into the Waterford bows given how all of the bows from before the Waterford bows were significantly longer than the Waterford bows. On the other side of the debate, Strickland and Hardy made no mention of the Waterford Bows in *The Great Warbow* which was a significant oversight. They emphasised the Balinderry bow, which was a great stand in for the *Mary Rose* bows, and argued that it was strong evidence for *Mary Rose* type bows from at least as early as the eleventh century.²²⁵ Both sides of the argument have prioritised a misleading detail of these longbows. By emphasising the length of these bows as the most important element of their design, they fail to give proper consideration to the other, arguably more important, elements of bow design. As Chapter One has explained, a medium-length longbow could easily out perform a large

Age", pp. 35-40.

J.G.D. Clarke, "Neolithic Bows from Somerset, England, and the Prehistory of Archery in North-western Europe", pp. 64-70, 89-95.

Clive Bartlett, Chris Boyton, Steve Jackson, Adam Jackson, Douglas McElvogue, Alexandra Hildred and Keith Watson, "The Longbow Assemblage", pp. 596-9.

Xenia Pauli Jensen and Lars Christian Nørbach, *Illerup Adal*, p. 49

Andrew Halpin, "Archery Material", pp. 546-52.

²²⁴ Clifford Rogers, "The development of the longbow in late medieval England and 'technological determinism'", pp. 322-6, 332-5.

²²⁵ Matthew Strickland and Robert Hardy, *The Great Warbow*, p. 40.

longbow if it was better made and more efficient.²²⁶ Length generally added to power but at the cost of efficiency. Thickness of the longbow was a much more accurate indicator of a longbow's power, and the design of the bow's limbs were a better indicator of bow quality. Interestingly, Rogers actually mentioned the thickness of the *Mary Rose* bows as an important contribution to what made them so powerful, but after his initial mention of this feature and its importance to the weapons design he did not bring it up again, not even when discussing other surviving longbows.²²⁷ The following paragraphs will examine these other elements of bow design, and explore what they can tell historians about the development of the longbow.

When examining the cross section of a bow it is important to consider the ratio of width to thickness. Thickness granted power to the longbow, but it must be in an appropriate ratio to the width for it to be truly effective. If the bow was too narrow it would have splintered or broken, while if it was too wide the limbs would have been heavy and efficiency would have been lost. The width to thickness ratio of the *Mary Rose* bows at their grips was generally 1.1:1.²²⁸ Strickland mentioned this ratio briefly in *The Great Warbow* but he drew his data entirely from Clark's article on neolithic longbows. Clark's article was excellent but it is also forty years old, and as such from many years before the *Mary Rose*'s rediscovery. It was also primarily concerned with prehistoric archery and the comparison to late medieval bows was made only in passing. While Clark did make some mention of the two *Mary Rose* bows that were extant when he was writing, they were not as robust a basis for the ratio argument as the plethora of *Mary Rose* data available now.²²⁹ The reliance on ratios exclusively can also mislead historians.

What ratios are best for is indicating the skill of the artisan who made the bow. The crafting of a longbow with the optimal width and thickness ratio suggested that the culture making the bow had a good understanding of the properties of the wood they were using. Some of the prehistoric bow designs suggest a culture that was still experimenting with their technology. There was no need to make wide-limbed yew bows but some prehistoric societies did, presumably because they did not fully understand the

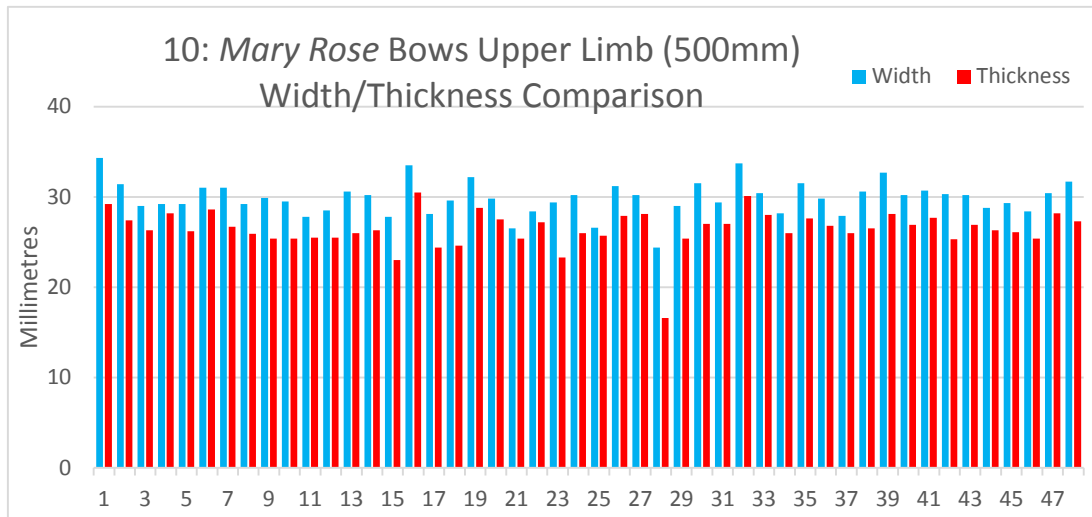
²²⁶ See Chapter 1.

²²⁷ Clifford Rogers, "The development of the longbow in late medieval England and 'technological determinism'", pp.324-5, 332-5.

²²⁸ Clive Bartlett, Chris Boyton, Steve Jackson, Adam Jackson, Douglas McElvogue, Alexandra Hildred and Keith Watson, "The Longbow Assemblage", pp. 596-9.

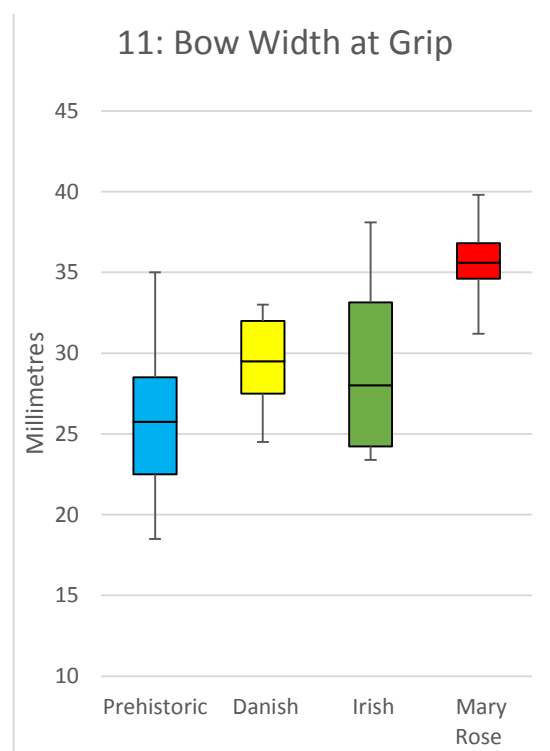
²²⁹ Matthew Strickland and Robert Hardy, *The Great Warbow*, p. 39.

J.G.D. Clarke, "Neolithic Bows from Somerset, England, and the Prehistory of Archery in North-western Europe", pp. 86-7.



Comparison of bow limb width and thickness for the first 48 Mary Rose bows in the Weapons of Warre catalogue. Data from Clive Bartlett et. al. 2011.

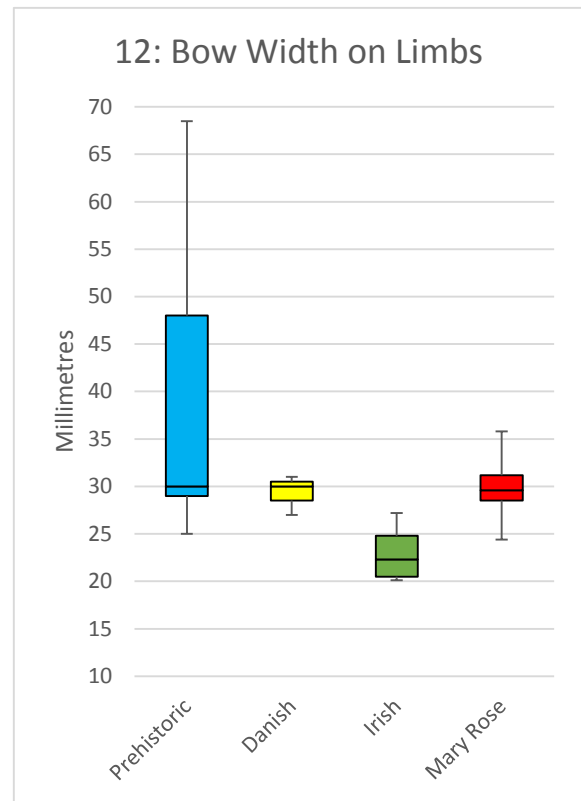
strengths and capabilities of yew, so they went for a safer and more reliable bow shape. A culture that understood bow making well, probably through years of experimentation and failure, could make bows with an optimal width to thickness ratio.²³⁰ Where focusing on this ratio exclusively, like Strickland does, causes problems is that it can hide the existence of an actual size difference between the bows from two different cultures. For example, while the Balinderry bow was of a similar length to the *Mary Rose* bows and had a similar ratio of width to thickness, its actual width and thickness were both significantly smaller than an average *Mary Rose* bow. This means that while the Balinderry bow shared many important design elements with the *Mary Rose* bow, it was a significantly weaker bow. It is important at this stage to actually



Comparison of width of the bow at the grip. Consist of 21 prehistoric bows, 17 Danish bows, 4 Irish bows, and 113 Mary Rose bows. Data from Clive Bartlett et. al. 2011, J.G.D. Clarke 1963, Xenia Pauli Jensen 2009, Halpin 1998.

²³⁰ Paul Comstock, "Ancient European Bows," *The Traditional Bowyer's Bible*, ed. Jim Hamm, 4 vols. (Fort Worth, 1992). pp. 2:86-96.
Tim Baker, "Bow Design and Performance", pp. 50-1, 65-74.

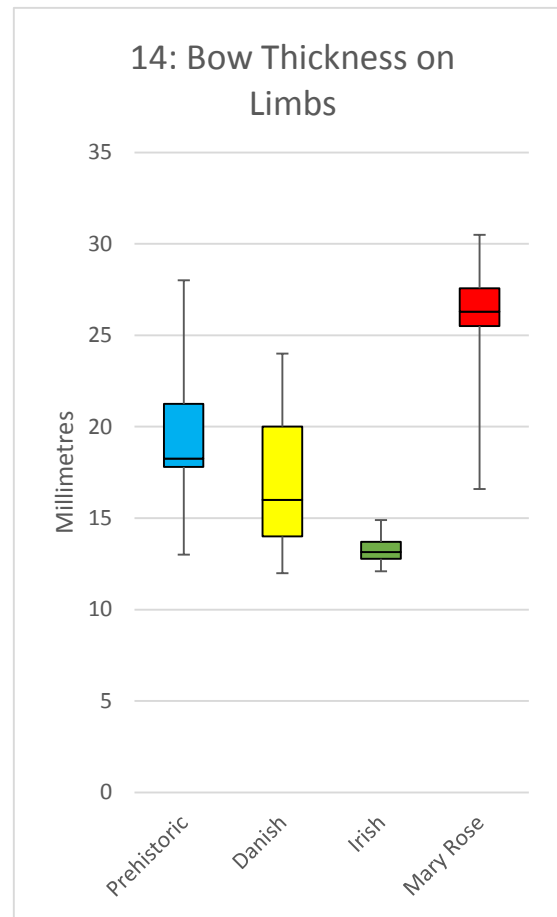
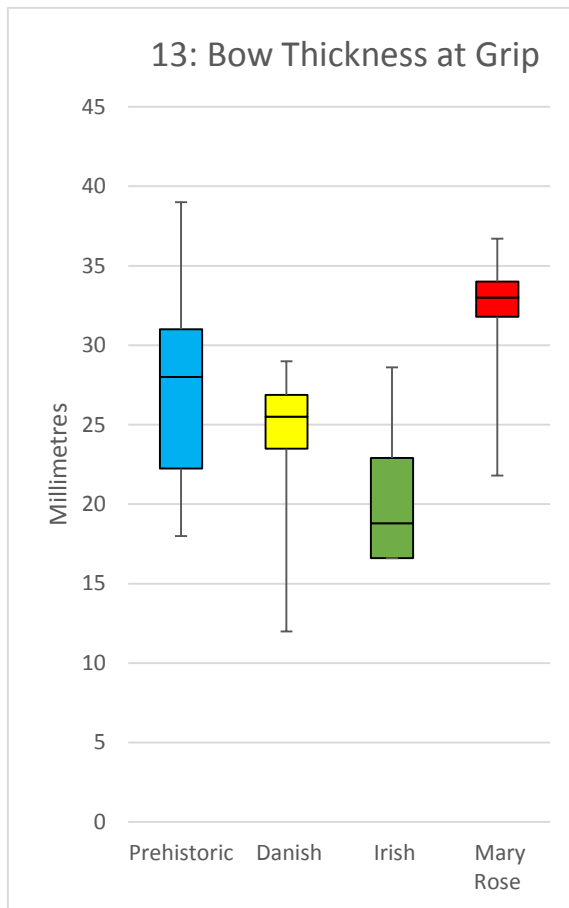
examine the widths and thicknesses of these bows in greater detail to see how these important design elements developed over time. **Graph 10** shows a comparison of *Mary Rose* limb widths and thicknesses. For the sake of keeping the graph relatively readable, only the first 49 bows from the *Mary Rose* data have been included. There was noticeable variation in the size of the limb cross-sections of the *Mary Rose* bows. For the vast majority of the bows, the difference between the width and thickness was less than ten millimetres, and somewhere around five millimetres appears to have been fairly standard. What this graph shows is that, while the ratio of 1:1.1 was standard for *Mary Rose* grips, the difference increased noticeably on the limbs.²³¹



Comparison of bow limb width, consists of 15 prehistoric bows, 3 Danish bows, 4 Irish bows, and 114 Mary Rose bows. Data from Clive Bartlett et. al. 2011, J.G.D. Clarke 1963, Xenia Pauli Jensen 2009, Halpin 1998.

The overall data show that the *Mary Rose* bows were the largest bows. The following series of box-plot graphs (**11-14**) show a comparison of the widths and thicknesses of the bows' grips and limbs. Where grips were not obvious, the largest part of the bow was treated as the grip for measurement purposes, since bows are usually thickest at their grips. The Danish limb data consists of only three measurements since most of the data was interpreted as referring to the bows' grip sections. The *Mary Rose* bows had their limb measurements taken at 500 mm from the grip, which was approximately midway between the grip and nock. The graphs show that a large variation existed in each of the data sets. As with the length data, there was a core of very similar bows in the *Mary Rose* data – as shown by the relatively small size of the box – but the full range of the data was quite broad. Each section outside of the central box is longer than the box is. The prehistoric bows are the most complicated of the data sets to consider, due to the presence of the wide limbed

²³¹ Clive Bartlett, Chris Boyton, Steve Jackson, Adam Jackson, Douglas McElvogue, Alexzandra Hildred and Keith Watson, "The Longbow Assemblage", pp. 2:596-9.



Comparison of thickness of bows at their grip. Consists of 16 prehistoric bows, 17 Danish bows, 4 Irish bows, and 114 Mary Rose bows. Data from Clive Bartlett et. al. 2011, J.G.D. Clarke 1963, Xenia Pauli Jensen 2009, Halpin 1998.

Comparison of thickness of bows on their limbs. Consists of 12 prehistoric bows, 3 Danish bows, 4 Irish bows, and 114 Mary Rose bows. Data from Clive Bartlett et. al. 2011, J.G.D. Clarke 1963, Xenia Pauli Jensen 2009, Halpin 1998.

bows with very thick grip sections. The grip sections could have been very thick since they did not have to bend when the bow is drawn, which was why the prehistoric bows had the bow with the thickest grip across all of the data sets. These bows also had very wide, thin limbs.

Thickness was probably the most important design element given that it was most closely related to power. When it comes to grip thickness the bows were more similar to one another. The *Mary Rose* bows seem to have had much thicker limbs than other bows. Some of this can be explained by the fact that the limb data for other bows was quite limited. For example, the Irish bow limb thickness did not include the Balinderry Bow. While the Waterford bows were significantly shorter than the *Mary Rose* bows, the difference in thickness at grip was often less than 5 mm. While this difference is significant, it must also be remembered that the Waterford bows have suffered substantial decay, especially to their cross-section, meaning the difference between them and the

Mary Rose bows was actually much smaller. These measurements were complicated by the fact that it is often not clear where on the limb they were taken. Only the measurements of the *Mary Rose* bows include information on where on the bow the measurements were taken. While the Waterford bows were almost certainly still smaller than the *Mary Rose* bows, and as a result less powerful, the difference between the two was much less significant than their lengths would have suggested. When only length is considered, the *Mary Rose* bows clearly stood well above the rest of the longbows, especially those from Waterford, but when considering other design elements the results were more complicated. When width and thickness were considered, especially in the grip section, the difference did not seem quite so great between the *Mary Rose* bows and those from earlier centuries. When length was considered on its own, the prehistoric or Danish bows seem to have been the closest to the *Mary Rose* bows. However, when thickness is considered, the differences become much smaller and the Waterford bows are shown to be more similar to the bows from the *Mary Rose* than their lengths would suggest. This is particularly true when one remembers that the Waterford bows have suffered significant decay and were originally thicker than they are now.²³²

Conclusion

Based on the preceding analysis, this chapter has taken a stance between the two main camps in the debate on longbow's history. Rogers' medium-long bows were something of a red herring, as they emphasised only one aspect of the longbow, and not the most important one. As the previous sections have shown, the Waterford bows may look based on length to have been an entirely different sort of bow from the *Mary Rose* but in fact shared several important design features with them. However, the earlier longbows did have distinct and important differences from the later *Mary Rose* bows that cannot be ignored. The Waterford and Balinderry bows, as well as the earlier Danish and prehistoric bows, all shared some features with the *Mary Rose* bows, such as comparable lengths or width to thickness ratios, but they also had very important and significant

²³² Andrew Halpin, "Archery and Warfare in Medieval Ireland: A Historical and Archaeological Study", pp. 2:5-9.

Xenia Pauli Jensen, "Alliances and Power Structures in Southern Scandinavia during the Roman Iron Age", pp. 35-40.

J.G.D. Clarke, "Neolithic Bows from Somerset, England, and the Prehistory of Archery in North-western Europe", pp. 64-70; 89-95.

Clive Bartlett, Chris Boyton, Steve Jackson, Adam Jackson, Douglas McElvogue, Alexandra Hildred and Keith Watson, "The Longbow Assemblage", pp. 596-9.

Xenia Pauli Jensen and Lars Christian Nørbach, *Illerup Adal*, p. 49

Andrew Halpin, "Archery Material", pp. 546-52.

differences. These weapons were not simply interchangeable. The most important difference was simply that of scale. The *Mary Rose* bows were bigger and more powerful than the other bows. While they were not double the size of other bows, and in some cases the difference was only a few millimetres, they were significantly bigger. However, there may have been a simple explanation for why these earlier bows were smaller, and therefore weaker: earlier soldiers may simply have had no need of bows with the power of the *Mary Rose* bows. While the relationship between the design and use of the longbow will be explored in a later chapter, it is worth considering here that longbows were difficult weapons to use, and the larger and more powerful they were the harder they would have been to use.²³³ The knowledge and the techniques required to make a *Mary Rose* style longbow existed well before those bows were in widespread use. At the time these earlier bows were being made, there would have been no need to equip an archer with a bow of *Mary Rose* draw weight. The *Mary Rose* bows required a significant investment in time and training to use effectively, and early medieval cultures may not have had the means or the need to invest that time and effort into building and using their bows. In his chapter on the decline of Tudor archery, Strickland showed how maintaining the training required to shoot a *Mary Rose* bow was no small feat even for an early modern government.²³⁴ It would have been a non-trivial feat for an early or high medieval king to have established the training regimen across his subjects to have made a force of archers wielding *Mary Rose* style bows effective. The requirement for heavier longbows would also have been related not only the quality of armour available in the High Middle Ages, but also to the the frequency with which soldiers, especially common levies, wore armour at all. Against an unarmoured opponent, the difference in performance between a 70 lbs bow and a 150 lbs bow would have been largely academic since, after a certain point, the extra energy primarily contributed to the force of impact rather than to the range.²³⁵ There was no revolution in the design or implementation of the longbow, simply a slow improvement of the weapon as the need for heavier bows developed and the infrastructure to train and maintain archers to use those bows became more sophisticated.

The archaeological evidence for the longbow shows that yew has long been the predominant wood for making longbows, and that bows over 4 ft in length were present as far back as prehistory. The layering of yew sapwood and heartwood can be dated

²³³ See Chapter 7.

²³⁴ Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 405-6.

²³⁵ W.F. Paterson, *A Guide to the Crossbow*, (Oldland, 1990). pp. 30-32.

reliably as far back as the fourth century, while the characteristic D-shape of the *Mary Rose* bows existed at least as early as the tenth century, if not before. The *Mary Rose* bows were unique in their size since they were both longer and larger in cross-sections than any of the other surviving bows, but an approximation of the ratio of their width and thickness can be seen in many of the surviving Danish bows suggesting that this concept was not entirely new. All of this evidence taken together suggests that, while the *Mary Rose* bows were likely more powerful than earlier longbows, they were an improvement upon an already existing weapon and not a brand new invention. The *Mary Rose* bows can be used as a rough approximation for fourteenth and fifteenth-century longbows with some reservations. It is likely that the *Mary Rose* bows were slightly more powerful than their predecessors but that is a minor problem, easily accounted for with an appropriately sceptical methodology.

Chapter Three

The Bow in Medieval Art

When studying the medieval longbow, the single most significant problem facing historians is the limited archaeological evidence. While ample textual evidence for the use of the bow has survived, texts that include detailed descriptions of longbows are quite rare.²³⁶ What archaeological evidence that has survived can be used to trace a general history of the longbow, but the lack of evidence from the period of the longbow's greatest importance – the fourteenth and fifteenth centuries – is a problem for this type of argument. A third possible source of evidence, in the form of surviving medieval art, is a tempting substitute for the sparse archaeological record. Warfare was a popular subject in many medieval works of art including illuminated manuscripts, wood block prints, sculpture, and late medieval paintings. Many images of warfare included bows. There were hundreds of depictions of bows in medieval art.²³⁷ These images have provided historians with valuable insight into medieval archery, but the stylistic forms used by medieval artists make them a difficult source to work with. Medieval art cannot be used as a literal substitution for archaeological evidence and should not be treated as one. However, there is still much that can be learned from medieval images of bows, both about how these weapons were used and about how they were perceived. Since it would be impractical to examine every surviving medieval image of a bow, a selection has been taken of iconic or representative pieces, primarily from the High and Later Middle Ages. These images have been drawn from several different artistic styles seen throughout the Middle Ages and showed ways in which the depiction of bows both did and did not change over the centuries. This chapter will not only focus on images of longbows, but also engage with the problem of artistic representations of both the short bow and the composite bow. The frequency with which these latter two weapons appeared in medieval art has wider repercussions for using the medium as an archaeological substitute.

The study of medieval art as a means of understanding medieval military equipment is not a new idea. In the case of longbows, historians have long made use of medieval images to support their theories or contradict those of their contemporaries.²³⁸ Clifford Rogers, most recently, has used medieval images as evidence for his theory that

²³⁶Jim Bradbury, *The Medieval Archer*, (Woodbridge, 1985). pp.71-83.

²³⁷ Clifford Rogers, "The development of the longbow in late medieval England and 'technological determinism'", *Journal of Medieval History*, 37:3 (2011).p. 337

²³⁸ For example see:

Ewart Oakeshott, *The Archaeology of Weapons Arms and Armour from Prehistory to the Age of Chivalry*, (London, 1960). pp. 170-2.

Ian Pierce, "Arms, Armour and Warfare in the Eleventh Century" in *Anglo Norman Studies X: Proceedings of the Battle Conference* ed. Allen Brown (Woodbridge, 1987). pp. 237-255.

the short bow was used in early medieval Europe. He acknowledged the problems inherent in using medieval art and, rightly, rejected arguments that entirely discard art as a viable source. His argument was that among the plentiful images of medieval archery there were some that could be trusted, but he did not establish a metric which could be used to determine which images were reliable. This leaves open the possibility of only images that supported Rogers' argument being deemed 'reliable'.²³⁹

This methodology perfectly encapsulated the problems with medieval art as an archaeological source that this chapter will be addressing. At its core the issue hinges on whether historians can trust the 'accuracy' of medieval artists. Rogers' argument was that, while the specifics might not be trustworthy in all cases, the iconography of the image probably was.²⁴⁰ Medieval art certainly did not represent the world with high levels of realism. Human forms were often distorted and unrealistically proportioned, both to each other and to their surrounding environments. There were, of course, differences depending on the region and time period the images were made. The crux of the issue is whether the artists were trying to create realistic images of the world around them, or if they intended other priorities. While Rogers opened his argument by being quite restrained on the extent that medieval art could be trusted, he quickly moved on to using it to 'prove' that the longbow was not invented, or at least widely adopted, until the Later Middle Ages. He stressed the absence of 'unambiguous' longbows in High Medieval art but cited distinctions between 'short' and 'medium length' bows in those same images. The actual length difference in these latter two bow types, assuming Rogers was correct, would have been approximately 300 mm, or one foot. Finding this distinction in High Medieval art is placing a remarkable level of faith in the accuracy of these artists, which seems contradictory if possible longbow depictions were discarded as 'unreliable'. Rogers' argument declared that it was not about the actual lengths of bows in art, but his conclusions seem to have been at least partly based on those very same lengths.²⁴¹ Rogers was not alone in his more literal interpretation of medieval art. Enrico Ascani and Francesco Gorgo undertook a brief 'technical study' of a fresco in Celle Macra Italy, which estimated the overall length of the longbows by comparing the lengths in the images, and then comparing that to the average height of an Italian man in the fifteenth

²³⁹ Clifford Rogers, "The development of the longbow in late medieval England and 'technological determinism'", pp. 327, 336-40.

²⁴⁰ Ibid. pp. 336-7.

²⁴¹ Ibid. pp. 336-40.

century.²⁴² While an interesting study, this work placed a lot of faith in the realism of the image in question to support their conclusions.

The following paragraphs will examine several images of medieval bows thematically by examining what the repeated use of different types of bows in art suggests about both the weapon and the artists who depicted it. There has been a tendency among historians to expect medieval depictions of equipment to approximately mirror developments contemporary to the artists who made them. While it is clear that medieval artists depicted historical figures with weapons and armour contemporary with the image's creation, and not the image's subject, this has at times led to historians forgetting that they should remain critical of these images. The idea that improvements in medieval technology were reflected in medieval images of those technologies fails to fully understand the complexities of medieval art. This thesis only considered sizes in terms of the general impression they give the viewer. No absolute lengths were measured for this work, nor will any be discussed. The first subject that is covered is images of the short bow, followed by the longbow, then the composite bow, and finally this chapter concludes with discussions what historians should try to learn from medieval images of bows.

The Short Bow

The mid-ninth-century *Stuttgarter Psalter* included what was very likely the earliest depiction of a medieval European bow. Made somewhere near Paris, it is one of the best surviving and finest Carolingian manuscripts.²⁴³ Among its illuminations were two images of archers, one was hunting while the other was shooting a holy man who had his arms raised and a halo around his head. These two scenes had similar artistic styles. The colours and several of minor details were different, however, which suggests they could have been made by different artists. The hunting figure's bow [Plate 15] was quite small, probably less than half his height overall. It had very slightly reflexed nocks and was of a uniform cream colour. While the bow was quite small, the image as a whole had several distortions that suggest that accuracy of proportions was not the highest priority of the artist. Most obviously, the archer's right hand was far too large and had one significantly elongated finger. Additionally, the male deer, which had an impressive full rack of antlers, was significantly smaller than the archer. The other archer had a bow

²⁴² Enrico Ascani and Francesco Gorgo, "A Technical Study of the Fresco in the 'St. Sebastian's Chapel' Celle Macra, Italy", *Journal of the Society of Archer-Antiquaries* 42 (1999). p. 86.

²⁴³ Stuttgart, Württemberg State Library, Cod.bibl., fol.23, f. 012v; 021r

that was slightly larger than that of the first archer. This bow, while still relatively small, appeared to be just over half his height in length. Again, the bow had slightly reflexed nocks but was made of what looked like a slightly darker coloured wood. This image also had significant size distortions. Both the archer's right hand and the arrowhead on his arrow were approximately the size of his head.

These two images provided evidence for the use of the bow in Carolingian France, but whether they should be treated as evidence for the 'short bow' is not clear. The severe distortion of the images means interpreting the scale literally is impossible. One would not look at these images and assume that Carolingian France was filled with large handed archers who shot their targets from nearly adjacent to them. Similarly, literally interpreting the size of the bows requires making assumptions about the intentions of the artists that there is no evidence to support. Whether the artists who made these images intended to show small bows in the hands of their characters, or simply made the bows small for another reason, is impossible to know for certain. That does not mean that these images cannot be used to support an argument supporting the idea of a Carolingian short bow, but that argument cannot rely on these images alone for its evidence.

Perhaps the most famous images of medieval archery were depicted in the *Bayeux Tapestry*. The *Bayeux Tapestry* was made sometime during the late eleventh or early twelfth centuries and depicted William the Conqueror's campaigns in Brittany and England.²⁴⁴ The section devoted to the Battle of Hastings (1066) contained the majority of the archers. Most of the archers were shown on the side of the Normans but there was one lone Anglo-Saxon archer. There were several interesting figures included in the tapestry, perhaps most notably the Norman horse archer shown during the pursuit, but the detail that has drawn the most attention is the fact that the bows shown in the Tapestry were quite small. The best example of this is a cluster of four Norman archers [Plate 16] where each was shown with a bow perhaps a third his height, and drawn only to the middle of their chest.²⁴⁵ It certainly looked as if the artists who made this were attempting to show a short bow being used by both the Normans and the Anglo-Saxons, as the lone Anglo-Saxon archer was nearly identical to these four. Three of these bows appeared to have a slight recurve to them, as the bows bent away from the archers near the nocks. This feature was normally indicative of composite bows, which will be

²⁴⁴ Lucien Musset, *The Bayeux Tapestry*, trans. Richard Rex (Woodbridge, 2005). pp. 14-7.

²⁴⁵ *Ibid.* pp.234-5.

discussed later, and it is not clear why these bows were made in this shape. The majority of the archers in the tapestry were actually figures in the borders. These figures [Plate 17] present an interesting contrast to the figures in the main narrative. Their bows were all approximately the same size as the archers wielding them, with some variation, which could be mean they were meant to be longbows. However, the border figures' scale is quite different to the central figures. The border figures were tiny compared to the main figures but they were all still approximately in proportion to each other. Given the general distortion of the tapestry as a whole, it seems unfair to declare that the figures in the central panels were accurate enough to draw conclusions about their bows from, but the marginal figures were too distorted to do the same.²⁴⁶

The *Bayeux Tapestry* was almost entirely unique in its artistic style which means it is practically impossible to resolve these problems by comparing it to other similar works of art. (It was technically not even a tapestry as the images are embroidered on rather than woven.) No other similar piece of medieval art has survived in such a complete form to the modern day. There are a few fragments of Scandinavian embroidery that were of a similar style to the *Bayeux Tapestry*, but even they only shared a few features. This very limited pool of art objects to compare it with makes establishing an artistic context for the *Bayeux Tapestry* virtually impossible and thus judging the 'accuracy' of its art is essentially non-viable.²⁴⁷ There has also already been some scholarly discussion as to the symbolism of some of the weaponry wielded in the tapestry. In a few scenes important figures, including Bishop Odo and Duke William, were shown wielding what is clearly a wooden club, a very unusual weapon for the time. This was almost certainly intended as a symbolic indication of status rather than historical reality. For example, William was shown wielding the wooden club in the famous scene where he took his helmet off to prove he was alive and prevent his army from fleeing.²⁴⁸ It is highly improbable that William would actually have been wielding what was essentially a large stick as a weapon; a far more likely explanation is that the club was a symbolic representation of his authority.²⁴⁹ While the bows in the tapestry were not as obviously out of place as a wooden club was, the fact that there was already reason to believe that the artist did not intend literal interpretation of the weapons in the Tapestry should warn historians against doing so. That the *Bayeux Tapestry* effectively

²⁴⁶ Ibid. pp. 250-3

²⁴⁷ Ibid. pp. 20-3.

²⁴⁸ For example, see *Bayeux Tapestry* scene 49.

²⁴⁹ P.F. Thorne, "Clubs and Maces in the Bayeux Tapestry", *History Today* (October, 1982). pp. 49-50.

existed in artistic isolation has made it a problematic basis for an argument about the specific details of its images. One can certainly argue that the bows shown in the *Bayeux Tapestry* were remarkably small, but the logical leap to arguing that the actual bows used at Hastings were equally small does not have a firm basis in reality.

The argument for artistic evidence 'proving' the transition from short bow to longbow relies on the core idea that a clear change was evident between images from before the advent of the longbow and those after. While this chapter has pointed out that early images of bows were not entirely reliable, it is still indisputable that they showed quite short bows. Depictions of short bows in art continued to appear in art even after the traditionally accepted period for when the longbow was adopted in England, that is, the reign of King Edward I (1272-1307).²⁵⁰ The *Queen Mary's Psalter* was made c.1310-20 and contained an impressive number of archery images in its margins.²⁵¹ The scenes were almost exclusively depictions of hunting and presented an interesting variety of activities and bow sizes. Only a minority of figures in the Psalter could be considered to have been using longbows. There was one hunting scene where a mounted figure was followed by a second man who was carrying what looks like a longbow over his shoulder and leading a pair of dogs [Plate 19].²⁵² This bow looked to be of comparable height to the figure carrying it. However, in most of the other images, and there were quite a few of them, the bows were much shorter than the archers wielding them.

The majority of archers in the margins of the Psalter were non-human. These figures were mostly grotesques with beasts for legs but there were also a few scenes of centaurs.²⁵³ The bows were not of a strange or impossible form, they were perfectly normal looking bows that happened to be quite short. None of the bows were drawn back, which leaves the answer to the question of whether they were drawn to the chest or the cheek ambiguous. It could be that the artist simply wished to avoid the awkwardness of drawing the archer mid-draw that is visible in some works of art, see for example the *Martyrdom of St Edmund* [Plate 18] discussed later in this chapter.²⁵⁴ The archers' elbows were in the correct position for the bow to have just been loosed. It could also have been that the artist preferred to show the archers post-release as a better

²⁵⁰ Jim Bradbury, *The Medieval Archer*, pp. 75-83.

Michael Prestwich, *Armies and Warfare in the Middle Ages: The English Experience*, (London, 1996). pp. 131-5.

²⁵¹ London, British Library, Royal 2 B VII, f. 40v; 82; 137v; 146; 147v; 151v; 153; 161; 162v; 165;

²⁵² London, British Library, Royal 2 B VII, f. 151v.

²⁵³ London, British Library, Royal 2 B VII, f. 82; 137v; 146; 147v.

²⁵⁴ See Chapter 3.

representation of the action of hunting. The fact that these were hunting scenes is significant as well. It can be inferred from this that the bows depicted were hunting bows, which could be made quite small while still remaining effective. A hunting bow had to be carried in pursuit in the woods and only needed sufficient power to kill an unarmoured beast at a few hundred paces.²⁵⁵ There were a few 'battle' scenes shown in the Psalter but these were all of a grotesque with a bow battling an armoured knightly figure [Plate 20].²⁵⁶ These could have been intended as a figure, very much in the tradition of St George, hunting a monster. Although this interpretation raises further questions as, in these scenes, the bow was being used by the hunted, not the hunter, and it was clearly being used in self-defence against an armoured opponent. One would expect the more powerful longbow to be preferred in this situation. Some of the knightly figures also appear to have been grotesques as well, which further confuses the purpose of these scenes.

The context in which the bows were used by the various figures in the Psalter is very important to our understanding of what the artist intended them to look like, but complicated by the fact that what the artist was drawing was not always obvious. It may have been significant that a piece of art made after the accepted advent of the longbow clearly showed an abundance of bows one would not call longbows. It could be that the longbow was not widely used in hunting in this period or, perhaps more simply, it could be that art was not always a realistic depiction of the time period it was made in. The fact that many of the scenes in the Psalter were clearly fantastical in nature does suggest that realism was not the artist's priority. In fact the only image showing a longbow was also the most mundane: that of a noble hunter and his retinue. The images in the *Queen Mary Psalter* suggest that medieval artists included the short bow in their drawings even during a time when historians have agreed the longbow had been widely adopted in England, if not elsewhere in Europe. It could be that the image of the short bow had some enduring popularity with artists throughout the Middle Ages regardless of the fact that it was not used in contemporary warfare. While that is certainly a speculative argument, it seems no more speculative than believing that these images were intended as literal representations of the artists' contemporary world.

The martyrdoms of several saints featured arrow shots as an important component, and images of these martyrdoms provide a wide selection of medieval

²⁵⁵ Tim Baker, "Bow Design and Performance" in *The Traditional Bowyers Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). pp. 1:78-80.

²⁵⁶ London, British Library, Royal 2 B VII, f. 137v; 146; 147v; 165.

archery scenes. Images of three of these saints will be covered in this chapter, the first of which is St Ursula. St Ursula, along with one thousand virgins, was martyred by a rampaging pagan army and she was killed by a single arrow shot to the heart.²⁵⁷ This arrow, and the archer who shot it, were not always shown in images of her martyrdom. An image of Ursula's martyrdom in the Wallraf-Richartz Museum in Cologne, which dates from between 1455 and 1460, [Plate 22] presents an interesting point of comparison with the *Bayeux Tapestry*.²⁵⁸ Specifically, the bows in the St Ursula image appeared to be of approximately the same size as those from the Tapestry, with respect to their archers. The comparison is not perfect, as the St Ursula martyrdom was a much later work in a different medium but the impression they both give is quite clear. The drawn bows were even of a similar shape to the ones from the *Bayeux Tapestry*. St Ursula was supposedly massacred by the Huns, and while in this image the archers' attire was not particularly Hunnic, there were indications that the artist probably meant for them to seem foreign to the viewer. This could explain why the image includes short bows. The bows could have been intended to look like composite bows, which were usually favoured by the peoples of the Russian steppes including the Mongols, Turks and Huns.²⁵⁹ Composite bows were significantly smaller than longbows, usually no longer than four feet in length. If the artist was trying to give an impression of composite bows they did not do a very good job of it. Composite bows did not generally have the kind of clear colour distinction shown in the image and tended to have more of a curve to their shape.²⁶⁰ These bows were a confusing mix of design features that do not particularly make sense when taken together. It is also worth considering that many of the more composite design elements seen here were also present in the *Bayeux Tapestry*, so if someone was to argue that these bows were intended to be composite, the same possibility must be considered for the bows in the *Bayeux Tapestry*. If, instead, the artist intended for these to be short wooden bows, there is the problem of determining why an artist would have shown this style of bow so late in the Middle Ages. This image was painted after the end of the Hundred Years War (1337-1453), when the longbow's

²⁵⁷ "St. Ursula (Christian Martyr)", *Encyclopaedia Britannica*, <http://www.britannica.com/biography/Saint-Ursula> [Accessed 23/9/15].

²⁵⁸ Anonymous, Legend of St Ursula; Return to Basel, c. 1455-1460, Collection of Ferdinand Franz Wallraf, Cologne

²⁵⁹ Jim Hamm, "Recurves" in *The Traditional Bowyers Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). p. 2:167.

Gad Rausing, *The Bow: Some Notes on its Origin and Development* (Manchester, 1967). pp. 149-151
Matthew Strickland and Robert Hardy, *The Great Warbow: From Hastings to the Mary Rose*, (2005; repr. Somerset, 2011). pp.109-12.

²⁶⁰ Jim Bradbury, *The Medieval Archer*, pp. 12-4.

reputation would have been well established even outside the kingdoms involved in that conflict. What this image demonstrated was that the problem of interpreting what artists intended by their use of short bows was not simply a problem of early and high medieval art. Short bows continued to be included in art in the Later Middle Ages, and these images have to have had some kind of explanation for why they included a bow that was almost certainly not used by contemporary archers.

St Sebastian was a frequent subject of late medieval art, and the scene most commonly depicted was him being shot by Roman archers while tied to a wooden post.²⁶¹ One interesting and unusual version of this scene was a German woodcut made c.1472 which is currently in Munich [Plate 24]. It was hand coloured and the page was half image, half text. It depicted three archers, two with crossbows and one with a bow, as well as two onlookers.²⁶² What was particularly intriguing about this image was that, like with the St Ursula image, the bowman most closely resembled the archers from the *Bayeux Tapestry*. While there were understandably some minor differences which were the result of these two images having been made centuries apart and in different mediums, the similarities were almost uncanny. The stance of the archer in the Martyrdom closely mirrored those of the Norman archers in the *Bayeux Tapestry*. Even more unusually, the bow he was using was nearly identical to the bows from that same tapestry. The bow was nearly half as tall as the archer and had the strange recurve element which was present in the *Bayeux Tapestry* figures. While recurved bows were certainly not unknown in depictions of the Martyrdom of St Sebastian – they were possibly even more common than longbows, especially in Italian works – the bow shown here much more closely resembled the *Bayeux Tapestry* bows than it did any contemporary Martyrdom image.²⁶³ The appearance of a bow so similar to the *Bayeux Tapestry* bows several hundred years after the Tapestry was made raises a few questions. It challenges the idea that the artistic representation of the bow in Europe mirrored the technological development of the same weapon. It is possible this image was a deliberate reference to the *Bayeux Tapestry* but it is very unlikely. A late medieval German woodcutter using a high medieval 'tapestry' that went entirely unmentioned by

²⁶¹ “St. Sebastian (Christian Martyr)”, *Encyclopaedia Britannica*.

<http://www.britannica.com/biography/Saint-Sebastian> [Accessed 23/9/15].

²⁶² Anonymous, Martyrdom of St. Sebastian, c. 1472, Staatliche Graphische Sammlung, Munich

²⁶³ For examples see:

Piero de Pollaiuolo, Martyrdom of St. Sebastian, c. 1475, National Gallery, London

Albrecht Dürer, Martyrdom of St. Sebastian, c. 1495, British Museum, London

Albrecht Altdorfer, Martyrdom of St. Sebastian, 1509-1516, St. Florian's Priory, Sankt Florian

Pietro Perugino, Martyrdom of St. Sebastian, 1505, Church of St. Sebastian, Panicale

contemporaries as a reference seems improbable.²⁶⁴ Instead, it was more likely that this was a medieval art style that had only a minor concern for realism in its depiction of weapons. St Sebastian was clearly the primary focus of this image and was shown towering over the other figures. His body and face contained much more detail than those of his attackers. It was his holy suffering that the viewer was meant to focus on.

While military historians may wish that the chief priority of medieval artists was to accurately represent the practical realities of their world that does not mean it was so. The emotional and spiritual elements of art were, almost certainly, more important to the medieval artist than mere temporal realism. This is why it is problematic to expect medieval art to function as a replacement for a missing archaeological record. When considered beside the nearly contemporary image of St Ursula, it looks as if this type of short bow was a popular way to represent the weapon in art during the Middle Ages. It could be that this was considered a simple and effective way to portray a bow with minimal effort when the artist was not particularly interested in the accuracy of the weapon used in their work. Tracing a continuous history is probably too speculative but it is worth considering that this kind of short bow would have been relatively quick and easy to paint which could explain why it periodically appeared in medieval images from several different regions of Europe that were made in different centuries.

The Longbow

Clifford Rogers pointed out that, in addition to the short bow being common in early and high medieval art, there were no longbows in medieval art before the High Middle Ages.²⁶⁵ Instead of discussing non-existent early medieval images of longbows, the following paragraphs will cover several images of high and later medieval longbows. These will be considered firstly in the context of whether Rogers' high medieval 'middle-length' longbow could clearly be distinguished in the art, especially in contrast to late medieval images, and secondly in an examination of the trends in depictions of medieval longbows.

Although much rarer than images of St Sebastian, images of St Edmund are another good source for depictions of bows in art. St Edmund was a ninth-century saint and the king of East Anglia. He was martyred by the Great Heathen Army in 869. His

²⁶⁴ Lucien Masset, *The Bayeux Tapestry*, p.14.

²⁶⁵ Clifford Rogers, "The development of the longbow in late medieval England and 'technological determinism'", pp. 337-8.

death was first mentioned in the *Anglo-Saxon Chronicle*.²⁶⁶ While the exact method of his death is not clear – the aforementioned Chronicle simply said when he died and provided no further detail – the usual form his martyrdom took in medieval art was of him tied to a tree and shot repeatedly with arrows. In one of these depictions, dating from the mid to late thirteenth century [Plate 18], a single archer was shown wielding a bow of greater size than those seen in the *Bayeux Tapestry*.²⁶⁷ While the image certainly had some stylized elements the characters were all approximately the same size. The bow was shown being drawn to the chest, rather than the cheek, but given the odd angle of the archer's elbow and head during this draw it seems the artist may have struggled to depict what an archer firing a bow would have looked like. It is also possible they did not wish to obscure the face of the archer with the hand or string of the bow. The archer's elbow broke the border of the image, something nothing else did, possibly indicating some trouble with the drawing. The bow shown was of comparable length to the height of the figures, certainly if the bow was not bent it would have been, which is indicative of a longbow.

If this image is accepted as an accurate substitution for reality, this is convincing evidence of a longbow in use. Whether this represented a *Mary Rose* style longbow or one of the type Clifford Rogers labelled the 'middle-length longbow' is impossible to determine from this image.²⁶⁸ The bow was of an impressive thickness, which would have been indicative of a powerful longbow. Even if the weapon this image was based on was not as long as a *Mary Rose* bow, the thickness of the bow would be indicative of a powerful weapon.²⁶⁹ It would be inconsistent to trust the accuracy of the weapons length without applying a similar level of trust to its thickness. However, this image's purpose was to show the martyrdom of a saint, not to accurately depict the minutia of the weapons used.

A very similar style and size of bow was found in the near contemporary *Lutrell Psalter* image of archers shooting at butts [Plate 33].²⁷⁰ These bows appeared to be identical to the Martyrdom bow. The archers in the background waiting to shoot had bows that were exactly as tall as they are. The lengths of the bows relative to their archers appeared to differ depending on the figure in the *Lutrell Psalter* image, however,

²⁶⁶ *Anglo-Saxon Chronicle* trans. G. N. Garmonsway, (1953, repr. London, 1972). pp. 70-1.

²⁶⁷ London, British Library, Royal MS. 2, B vi. f. 10.

²⁶⁸ Clifford Rogers, "The development of the longbow in late medieval England and 'technological determinism,'" pp. 324-6.

²⁶⁹ Tim Baker "Bow Design and Performance", pp. 1:51-3.

²⁷⁰ London, British Library, Add MS 42130, f. 147v.

ruining any hope of establishing a fixed length for these bows. The archers who were shooting, and the archer standing in the middle of the image, had bows that looked much smaller than the bows of the archers who were not shooting. The thicknesses of the bows were also quite varied. The thickest bow was as thick as the archer's wrist, while other bows were half that thickness or less. These two near-contemporaneous images were representative of artists' desire to depict archers firing large bows, but whether these were six foot long bows or five foot long bows cannot be determined from the images.

The *Holkham Picture Bible*, which has been dated to sometime in the first half of the fourteenth century, included in its fortieth folio an interesting image of two archers in the middle of a battle scene [Plate 25].²⁷¹ The archers were not prominently positioned; one of them had both his body and part of his bow obscured, while the other was at the edge of the page and remained completely visible. The bow's lengths were difficult to determine exactly but they were not short. They were possibly of different lengths. The archer on the left looked to have a longer bow than his counterpart but the archer on the right's bow was drawn further. The artist could have struggled with the difficulty in keeping size consistent over two different degrees of bend in the bows. The longer bow looked nearly straight while the shorter bow was curved as the archer neared the completion of his draw.

The interesting part of this image was in the construction of the bows, not their length. The bows in this image were not smooth. They had knobs and protrusions along their backs that protrude quite significantly. While it is impossible to say exactly what these were intended to be, a likely explanation is that they were knots in the wood. When carving a piece of wood into a bow, it was common for bowyers to make the area around a knot thicker than the rest of the bow. A knot could have been a point of weakness in a bow where cracks and fragmentation could have occurred, so it required extra reinforcement. If this was well done it did not have to have a significant negative impact on the bows' performance and could actually help its durability. Yew, the traditional wood for longbows, often has quite a few knots and so it was a reasonably common feature of these bows to have this kind of workmanship on them.²⁷² Matthew Strickland argued that the protrusions in this image were simply an artistic flourish common to other images of the time.²⁷³ It was certainly an exaggeration of reality, the knots on

²⁷¹ London, British Library, Add MS 47682, f. 40

²⁷² John Strunk, "Yew Longbow" in *The Traditional Bowyer's Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). pp. 1:117-9

²⁷³ Matthew Strickland and Robert Hardy, *The Great Warbow*, p. 46.

wooden bows would hardly have been as pronounced as in this image, but it does not seem fair to entirely dismiss the image because of this. This image was an exaggeration, but it still showed that the artist was familiar with some aspects of bow making and design.

The second interesting thing to note about these bows was the colour distinction in the wood. Yew bows traditionally were made with a thin layer of sapwood along the back while the majority of the bow is made of heartwood. Yew sapwood is a very distinctive creamy white while the heartwood is much darker, which gives them a very noticeable colour difference.²⁷⁴ While there were distinct layers of colour on these bows, the creamy white and darker brown colours were on the opposite sides of the bow from what would be expected for a yew bow. Usually the sapwood would be along the back and building a yew bow backwards like this image showed would be largely ineffective. It is not clear why the artist chose these colours for the bows. It could simply have been artistic confusion on the part of whoever added the colour. It is also possible that a different type of wood than yew was intended, but if another wood was used one would expect the bow to have been only one colour. This image managed to capture an interesting detail in the crafting of wooden bows – the use of knots in bow wood – but also raised concerns about its accuracy with a significant error in the colouration of wooden self bows. This image presents a great example of how simply because one aspect of a work of medieval art was accurate, it does not mean that all, or even most, of the rest of the image was an accurate representation of reality.

Gaston de Foix's fourteenth-century hunting manual the *Livre de Chasse* contained one of the few detailed descriptions of a medieval longbow.²⁷⁵ It is fitting, then, that an early fifteenth-century copy of this manuscript contained one of the best images of hunting with a longbow from that century [Plate 23].²⁷⁶ The illumination was of two archers and a crossbowman hunting in the woods. The first archer had just loosed his weapon while the other was still drawing his bow. The bows appeared to be approximately two thirds of the height of the archers. There were some indications that the sizes of the bows should not be taken too literally. For instance, the trees were of approximately the same size as the archers standing near them. This created an image of archers hiding in what looks more like brush than a forest, and suggests that the relative

²⁷⁴ Ibid. p. 1:118

²⁷⁵ Gaston Phoebus, *The Hunting Book of Gaston Phébus: Manuscrit Français 616, Paris, Bibliothèque Nationale* ed. Marcel Thomas, François Avril and Wilhelm Schlag (London, 1998). p. 269

²⁷⁶ Paris, Bibliothèque Nationale de France, MS fr. 616, f. 11v

sizes were determined with little regard for realism. This image, like the one in the *Holkham Picture Bible*, included bows that had a clear colour distinction. In this case, there was a layer of black along the backs of the bows while the bellies were dark brown, which is more in line with the colour of yew heartwood. This image was closer to what a yew longbow would look like – the heartwood was correct – but the layer of black is difficult to interpret. The choice of black was confusing, since no wood commonly used in bowmaking has a natural black colour.²⁷⁷ The lathe on the crossbow in the image had the exact same colour distinction. While several types of wood were used in bows only one type of wood was used for crossbow lathes: yew. This layer of black is confusing since there is no obvious explanation for why an artist would have chosen to include it in their illumination. This image was not the only case where a layer of black was visible on a medieval bow.

An image of the French destroying Genoa from a late fourteenth-century copy of the *Chroniques de France ou de St Denis*, now in the British Library, included a French Bowman with a longbow of similar size to those in the *Livre de Chasse*.²⁷⁸ The belly of this bow was a creamy white colour while the back was black. In this case, the belly appeared to be the colour of sapwood while the back was the same confusing black. This presented a significant problem in interpretation. These images could be easily discarded as artistic error and ignored, but overall the images are carefully made and detailed, suggesting that they should not simply be cast aside as 'wrong.' It seems likely that the black along the back of bows was a deliberate choice on the part of the artist. There are two broad explanations that could account for this colour: firstly, some medieval bows could have been decorated with a black coloured backing layer, possibly paint, parchment, or another material. Alternatively, there could have been a trend among artists to colour bows this way. It is impossible to know for certain why the artists made these images this way, however, so these images will most probably remain an unanswered question in the history of medieval bow images.

The Battle of Crecy (1346) was the first great triumph of the English longbow.²⁷⁹ It should be no surprise, then, that images of that battle frequently included archers in prominent positions. One such example, from a late fifteenth-century copy of Jean Froissart's *Chronicles*, prominently featured the 'duel' between the English longbowmen

²⁷⁷ Ron Hardcastle, "Cutting and Seasoning Wood" in *The Traditional Bowyer's Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). pp. 1:19-29

²⁷⁸ London, British Library, Royal 20 C VII, f. 19

²⁷⁹ Jim Bradbury, *The Medieval Archer*, pp. 105-9.

and the Genoese crossbowmen [Plate 26].²⁸⁰ The English were shown on the right while their Italian enemies are on the left. Both weapons clearly received quite detailed attention from the artist. The longbows were approximately the same height as the archers. Determining how long they would have been is impossible due to the curvature of the bows, all of which were illustrated mid-draw, and also because of the spread legged stance taken by the archers making it difficult to estimate their height. Even with these caveats, though, it can be said that these were definitely intended to be longbows, based on both the size of the bows and when the image was made.

The longbows had a clear division in the colouration of their wood. The backs had a layer of cream colour, while the rest of the bow were a light brown colour. In this image, yew longbows were 'accurately' depicted, meaning that they match expectations of what these weapons ought to look like based on surviving evidence. The human characters were more distorted than those in the *Livre de Chasse* illuminations, but the weapons were much more detailed. This could reflect a specific priority of the artist, or the individual who commissioned the work, or it could just be a coincidence.

One of the most interesting things about this image is the equipment of the archers. Very little is known about the equipment of a medieval English archer and this image suggests that they might have been very well equipped.²⁸¹ The archers were all shown wearing some kind of chest armour; possibly mail, although equally possibly a coat of plates that had mail along the edges. They had metal helmets, plate knee protection, and, in several cases, swords. Even more significantly, the main hosts of the army shown behind the archers were wearing suits of full plate, which would not become widely used until the early fifteenth century.²⁸² These problems can be explained away as the artist depicting the battle in equipment contemporary to the creation of the image, and not the original battle. If this image is treated as representative of the mid-late fifteenth century rather than the mid-fourteenth century then these problems are easily ignored.

The two largest groups of soldiers shown in this image were archers and mounted knights. The image included three figures who could have been intended as foot soldiers, but they were more likely intended as fleeing Genoese crossbowmen. The number of

²⁸⁰ Paris, Bibliothèque Nationale de France, Fr 2643, f.165v

²⁸¹ Andrew Ayton, "Arms, Armour, and Horses" in *Medieval Warfare* ed. Maurice Keen, (Oxford, 1999). pp. 198-208.

²⁸² Claude Blair, *European Armour circa 1066 to circa 1700* (London, 1958). pp. 62-6.
Kelly, Francis, "A Knight's Armour of the Early XIV Century Being the Inventory of Raoul de Nesle", *The Burlington Magazine for Connoisseurs* 6;24 (1905). pp. 457-60.

mounted knights is strange since, while the French famously had a large number of mounted soldiers, the English army was composed almost entirely of dismounted foot soldiers.²⁸³ The mounted knights were depicted as faceless beneath their helmets while the faces and expressions of the archers were shown. This attention to the lower class soldiers is a testament to the contemporary fame of the English longbowmen and their role in the victory at Crecy.²⁸⁴ This image was one of the most realistic medieval depictions of the medieval English longbow, but it was also made when the period of the longbow's greatest dominance was coming to an end. If one were to accept the idea of medieval art accurately reflecting the development of the longbow, then it is hard to explain why what was possibly the greatest medieval image of the longbow would have been made so late. This idea is made even more complicated if one looks at a rather famous fifteenth-century image of the only battle of the Hundred Years War that can claim to be more well-known than Crecy: Agincourt.²⁸⁵

While Crecy was the first triumph of the longbow, the Battle of Agincourt (1415) was perhaps the greatest English victory of the Middle Ages, and its success has often been attributed to the archers that made up a vast proportion of Henry V's army.²⁸⁶ It was quickly immortalized in both art and text in chronicles. One chronicle illumination, found in a mid-fifteenth-century copy of Enguerrand de Monstrelet's *Chronique*, was one of the more confounding images of medieval archery ever made [Plate 27].²⁸⁷ The image showed the battle lines of the French and English as almost a mirror of each other. Archers were lined up in the centre firing at each other while mounted knights waited behind them. This image had several problems with it, including some rather pronounced historical errors. The French and English armies were both shown using the longbow, despite the fact that only the English used the longbow at Agincourt. The longbows in question, while obviously fairly long, were completely black and very thin. The two armies were shown as having been equal in size, when in fact the French army outnumbered the English. The archers were all shown in full plate identical to that worn by the mounted soldiers behind them, including the vision-obscuring helmets that would

²⁸³ Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 224-6.

²⁸⁴ For another example see:

Jean Froissart, *Chronicles*, trans. Geoffrey Brereton, (1968, repr. London, 1978). pp. 87-9; 93.

²⁸⁵ This image appears in many books on the subject of medieval archery. For example:

Jim Bradbury, *The Medieval Archer*, p.102.

Matthew Strickland and Robert Hardy, *The Great Warbow*, p. 288.

Robert Hardy, *The Longbow: A Social and Military History*, 3rd ed. (1978, Fort Worth, 1993). p. 129

²⁸⁶ Jim Bradbury, *The Medieval Archer*, pp.116-20.

²⁸⁷ Paris, Bibliothèque Nationale de France, Fr. 2680, f. 208

likely have interfered with the accuracy of the archers' shots.

This was certainly not an accurate reflection of the historical events of the battle, and this image is fascinating not despite but because of its inaccuracies. Anyone who read about Agincourt would have known that this image was not an accurate account of it.²⁸⁸ The image nearly mirrored the aforementioned image of battle of Crecy, except that both sides were shown using longbows. One possible theory about weaponry and warfare in medieval art is the idea that, while what is shown might not literally show what happened, it at least reflected something that contemporaries believed could have happened. This image presents a possible challenge to that idea. This level of error about a famous and well known battle, in an image that was made soon after that very battle happened, in a chronicle that included an account of that same battle, suggests that the average medieval reader would have known this picture was wrong. For example, the text of the *Chronique* explicitly mentioned that the English archers in the battle wore barely any armour, and this image showed them in full plate.²⁸⁹ This is an engaging image, lovingly made, with an appealing backdrop, and it would probably have been appreciated by contemporaries as a piece of aesthetically pleasing art, not as a work of history. This image is fantastical in its depiction of a famous battle, and medieval readers almost certainly did not believe that it was accurate. A testament to just how unusual this image was, and how difficult its interpretation has been, is that Robert Hardy included it in his book *The Longbow* and incorrectly implied it was a depiction of a battle from the War of the Roses (1455-85). If the image is isolated from its original context, it certainly would fit better in the War of the Roses, as English fighting English would explain several of its problems.²⁹⁰

The longbow also appeared in several images of the martyrdom of St Sebastian. German born artist Hans Memling painted a particularly detailed martyrdom in c.1475, while he was resident in Bruges [Plate 28].²⁹¹ The painting showed two archers, St Sebastian, a slightly obscured onlooker, and a backdrop of a coastal city. One archer had just loosed his bow while the other was stringing his. The bows looked as though they would have been about the height of the archers if they were unstrung. The wood of the bow on the left appeared to have a gradation of colour, but it was likely just the result of

²⁸⁸ Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 325-8.

Jim Bradbury, *The Medieval Archer*, pp.116-20.

²⁸⁹ Enguerrand de Monstrelet, *The Chronicles of Enguerrand de Monstrelet*, trans. Thomas Johnes (London, 1840). p. 341.

²⁹⁰ Robert Hardy, *The Longbow*, p. 129

²⁹¹ Hans Memling, *Martyrdom of St. Sebastian*, c. 1475, Musées Royaux des Beaux Arts, Brussels

shading along the belly of the bow. No similar gradation was visible on the other bow. There was an odd error in the string of the firing archer. If the line of the string is traced from the top of the bow to the bottom it ends well short of the nock. In general, the human forms were of very high fidelity while the bows were not quite as detailed. The fact that this kind of painting was being made at this time in the Low Countries is interesting, since the longbow is not a weapon often associated with that part of Europe. It was also rare for a medieval image of the martyrdom of St Sebastian to have portrayed exclusively longbows; most included at least one crossbow.²⁹² This could reflect a deliberate choice, on the part of the artist or whoever commissioned this painting, to choose a weapon commonly associated with England rather than one more closely associated with continental armies. The Low Countries was a region of frequent conflict between the English and French. From the mid-fifteenth century it was controlled by the Valois Dukes of Burgundy whose alliance with the English fell apart near the end of the Hundred Year's War.²⁹³ Still, the longbow's association with England above all other kingdoms made it a prime subject for subtle political expression in art. That the longbow could have been chosen not as a reflection of its military success but rather as an act of political loyalty is an interpretation that, while less obvious, is perhaps just as valid. It is also interesting at this stage to note that many of the images of England's most famous weapon discussed in this chapter were not made in England. Clearly, areas outside of England were aware of the longbow and included it in their art, even if they did not choose to adopt it as the primary weapon of their armies.

An image of St Sebastian that was made at almost the same time as the previous painting is currently located in the Wallraf-Richartz Museum [Plate 29]. This painting was by an anonymous artist, usually referred to as Meister der Heiligen Sippe d. J., who was working in Cologne sometime between 1460 and 1490.²⁹⁴ This was one of the finest paintings of the Martyrdom made in the Later Middle Ages. The seven bows in the painting were all of a very impressive size. Several were drawn, with the arrows pulled back nearly to the cheek. The fact that they stop just before the cheek can easily be excused as a desire by the artist to show the archers' faces without them being obscured by the arrows' fletching. The bows had a clear distinction between heartwood and sapwood, with the lighter coloured yew sapwood on the back of the bows. Horn nocks

²⁹² For examples see Plates: 10, 15, 16, 23, 24, and 25.

²⁹³ David Green, *The Hundred Years War: A People's History*, (Padstow, 2014), pp. 18-21.

²⁹⁴ Meister der Heiligen Sippe d. J., Martyrdom of St. Sebastian, c.1480, Bildarchiv & Wallraf-Richartz Museum, Cologne

could even be made out on the ends of the bow. None of these elements were completely unique to this work, though. What makes this work important was the thickness of the longbows. These longbows were not just tall, they were enormous. These were not the thin staves shown in the Crecy image, they were very thick, particularly at the grip. If any painting included longbows of the type found in the *Mary Rose*, it was this one. This was perhaps the most 'accurate' image of medieval longbows, and it was made in Germany at the very end of the Middle Ages.

The Composite Bow

The composite bow, while not a primary focus of this thesis, provides an important perspective on medieval artists' depictions of bows. Before the composite bow in art can be examined, however, it is important to first establish a basic familiarity with the weapon, how it was made, and its general history in Europe. This information will then be used to show how the composite bow's appearance in medieval art has intriguing, and possibly problematic, implications for historians' understanding of medieval military equipment.

The composite bow was first used in antiquity; its exact date and area of origin are unknown. It is usually associated with those Central Asian cultures that made extensive use of mounted archers, such as the Huns, Parthians, Mongols, Arabs, and Turks.²⁹⁵ What has generally been accepted, however, is that it was never widely adopted in Western Europe.²⁹⁶ While composite materials were used in crossbow lathes, they were never adopted for Western European hand bows. There have been many theories put forward as to why not, but none were without their problems. The most common is that the damp European climate would cause the glue that held a composite bow together to decay, thus ruining the weapon.²⁹⁷ The problem with this argument is that composite crossbows were successfully used across nearly all of Western Europe for centuries. Still, even without an accepted explanation of why it was the case, it is generally agreed that Western European soldiers did not use the composite bow. There is, however, some artistic evidence to challenge, or at least confuse, this widely held idea.

The unique design and materials of the composite bow make it possible for

²⁹⁵ Matthew Strickland and Robert Hardy, *The Great Warbow*, p. 99.

²⁹⁶ Jim Hamm, "Recurves", p. 2:167.

Gad Rausing, *The Bow*, pp. 149-151

Matthew Strickland and Robert Hardy, *The Great Warbow*, pp.109-12.

²⁹⁷ Helmut Nickel, "The Mutual Influence of Europe and Asia in the Field of Arms and Armour," in *A Companion to Medieval Arms and Armour* ed. David Nicolle (Cambridge, 2002). pp. 122-3.

Matthew Strickland and Robert Hardy, *The Great Warbow*, p. 112.

historians to reliably identify them in medieval art. Composite bows were primarily made of three materials: wood, horn and sinew. All of three were held together with glue and often the whole bow was wrapped in another material, like bark or paper. They had a fairly uniform method of construction. The core is made of wood with a layer of horn glued to the belly and sinew wrapped all around it, thickest along the back.²⁹⁸ This is not to say that all composite bows are identical. The type of wood, horn or sinew used could all vary and had significant implications for how the bow was made.²⁹⁹

While there were significant variations in the details of its overall design, the composite bow's general shape was quite distinctive. There is no need to debate length or colouration when it comes to composite bows as they could be made in a range of lengths and their protective layer could be painted any colour.³⁰⁰ The significant design feature of the composite bow that stood out in art was the shape of the *siyah*, which was the name for the working section of the limb of a composite bow. While individual cultures would create composite bows with different shaped *siyahs* there were some features that all composite bows shared. The *siyah* gave the composite bow a curved shape as it first bent back towards the archer, before curving forward near the nocks. The extent of this curve varied between cultures and sometimes the end of the curve could almost be at a right angle to the rest of the arm.³⁰¹ This sort of S-shape was unique to composite bows. Self bows could not be made in this shape. While longbows could have their nocks reflexed, this curve was relatively minor and only occurred at the tips of the bow. If an image had a bow with a pronounced curve to it, especially if the bow looked to change its curvature midway along its limb, that bow was almost certainly a composite bow.

Some bows had only a very slight curve near their nocks which could mean they were intended as composite bows, or could simply be an artistic anomaly. Several of these type of bows were already discussed in the Short Bows section of this chapter. This section will be focused exclusively on bows that were clearly intended as composite

²⁹⁸ Charles Grayson, "Composite Bows" in *The Traditional Bowyers Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). pp. 2:113-20.

Jim Hamm, "Recurves", pp.2:167-71

Karpowicz, Adam, "Ottoman Bows - An Assessment of Draw Weight, Performance and Tactical Use", *Antiquity* 81:313 (2007). pp. 676-80..

²⁹⁹ *Arab Archery*, trans. Nabih Amin Faris and Robert Potter Elmer (Princeton, 1945). pp. 10-16; 85-93.

Achim Boie and H.D. Bade, "Bows Used by the 'Huns,'" *Journal of the Society of Archer-Antiquaries* 38 (1995). pp. 28-31.

³⁰⁰ Helmut Nickel, "The Mutual Influence of Europe and Asia in the Field of Arms and Armour," pp. 122-3.

³⁰¹ B.W. Kooi, "Functioning of the Ears and Set-Back at the Grip of Asiatic Bows", *Journal of the Society of Archer-Antiquaries* 39 (1996). pp. 73-7.

bows, and not attempt to clarify those ambiguous images. The reason why a given bow was clearly intended as a composite bow, and not a wooden short bow, will be covered in the paragraph on the relevant image as each case has to be treated separately. This is because due to cultural differences in composite bow design, as well as differences in artistic style, no single overarching rule can be laid down to consistently determine when a bow was a composite bow and when it was not.³⁰²

The idea that composite bows were not widely used in Western Europe has been generally accepted by historians because there is hardly any evidence to support their use in Western Europe at all. There are some gaps in the available evidence where composite bows could theoretically have been used, since many mentions of bows in medieval sources simply described them as bows rather than as a specific kind of bow. An argument based on a lack of evidence is hardly a convincing one, though.³⁰³ There is no archaeological evidence of composite bows in a medieval Western European context. There is no evidence that it was widely used in armies, or even widely adopted by hunters and sportsmen. Certainly there is no positive evidence for its use as there is for the wooden longbow. As sparse as the latter's evidence is, evidence for the composite bow is even rarer, at least in Northern and Central Europe. There is evidence for the composite bow at the end of the Middle Ages. In particular, there is some textual and possible late medieval or early modern archaeological evidence for the composite bow in certain regions of Italy.³⁰⁴

Despite its rarity in textual and archaeological evidence the composite bow was included in many medieval works of art. While hardly irrefutable evidence for the use of the weapon this artistic evidence does raise a few questions. Military historians have used artistic evidence to supplement the limited archaeological evidence for arms and armour, particularly for the High Middle Ages.³⁰⁵ If the composite bow was not widely used in Western Europe, but does appear in its art with relative frequency, this could highlight a problem with this kind of methodology.

In several cases, there was a clear explanation for why an artist included a warrior with a composite bow. While there is no mystery in these images, they do present an important point of comparison with the images examined later. These images were all

³⁰² *Arab Archery*, trans. Nabih Amin Faris and Robert Potter Elmer (Princeton, 1945). pp. 10-16
B.W. Kooi, "Functioning of the Ears and Set-Back at the Grip of Asiatic Bows", *Journal of the Society of Archer-Antiquaries* 39 (1996). pp. 73-4.

³⁰³ Gad Rausing, *The Bow*, pp. 149-51.

³⁰⁴ Stefano Benini, "The Bow in Italy", *Journal of the Society of Archer-Antiquaries* 36 (1993). pp. 9-13.

³⁰⁵ Ewart Oakeshott, *The Archaeology of Weapons*, pp. 170-3.

either primarily of Balkan origin, or were depicting events from the Crusades. In either case, the composite bow was in the hands of a warrior of non-Western European origin and thus someone who actually might have used a composite bow. As an example, an image from a late thirteenth-century copy of William of Tyre's *Historia* included a depiction of the siege of Nicaea (1097), wherein one of the defenders had what was probably a composite bow.³⁰⁶ The defenders at Nicaea were Muslim – another defender was even shown with the crescent of Islam on his shield – so the defender having a composite bow was hardly unusual.³⁰⁷ In contrast, the crusaders were all shown wielding crossbows. The image was actually reasonably accurate to the style and type of equipment used by the forces present at the siege. This was not the only example of art depicting scenes from the Crusades placing composite bows in the hands of Muslims, but it is not necessary to examine every single instance in detail. This image was indicative of Christian knowledge of the composite bow, but does nothing to challenge historians' expectations about the use of composite bows by Christians.

A copy of the Hungarian *Illuminated Chronicle*, dating to c. 1360 and currently in National Széchényi Library in Budapest, contained several images of warriors with composite bows.³⁰⁸ An image in the opening letter of the Legend of St Ladislav featured two mounted warriors carrying composite bows. St Ladislav was an eleventh-century Hungarian king who was canonised in the twelfth century. He struggled through several civil wars while also successfully expanding the influence of the Kingdom of Hungary into neighbouring territory.³⁰⁹ This image appeared to show him hiding from an opposing army, possibly during a time of civil unrest. A second image in the same text depicted the Battle of Posada (1330), where Wallachian defenders were shown wielding composite bows against their Hungarian attackers [Plate 31]. These bows were clearly composite; they have the very distinctive curve indicative of *siyahs*. Andrew Ayton has suggested that, in the image of St Ladislav, the army depicted was a substitute for the armies of the Hungarian monarchy contemporary with the chronicle's creation.³¹⁰ Similarly, while the Wallachians were shown using composite bows against the Hungarians, Wallachia was a vassal state of Hungary, and so at least some of the time they would have used those

³⁰⁶ Paris, Bibliothèque Nationale de France, MS fr. 9084, f. 53r

³⁰⁷ Thomas Asbridge, *The Crusades The War for the Holy Land*, (London, 2010). pp. 63-74.

³⁰⁸ Budapest, Országos Széchényi Könyvtár, *Képes Krónika*, f. 146

³⁰⁹ "Ladislav I: King of Hungary", *Encyclopedia Britannica*,
<http://www.britannica.com/EBchecked/topic/327524/Ladislav-I> [Accessed 27/5/15].

³¹⁰ Andrew Ayton, "Arms, Armour, and Horses", pp.197-203.

bows to support the Kingdom of Hungary.³¹¹

These images were not the only evidence that suggests that the composite bow was used in Eastern and South-Eastern Europe during the Middle Ages.³¹² Western military historians have generally focused on the armies of France, Spain, Germany, Italy, and the British Isles. Areas east of the Danube have received only minimal attention. Hungary along with several of its neighbouring territories were a part of Christendom, and periodically participated in Western European conflicts; perhaps most famously, as Froissart was keen to remind posterity, the king of Bohemia died at Crecy in 1346. While evidence from Hungarian sources certainly cannot be used to prove anything about the use of composite bows in Western Europe, it is worth bearing in mind composite bows probably were used within the bounds of European Christendom. The occasional participation of Eastern Europe within the conflicts of the west, as well as their periodic conflicts with the German Emperors, could suggest that the composite bow, while not a primary weapon of warfare in Western Europe, was at least present from time to time at various battles and sieges.³¹³ The narrow focus often taken by military historians can obscure the role the 'fringe' of Europe played in the main conflicts of the west.

Perhaps the single most problematic source, and in many ways the inspiration for this section, was the *Morgan Picture Bible*. The *Morgan Picture Bible* was a collection of 46 folios, each of which depicted two scenes from the Old Testament. It was made in the mid-thirteenth century, possibly for King Louis IX (r. 1214-1270).³¹⁴ It was alternatively known as the *Maciejowski Bible* due to the name of its owner before the Morgan Library acquired the majority of the folios. Of the folios that the Morgan Library does not own, two are in the Bibliothèque Nationale de France and one is in the J. Paul Getty Museum in Los Angeles.³¹⁵ Included among the *Morgan Picture Bible's* folios were several battle scenes from the Old Testament which contained images of warriors wielding composite bows. The nocks of these bows were attached to the arms at a nearly ninety degree angle,

³¹¹ Maurice Keen, "Guns, Gunpowder, and Permanent Armies" in *Medieval Warfare* ed. Maurice Keen (Oxford, 1999). p. 281.

³¹² Robert Hardy and Matthew Strickland, *The Great Warbow*, pp.109-12.

³¹³ Jean Froissart, *Chronicles*, pp. 89-90.

Clifford Rogers, "The Age of the Hundred Years War" in *Medieval Warfare* ed. Maurice Keen, (Oxford, 1999). pp. 158-60.

³¹⁴ Daniel Weiss, "Portraying the Past, Illuminating the Present: The Art of the Morgan Library Picture Bible" in *The Book of Kings: Art, War, and the Morgan Library's Medieval Picture Bible*, ed. William Noel and Daniel Weiss (Baltimore, 2002). p. 14

³¹⁵ New York City, Pierpont Morgan Library, Ms M. 638
Paris, Bibliothèque nationale de France, MS nouv. acq. lat. 2294
Los Angeles, J. Paul Getty Museum, MS 16

strongly indicative of composite design. When examining the scenes featuring composite bows in this bible, it is important to establish if they were depicted in the hands of perceived enemies of Christians – essentially surrogates for Islam – or if they could be seen as showing the composite bow in the hands of characters that a Christian reader would have identified with. In some cases, these bows were placed in the hands of an enemy of the Jewish people and, as such, seen as a continuation of the practice of assigning composite bows as 'other' or 'foreign' weapons that was prevalent in Crusading images. For example, in the 'Death of Saul' there were two Canaanite archers shown wielding composite bows.³¹⁶ In the battle scene of 'David Sends a Letter to Joab' [Plate 34], in which Uriah is slain, one of Joab's soldiers was depicted with a composite bow.³¹⁷ This soldier would have been serving under King David, and so not likely to have been interpreted as an enemy of Christendom. There were two more images of composite bows that are significantly harder to interpret. In 'Lamech Kills Cain'³¹⁸ and in 'Jonathan Warns David' [Plate 35]³¹⁹, one character in both was shown carrying a bow that looked like it was meant to be composite. Most of the bows illustrated in the bible had a clear curve to them (indicative of composite construction) while in these two images, the curve was much more gradual and the reflex of the nocks less extreme. The bow shown in 'Lamech Kills Cain' had nocks were at 90 degree angles to the part of the bow they connected to, so it was probably intended to be a composite bow, but the rest of the bow had a curve closer to that of a self bow. Whether Lamech was meant to be an 'other' or not, especially in the scene of him killing Cain, is difficult to know and likely involves a glimpse into the mind of the medieval artist that is impossible to achieve. Jonathan's bow was probably a composite bow, but due to its shape it is less clear than other examples discussed in this chapter. It could theoretically be a wooden bow with very slightly reflexed limbs. This image once again showed a composite bow in the hands of an ally of King David, though.

The reason these images are significant, and not just a case of one book having unusual art, is that the *Morgan Picture Bible* is one of the most detailed and accurate medieval works in its depictions of high medieval arms and armour. It has often been pointed to for its detailed illustrations of mail, swords, shields, and helmets. These images have provided useful evidence for the state of medieval equipment before the

³¹⁶ New York City, Pierpont Morgan Library, Ms M. 638, f. 34

³¹⁷ New York City, Pierpont Morgan Library, Ms M. 638, f. 42

³¹⁸ New York City, Pierpont Morgan Library, Ms M. 638, f. 2

³¹⁹ New York City, Pierpont Morgan Library, Ms M. 638, f. 32

advent of plate armour.³²⁰ While a handful of composite bows in the hands of soldiers in this bible is not enough evidence to convincingly argue for the widespread use of the weapon in Europe, it should at least raise a few questions about how much historians can rely on the *Morgan Picture Bible's* accuracy. The composite bows are a question that requires an answer. Did this bible have a historically inaccurate weapon in its images, which could challenge the assumptions that have been made about the accuracy of other pieces of military equipment shown in the art? It is possible, since it was made during the reign of Louis IX, that the bible intentionally drew on the already established styles of Crusader imagery, and the artists used a weapon common to that conflict to better capture the Levantine setting of the Old Testament.³²¹ This line of argument is not without its flaws, particularly as it raises the question of what other items in the images could have been uniquely Syrian in nature. The fact that the composite bows were still in the hands of individuals wearing Western European armour is still problematic. It could be possible, maybe even likely, that composite bows were used in the Crusader States. In any case, there is a discussion worth having on the practice of using medieval art as evidence for the use of certain weapons during that same era. Even a source that seems as reliable as the *Morgan Picture Bible* is not without its complications.

While the *Morgan Picture Bible* is nearly unique in its the representation of composite bows during the High Middle Ages, composite bows began to appear much more frequently in European art in the Later Middle Ages. They became relatively common in images of the Martyrdom of St Sebastian. There are so many St Sebastian images that going through each one in detail would be tedious and provide little benefit. Instead, a broad survey will be taken of the shared features of images of the martyrdom of St Sebastian that included composite bows. Composite bows can be seen in Martyrdoms by Piero de Pollaiuolo [Plate 39] and Albrecht Dürer [Plate 30], both of which are particularly impressive and date to the end of the fifteenth century.³²² These were hardly the only examples of this trend and there were even several examples from

³²⁰ Ian Pierce, "The Knight, his Arms and Armour c. 1150-1250" in *Anglo Norman studies XV The Battle Conference* ed. Marjorie Chibnall (Woodbridge, 1992). pp. 253, 270.

Ewart Oakeshott, *The Archaeology of Weapons*, pp. 262-3.

Stephen N. Fliegel, "The Art of War: Thirteenth Century Arms and Armour" in *The Book of Kings: Art, War, and the Morgan Library's Medieval Picture Bible*, ed. William Noel and Daniel Weiss (Baltimore, 2002). pp. 83-4.

Matthew Strickland and Robert Hardy, *The Great Warbow*, p. 46.

³²¹ Daniel Weiss, "Portraying the Past, Illuminating the Present: The Art of the Morgan Library Picture Bible," pp. 15-6.

³²² Piero de Pollaiuolo, Martyrdom of St. Sebastian, c. 1475, National Gallery, London
Albrecht Dürer, Martyrdom of St. Sebastian, c. 1495, British Museum, London
Benozzo Gozzoli, Martyrdom of St. Sebastian, Collegiate Church, San Gimignano

the sixteenth century.³²³ These images were made in several regions of Europe, but by far the majority were Italian in origin, with Germany being the second most common. No martyrdom image included both a longbow and a composite bow. Every image that included a composite bow also included at least one crossbow. Why the artists chose to include composite bows is not clear. In the late fifteenth century, the bow was beginning its decline as gunpowder took its place, but it had never been dominant in any of the regions producing these images.³²⁴ St Sebastian was a Roman era saint, so it is possible that the composite bow was seen as a more appropriate weapon to depict in that context, but the fact that the archers were depicted as dressed in contemporary European styles and wielding contemporary crossbows means that an attempt at historical accuracy is not the most likely explanation. In the case of the Italian paintings, trade with Islamic regions in North Africa and the Levant could have caused an artistic influence which encouraged them to include composite bows.³²⁵ The inclusion of these bows could have been no more than an artistic flourish added by artists who had no reason to include the longbow in their art. However, the crossbows shown in these images were generally quite accurate, which could suggest that the bows were equally accurate, and therefore reflect the possibility of composite bows having been used in Italy and Germany at this time.³²⁶ There was some evidence to suggest that the composite bow had a continuous, if never dominant, use throughout the Middle Ages in Italy, at least. This art could simply be more evidence supporting the idea of Italian use of the composite bow.³²⁷ There does not appear to have been any similar German connection with the composite bow, so its presence in so many German images of the St Sebastian must remain a mystery for now.

Lessons from Medieval Art

This chapter has so far focused almost exclusively on the difficulties inherent in relying on medieval art to inform historians' understanding of the detailed reality of the Middle Ages, but there are areas where art is undeniably valuable. Archaeological items on their own do not provide information on their use. Art can show historians ways in

³²³ Albrecht Altdorfer, *Martyrdom of St. Sebastian*, 1509-1516, St. Florian's Priory, Sankt Florian
Pietro Perugino, *Martyrdom of St. Sebastian*, 1505, Church of St. Sebastian, Panicale

³²⁴ Holger Riesch, "Archery in Renaissance Germany", *Journal of the Society of Archer-Antiquaries* 38 (1995). pp. 63-6.

Matthew Strickland and Robert Hardy, *The Great Warbow*, p. 391.

³²⁵ Robin Fritze, *New Worlds: The Great Voyages of Discovery 1400-1600*, (Westport, 2002). pp. 30-52.

³²⁶ Gad Rausing, *The Bow*, pp. 149-51.

Jim Bradbury, *The Medieval Archer*, pp. 12-4.

³²⁷ Franco Carminati, "Piedmontese Archery", *The Journal of the Society of Archer-Antiquaries* 36 (1993). 49-50.

which contemporary people would have handled a given artefact. For example, in the case of longbows, art can show how bows were strung, drawn, and shot. There were several images of archery from the Middle Ages which contained figures in the act of what was, presumably, stringing a bow. The first of these was a marginalia figure found beneath Psalm 29 in the *Lutrell Psalter* [Plate 32].³²⁸ This image contained two figures, one was stringing a bow while the other spanned a crossbow. One end of the bow was near the archer's foot – the artist may have intended to show him standing on it – while he gripped the mid-section of his bow with one hand and adjusted the string on the nock near his head. The figures were clearly somewhat stylised; the archer's arrow was nearly as long as his leg with an arrowhead the size of his hand, but there was still an impressive amount of detail in the image.

Two images of the Martyrdom of St Sebastian also contained archers stringing their bows. The Martyrdom by Meister der Heiligen Sippe [Plate 15] and the Martyrdom by Hans Memling [Plate 28] each included a figure stringing his bow. These two figures were very similar to each other, and differed slightly from the figure in the *Lutrell Psalter*, but all three contained two nearly identical elements: the archer had one foot on one nock of the bow, while his hand was adjusting the string on the other. From there the images diverged. The two Martyrdom figures had the bow positioned so that the back of the bow faced them, while the Psalter figure had the belly of the bow pointed towards him. The figure in Hans Memling's Martyrdom was standing upright, but leaning over his bow while in the other Martyrdom, the man stringing his bow was crouching, or possibly kneeling. The similarities in these three images suggests that there was an established method of stringing a longbow in the Middle Ages, but there was also some individual variation in how best to perform those actions. It is worth noting that in the Martyrdom by Meister der Heiligen Sippe, the crouching figure was filling an empty space in the scene, and if he had been upright he would have been obscured by other figures, so it is possible he was painted in a crouched position for artistic convenience. In contrast, in Memling's Martyrdom, there were fewer figures and ample open space, so having the figure standing upright caused no major composition problems for the artist. In any case, the fact that there were similarities in depictions of how medieval archers strung longbows does suggest that there was something of an established method for performing this action. Seeing this style shown across several centuries lends credence to its accuracy. These images, and others like them, can inform historians about the

³²⁸ London, British Library, Add MS 42130, f. 56

mundane practice of archery.

Conclusion

The validity of using medieval art as a substitute for archaeological evidence is a complicated and interesting topic. In this chapter, evidence for the development of the longbow through art has been examined, as well as the possibility of Western European use of the composite bow. Composite bows were not a common feature of medieval art, but they were certainly not unknown to the medieval artist. What this means exactly, however, is debatable. The existence alone of the composite bow in art is not enough to completely contradict the lack of archaeological or textual evidence supporting the use of the composite bow in Europe. The complete absence of any good physical evidence is an insurmountable obstacle.³²⁹ Instead, the use of the composite bow in art should raise questions about the validity of medieval art as a stand in for other data. Medieval art has been used to bridge the archaeological gap in the study of longbows, mail, swords, plate armour, and many more aspects of medieval warfare. Historians have depended on these images to provide valuable evidence.³³⁰

The aim of this chapter was not to point out that this was a mistake. Far from it; medieval art is an invaluable resource to historians of medieval technology. Instead, it is to suggest that historians need to be careful in their use of these sources, and consider the possibility that technologies represented in these images may not have been widely used. An artist could have chosen to include a composite bow in his work, when it was probably not commonly used around him, for any number of reasons. The smaller size of the bow and the rather graceful curves of its form could have perhaps engaged an artist's imagination, but just as easily it could have been included for a reason that historians will never guess. This chapter was in part a challenge to the idea that the details of a medieval work of art might not have been completely correct, but the broad sweeping essence of the image was accurate. For example, advocates for the power of the longbow have pointed to images of longbow arrows piercing plate armour as evidence that, even if the archers did not kill knights at the specific battle depicted in the image, medieval contemporaries certainly accepted that bows could and did penetrate plate armour.³³¹ That composite bows were popular artistically in regions that did not generally use them

³²⁹ Gad Rausing, *The Bow*, pp. 149-51.

Jim Bradbury, *The Medieval Archer*, pp. 12-4.

³³⁰ Ewart Oakeshott, *The Archaeology of Weapons*, pp. 262-3.

³³¹ Robert Hardy, *Longbow*, p. 110.

should suggest that sometimes even the broad details can be questionable, if not outright wrong, and that there were more factors at work in the creation of these images than a desire to accurately depict a given scene to the best of the artist's ability.

The second purpose of this chapter was to call attention to the fact that, in the discussion of medieval European bows and crossbows, the fringes of Europe are often entirely neglected in favour of the traditionally dominant Western territories. The Balkan regions, especially the Kingdom of Hungary, were a part of Christendom, and they deserve more consideration beyond only those instances when a Western army marched through their territories. If a kingdom neighbouring Germany and Italy was using the composite bow, the reasons why it never crossed into those two regions are worth exploring. Often, the debate on the European use of the composite bow has been framed around a 'Christian versus Muslim' weapon division, or 'Western versus Eastern' division during the era of the Mongol Horde, which completely ignores this neighbouring Christian kingdom that was using this weapon.³³² The Hungarian evidence did not suggest that the French were secretly using the composite bow and historians simply never noticed. However, it did raise some questions about the traditional argument that the European climate was ill-suited for composite bows, on top of the fact that composite crossbows were widely used in Europe.³³³ The overly western focus of English language medieval scholarship has neglected this area, and its weapons technology, to the detriment of our understanding of medieval ranged warfare and the technologies used therein.

³³² Gad Rausing, *The Bow*, pp. 149-51.

Jim Bradbury, *The Medieval Archer*, pp. 12-4.

³³³ Helmut Nickel, "The Mutual Influence of Europe and Asia in the Field of Arms and Armour", pp. 122-3.

Matthew Strickland and Robert Hardy, *The Great Warbow*, p. 112.



Plate 15: Stuttgart, Württemberg State Library, Cod.bibl., fol.23, f. 021r



Plate 16: Bayeux Tapestry, Musée de la Tapisserie de Bayeux, Bayeux, Scene 51



Plate 17: Bayeux Tapestry, Musée de la Tapisserie de Bayeux, Bayeux, Scene 55-6.



Plate 18: *Martyrdom of St. Edmund, MS. Royal. 2, B vi, f. 10.*



Plate 19: *Queen Mary's Psalter, London, British Library, Royal 2 B VII, f. 151v*



Plate 20: *Queen Mary's Psalter, London, British Library, Royal 2 B VII, f. 146*



Plate 21: *Queen Mary's Psalter*, London, British Library, Royal 2 B VII, f.162v



Plate 22: *Anonymous, Legend of St Ursula; Return to Basel*, c. 1455-1460, Collection of Ferdinand Franz Wallraf, Cologne



Plate 23: *Livre de Chasse*, Paris, Bibliothèque Nationale de France, MS fr. 616, f. 11v

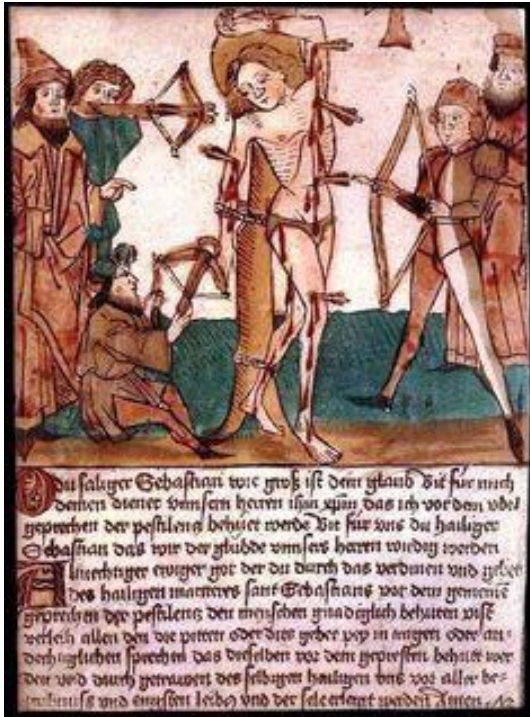


Plate 24: *The Martyrdom of St Sebastian* c. 1472 Woodcut, hand-coloured, 255 x 182 mm
 Staatliche Graphische Sammlung, Munich



Plate 25: *Holkham Picture Bible*, London, British Library, Add MS 47682, f. 40



Plate 26: Battle of Crecy, Paris, Bibliothèque Nationale de France, Fr 2643, f.165v



Plate 27: Battle of Agincourt, Paris, Bibliothèque Nationale de France, Fr. 2680, f. 208



Plate 28: Hans Memling, *Martyrdom of St. Sebastian*, 1475.



Plate 29: Meister der Heiligen Sippe d. J., *Martyrdom of St. Sebastian*, c.1480, Bildarchiv & Wallraf-Richartz Museum, Cologne.



Plate 30: Albrecht Dürer, *Martyrdom of St. Sebastian*, c. 1495, British Museum, London.



Plate 31: Budapest, Országos Szechenyi Könyvtár, *Képes Krónika*, f. 146.



Plate 32: Lutrell Psalter, London, British Library, Add MS 42130, f. 56.



Plate 33: Lutrell Psalter, London, British Library, Add MS 42130, f. 147v.

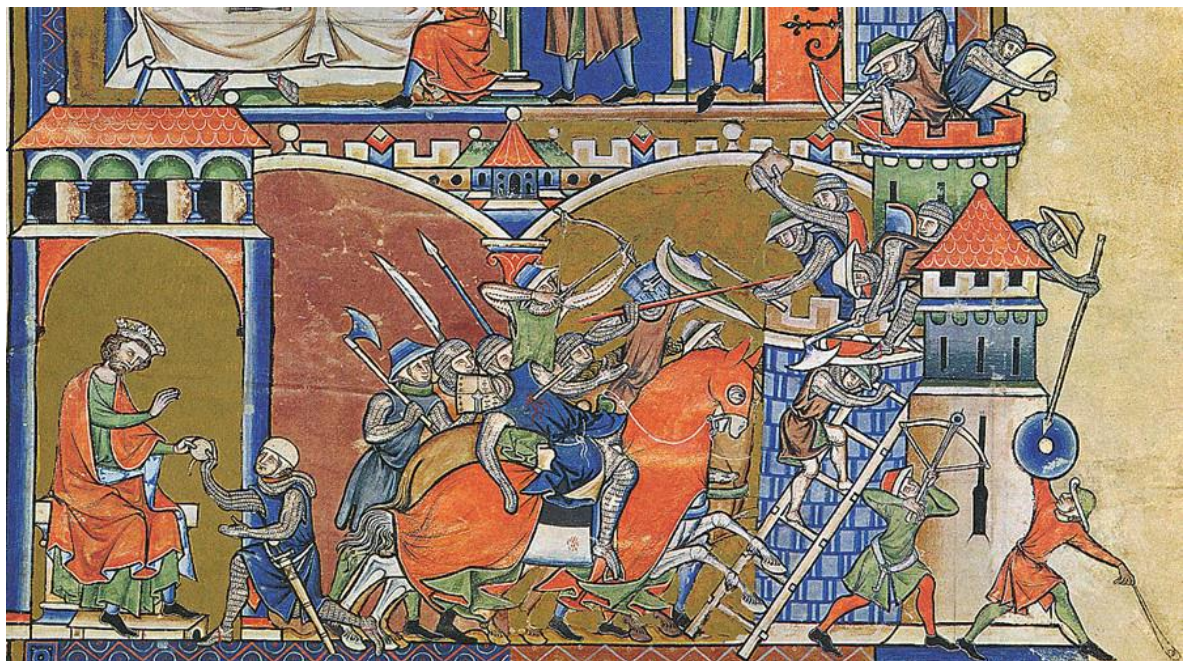


Plate 34: Morgan Picture Bible, New York City, Pierpont Morgan Library, Ms M. 638, f. 42, David Sends a Letter to Joab

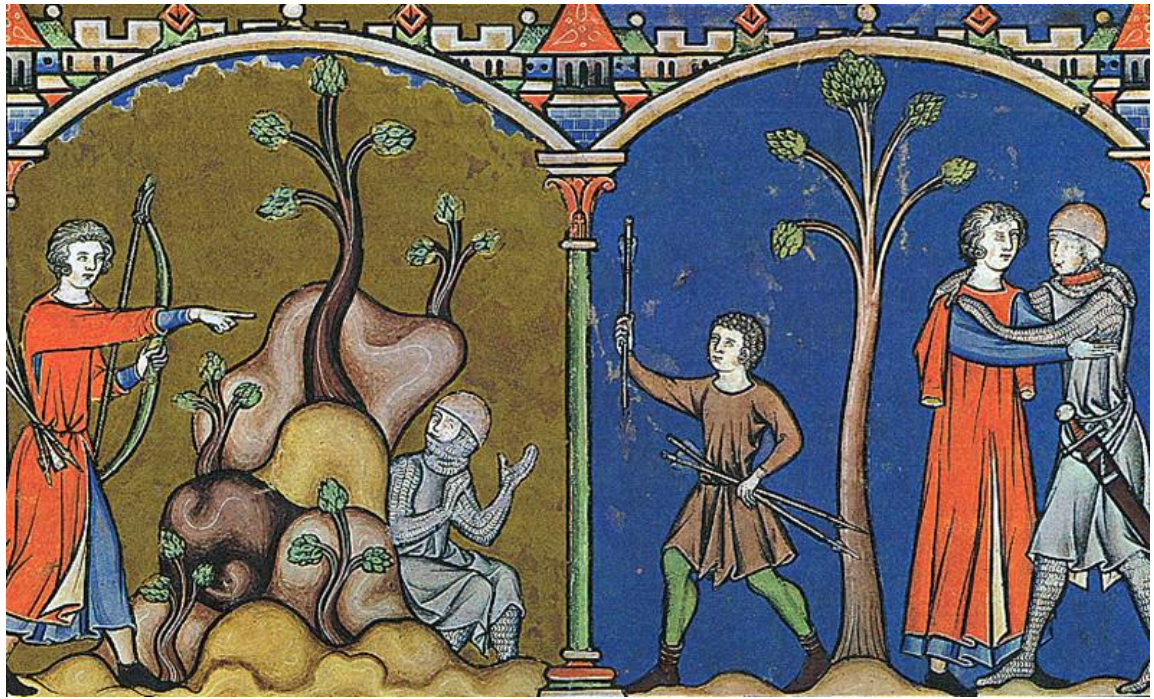


Plate 35: *Morgan Picture Bible*, New York City, Pierpont Morgan Library, Ms M. 638, f. 32, Jonathan Warns David



Bow and crossbow.
Bodleian Library, MS Bodley 264 fol 51v.

Plate 36: *Romance of Alexander*, Oxford, Bodleian Library, MS Bodley 264, fol 51v

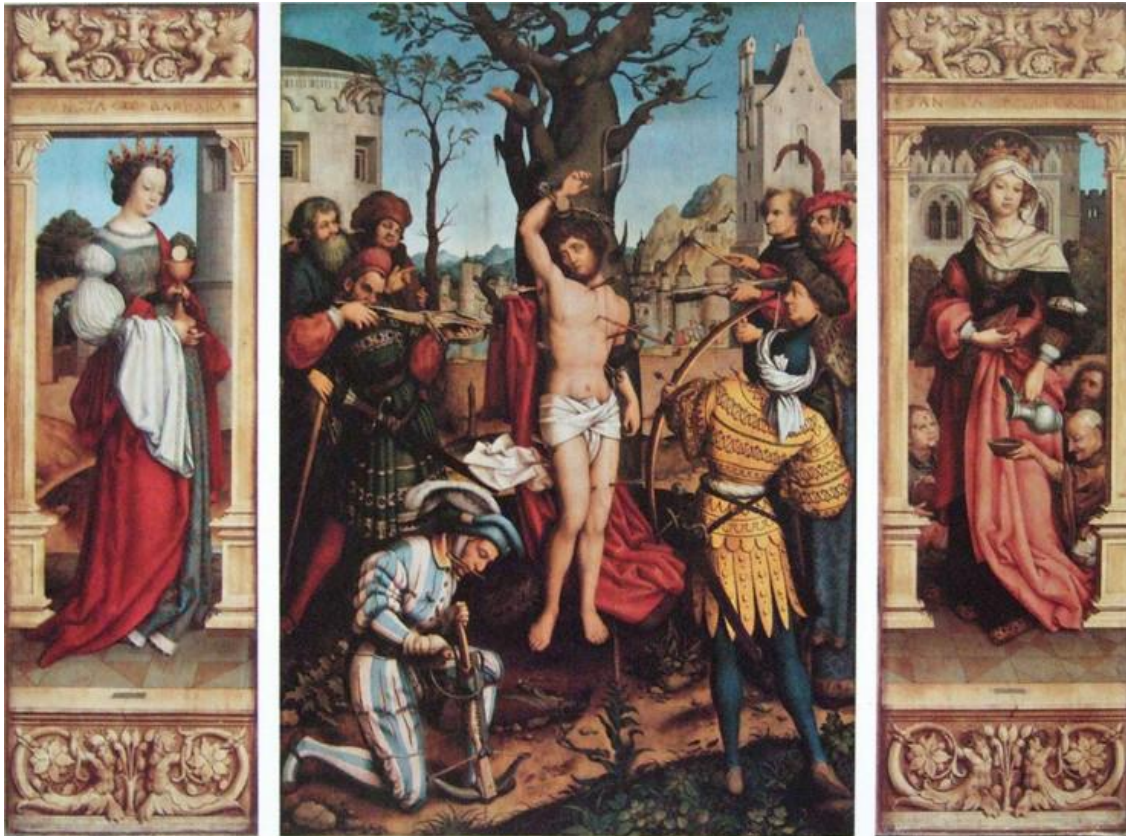


Plate 37: Hans Holbein the Elder, Martyrdom of St. Sebastian, 1516, Alte Pinakothek, Munich.



Plate 38: Pietro Perugino, Martyrdom of St. Sebastian, 1505, Church of St. Sebastian, Panicale



Plate 39: Piero de Pollaiuolo, Martyrdom of St. Sebastian, c. 1475, National Gallery, London.

Chapter Four

Crossbow Data and Methodology

Chapter Five will contain the analysis of the crossbow data collected as part of this thesis. Before that can be done, however, it is necessary to explain how the crossbow data for this thesis were collected, to cover the methodology behind the crossbow analysis in this thesis, and to briefly discuss two parts of the crossbow that were not included in the analysis. Previous works on the medieval crossbow drew on a relatively small proportion of archaeological examples to make their arguments. For example, Dirk Breiding's book *A Deadly Art* included only five crossbows that dated from before the middle of the sixteenth century.³³⁴ Breiding consulted and examined more crossbows than that, but many of those crossbows go largely unmentioned in the main text. Given that there are scores of surviving medieval crossbows, this was a very small sample size. This chapter will first explain the methodology used in the collection and analysis of the crossbow data used in this thesis. Next the data used in this thesis will be outlined to establish a basic familiarity with the archaeological record of the crossbow. Finally, an explanation will be provided for why two parts of the crossbow, the nut and the trigger, were left out of the analysis in this thesis.³³⁵

Methodology

The advantages to studying a relatively small sample of crossbows - i.e. less than twenty - are significant. It is much more manageable to study a relatively small number of items; each sample can be examined in detail personally by the author, and the author can ensure that they have acquired all the necessary information and that that information is accurate. The author does not have to struggle with vague museum catalogue descriptions or wonder if a published description might have been wrong, since all of the information was collected in person. It is also easier to maintain close contact with only a handful of museums or collections. The smaller sample size is also easier to manage when writing, since readers will not be overwhelmed with a plethora of similar but distinct crossbows, presented in dozens of complex charts. With a relatively small number of items to study, each individual crossbow could be written about in great detail; every aspect explored and compared to the other crossbows in the study. This

³³⁴ Overall Breiding discussed 28 specific crossbows in his book.

Dirk Breiding, *A Deadly Art European Crossbows, 1250-1850*, (New York, 2014). pp. 21-27; 35-65; 69-79; 84-91.

³³⁵ Josef Alm includes photographs of 16 specific crossbows from c.1200-c.1600 in his book. While some others are mentioned in his text, and certainly more were consulted, these do represent the main examples he uses in his discussion of the crossbow during this period.

Josef Alm, *European Crossbows: A Survey*, ed. and trans. G.M. Wilson and H. Bartlett Wells, (1994, repr. Dorchester, 1998). pp. 8-11; 16; 34-6; 48, 56; 58-9; 65.

makes for a very detailed and thorough study, and this kind of work certainly has great merit.

The biggest problem with this study is attempting to apply what has been learned from a relatively small sample to the medieval crossbow as a whole. It is very difficult to determine whether the chosen sample of crossbows can fairly represent the technology as a whole, without undertaking a broad study of crossbows first. There was no standardized manufacturing in the Middle Ages, so each crossbow was necessarily a unique piece of craftsmanship. This means that historians must determine whether differences between weapons were deliberate design decisions, or simply the result of different craftsmen working by hand. It is also nearly impossible to account for regional differences in a study of a small selection of crossbows. While it is possible to examine crossbows from Spain and from Austria and compare them, this type of analysis quickly becomes difficult as the need to include sufficient examples for comparison will quickly cause the data pool to exceed what is manageable in a small study. This becomes even harder if crossbows from multiple centuries are included. Eventually, the number of crossbows that would have to be included to discuss crossbows from across several regions over a couple of centuries inevitably becomes too much for an in-depth study to manage. In theory, this problem can be overcome with a sufficient amount of time and a willingness to produce an extremely lengthy final work. In practice, the amount of time required to do this kind of large, detailed study is prohibitively long, likely several decades worth of work.

Broad studies have the advantage that their conclusions are more generally applicable to the technology as a whole than those of narrow studies are, but that is not the only advantage of this kind of study. The wider focus also makes it easier to identify general trends in crossbow design and construction across centuries and geographical regions. While an individual Spanish crossbow tiller being a hundred millimetres shorter than a central European tiller of a similar time period could just have been a meaningless fluke of a single craftsman's design, if it can be shown that the vast majority of crossbows from Spain had shorter tillers than their Central European counterparts, that would be indicative of a deliberate and widespread difference in design. This would then provide a new avenue for inquiry as historians try to explain why this difference existed. While it is possible to identify broader trends using only a small data sample, it is much easier to do so with a broader data set. The broader data set also allows for greater confidence that those differences are true of all of a particular type of medieval

crossbow, and not just the handful of crossbows included in the small sample.

A broad survey completely rules out the possibility of personally collecting all the measurements used in the study. Visiting every surviving medieval crossbow and taking measurements is simply not a viable option. Travel expenses, limited access to certain collections, and the time necessary to produce the final body of work all restrict the amount of data collection a single researcher can do, and mean that doing a detailed analysis on a broad range of data is not feasible as a lone researcher. As a result, this kind of study is far more dependent on the works of others than the narrow study. The major disadvantage of this is that not every publication containing information on surviving medieval crossbows was written with the same attention to detail and quality of information. Some have only provided sparse or vague descriptions and measurements. Others were very detailed. Some collections were difficult to contact, or unresponsive when contacted, and sometimes collections, such as the one in Churburg Castle in Italy, do not even have any permanent curatorial staff assigned to help researchers. The limited available information from several of these sources meant that only certain, general aspects of crossbow design could be examined. Measurements that have not usually been published, such as tiller height or trigger length, cannot be readily used or compared. Additionally, not all collections followed the same principles when taking measurements, meaning the measurements cannot be directly compared. For example, some lathes were measured from tip to tip along their arc, while others have only had their string distance – the direct line between the nocks – measured. Some collections have measured and published both, but most only measured one of the two. In some cases, the specifics of which measurement was taken has not been clearly denoted and had to be determined either through the context of the weapon's description or through direct communication with a curator. Other measurements were often missing entirely from most of the data. For example, the widths of both tillers and lathes were generally not measured.

The measurements that almost all collections had taken were the length of the tiller, and the length of the lathe (often described as the crossbow's width). Tiller length was sometimes measured to include the stirrup at the front of the crossbow as part of the length, but sometimes including only the length of the wooden part of the tiller and not the length added by the stirrup. Crossbow weight was a common, but by no means universal, measurement with some variability in whether it was provided in metric or imperial units.

Presenting a broad range of data in a manner that is easy to read and comprehend

is a further challenge to this kind of study. Every single crossbow in a broad study cannot be discussed in detail. Even a straight comparison of each crossbow, with no discussion, would run far too long for a reader to reasonably be expected to engage with. Instead, the large amounts of data must be condensed and presented in a more accessible format. The most straightforward method is to take averages from the data and use them to represent broad ranges of similar data. However, this has its own drawbacks. Mean averages do not account for the variance in the data, and can oversimplify broad, variable data sets which should be studied with more nuance. Using mean, median, and mode averages together can mitigate this problem, but any average is, by definition, biased towards the middle of the data. The extremes and outliers of the data set also warrant consideration. Averages are not useless, they do give valuable information, but they cannot be relied upon exclusively. Instead, they must be one of several tools for analysing the data set and presenting it in a useful form. Graphs of sections of the data are a good way of showing large amounts of information without overwhelming the reader. Graphs allow comparison of grouped data in a format that intuitively demonstrates clusters, extremes, and outliers. Bar graphs are the simplest method of presenting straightforward measurement data, but not the only one. Box plot graphs show the range of data, and provide many of the benefits of using averages without neglecting extremes and outliers. A combination of these tools, as well as some detailed discussion of particularly noteworthy or important crossbows from the data, can be used to take a very large pool of data from a wide variety of sources and turn it into a readable and comprehensible argument.

The Evidence

The archaeological focus of this thesis means the time period it can cover is necessarily bounded by the availability of evidence. European crossbows have survived only very rarely from before the fifteenth century, and so it is impossible to engage in any broad archaeological analysis of crossbows from before then. Instead, these older crossbows must be studied almost exclusively through references to them in contemporary documents and art. The following section will broadly outline the existing archaeological record for medieval crossbows, specifically focussing on the number of surviving crossbows. The crossbow data set – which will be explored more fully in the next chapter – will be also be explained; what it consisted of and what possible gaps there were in it.

The exact definition of the word “crossbow” has caused some confusion as to

how early the technology can be considered to have been in use in Europe. At the centre of the dispute is the question of whether or not the trigger mechanism is necessary for a weapon to be considered a crossbow, or if any instance of a bow mounted horizontally on a tiller of some kind could be considered a crossbow. This debate is of primary significance for weapons before the eleventh century, the point at which the trigger had become essentially universal.³³⁶ While this is an important debate, and gets right to the point of what is meant by the labels applied to weapons, it lies outside the scope of this thesis. When it comes to the archaeological record, there are no complete European crossbows from the eleventh through the thirteenth centuries. Even then, examples of surviving crossbows do not become numerous until the fifteenth century. Josef Alm studied nineteenth-century African crossbows for his book and discussed whether these might be seen as a suitable proxy for the type of crossbow medieval Europeans may have been using before the fourteenth century.³³⁷ Given that weaponry style can change so drastically over relatively short geographic distances, it seems unlikely that weapons from thousands of miles away could give any meaningful insight.

High medieval crossbows have suffered from a significant problem with accurate dating. They can often only be dated to a century, and sometimes even that cannot be determined with certainty. Take, for example, the Berkhamsted bow, which was a crossbow lathe found in a filled-in moat at Berkhamsted Castle in England. The original excavation dated it to the thirteenth century. However, these excavators also believed it to be a short bow rather than a crossbow lathe, so their analysis may not be entirely reliable. It was made of yew and was one of only two wooden crossbow lathes included in this thesis. It was also the only crossbow fragment in this thesis that could possibly date from the thirteenth century. It was, however, very possible that it should instead have been dated to the early fourteenth century, as its date of manufacture cannot be easily determined.³³⁸ Excluding the Berkhamsted Bow, there were three crossbows that were probably from the fourteenth century. All three of these crossbows could, however, have been very early fifteenth-century weapons. They consisted of two lathes – one

³³⁶ Nicole Pétrin, “Philological notes on the crossbow and related missile weapons”, *Greek, Roman and Byzantine studies* 33:3 (1992). pp. 280-91.

³³⁷ Josef Alm, *European Crossbows*, pp. 11-13.

³³⁸ Robert Brown, “Observations on the Berkhamstead Bow”, *Journal of the Society of Archer-Antiquaries* 10 (1967). pp. 12-3.

Arthur Credland, “Crossbow Remains (Part 2)”, *Journal of the Society of Archer-Antiquaries* 24 (1991). p. 9.

G.M. Wilson, “Notes on Some Crossbows in the Collection of Glasgow Museum and Art Gallery”, (Unpublished Notes, 2006). pp. 2-4.

wooden and one composite – and one complete composite crossbow. The composite crossbow and composite lathe were both German, while the wooden lathe's origin was not clear (it is now in the Kelvingrove Art Gallery in Glasgow, Scotland). While this small handful of crossbows does not represent the entirety of examples from this era, it is unlikely that there are many more, due to the rarity of weapons surviving from this era in general. As a result of this lack of archaeological data, this thesis will primarily focus on crossbows from later centuries.³³⁹

Only from the fifteenth century onwards does the number of surviving crossbows become substantial enough for a broad survey. This century also saw the first examples of surviving steel crossbows. Excluding the crossbows that could date from either the fourteenth or the fifteenth century already discussed above, there were 40 crossbows that can definitely be dated to the fifteenth century. There were a further eight crossbows that could be dated to either the late fifteenth century or the early sixteenth century. In general throughout this thesis, crossbows whose possible dates of origin span two centuries have been referred to as intermediary crossbows. Of the 40 crossbows definitely from the fifteenth century, 34 were composite crossbows and six were steel crossbows. The vast majority of these crossbows were still complete. Three of the composite crossbows only survived as lathes. In a few cases, a crossbow survived completely, but the lathe and tiller had separated. Provided the lathe and tiller were certainly a match, they could be taken together as a single complete crossbow.³⁴⁰ All of the steel crossbows were complete but, in at least one case, the lathe now on the crossbow was a later restoration.³⁴¹ The fifteenth-sixteenth-century intermediary crossbows consisted of two composite crossbows and six steel crossbows, and all were complete.

Determining a crossbow's origin, defined here as where it was made, is very difficult. Most of these weapons have been moved numerous times between collections during the modern era, often without a clear record of where they were originally found.³⁴² This means that the region of origin is unknown for many crossbows, and even

³³⁹ Ibid. pp. 2-7

Egon Harmuth, "Concerning the One-Foot Crossbow of the High Gothic", *Journal of the Society of Archer-Antiquaries* 28 (1985). pp. 9-11.

Appendix I, p. 240

³⁴⁰ Example: Appendix I, p. 247.

³⁴¹ Appendix I, p. 255

³⁴² Oswald Graf Trapp, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). pp. xxxviii-xli.

Ian Ashdown, pers. comm. [20/2/15].

when it is known, it is often an educated guess rather than a provable fact. All of the fifteenth-century composite crossbows whose origin can be accurately determined were from Central Europe, which for the purposes of this thesis includes modern day Germany, Austria, and Switzerland. The steel crossbows had a more diverse set of origins. Two fifteenth-century crossbows and one intermediary were Spanish, another was Italian, while three more were from Central Europe. The rest of the crossbows did not have a recorded place of origin. The fifteenth-century crossbows used in this study are currently held in a wide selection of collections across several different countries and continents. The majority are still in Central Europe, mostly in Swiss collections like Grandson Castle and the Historisches Museums of Luzern and Bern. The Metropolitan Museum of Art in New York City has five fifteenth-century crossbows and one intermediary. There are more crossbows from this century in the Wallace Collection in London, the Armeria Alava in Spain, the Polish Military Museum in Warsaw, and the Kelvingrove Art Gallery in Glasgow. A few smaller collections have one or two crossbows each, but the above list represents the majority of the fifteenth-century crossbows, and gives an idea of how widespread the crossbows are.

The sixteenth century had significantly more surviving crossbows than all of the previous centuries combined. This study has been limited to only the first half of the sixteenth century, with some flexibility around that cut-off. This was in part an attempt to keep the data manageable, but it was also to try to stay at least approximately within the bounds of the Middle Ages. With the *Mary Rose* (1545) being the largest source of surviving bows, it seemed reasonable to pick a similar end date for the study of crossbows. The sixteenth century featured the decline of the composite crossbow and its near total replacement by the steel crossbow. Composite crossbows from previous centuries were likely still used, but new ones do not appear to have been made very often.³⁴³ It should also be remembered that the sixteenth century saw the beginnings of the widespread adoption of gunpowder weaponry, which would become the exclusive ranged weapon of Europe. While England did not retire the longbow from its armies until 1592, France had already stopped using the crossbow as a standard weapon in its armies by the 1530s.³⁴⁴ That means that many of the crossbows from this century would

³⁴³ Josef Alm, *European Crossbows*, p. 56.

Dirk Breiding, *A Deadly Art*, pp. 30-2.

Ian Ashdown, pers. comm. [20/2/15]

³⁴⁴ Matthew Strickland, and Robert Hardy, *The Great Warbow: From Hastings to the Mary Rose*, (2005; repr. Somerset, 2011). pp. 399-400, 402-4.

Gervase Phillips, "Longbow and Hackutt: Weapons Technology and Technology Transfer in Early Modern

not have been intended for warfare. All examples discussed from this century should probably be treated as transition pieces between the crossbow's history as a weapon of war and its modern role as a popular tool in a hunter's arsenal.

The data set used in this thesis includes 85 sixteenth-century crossbows. Of these only six were composite, while the rest were steel crossbows. All of the crossbows were complete, although one of the composite crossbows is currently in two parts. The steel crossbows can be further sub-divided based on how they have been dated. Twenty-seven steel crossbows have been dated to the early sixteenth century, meaning they were definitely made before 1550, with many of them from before 1525. Twenty-one of the steel crossbows have been dated to the mid-sixteenth century, which has generally been considered as between 1525 and 1575, but usually closer to 1550. Thirty-one of the steel crossbows could only be dated to the sixteenth century in general. A final five crossbows were from beyond the 1550 end date used in this thesis but have been included despite this, due to specific benefits they offer this study; often as a valuable point of comparison with another crossbow or group of crossbows. Crossbows in this century were made in areas all across Europe including: Germany, Switzerland, Poland, Italy, Spain, Sweden, and England. That said, the vast majority of the crossbows from this century did not have recorded places of origin. They are also contained in collections all around the world. In addition to the collections mentioned for the fifteenth-century crossbows, many of which also include sixteenth-century crossbows, there are crossbows from Churburg Castle in Italy, the Swedish Royal Armoury, the Royal Armouries in Leeds and the Cleveland Museum of Art, to name but a few.

While this thesis drew on a large number of crossbows from a range of collections, it is not a complete survey of all medieval European crossbows or the collections that hold them. There are some very large collections that, unfortunately, have not been included in this study, along with several small museums with a handful of medieval crossbows. The two most significant absences from this study are two Italian armouries; in the Doge's Palace in Venice, and in the city of Turin. The latter is the greater loss as it holds the crossbows that once belonged to the city of Genoa, famed for its medieval crossbow-wielding mercenaries. Both of these collections have proven unresponsive to attempts by the author to contact them, and publications on their collections are so sparse on details as to be largely useless for the type of study undertaken in this thesis. The publications that are available serve largely to point out

England", *Technology and Culture* 40:3 (1999). pp. 576-9.

how many crossbows are in these collections, and thus highlight how useful data from them could have been if accessible, but provide little else, not even a rough idea of the crossbows dimensions. The Royal Armoury of Madrid is another large collection that has proved impossible to contact. This collection does not even have an email address, and its only catalogue is from the late nineteenth century and as sparse on details as those of the Italian collections. While analysis in this thesis would undoubtedly be enhanced by the inclusion of the contents of these collections, they had to be excluded as there was neither time nor money enough to visit every one of these armouries and convince them in person to allow a close examination of their crossbows.³⁴⁵

The Nut and Trigger

Crossbow nuts were an essential component of the crossbow that this thesis will not be exploring in detail, but are worth discussing at least briefly. This was the piece of the crossbow that survived in the greatest number. They were usually made out of antler, which is a type of bone, and bone is very resistant to decay under most circumstances.³⁴⁶ That means that even when the rest of the crossbow decayed away, the nut could still be found by excavators. The presence of a crossbow nut at an excavation site makes a strong case for the existence of crossbows in or around that location. The crossbow nut is useful archaeological data when studying the broader trends in how the crossbow was used and where it was made. Surviving crossbows have inevitably been moved several times between their original construction and where they are stored now. In contrast, crossbow nuts often indicate places where crossbows were left or discarded, possibly very close to where they would have been used. A group of broken crossbow nuts could also suggest a place of manufacture for crossbows, since a nut which broke while it was being made would simply be discarded nearby. Annette Holts Booth used evidence of broken crossbow nuts to argue that crossbows were likely manufactured in the Archbishop's palace in Trondheim, Norway, for example.³⁴⁷ However, as a piece of technology, the crossbow nut was not particularly complex, which is why it is not dealt with in great detail in this thesis. Crossbow nuts came in two forms: single and double

³⁴⁵ Angelo Angelucci, *Catalogo della armeria reale : illustrato con incisioni in legno* (Torino, 1890). pp. 384-401.

Juan Bautista Crooke, *Catálogo Histórico-descriptivo De La Real Armería De Madrid* (Rivadeneira, 1898). pp. 279-296.

Umberto Franzoi, *Armour of the Doges Palace in Venice*, (Venice, 1966). pp. 48, 55, 58, 66.

³⁴⁶ Arthur Graves Credland, "Crossbow Remains", *Journal of the Society of Archer-Antiquaries* 23 (1980). p. 12

³⁴⁷ Annette Holts Booth, "Crossbow Production at the Archbishop's Palace, Trondheim, Norway", *Journal of the Society of Archer-Antiquaries* 39 (1996). pp. 94-100.

hook. This name describes the number of clawed hooks carved into the nut that stick up and hold the string in place. Double hooks appeared to have been the more common of the two, but this work did not undertake a broad enough study of the subject to independently verify the truth of this statement.³⁴⁸ There were some slight improvements in crossbow nut design during the Middle Ages. Initially they had perfectly round undersides that the trigger pressed up against, while later examples had a notch carved into their underside that let the trigger rest more securely when the crossbow was spanned. This slight change is certainly noteworthy for the smoothness of operation it offered the crossbow; early crossbows suffered from a somewhat jerking motion of the trigger on release which would have hindered accuracy.³⁴⁹ The development of the crossbow nut and trigger has already been examined and explained in thorough detail by Josef Alm and Arthur Credland. There is little a greater understanding of crossbow nuts could offer the type of study being undertaken in this thesis, and therefore nuts have not played a large role in this thesis, despite being one of the core elements in the actual operation of the crossbow.³⁵⁰

The crossbow trigger was another important element of the crossbow that this thesis will leave largely unexamined. A study of the trigger was omitted for similar reasons to that of the crossbow nut; the triggers during the period covered by this thesis only came in two types, and other works have already discussed them in detail. Josef Alm included brilliant discussions of the trigger mechanisms of crossbows in his book and described the two kinds common in the Middle Ages.³⁵¹ The first is the standard Z-Trigger which is so called because it resembles an elongated letter Z. This trigger is a simple lever where one end presses up against the nut, holding it in place. When the other end is lifted, by squeezing it against the tiller, the nut is released so it is free to rotate forward under the pressure of the string, thus releasing the string and firing the bolt. This is a simple and reliable trigger system. The problem it suffered was that it often required great force to pull the trigger. This was because it was not a very efficient lever and the nut posed significant resistance.³⁵² This hard trigger pull would have impaired accuracy because it shifted concentration away from aiming, and the actual

³⁴⁸ Arthur Graves Credland, "Crossbow Remains", pp. 15-7.

³⁴⁹ Josef Alm, *European Crossbows*, pp. 33-4, 55-6.

³⁵⁰ Arthur Graves Credland, "Crossbow Remains", *Journal of the Society of Archer-Antiquaries* 23 (1980). pp. 12, 15-17.

Josef Alm, *European Crossbows*, pp. 33-4, 55-6.

³⁵¹ Ibid. pp.33-4, 55-6.

³⁵² Ibid. p. 55

trigger pull and string release would often have caused the crossbow to jerk suddenly. This led to another innovation which was also fairly simple. A simple mechanism was inserted into the middle of the process so that the amount of force applied to the trigger was amplified, meaning it required less force overall to shoot the crossbow.³⁵³ This trigger had extra complexity in that it required a re-arming process of the middle mechanism before it could be shot again. The archer had to pull a string that hung outside from the middle of the tiller and that would have lifted the mechanism back to its starting location.³⁵⁴ While this was a simple enough procedure, it would still have added to the overall time required to reload the weapon. This difference in trigger was significant in the quality it added to the firing of the crossbow, but it does not require detailed analysis to explain its development and benefits. Another problem with discussing the differences in crossbow triggers is that the type of trigger a crossbow had was often not included in descriptions published by museums. Without high quality pictures, or seeing the crossbow in person, it can be hard to identify the type of trigger used. Additionally, the only way to identify the type of trigger is by whether or not the crossbow had a piece of string, or a hole where a string once was, for re-arming a mechanism inside the crossbow. This was, in turn, complicated by the fact that many medieval crossbows have been modified since they were originally made, and a single hole might just have been a later modification. The only way to be sure of what trigger is inside a given crossbow is to take apart the trigger mechanism, or to scan it, usually with X-rays. Few museums have been willing to take either of these latter steps. Dirk Breiding included some X-rays of crossbows from the collection in the Metropolitan Museum of Art in his recent book, but this method of analysis is expensive and time consuming and so it is not common.³⁵⁵

Conclusion

This chapter has served to outline both what this thesis intends to do and what it does not with regard to the study of the medieval crossbow as it developed from the Later Middle Ages into the early modern period. The next chapter will contain all of the detailed figures and analysis that compose the argument this thesis will make about the crossbow. First, however, it was necessary for this chapter to provide a basis for understanding where the following chapter's data came from and why it has taken on the

³⁵³ Ibid. p. 55

³⁵⁴ Ibid. p. 55

³⁵⁵ Dirk Breiding, *A Deadly Art*, p. 34

methodology it has. That methodology is one that is broad and trades depth in favour of showing trends over a wider selection of data. Its purpose is to establish the general trends, design features, and differences in the crossbow from the fifteenth through the early sixteenth century. The lack of a solid archaeological foundation to work from for the majority of the Middle Ages means that this thesis is focused primarily on the fifteenth and early sixteenth centuries.

Chapter Five

The Development and Design of the Late Medieval Crossbow

The crossbow was one of the iconic weapons of the Middle Ages, but while the word 'crossbow' conjures an image of a singular weapon the historical reality was that crossbows came in many different sizes and styles. This chapter will discuss and analyse the archaeological data on surviving medieval crossbows collected for this thesis. This chapter will first explore the data chronologically, with crossbows grouped into types within their given century. The initial portion of this chapter will focus on the broad survey of all of the data collected for this thesis. Since the earliest crossbows form a relatively small sample, each one will be discussed individually. Each century will be compared to the previous century, to see if a clear developmental chronology can be determined based on the data alone. Later in the chapter, more detailed elements of crossbow design, such as lathe cross-sections, will be discussed. Finally this chapter will conclude with a brief discussion of crossbow design by region, focussing specifically on the unique case of Spanish crossbows. It is not the purpose of this chapter to answer all possible questions historians might have about the crossbow by the application of these data. Instead, these data open up new lines of inquiry and questions that have not been sufficiently considered within the wider field of medieval military history. These data will show how treating crossbows as if they were a monolith, a single unified technology that can be labelled 'crossbow', is a problematic idea.

Fourteenth-Century Crossbows

Only a handful of crossbows have survived from before the fifteenth century, so the data pool for any given century during this period is quite limited. The only surviving thirteenth-century crossbow was the Berkhamsted Bow.³⁵⁶ The Berkhamsted Bow was a wooden crossbow lathe made of yew. It is possible that it was from the early fourteenth century rather than the end of the thirteenth, but even so it remains one of the oldest surviving crossbow lathes. The Berkhamsted Bow did not survive unscathed, there have been two significant points of damage: one of the nocks was broken, and the lathe has suffered severe splintering along one of its limbs which would render it unusable. The latter break was likely the reason it ended up in the castle trench where it was eventually found. This splintering does allow for a glimpse into the lathe itself which has provided some insight into the type of yew it was made from. The laminates and wood grain therein suggest that the yew was from lowland country. The lathe has been measured as

³⁵⁶ Robert C. Brown, "Observations on the Berkhamstead Bow", *Journal of the Society of Archer-Antiquaries*, 10 (1967). pp. 12-17.

1235 mm long along its back, and 1238 mm long along its belly. This difference in lengths is a feature only ever noted in the descriptions of wooden lathes. The lathe has been measured as 55.88 mm wide at its widest point. It has been estimated as having a draw weight of 150 lbs (68 kg) at somewhere between eight and twelve inches (200-300 mm) draw. The nocks were cut directly into the wood, there is no evidence of horn nocks having been used. The bow currently has a curve approximately 60 mm deep as a result of the set it likely acquired from use. There has also been wear on the centre of the lathe that was likely caused by other pieces of wood, possibly made of oak, used to help keep the lathe in place when it was in its tiller. Because of where it was found, it is often assumed that the Berkhamsted Bow was made in England. This is one of only two surviving medieval wooden crossbow lathes in this thesis, making it a near unique artefact.³⁵⁷

The second wooden crossbow included in this thesis is one of three crossbows to have survived from the fourteenth century. This wooden crossbow is currently held the Kelvingrove Art Gallery in Glasgow, Scotland. The wooden lathe was medieval but it is currently attached to a replica medieval tiller, likely dating from the nineteenth century. G.M. Wilson has suggested that this crossbow actually could be from as early as the thirteenth century based on its strong resemblance to the Berkhamsted bow, but it cannot be precisely dated as such. Like the Berkhamsted bow, it has been measured with two different lengths, one for the belly and one for the back. The belly length was measured as 1156 mm, while the back was 1099 mm long. This was a much greater difference in length than in the case of the Berkhamsted Bow, but with only two data points for wooden lathes it is impossible to say which proportions would have been the more common, or even speculate as to why the two crossbows were different. Wilson also noted that the cross-sections of both lathes are in the D-shape, similar to the longbows discussed in Chapter 2. This could suggest an overlap in the practices of making longbows and wooden crossbow lathes, but it could just as easily be that a D-shape was the best way to make a powerful bow out of yew and so both groups of craftsmen chose it independently. Both lathes were also made in such a way that they incorporated the knots in the wood. The width of the Glasgow lathe is somewhat obfuscated by an error in Wilson's notes. He noted the lathe is 2.25 in at its thickest, but converted this to 85.1 centimetres, which is incorrect.³⁵⁸ Assuming the imperial measurement is correct, since

³⁵⁷ See Appendix I, pp. 254-55

³⁵⁸ G.M. Wilson, "Notes on Some Crossbows in the Collection of Glasgow Museum and Art Gallery", pp. 2-8.

the size given in metric is much too large to be realistic, as the lathe would then be as thick as the tiller is long, the actual thickness in metric would be 57.2 mm. This is thicker than the Berkhamsted Bow but by less than 2 mm. The similarities between these two lathes do suggest that wooden crossbow lathes of this time were typically over a metre long and at least 50 mm at their thickest, but with only two examples to draw conclusions from, it is impossible to know how representative these data are.

The other two surviving fourteenth-century crossbows both had composite lathes. Due to the difficulty with dating crossbows in general and especially early examples, these crossbows could possibly have been from the early fifteenth century. The first composite crossbow is from the Rustkammer Dresden, and only the lathe has survived. It was likely of Central European origin. The lathe was measured as 1018 mm long with a string length of 745 mm. The string length is the length measured directly between the nocks, while the lathe length is the length of lathe measured along its arc. The difference between these two lengths is very pronounced in this lathe. The lathe has a pronounced recurve to it which may have been its original position when it was not strung, or it could have been the result of its glue and sinew drying out.³⁵⁹

The second composite crossbow has been tentatively dated to c.1400, so it could have been a very early fifteenth-century crossbow. It has been included here since it could have come from the end of the fourteenth century and Egon Harmuth argued that the c.1400 date was likely a latest possible estimate.³⁶⁰ This crossbow is now in Cologne and was of Central European origin. This was the earliest crossbow in the data set where both the lathe and the tiller have survived. The crossbow was altered at some point in the past as the lathe has been attached to the tiller backwards, presumably as part of a restoration. The lathe has been measured as 946 mm long with a string length of 720 mm. The lathe was significantly reflexed. The tiller was 875 mm long and, at its narrowest, it was 30 mm wide and 25 mm thick. The whole crossbow weighed 2000 g. The crossbow appears to be missing a stirrup, it could have been removed before or around the time when the lathe was reattached. Egon Harmuth has argued that the crossbow was likely what some texts refer to as a 'one-foot crossbow'.³⁶¹

³⁵⁹ Holger Richter, *Die Horgenarmbrust*, (Ludwigshafen, 2006). pp. 32-4.

³⁶⁰ Egon Harmuth, "Concerning the One-Foot Crossbow of the High Gothic", *Journal of the Society of Archer-Antiquaries* 28 (1985). pp. 10-1.

³⁶¹ *Ibid.* pp. 9-11.

Holger Richter, *Die Horgenarmbrust*, pp. 26-31.

David S. Bachrach, "Crossbows for the King: The Crossbow During the Reign of John and Henry III of England", *Technology and Culture* 45:1 (2004). pp. 109-11.

The most distinctive feature of these crossbows was their size. As the analysis in the following paragraphs will show, the handful of lathes from the thirteenth and fourteenth centuries were the longest lathes of any century covered by this thesis. While the composite crossbows were definitely distinctive when compared to later examples, it is impossible to know if these high medieval wooden crossbows were different from late medieval wooden crossbows without any points of comparison. In general, the data pool was too small to prove anything definitively, but it does raise several interesting questions. It was at the very least suggestive that design trends changed significantly during the transition from the High to Later Middle Ages.

Fifteenth-Century Composite Crossbows

The number of crossbows, and the data available on them, first became sufficient for a broader comparative analysis in the fifteenth century. The majority of the crossbows from this century have survived in their entirety, and those that survived as only a lathe were often still in very good condition. In total, 51 crossbows could be dated to this century. Of these, 43 were almost certainly from the fifteenth century, while eight could possibly be from as late as the early sixteenth century.³⁶² For the following analysis, these crossbows were divided based upon their lathe types. Within those categories, they were broken down even further into their component parts, with the lathes examined first, followed by the tillers. From there, broader trends will be considered, such as how the lathe and tiller sizes interact and, when there was sufficient data, how heavy the full crossbows were. Finally, the crossbows will be compared with similar crossbows from the preceding century, to see if observations can be made about how the technology changed between the two time periods.

Before analysis can begin, a few problems with these data must be discussed. While many lathes had both their string length and a total length included in the data, there were some exceptions where only one was available. The differences between these lengths were often more indicative of the conditions of the survival of the lathe than they were of how the lathe was used in the Middle Ages. All of the glue in the composite crossbow lathes has long since dried out, meaning the weapons cannot be bent without breaking them, and therefore they have been locked in the position they were in when the glue dried. In some cases, these lathes are now completely straight, as they would have been when left unstrung, others are in a curve likely to reflect their shape when they were

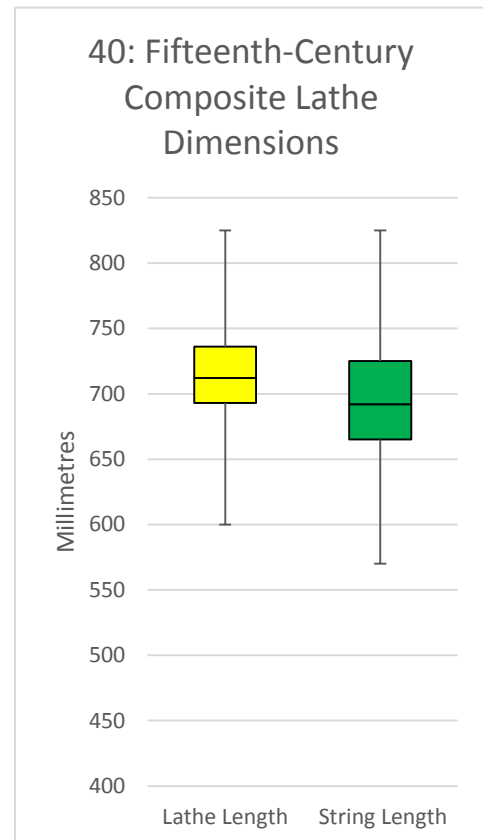
³⁶² See Appendix I, pp. 255-70

strung and ready to shoot, and a few have taken on a recurve, either because that was their shape when unstrung, or possibly as a result of the glue drying and shrinking.

Graph 40 plots all the string lengths and total lengths for the fifteenth-century composite crossbows, which shows how minor the differences were. The string length plot covers a slightly broader range of lengths, but the centres of the two graphs are very near each other. What this graph suggests is that, while there are some differences in the two data groups, these differences are not so great that one type of measurement cannot be

substituted for another if only one of string length or lathe length is available. So, in cases where only one of the two length measurements was available for a crossbow, for example, only string length, that measurement could be used as a substitute of the other kind, i.e. lathe length, and it would be an adequate approximation. In this section, all of the broad analysis was done using lathe lengths. When a crossbow's lathe length was not measured, its string length was treated as if it were its lathe length. The reason lathe length was chosen is that it better reflected the reality of the lathes. Many composite lathes have dried with their lathes straight, or at least straighter than if they were strung. When the length of these were measured, the measurement was the lathe length, and since the lathes cannot be bent anymore it was impossible to determine their string lengths. While many of the lathes in this data have both measurements taken, the string length reflected how bent the lathe was having survived several centuries, which was only sometimes the same as they would have been when strung. In contrast, the lathe length was consistent from when the lathe was made to the present.

The shortest fifteenth-century composite lathe was 600 mm long while the longest was 825 mm long. The median lathe length was 706.5 mm. Only four of the 39 crossbows in the data set were over 750 mm long. Only two were 650 mm or shorter. Over half of the crossbows were between 680 and 740 mm long. These data showed that,



Comparison of the lathe lengths and string lengths of composite crossbows. Consists of 31 lathe lengths and 30 string lengths. Data from Appendix I.

while there was a significant amount of variation in the lengths of fifteenth-century composite crossbow lathes, they clustered around 700 mm in length. It should be noted that these data did include two transitional crossbows, but those crossbows did not stand out when compared to the data in general; one was 690 mm long while the other was 715 mm long. When dealing with these figures, it was hard to determine what exactly was a significant difference in lathe length, and what was just the inevitable difference between individual hand-crafted objects. An important factor was the degree of difference. For example, the greatest difference between two lathes in the data was 225 mm. The shorter of these lathes was 600 mm long. The difference between the two was over a third of the total length of the shorter lathe, which was a significant fraction of the overall length. In contrast, looking at the longest and shortest lathes of the central cluster: one was 680 mm long while the other was 740 mm long. This was a difference of 60 mm, which was less than one-tenth of the length of the shorter lathe. This could be considered a minor degree of difference. The data in general suggest there was a level of standardisation to the construction of composite crossbows in Europe at this time. Both extremes of the data, the 600 millimetre and 825 millimetre long lathes, were nearly symmetrically positioned at approximately 100 mm less than and greater than the middle datum point. The extreme ends of the data could easily just be exceptions to what was a dominant style of lathe design represented by the central cluster of data.³⁶³

What was perhaps the most surprising aspect of these data was how much shorter these lathes were than the two from the fourteenth century. Both of those earlier crossbow lathes lay well above the maximum length of the data for this century. The Cologne crossbow was over 100 mm longer than the longest fifteenth-century lathe, while the Dresden crossbow was a further 70 mm longer than the Cologne lathe.³⁶⁴ Two crossbows is a very small sample for comparison, though which means that it is difficult to be confident in these results. More data on fourteenth-century composite lathes would have to be gathered in order to determine whether these two crossbows were representative of the norm for that century. There is also the problem that these lathes could have been from the early fifteenth century. Even if this later date is accepted, the data still suggest that, as the fifteenth century progressed, the composite lathes shortened to generally be approximately 700 mm in length.

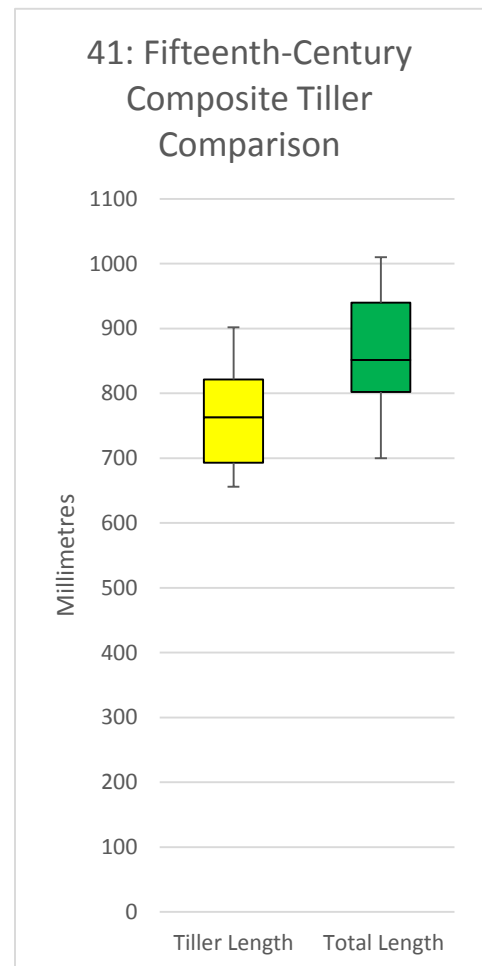
Just like with the lathe, a crossbow's tiller can have been measured in two

³⁶³ Appendix I, pp. 255-70.

³⁶⁴ Egon Harmuth, "Concerning the One-Foot Crossbow of the High Gothic", pp. 9-11. Holger Richter, *Die Horgenarmbrust*, pp. 26-31, 32-4.

different ways. The first method, which will be referred to as the tiller length, was to measure only the wooden tiller: the distance from the tiller's butt to the crossbow's lathe. The second method, here called the total length, was to measure the whole crossbow from end to end. This latter method included any stirrup the crossbow had, as well as the parts of the lathe that may have extended beyond the wooden tiller. These two different measurements create similar issues to those of the total length versus string length problem with lathes. Few collections mentioned whether the stirrup was or was not included in their measurements. In most cases, museum descriptions simply gave a length for the crossbow, with no indication as to how it was measured. In general for this thesis, when a museum had given its measurement as simply “length” then it has been treated as total length.

Graph 41 shows a comparison of the collected tiller lengths versus total lengths of fifteenth-century composite crossbows. It should not be a surprise that the total lengths were on average longer than the tiller lengths. There is significant overlap in the two graphs and no individual crossbow had a difference between its total length and tiller length of over 200 mm. Of the 35 tillers included in this graph, fifteen had measurements for both lengths, seven had only measurements for total length, and the remaining thirteen crossbows only had measurements for tiller length.³⁶⁵ Fifteenth-century crossbows were the most likely to have had both their total lengths and tiller lengths measured. The shortest crossbow had a tiller length of 670 mm, while the longest tiller length was 956 mm long, and the median was 763 mm long. The shortest total length was 700 mm long, while the longest was 1010 mm long, with a median of 865 mm. The crossbow with the longest total length was the only one that was over a metre long. Overall, the data look very similar to those of the composite



Comparison of tiller and total lengths for composite crossbows. Consists of 29 tiller lengths and 23 total lengths. Data from Appendix I.

³⁶⁵ Appendix I, pp. 255-70.

lathes: there was a noticeable variation in lengths, but they also tended to cluster around a central area. For tiller lengths, all of the lengths were within 100 mm of the median, while for total lengths the variation was a little over 150 mm to either side of the median value. What these data suggest is that there was at least some level of standardisation to composite crossbow tillers by this period. While there were outliers and exceptions, most of the tillers were close enough in length that their differences could be explained as simply having been the result of variations in the properties of the wood they were made from and the preferences of the craftsmen who made them.³⁶⁶

One of the most intriguing results from examining composite lathes and tillers was just how similar the two were in length. To determine whether this was just a

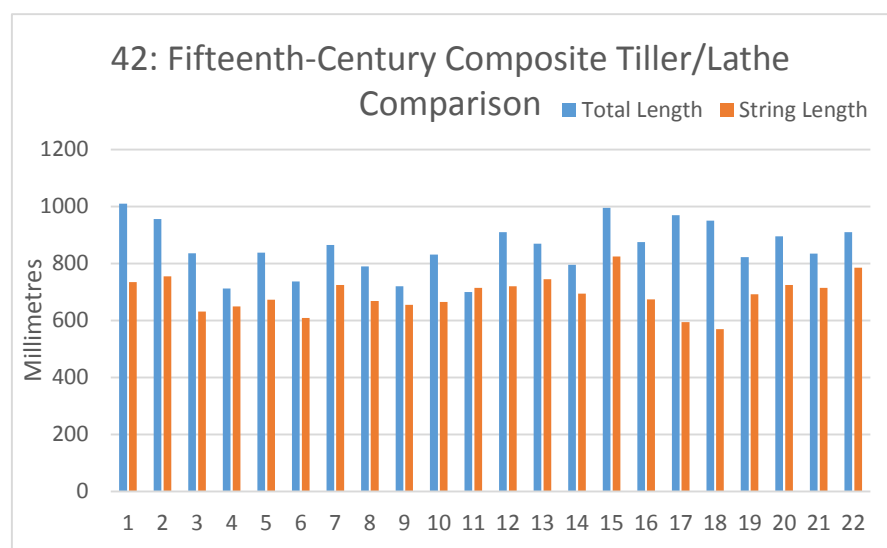
coincidence of the data, or if it shows some feature of composite crossbow design, the lengths of the lathes were compared to their attached tillers.

For the sake of

consistency with later comparisons, string

length was compared to the total length. This restriction gave a data set of 22 crossbows to study.³⁶⁷ The alternative – comparing lathe length to tiller length – had a sample equal

in size but was not chosen, in order to be more consistent with similar analysis of other crossbows later in this chapter. **Graph 42** shows the comparative lengths of the full data set. The differences between crossbows were impressive. On one end was a crossbow from Luzern, whose lathe was a mere 15 mm longer than its tiller while on the other end was a crossbow from the Metropolitan Museum of Art, whose tiller was 380 mm longer than its lathe. In all, only one crossbow had a lathe longer than its tiller (crossbow 22 in **Graph 42**). Two other crossbows (crossbows 4 and 9 on **Graph 42**) had tillers that were less than 100 mm longer than their lathes. Ian Ashdown, a curator and restorer of



Comparison of total crossbow length with string length for composite crossbows. Data from Appendix I.

³⁶⁶ Appendix I, pp. 255-70.

³⁶⁷ Appendix I, pp. 255-70.

crossbows at Grandson Castle in Switzerland, commented to the author that several medieval composite crossbows had their tillers cut short in the sixteenth century by individuals who wanted shorter hunting weapons. This could be seen in damage done to the end of the tiller, particularly in damage done to decorative horn inlays. In his opinion, the average length of a composite crossbow tiller was best represented by Grandson Castle B2, which was 795 mm long.³⁶⁸ Three crossbows in the data set had tillers that were under 700 mm in length. The majority of the crossbows had tillers that are between 100 and 200 mm longer than their lathes. Only six crossbows had a tiller that was over 200 mm longer than its lathe, and half of those were only just over that line, with differences of 205 mm or less.³⁶⁹ The median string length of the composite lathes was 692 mm while the median total length was 851.5 mm. If these are accepted as representative for the central cluster of their respective data pools, then the projected median difference for this comparative data would be 159.5 mm. The actual median was 152.5 mm, so the projected difference was only off by 7 mm. This seems to confirm the trend of the previous analysis; there was some uniformity within the data, reflecting that there was an approximate ratio for how long a tiller should be in relation to its lathe. That is not to say that there was no variation in the data, however, as the extremes in this case were significant. However, it is hard to reject the idea that composite crossbows in the fifteenth century had some form of standard dimensions, and the outliers were simply exceptions to the rule. This thesis is not arguing that all composite crossbows were designed to be of a single uniform style, instead it has suggested that a dominant type of composite crossbow existed in the fifteenth century, which the majority of surviving examples appear to have conformed to.

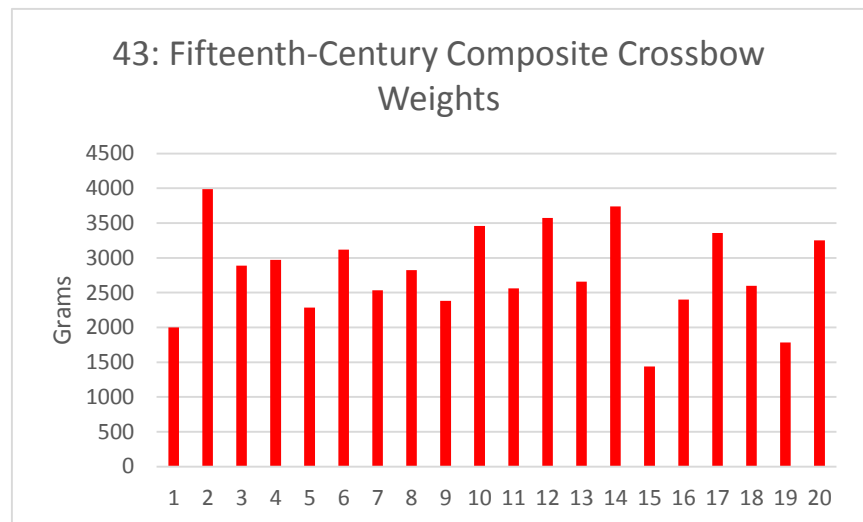
The final aspect of fifteenth-century composite crossbows examined here was their weight. Nineteen of the complete composite crossbows have had weight included with their published information, the second most likely of any group in the data set to have had their weights published. There were also weights for two crossbow lathes. The tiller of one of these lathes has also been weighed, and the two weights have been added together and used alongside the nineteen complete crossbows to form a total data set of twenty whole crossbows.³⁷⁰ **Graph 43** shows the crossbow weights, all measured in grams. The lightest crossbow, which is also the crossbow that was in two pieces, was 1440 g, while the heaviest was 3989 g. Composite crossbows clearly came in a wide

³⁶⁸ Ian Ashdown, pers. comm. [20/2/15]

³⁶⁹ Appendix I, pp. 255-70.

³⁷⁰ Appendix I, pp. 255-70., 276-7.

range of weights, but the majority clustered in the 2500-3500 gram range. This is a fairly wide range. A difference of a kilogram in weight was well over a third of the total weight of the crossbows on the lighter end of the range, and in some cases, well over half the total weight. Altogether, six of the crossbows weighed over 3000 g, but only two weighed over 3500 gram. Only two crossbows weighed less than 2000 g. The two solitary lathes did not provide any answers as to what the most important contributing factors to a crossbow's weight were. Crossbow B132-a, from Grandson Castle, had a lathe weight of 560 g and a tiller weight of 880 g. In contrast, lathe W1980, from the Bernisches Historisches museum, weighed 1335 g; almost as much as the entire Grandson crossbow.³⁷¹ What these data suggest is that, while the lengths and widths of the composite crossbows seem to have been relatively uniform, some component of design, other than tiller or lathe length, must have contributed to the weight differences in the data. The very different weights of the two lathes suggest that differences in lathe design could have had a significant impact on their weight. Bern W1980 was only 15 mm longer than Grandson B132-a, but weighed over 700 g more.



Fifteenth-Century Steel Crossbows

Comparison of composite crossbow weights, data from Appendix I.

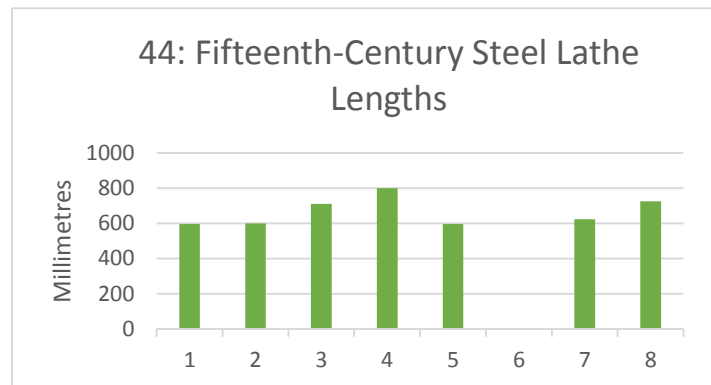
The fifteenth century had a much smaller pool of surviving steel crossbows than it did composite crossbows. In total, this data set included only six fifteenth-century crossbows, with a further seven transitional crossbows. However, there have been some problems with the dating of some of these crossbows. One of the fifteenth-century crossbows and five of the transition crossbows were very similar in design and were of a type that is very difficult to date. These crossbows will be discussed separately in another section. That leaves this study with five fifteenth-century steel crossbows and two

³⁷¹ Appendix I, pp. 260-1, 265.

transition crossbows. Furthermore, one of the fifteenth-century crossbows, crossbow B111 from Grandson Castle, could have had a replacement lathe, possibly sixteenth or even early seventeenth century in origin, which limited how useful it could be to the analysis.³⁷² Despite these problems, these data can still provide useful insights, and there is much to discuss about the crossbows that are not excluded from this sample.³⁷³

All of the fifteenth-century steel crossbows lathes have had their string lengths measured. While in theory it is possible to calculate the total length of these lathes based on the other dimensions of the lathes, those calculations are of sufficient complexity to

be beyond the scope of this thesis.³⁷⁴ The shortest steel lathe had a string length of 596 mm, while the longest had a string length of 800 mm. There were actually two crossbows with lengths of 596 mm, but one of them was the crossbow with the probable replacement lathe, Grandson B111, mentioned above. **Graph 44** shows all of



Comparison of fifteenth-century steel lathe lengths. Number 6 represents the break between fifteenth-century lathes and transitional lathes. Data from Appendix I.

the lengths of the steel crossbow lathes, including B111.³⁷⁵ The steel crossbows break down into approximately three groups; those around 600 mm in length, those around 700 mm in length, and those around 800 mm in length. The gap in the graph is to distinguish between the fifteenth-century lathes (1-5) and the transition lathes (7-8). While the data set was small, the difference between the fifteenth-century and the transition crossbows did not seem significant. The transition crossbows fitted in between the minimum and maximum lengths of the fifteenth-century lathes.

What was most interesting about this data set is how similar it was to the composite lathe lengths. While at first glance the steel lathes might seem a little shorter than the composite lathes, it is important to remember that these were string lengths while many of the composite lengths discussed earlier were lathe lengths. When compared to just string lengths, which can be seen in **Graph 40**, the steel lathe lengths

³⁷² Appendix I, p. 270

³⁷³ Appendix I, pp. 270-6.

³⁷⁴ See Chapter 1.

³⁷⁵ Appendix I, pp. 270-6.

fitted in closely with the composite lathe lengths. This could be indicative of a shared design philosophy between the two weapons. In the fifteenth century, the steel crossbow was still relatively new, so it is not impossible that some of the design concepts of the composite lathe would have also been applied to steel lathes.³⁷⁶ Alternatively, this could reflect the types of crossbows that were in demand in the fifteenth century. The outliers in both sets of data could possibly represent different types of crossbows for different purposes, but that is merely speculation without more data.

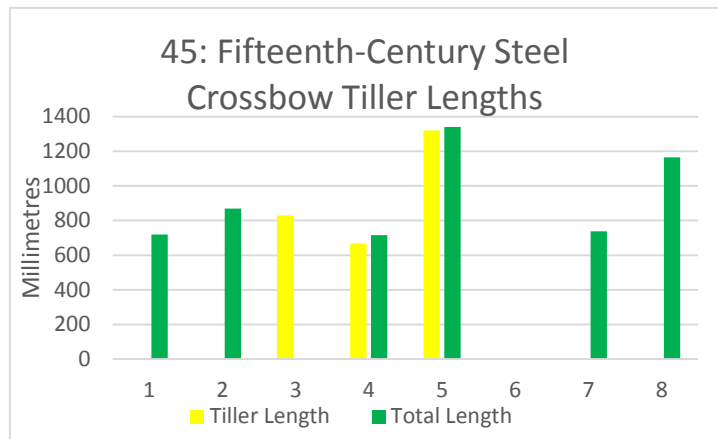
Most of the fifteenth-century steel crossbows only had one measurement for their length, and that measurement was usually the total length. Two crossbows – B111 from Grandson and MWP 57 from the Polish Military Museum – had measurements for both lengths, while one crossbow – from the Armoria Alava – had only a tiller length measurement.³⁷⁷ This mix of measurements makes analysing the relative lengths complicated. Normally, it would be a small matter to drop the Armoria Alava crossbow, since it is the only one without a total length, but it also represents one-seventh of the total data set, so dropping it entirely would significantly diminish an already limited data pool. **Graph 45** attempts to address this problem by showing both measurements for crossbow length. Once again, the gap at number six marks the separation between transition crossbows and the rest of the data. The shortest crossbow had a total length of 720 mm, while the longest had a total length of 1340 mm, nearly twice the length of the former. Two of the tillers in this data set are significantly longer than a metre. In contrast, the much larger sample of composite tillers contained only one tiller that was over a metre long, and it was only just barely over that line. Two crossbows out of seven that are over 1100 mm long is much more significant than one out of 22 crossbows being just barely over 1000 mm. That said, seven crossbows is a much smaller sample size and so there is a greater chance of these two crossbows being flukes. Still, the existence of these tillers does suggest that at least some differences in design were present in how steel crossbows were made compared to composite crossbows. This is particularly interesting since there was not anything inherent in the tiller technology to necessitate this difference. A steel lathe could be mounted to the same kind of tiller as a composite crossbow. Some modifications to how the lathe attached would have been necessary, but

³⁷⁶ Josef Alm, *European Crossbows*, pp. 34-5.

Erhard Franken-Stellamans, "A Mathematical Method for Determination of the Appropriate Draw Length for a Given Steel Bow", *Journal of the Society of Archer-Antiquaries* 47 (2004). pp. 92-4.

³⁷⁷ Appendix I, pp. 270-6.

there would have been no reason to change the length of the tiller. These differences are suggestive of many possibilities but unfortunately without further research they do not prove anything on their own. The rest of the tiller data did not present a clear pattern. The remaining five tillers were all between 700 and 900 mm long, and with such a small sample size

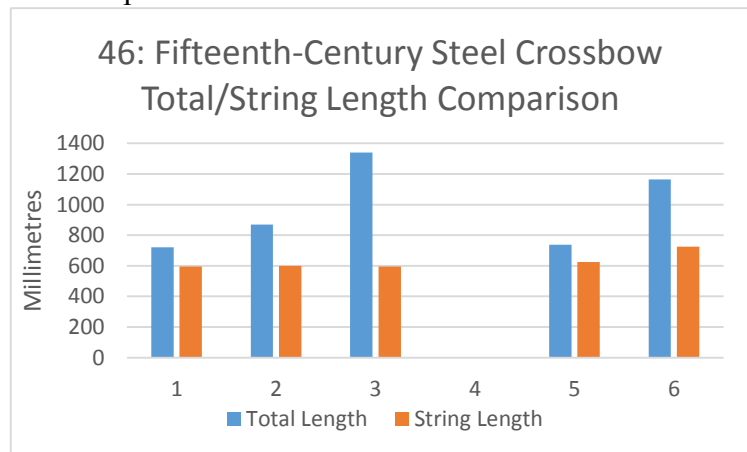


Comparison of tiller and total lengths for steel crossbows. Number six marks the break between fifteenth-century crossbows and the transitional crossbows. Data from Appendix I.

it is impossible to know if steel crossbows in this century were usually of such a wide range of lengths, or if there was a typical length, and if there was, whether that typical length was closer to 700 mm or 900 mm.

Comparing the steel lathes to their attached tillers compounds the problems already presented above. Grandson B111 and Armoria Alava 0479 both have to be dropped from this analysis as a result of problems with either their lathe or their tiller.

This means that the already small pool of crossbows has been further reduced to a total of only five crossbows.³⁷⁸ For this study, string lengths were compared to total lengths, the results of which can be seen in **Graph**



Comparison of total and string lengths for steel crossbows. Number 4 marks the break between fifteenth-century crossbows and transitional crossbows. Data from Appendix I.

46. No lathe was longer than its attached tiller. The smallest difference between lathe and tiller was 120 mm,

while the greatest difference was a staggering 744 mm. This was a much larger variance than was seen in contemporary composite crossbows. The data in the previous paragraphs suggested that steel crossbows most likely had longer tillers, which would

³⁷⁸ Appendix I, pp. 270-6.

explain the difference. However, with a sample of only five crossbows, these data could very easily be non-representative of the steel crossbow in the fifteenth century more generally. What was perhaps the most interesting result of this analysis was the fact that the shortest lathe was attached to the longest tiller. It certainly suggests that, at least in some cases, the length of a lathe probably had no impact on the length of the tiller it was attached to. It seems likely that this crossbow was an outlier. Even if it was an outlier, though, its existence does at the very least raise some questions about how these weapons were designed and made.

Only three of the fifteenth-century crossbows have been weighed, so the sample size for discussion of steel crossbow weight in this century was tiny. This discussion becomes yet more problematic as the three crossbows that have been weighed were all very different. They weigh, from lightest to heaviest, 3140 g, 4400 g, and 6110 g.³⁷⁹ With this wide range of weights – none of them were even within a kilogram of each other – it was impossible to determine what would have been the norm for steel crossbows in this century. There was no clear connection between the lengths of the crossbows and their weights. Grandson B111 and Wallace Collection A1032 had nearly identical dimensions, including lathes that were the exact same length, but they weighed 3140 g and 4400 g respectively. MWP 57, which weighed 6110 g, was significantly larger than the other two crossbows. It also had an attached windlass, which likely had increased its overall weight by at least a kilogram. What is clear from this data is that steel crossbows were much heavier than their composite counterparts. No composite crossbow from this century weighed over 4000 g, and most of them weighed less than 3000 g.³⁸⁰ Whether this was the result of heavier lathe materials or if it was simply representative of general design differences, is impossible to know with the data available.

Heavy-Steel Crossbows

The single greatest problem in the study of surviving medieval crossbows, and often the least discussed, is how to date them. Few museums included explanations of why they have dated a crossbow to a certain period in their published material. There were relatively few cases where a curator or historian had provided a detailed justifications of the dates they assigned to their crossbows.³⁸¹ This has created some problems, as well as some disagreements, about the dates of crossbows. While by and

³⁷⁹ Appendix I, pp. 270-6.

³⁸⁰ Appendix I, pp. 255-70.

³⁸¹ Mario Scalini, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

large this thesis has accepted the dates given by museums and catalogues, it is worth exploring one of the most interesting, and troubling, cases that arose in this research. This case is of a group of possibly fifteenth-century steel crossbows. These crossbows were found in several museums including: the Almeria Alava, the Polish Military Museum, the Bernisches Historisches Museum, and Grandson Castle. They all shared several prominent design features and may represent a specific type of crossbow. The style of crossbow was exemplified by Bern W1982, a photo of which is included as **Image 47**.³⁸² It was clearly different from most other fifteenth-century crossbows.³⁸³ For the sake of consistency, this group of crossbows will be referred to as heavy-steel crossbows throughout this thesis.

These crossbows were large – just how large will be examined later – and very heavy. Many of them had an attached windlass that, at least in the Bern example and likely in the others, was removable. In total, the data set included eight crossbows that could be placed in this category.³⁸⁴ Five of them were from the Polish Military Museum and had been dated to the fifteenth century by that museum's curators.³⁸⁵ The one in Armeria Alava was also dated to the fifteenth century, while the Bern example had been dated as a transition crossbow from the late fifteenth or early sixteenth century. In contrast, Jens Sensfelder dated a very similar crossbow from Grandson as being from 1550 at the earliest and very possibly as being from as late as 1750.³⁸⁶ Ian Ashdown, a curator at Grandson, agreed with Sensfelder's assessment and did not believe this

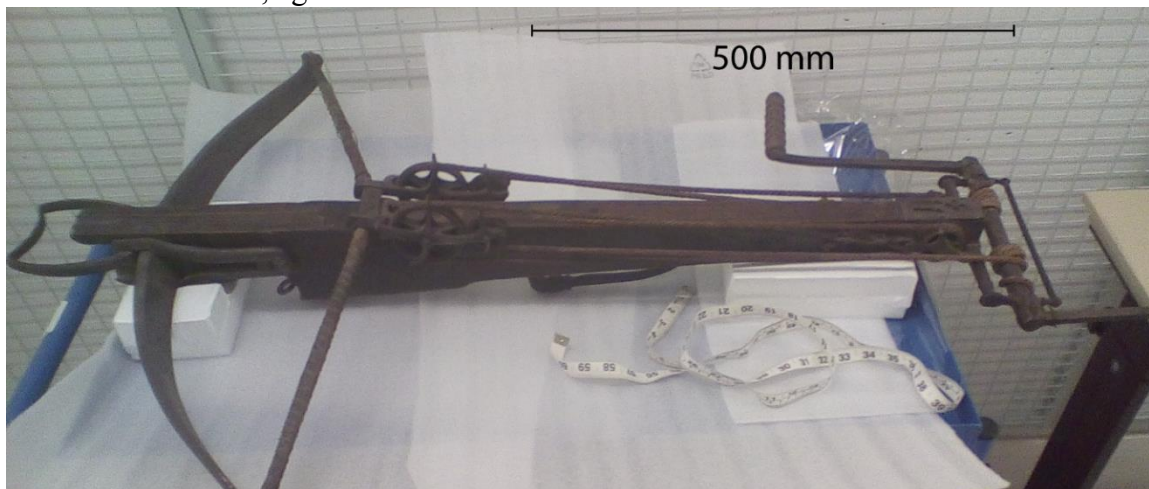


Image 47: Bern W1982, a heavy-steel crossbow in the Bernisches Historisches Museum that has been dated to between the fifteenth and sixteenth centuries, photo by author

³⁸² Appendix I, pp. 274-5.

³⁸³ For examples, see Appendix I, pp. 260-6.

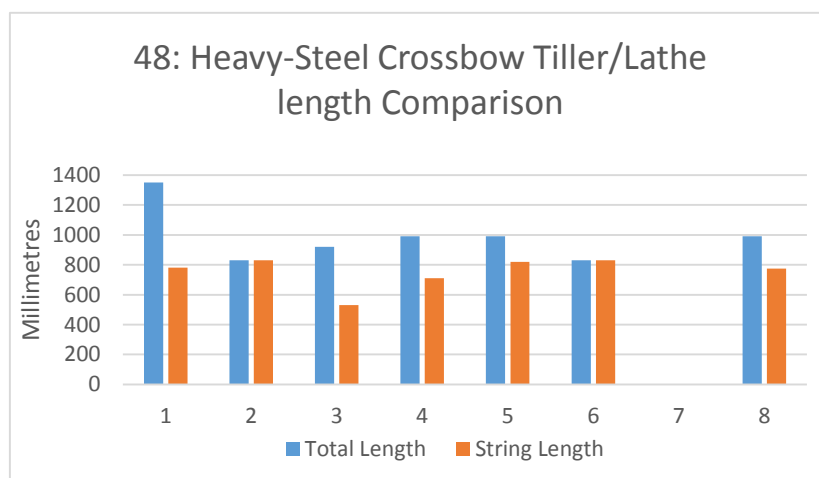
³⁸⁴ Appendix I, pp. 271-6

³⁸⁵ Appendix I, p. 276, MWP 58/1-2, has only one dimension given in its description and so is left out of this analysis.

³⁸⁶ Appendix I, p. 305

weapon to be medieval.³⁸⁷ This disagreement over when these weapons were made presented an interesting problem; while the majority of collections contacted for this thesis dated them to the fifteenth century, there are good reasons to doubt the validity of these dates. Sensfelder included some justification for his chosen date, while most of the other catalogues did not. This section will examine the shape and design of these crossbows, before moving on to the question of their dating and what can be learned from studying this sample of crossbows.

Analysis of the heavy-steel crossbows was complicated by some inconsistencies in the available measurements. The string lengths of the lathes had been measured, but the tillers were a mix of total and tiller lengths. These latter lengths were further complicated by the fact that some had windlasses attached to them, and it was not always clear if their length without the windlass, when it was given at all, included the stirrup or not. **Graph 48** shows the comparison of total lengths and string lengths of these six crossbows.³⁸⁸ The two questionable data points were the total lengths of number one, which included the attached windlass, and number five, which excluded the stirrup. The former crossbow had a tiller length of 910 mm, but since it was not clear how much the



Comparison of total and string lengths for heavy-steel crossbows. Number seven marks break between most of the data and Grandson F31. Data from Appendix I.

While there was clearly some uniformity to their lathe lengths – all but one of the lathes were between 700 and 850 mm long – they were attached to a wide range of tillers. The tillers ranged in length from 830 mm to 1340 mm in length. The maximum total length

windlass added to that length and how much was added by the stirrup the total length has been included in the graph. The gap at number seven separates the main body of data from Grandson F31, the

crossbow that Sensfelder dated to c.1550-1750.³⁸⁹

³⁸⁷ Ian Ashdown, pers. comm. [20/2/15]

³⁸⁸ Appendix I, pp. 271-6.

³⁸⁹ Appendix I, p. 305.

was reduced to 990 mm if MWP 58/1 was excluded.³⁹⁰ The tiller measurements were particularly problematic, however, since some included an attached windlass while others were probably tiller lengths, not total lengths. The Bern W1982 crossbow, whose measurements were taken by the author, had a difference between its tiller and total lengths, excluding the windlass, of 52 mm. Armeria Alava 0471's length, which was 990 mm, explicitly did not include its stirrup, so its total length was likely over a metre long.³⁹¹

What the comparison of string lengths and total lengths shows is difficult to interpret. The greatest difference between tiller and lathe length for an individual crossbow was that of MWP 58/1, whose tiller was 570 mm longer than its lathe. MWP 58/1's total length included a windlass, though, which exaggerated the difference. If that crossbow was excluded, then the greatest difference in lengths belonged to MWP 60, whose tiller was 390 mm longer than its lathe. MWP 60 also had the shortest lathe at 530 mm in length which went some way to explaining the difference. The longest lathe was a tie between MWP 59/1 and 59/1-2, both of which had a string length of 830 mm. What was particularly strange was that the total lengths of these two crossbows were also 830 mm each. They were an odd, and slightly suspicious, pair of data points and it is hard to feel confident in the accuracy of their measurements.

Despite all the problems present with these crossbows, the data did show one trend with them: these crossbows were large. Most of the other fifteenth-century steel crossbow lathes were around 600 mm long and none were over 800 mm long. Three of these crossbows had lathes over 800 mm long and only one was shorter than 700 mm. The tillers were not quite as dramatically different but were still, on average, longer than the fifteenth-century steel crossbow tillers. None of these tillers were shorter than 800 mm long and all but two were longer than 900 mm. In contrast, only two of the fifteenth-century tillers were over 900 mm long and another two were shorter than 800 mm long. It is safe to say, then, that while the crossbows in this category did not necessarily form a tight cluster, they were consistently larger than the fifteenth-century steel crossbows they were generally considered to have been contemporary with.³⁹²

Although there were even fewer data available on weight than there were on dimensions, these crossbows also appear to have been very heavy. Only three have been

³⁹⁰ Appendix I, p. 272.

³⁹¹ Appendix I, p. 273.

³⁹² Appendix I, pp. 270-6.
Appendix I, pp. 271-6.

weighed and they were all on the smaller end of the spectrum. MWP 60 weighed 10150 g, Bern W1982 weighed 9165 g, and Grandson F31 weighed 6120 g excluding its windlass. These weights were, on average, much larger than those of any fifteenth-century crossbows, steel or composite. Only one other fifteenth-century steel crossbow weighed anything close to as much as these crossbows, and it was so heavy that it could actually belong in this data set.³⁹³ What is clear, however, is that these heavy-steel crossbows were much heavier than the norm for the fifteenth century.

While there were significant differences in the sizes of these crossbows, it was their similarities of design that presented the clearest signs that this group of crossbows should be categorised as a single type of crossbow. Some of these similarities were relatively minor, such as how they all had stirrups with the same shape, but others were

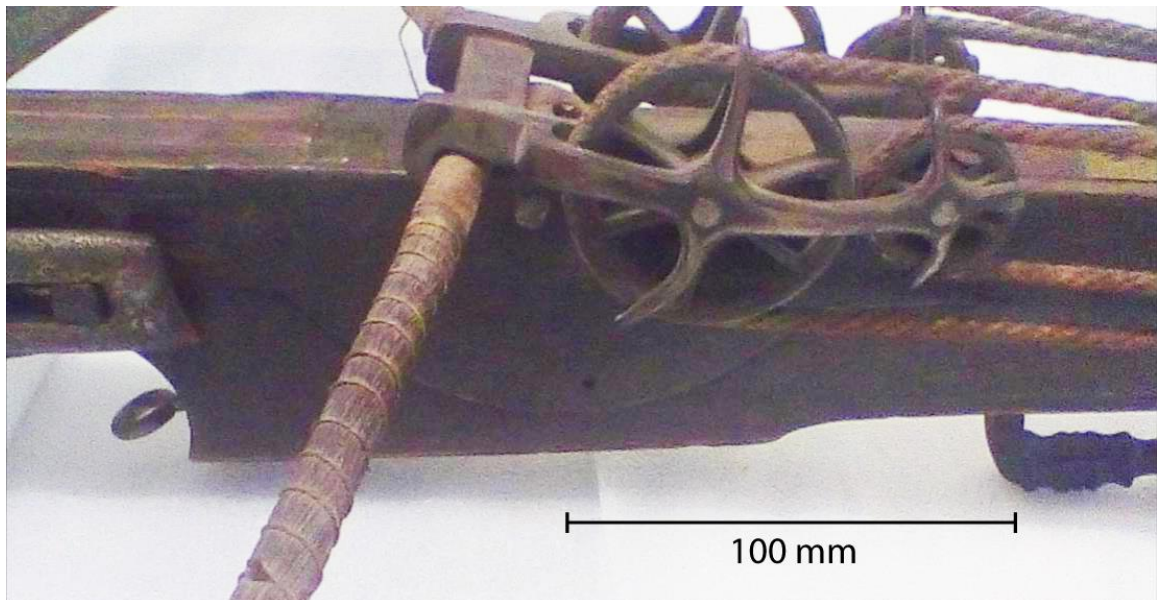


Image 49: Close up of the lock area of the heavy-steel crossbow Bern W1982. This image shows the area of the tiller that likely would have rested flat on a surface when the weapon was shot. Photo by author

much more significant. One of the most unusual design features was the shape of their tiller. Their tillers were very thick near the lock; **Image 49** shows this section of Bern W1982, and was on the narrower end of the sample. This shape suggested, especially when considered alongside their weight, that these crossbows were shot from a resting position. Likely the crossbow was placed on a shelf of some kind when it was being aimed. This could mean that these crossbows were intended to be used for target archery, but it does not rule out the possibility that they could have been intended to shoot from a fortified wall, such as a castle, instead. The shape and size of these sections varied, for

³⁹³ Appendix I, pp. 271-6.

example, Bern W1982 had a relatively small rest when compared to MWP 59/1, but they were universally present in these crossbows.³⁹⁴ The tillers on these crossbows extended beyond the lathe, and the tillers were attached with metal brackets instead of leather or string lashing. When compared, these crossbows had very similar profiles.³⁹⁵

In theory, the identification of a distinct style of fifteenth-century crossbow should be an exciting discovery. However, there are reasons to doubt that these weapons were actually made in the fifteenth, or even the early sixteenth century, despite the fact that they have been dated to that time period by several museums. Many of these crossbows included design elements indicative of seventeenth-century crossbows. For one thing, MWP 59/1 and 59/1-2 appear to have had triggers of a seventeenth - or even eighteenth - century design. The older Z-trigger was present on these crossbows, but it was a decorative hand guard for the real trigger, which was positioned further back on the tiller. Josef Alm dated triggers of this type to the second half of the sixteenth century at the earliest.³⁹⁶ While it is possible that these triggers could have been later modifications to the weapons, this is not likely. These triggers were extremely complicated and it would have been a complex procedure to place them into a tiller that was not specially made to accommodate one. Steel brackets to hold the lathe in place, common to all of these crossbows, were not found on any other fifteenth-century crossbows and appeared to have only become standard in seventeenth-century crossbows.³⁹⁷ Several of these crossbows also had detailed decorative metal work and wood carving on them, which is a feature most common in hunting or target weapons, rather than weapons of war. Elaborate decoration on crossbows became increasingly common in the modern era.³⁹⁸ Then there is Sensfelder's dating of one of the crossbows in this data set to the early modern period.³⁹⁹

These crossbows did not appear to be of a singular date of origin. The aforementioned MWP 59/1 and 59/1-2 were probably from the mid-sixteenth century at the earliest due to their triggers, but Bern W1982 crossbow had a relatively standard trigger and fewer decorative flourishes, so it could have been made earlier. Josef Alm accepted the Bern crossbow's date as fifteenth or sixteenth century, and the possibility

³⁹⁴ Appendix I, pp. 273-5.

³⁹⁵ For images see Appendix I, pp. 271-6.

³⁹⁶ Josef Alm, *European Crossbows: A Survey*, ed. and trans. G.M. Wilson and H. Bartlett Wells (1994, repr. Dorchester, 1998). pp. 57-8.

³⁹⁷ *Ibid.* pp. 67-8.

³⁹⁸ Dirk Breiding, *A Deadly Art*, pp. 33-4.

³⁹⁹ Appendix I, 304-5.

that all of these weapons have been correctly dated should not be rejected out of hand.

It seems likely that these weapons actually represent a style of crossbow that originated at the turn of the sixteenth century, with examples like Bern W1982, and developed over the following centuries with later examples including MWP 59/1 and Grandson F31. Many of these crossbows are likely not of medieval design, and are instead early modern target crossbows. Whether any of these weapons have their roots in the Middle Ages is impossible to know for certain without first establishing a new timeline for the development of the medieval crossbow.

Sixteenth-Century Composite Crossbows

The data for the sixteenth-century composite crossbows were a stark change in size from the previous century. There were only five composite crossbows from the sixteenth century in the data, all of which dated from c.1500-1520.⁴⁰⁰ The lack of later examples, given that in general more crossbows survive from this century, represents the most obvious, and possibly most significant, change in composite crossbows between the two centuries. It was strong evidence supporting the idea that the composite crossbow was nearly completely replaced by the steel crossbow in the sixteenth century. These few crossbows were the last examples of a technology that had been around for centuries.

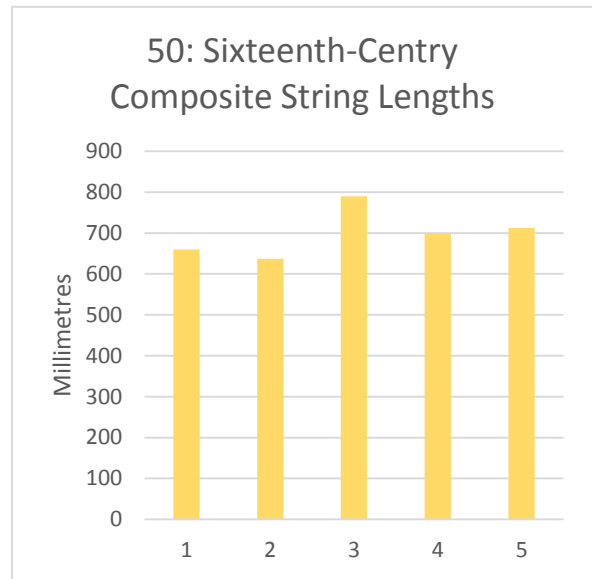
Graph 50 shows the string lengths of all of these crossbows.⁴⁰¹ All of these lathes have had their string lengths measured. Many of these lathes have dried mostly straight, so some of these “string lengths” were more representative of what their total lengths were, rather than what the actual length of their string would have been. The shortest lathe was 637 mm long while the longest was 790 mm long. The rest of the data were fairly evenly distributed between these two points, but skewing slightly shorter. These lengths would not stand out if they were from crossbows from the previous century. They showed less variation between their extremes than the fifteenth-century composite lathes and had a nearly identical median to the fifteenth-century composite lathes. While the sample was quite small, there was no evidence to suggest a drastic change in how composite lathes were made between the fifteenth and early sixteenth century. Whether this lack of change was the result of a stagnation in the technology as a result of it falling out of favour, or if it had just reached the apex of what was possible with the materials, cannot be determined from these data alone.

⁴⁰⁰ Appendix I, pp. 276-7.

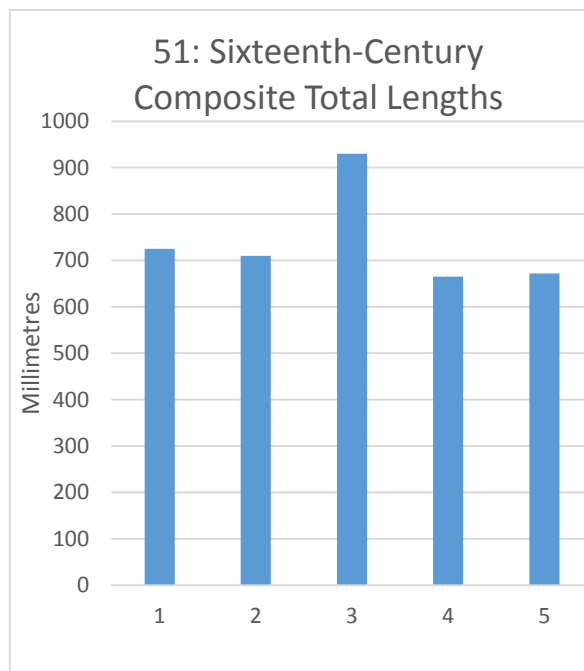
⁴⁰¹ Appendix I, pp. 276-7.

While there was consistency in which measurement was taken across all the lathes, the tillers of these crossbows were more problematic. Two of the crossbows had only total lengths, two more had both measurements, and the final one only had a tiller length. For the two that had both lengths, they had both because the measurements are virtually identical; neither crossbow has a stirrup. It is hard to know if the lack of a stirrup was an original feature of these crossbows or if it was just lost, possibly during a restoration. The latter seems

more likely as stirrups were a near-universal piece of crossbow design, but it was still possible for them to have not had stirrups. The one crossbow that had only a tiller length,



Comparison of string lengths for sixteenth-century composite crossbows. Data from Appendix I.

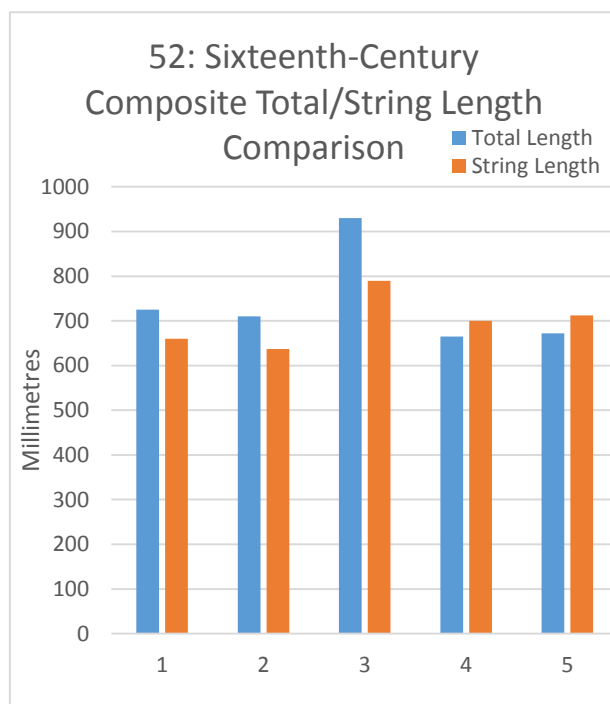


Comparison of total lengths for sixteenth-century composite crossbows. Data from Appendix I.

Grandson B132-b, did not have an attached lathe, so it was impossible to measure its total length. It is included the following graph because the difference between these two measurements for this data set is expected to be relatively minor, certainly less than twenty millimetres. The reason this is expected is because two of the crossbows did not have stirrups while a third, Wallace Collection A1034, only had a small spanning ring with a diameter of no more than a few millimetres. Since the stirrup was usually the most significant contributor to the difference between total and tiller length, the lack of a stirrup for many of these crossbows limited the problems with the measurements available for them. Most of these total lengths were probably closer to tiller lengths. **Graph 51** shows the lengths of these

tillers (number five on the chart is Grandson B132-b).⁴⁰² The shortest tiller was 672 mm long while the longest was 930 mm long. Just like with the lathe lengths, the tillers very closely resembled the trends from the previous century. There was nothing to really distinguish these crossbows from their fifteenth century counterparts. This further reinforces the supposition that no major design changes for composite crossbows occurred between the fifteenth and early-sixteenth century.

The comparison of a crossbow's tiller length with its lathe length was complicated by the problems with the tiller lengths, already discussed above. The total



Comparison of total and string lengths for sixteenth-century composite crossbows. Data from Appendix I.

lengths were used for this analysis, with Grandson B132-b as the only exception. **Graph 52** shows what this comparison looks like (number five on this graph is Grandson B132-b). In general, the two lengths were much closer to each other than in the data from the previous century.⁴⁰³ This is not particularly surprising since the lack of stirrups on most of the tillers meant their total lengths were on average shorter than the fifteenth-century tiller data. A much higher proportion of the sixteenth-century crossbows had lathes that were longer than their tillers, as well. However, these trends could just have resulted from the small sample size since there was only one more example than in the fifteenth-century data. None of the crossbows from this century were so outlandish that they could not have fitted in with the fifteenth-century data. They simply seemed to trend closer to one end of that data. While this data showed a greater difference between the two centuries than any of the previous information had, that difference was still very small. In general, it seemed that sixteenth-century composite crossbows did not differ very much from their predecessors in the fifteenth century. They may have primarily represented the continuation of just one style of crossbow that was present in that same

⁴⁰² Appendix I, pp. 276-7.

⁴⁰³ Appendix I, pp. 276-7.

century.

Only two sixteenth-century crossbows were weighed so the discussion of their weight will necessarily be quite brief. Grandson B132-b's tiller weighed 860 g while its lathe weighed 1380 g. The total weight of its two halves was 2240 g.⁴⁰⁴ Wallace Collection A1034 weighed 2170 g.⁴⁰⁵ Neither of these weights particularly stood out when compared to the fifteenth-century composite crossbows. They were both on the lighter end, but that was about all that set them apart from the data in general. This evidence was minimal, but it did not suggest that there was any significant change in composite crossbow weight between the fifteenth and sixteenth centuries.

Sixteenth-Century Steel Crossbows

The sixteenth century may have been lacking in a large number of composite crossbows to study but the same was not true of steel crossbows. There were data on 80 steel crossbows for this century. While this data set was the single largest sampling of crossbows in this thesis, it was not without its problems. Firstly, the origin of most could not be narrowed down to less than a 50 year period. This could be somewhat mitigated by classifying them into categories, based on when they were most likely made. With this purpose in mind, the majority of crossbows from this century have been classified into one of three broad categories. The first category, which consisted of 27 crossbows, contained crossbows that definitely dated from between 1500 and 1550 and will be referred to hereafter as Early.⁴⁰⁶ The second category, which included 22 crossbows, included crossbows that could only be narrowed down to the period from 1525 to 1575, and will be referred to as Mid.⁴⁰⁷ The final category, which also included 27 crossbows, has been labelled 'General', and refers to crossbows whose date could not be narrowed down more specifically than to the sixteenth century.⁴⁰⁸ There were four crossbows that were not classified into any of the categories. These crossbows definitely dated from after 1550, which was the cut-off date for this thesis, but have been included in some specific studies as they provided a valuable comparison point in some cases. Due to their late date, however, they have been left out of the broad analysis.⁴⁰⁹

The most common lathe measurement taken for steel crossbows was the string

⁴⁰⁴ Appendix I, pp. 276-7.

⁴⁰⁵ Appendix I, pp. 276-7.

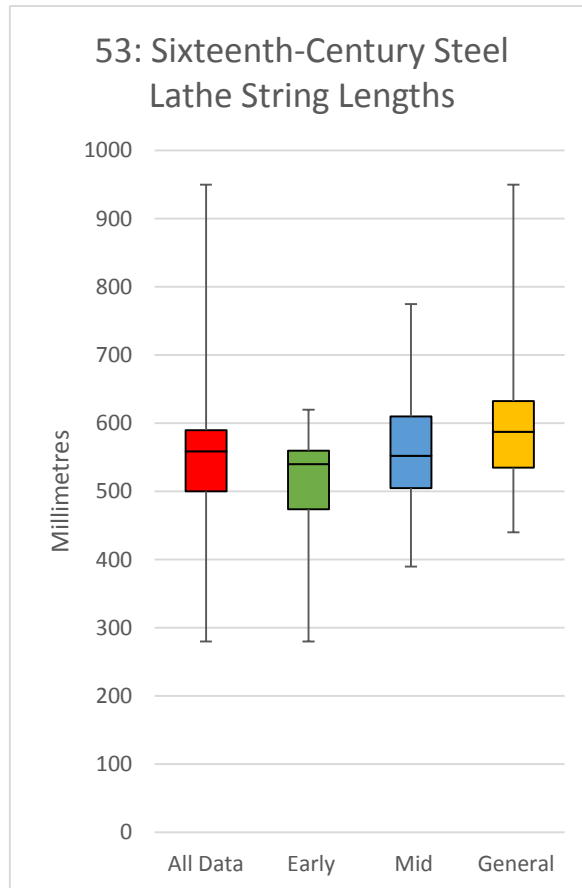
⁴⁰⁶ Appendix I, pp. 277-87.

⁴⁰⁷ Appendix I, pp. 288-95.

⁴⁰⁸ Appendix I, pp. 295-310.

⁴⁰⁹ Appendix I, pp. 304-6.

length. Only two collections seem to have consistently measured lathe lengths: the Swedish Royal Armoury and the Kelvingrove Gallery in Glasgow; combined, these accounted for twelve of the steel crossbows from this century.⁴¹⁰ These dozen crossbows, two from the ‘Mid’ category and the other ten from the General category, were therefore



Comparison of sixteenth-century crossbow string lengths. Consists of 59 crossbows total: 27 Early, 16 Mid, and 16 General. Data from Appendix I.

the only crossbows where only a lathe length is available. Five crossbows had both total and string lengths, while the remaining 55 crossbows had only string lengths. **Graph 53** shows a comparison of the string lengths.⁴¹¹ The first box-plot contains all of the string lengths, while the others showed the data from Early, Mid, and General categories, in that order. What stood out the most about this data was just how extreme the limits of the plots are. The smallest crossbow was only 280 mm long, while the longest was 950 mm. The median of all of the steel lathes was 559 mm long. Half of all of the lathes were between 500 and 600 mm long, and each of the individual graphs had their median length somewhere in that range.

This suggests that, while there was a vast amount of variation in possible lengths for

steel lathes, most belonged somewhere near the middle of the two extremes.

The graphs suggest that shorter crossbows were more prevalent in the first half of the century and less popular later, but there are some issues with this interpretation. Firstly, it should be remembered that the General category was not composed of crossbows that were necessarily dated to later than the other two groups. Instead it was composed of crossbows that were difficult to date, and could have been from any time during the sixteenth century. This means that while it appeared to have, on average, the longest lathes, that was not necessarily indicative of a broader trend across time. Most of

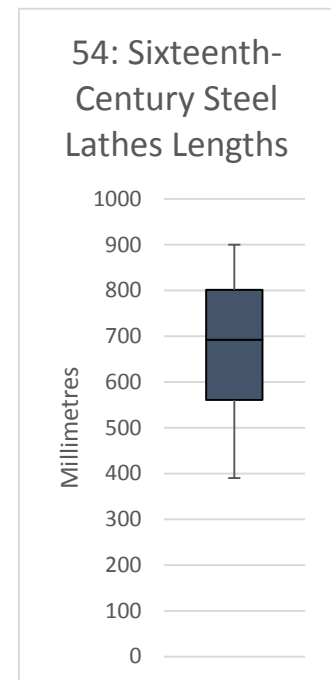
⁴¹⁰ Appendix I, pp. 254, 263-5, 277, 289-90, 299-303, 317-20.

⁴¹¹ Appendix I, pp. 277-304.

the very short crossbows, meaning less than 400 mm long, were from the collection at Churburg Castle.⁴¹² These crossbows, which were likely for target shooting, were all from one collection and were not necessarily representative of a broader trend across Europe.⁴¹³ Churburg Castle collected most of its artefacts in the early modern period, mostly between the sixteenth and eighteenth centuries. These items were intended primarily for collection and display rather than strictly for military purposes, so it was very likely that weapons were collected from across Europe rather than just in the region around the castle.⁴¹⁴

Graph 54 shows the data for the eighteen crossbows whose lathe lengths were measured.⁴¹⁵ Unsurprisingly, the average length of these crossbows was greater than with the string lengths, but the extreme ends were not substantially different. The minimum length was 390 mm, while the longest lathe was 900 mm. The median length was 645 mm. The centre of this data formed a broader cluster than the string lengths did, which is possibly the result of the smaller sample size. While the central box for the string length graphs tended to only span approximately 100 mm, the box for total lengths extended from 560 mm to 815 mm, a span of over 200 mm.

The sixteenth-century steel lathes were significantly different from those found in the fifteenth century. While the fifteenth-century lathes largely mirrored their composite counterparts, the sixteenth-century lathes came in a wide variety of sizes. **Graph 55** shows a comparison of the string lengths of the fifteenth-century lathes versus the sixteenth-century lathes. This indicates some quite strong evidence that lathes from the sixteenth century were, on average, shorter than in the fifteenth century, even if the longest lathes were also from the sixteenth century. The sheer variety of lengths that could be seen in sixteenth-century steel lathes was impressive as well, especially when compared to the previous century. There were no lathes with a string length less than 500 mm in any of the other groups of



Lengths for crossbows where only the lathe length was measured. Includes 18 crossbows. Data from Appendix I.

⁴¹² Appendix I, pp. 277-80, 282-8, 291-5.

⁴¹³ Oswald Graf Trapp, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). pp. 264-76.

Mario Scalini, *L'Armeria Trapp de Castel Coira*, pp. 211-2.

⁴¹⁴ Oswald Graf Trapp, *The Armoury of the Castle of Churburg*, pp. xxxviii-xli.

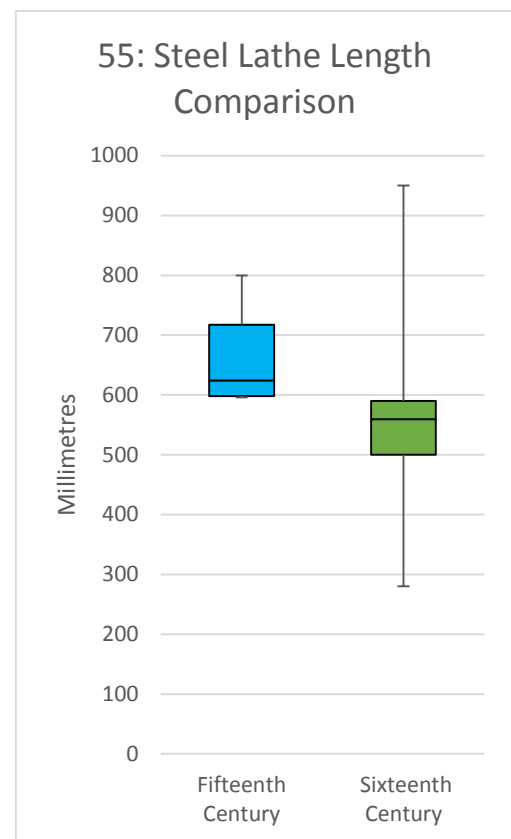
⁴¹⁵ Appendix I, pp. 277-304.

crossbows, but there were twelve sixteenth-century steel lathes that were shorter than 500 mm, and eight that were between 500 and 510 mm in length.⁴¹⁶ These shorter crossbows were likely indicative of a trend in lathe construction, possibly a result of greater experimentation with steel as a material for crossbow lathes. The sheer variety of lathes in the sixteenth century, especially when compared to the fifteenth century, suggested that changes in manufacturing or changes in demand, or both, were influencing crossbow lathe design in this century. The crossbow was losing its relevance as a weapon of war at that time and, as a result, target archery and hunting started to have a more significant impact on lathe design.⁴¹⁷ This

is unlikely to be the sole explanation, however, since crossbows were used for both hunting and target shooting well before this, so while

changes in the practice of these activities could have had an impact on lathe design, they could not on their own explain the new developments in steel lathes in the sixteenth century.

There were 75 sixteenth-century steel crossbow tillers in the data set for this thesis.⁴¹⁸ The measurements of these tillers included 26 which only had total lengths, 38 that only had tiller lengths, and eleven that had both measurements. This division presented an extra level of complexity to the analysis. While the single largest set of measurements was tiller lengths, ignoring the total lengths entirely would have involved discarding a lot of data. There was also the problem that, for many of these measurements, it was not clear as to what the original curator considered tiller length. The majority of the tiller lengths were limited to the Early and Mid categories, only one was in the General category. In contrast, only five total lengths were included in those



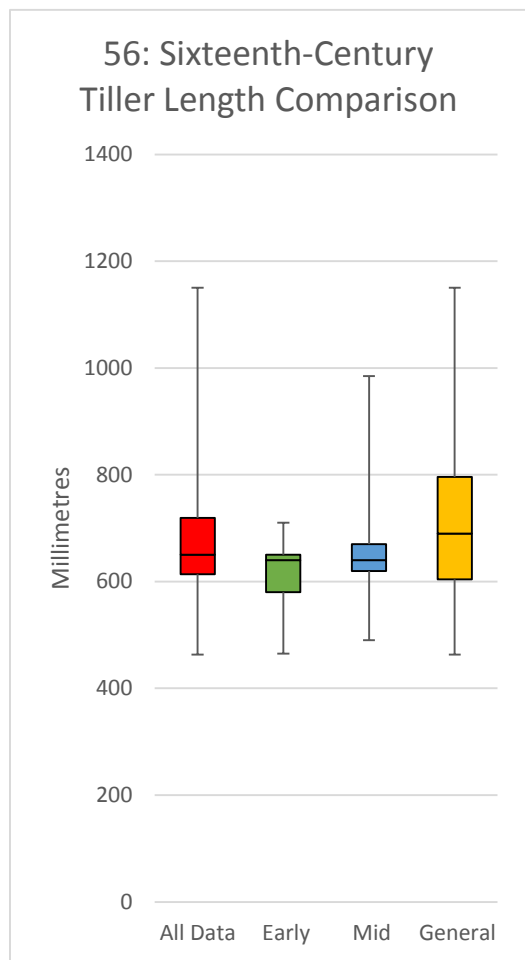
Comparison of string lengths between 7 fifteenth-century crossbows and 59 sixteenth-century steel crossbows. Data from Appendix I.

⁴¹⁶ Appendix I, pp. 270-304.

⁴¹⁷ Matthew Strickland and Robert Hardy, *The Great Warbow: From Hastings to the Mary Rose*, (2005, repr. Somerset, 2011). pp. 399-400.

⁴¹⁸ Appendix I, pp. 277-304.

same first two categories, the remainder were in the general category. Due to this division, and the aforementioned measurement problems, the Early and Mid sections of **Graph 56** were composed of tiller length data while the General category graph has used total length data.⁴¹⁹ For the overall data that compose the first graph, the measurements have been combined, but in cases where both measurements were present for a crossbow, the total length was used. While there were problems with combining these two kinds of data together, these were mitigated by the large sample size. Including both measurements very likely extends the extremes of the data than separate categories would, but the other three graphs already show the trends in the tiller length data and this broad analysis provided a useful comparison. In total, there were 25 crossbows in the General category, seventeen crossbows in the Mid category, and 25 crossbows in the Early category. Altogether the graph contained 75 crossbows.



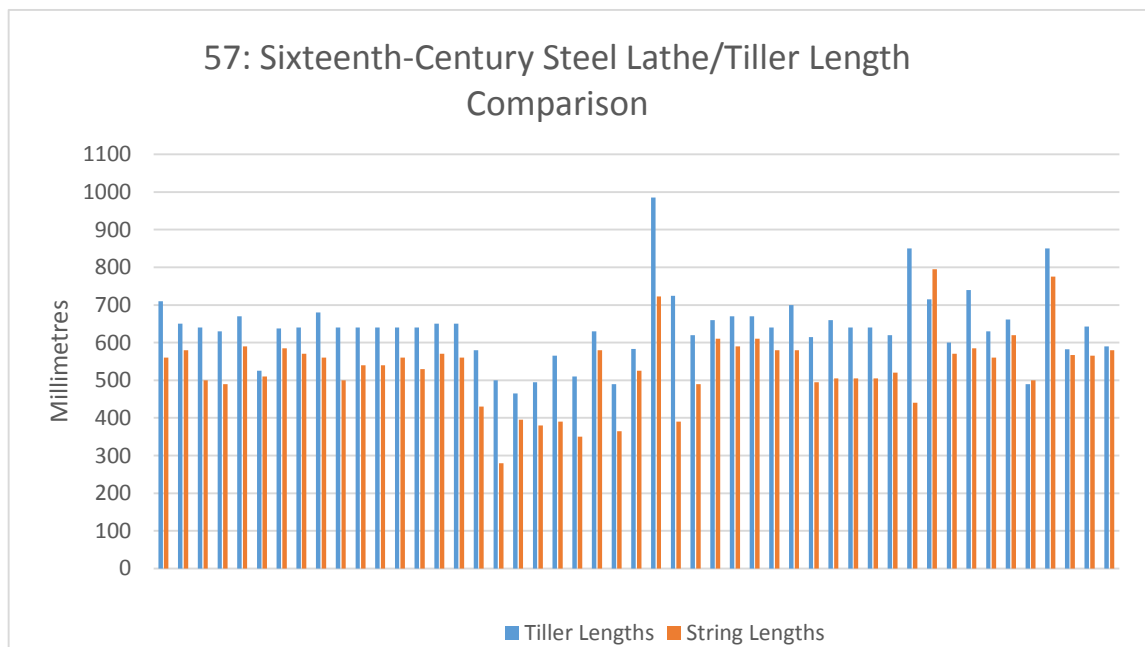
Tiller lengths of sixteenth century steel crossbows. Consists of 75 crossbows total: 25 Early, 17 Mid, 26 General. Includes several Total lengths in the overall data that are excluded from the sub-categories. Data from Appendix I.

Once again, there was significant variety to the sizes of steel crossbow tillers but there was still a core grouping of lengths, this time including crossbows between approximately 610 and 710 mm in length. The longest tiller was 1150 mm, while the shortest was 463 mm long. The median of all of the data was 650 mm. The medians of the Early, Mid, and General graphs were all within 40 mm of this point. There was already a lot of variation in steel crossbow tillers in the fifteenth century, as shown in **Graph 45**, so the change in tillers was never going to be as extreme as the change seen in the lathe data. The sixteenth-century tillers did seem to be on average smaller, although with such a small sample from the fifteenth century it is hard to be confident in

⁴¹⁹ Appendix I, pp. 277-304.

that assertion. No sixteenth-century tiller was anywhere near as long as MWP 57.⁴²⁰ On the other hand, no fifteenth-century steel tiller was shorter than 600 mm, while fourteen sixteenth-century crossbows are. In general, the sixteenth-century data clustered closer to the shorter end of the data. This suggests that the very long tillers were more likely to be outliers. While there was a general trend towards shorter tillers when compared to the previous century, the longer style of tiller did not disappear entirely from use.⁴²¹

The comparison of tiller and lathe lengths offers some promising insight into the trends of sixteenth-century steel crossbow design. The lengths of tillers and lathes taken independently have shown significant variation, and how these lengths related to each other had the possibility creating further confusion. The problems with the different tiller measurements made a straightforward comparison of tillers and lathes difficult. A sample of 59 crossbows could be assembled by comparing string lengths to tiller lengths, while a sample comparing string length with total lengths included only 31 crossbows.⁴²² While the tiller length sample was the larger of the two, the comparative analysis in previous sections had compared string length to total length. So as not to discard the larger sample size, both types of tiller measurement were used in the following discussion. **Graph 57** shows the comparison for the tiller lengths while **Graph 58** shows the comparison with total lengths. What these data show is that lathes did not scale in size alongside the



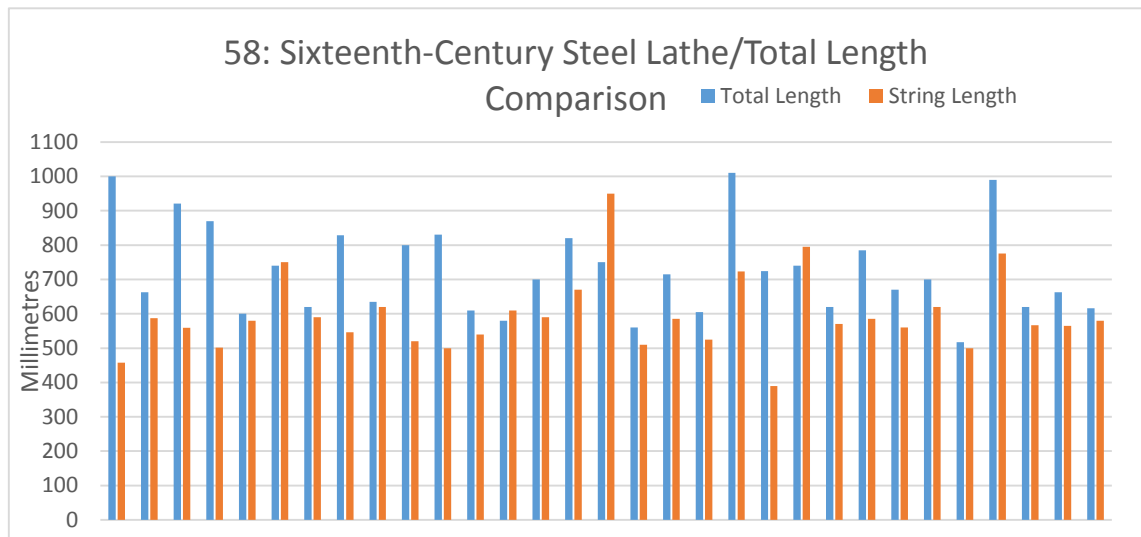
Comparison of tiller and string lengths for sixteenth-century steel crossbows. Consists of 49 examples. Data from Appendix I.

⁴²⁰ Appendix I, p. 271.

⁴²¹ Appendix I, pp. 277-304.

⁴²² Appendix I, pp. 277-304.

tillers, i.e. short lathes were not always attached to short tillers. The total length data had wider extremes than the tiller lengths, but the two data sets had very similar medians. The two extreme ends of the data, both from **Graph 58**, were Wallace Collection A1033, whose tiller was 542 mm longer than its lathe, and MWP 24639, whose lathe was 200 mm longer than its tiller.⁴²³ These two crossbows were very far removed from most of the data, however. In total, only four crossbows had lathes longer than their total lengths. On the other extreme, only five crossbows had tillers that were more than 300 mm longer



Comparison of total and string lengths for sixteenth-century steel crossbows. Consists of 42 examples. Data from Appendix I.

than their lathes, four from the total length data and one from the tiller length data. The median difference for the tiller length comparison was for the tiller to be 100 mm longer than the lathe. The median for the total length comparison was for the tiller to be 80 mm longer than the lathe. In the end, this comparative study did not clarify the mystery of sixteenth-century crossbow design. It did however broadly mirror the trends of the lathe and tiller data on their own. The majority of crossbows existed in a central cluster of data, while the extremes are very far removed from this centre. It is possible that these odd crossbows represented experimentation with the technology. The decline of military crossbows would have meant that crossbow-makers had to find new buyers for their wares, and this could have encouraged them to experiment with new crossbow designs.⁴²⁴ Speculation aside, what is certain is that sixteenth-century steel crossbow design was complex, with many different designs and ideas clearly visible in the

⁴²³ Appendix I, p. 303.

⁴²⁴ Josef Alm, *European Crossbows*, pp. 56-7.

construction of these weapons.⁴²⁵

One of the crossbows in **Graph 58**, MWP 24639, had a lathe that is 200 mm longer than its tiller.⁴²⁶ This was a significant difference, it was over a quarter of the total length of the tiller. It was not the only crossbow in the data that has a difference of this magnitude though, it was just the only one that fit the criteria for the graphs. Crossbows from the Royal Swedish Armouries have all had their lathe lengths measured instead of string lengths, which has resulted in them being left out of much of the broad lathe-related analysis in this chapter. They are relevant here because two of the crossbows in this collection had lathes that are over 100 mm longer than their tillers. Swedish Royal Armoury 6815 (4698) had a lathe that is 283 mm longer than its tiller, while Swedish Royal Armoury 26597 (4698) had a lathe that was 145 mm longer than its tiller.⁴²⁷ The data on these crossbows included images that offer a significant and valuable insight into why these weapons were such outliers from the rest of the data. The pictures of these crossbows showed the tillers ending abruptly after the *cranequin* lug. While this could have been an intentional design feature it does not seem likely. Instead, it was more likely that these tillers were broken. There was very little space after the lug to actually mount a *cranequin* on and without that space it would have been very difficult, if not impossible, to actually span these crossbows. If these tillers were broken, a similar break could explain the massive lathe-tiller length disparity with MWP 24639. Alternatively, these could all have been trap crossbows. Trap crossbows were primarily used for hunting, usually of foxes, and did not have to be reloaded in the stressful situation of combat. At least one of these Nordic crossbows was likely a trap crossbow as Josef Alm mentioned one was in the Nordic armoury when he was writing his book in the 1940s. Whether that crossbow was the same as the one currently in the armoury would require a closer study than was possible for this thesis.⁴²⁸

In total, 61 sixteenth-century crossbows have been weighed, making this the largest sample size of crossbow weights in this thesis.⁴²⁹ **Graph 59** shows the distribution of these weights. Like most of the data so far, this graph shows two extreme ends of the data that are separate from a central block of data. Half of the sixteenth-century steel crossbows in this study lay between 1835 g and 3440 g in weight which, at

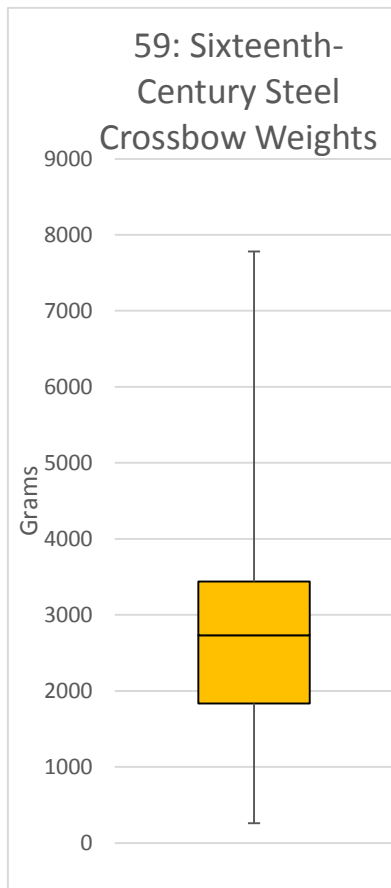
⁴²⁵ Appendix I, pp. 278-304.

⁴²⁶ Appendix I, p. 303.

⁴²⁷ Appendix I, pp. 299-300.

⁴²⁸ Josef Alm, *European Crossbows*, pp. 90-1.

⁴²⁹ Appendix I, pp. 277-304.



Sixteenth-century steel crossbow weights. Consists of 61 crossbows. Data from Appendix I.

a difference of over one and a half kilograms, is certainly not insignificant. A crossbow at the upper end of this box was nearly twice as heavy as one at the lighter end. The ends of the data make the central box look almost uniform in comparison, though. The lightest crossbow in this century was only 260 g while the heaviest was 7780 g. That's a weight difference of over seven and a half kilograms. The heaviest crossbow was over thirty times the weight of the lightest crossbow. There was more variation in the weights of sixteenth-century steel crossbows than there was in their general dimensions. This could have been the result of several factors including: the type of wood used to make the tillers, the thickness of the lathe, the height and thickness of the tiller, and the types of decoration added to the tillers. Without significantly more detail, it is impossible to determine which factors would have been the most important in determining the weight of these crossbows. Even without those details, these data show how much variety existed in sixteenth-century steel crossbows.

All of the crossbows that weighed less than 1000 g came from Churburg Castle in Italy. In total, there were seven of these crossbows, which varied in weight from 260 g to 515 g.⁴³⁰ While these crossbows also represented some of the smallest examples of the century in size, their difference in weight was much greater than one would expect based on their dimensions alone. For example, the heaviest of these crossbows had a string length of 430 mm and a total length of 580 mm.⁴³¹ Another crossbow from Churburg Castle, with similar dimensions (a string length of 490 mm and a total length of 620 mm), weighed 2585 g.⁴³² This latter crossbow was only 60 mm wider and 40 mm longer, but over 2 kg heavier than the first crossbow. This highlights how there are more differences in design than can be represented simply in length and width. These very light crossbows are an interesting conundrum, though, as it is not clear what purpose a crossbow of their size would have fulfilled. All of these crossbows appeared to be of

⁴³⁰ Appendix I, pp. 285-8.

⁴³¹ Appendix I, p. 285.

⁴³² Appendix I, pp. 291-2.

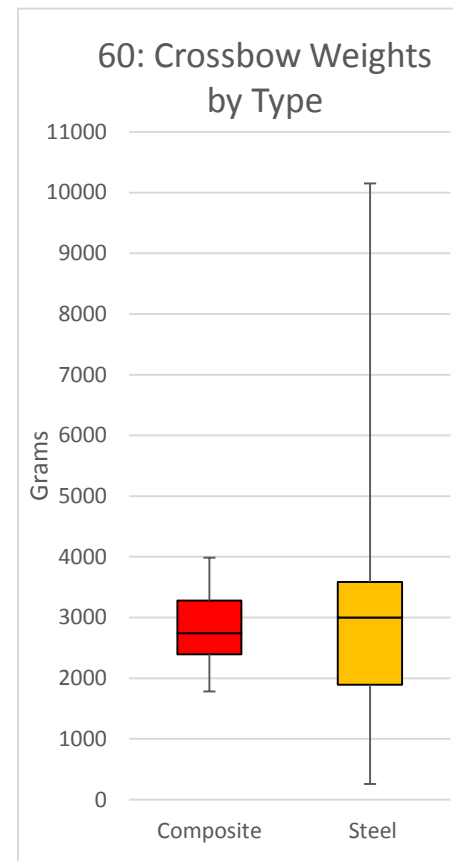
approximately similar design, and were apparently the remains of what was once a larger collection of a dozen crossbows. Scalini believed them to be of Austrian origin, so it is possible they represented the output or style of a single region or workshop.⁴³³

Graph 60 shows a comparison of composite and steel crossbow weights. The composite crossbow weights were composed of the twenty fifteenth-century crossbows and the two sixteenth-century crossbows that have been weighed, for a total pool of 22 crossbows.⁴³⁴ The steel crossbows box plot included

the three fifteenth-century crossbows, the 61 sixteenth-century crossbows, and the three heavy-steel crossbows discussed above which could possibly be from the seventeenth century or later, for a total pool of 64 crossbows.⁴³⁵ These two graphs take the broadest views of the data, which has some problems, such as possibly including crossbows from a later period. However, these problems were mitigated by the fact that the size of the data set used prevented one or two problematic crossbows from skewing the bulk of the data. The minimum weight of the steel crossbows was 260 g, the median was 3000 g, and the maximum weight was 10150 g. It is likely that the heaviest crossbows, which were the heavy-steel crossbows from earlier in this chapter, pulled the average up slightly. In general, though, the graph does not differ substantially from what is shown in **Graph 58**, which is no surprise given how

the bulk of the data overlaps. The composite crossbows look almost uniform when compared to the steel crossbows, even though there was over 2000 g of weight difference between the heaviest and lightest composite crossbows.

The steel crossbows appeared to be, at least generally, heavier than their composite counterparts, even if some of the steel crossbows were also by far the lightest crossbows from any period. There are, of course, some problems with this graph, since it mostly compares sixteenth-century steel crossbows to fifteenth-century composite ones.



Weight comparison between 22 composite crossbows and 64 steel crossbows. Data from Appendix I.

⁴³³ Mario Scalini, *L'Armeria Trapp de Castel Coira*, pp. 213; 381.

⁴³⁴ Appendix I, pp. 255-70, 276-7

⁴³⁵ Appendix I, pp. 270-304.

However, earlier in this chapter, it was shown how similar fifteenth and sixteenth-century composite crossbows were, meaning that substituting one group for the other is at least slightly less problematic. The limited data on fifteenth-century steel crossbows means that these conclusions can be applied to sixteenth-century crossbows with only some reservations, but it becomes increasingly problematic to assume that the same patterns of weight hold true the further back in time one goes.

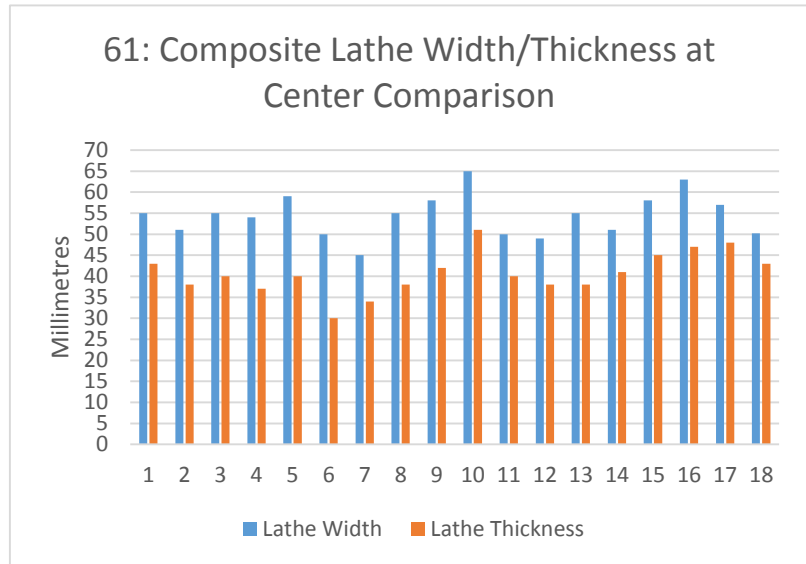
Lathe Dimensions and Draw Distance

There were more aspects to a crossbows shape and design than can be encapsulated in the broad measurements analysed so far in this chapter. Absences and inconsistencies with the type of data available on many of the crossbows covered by this thesis has meant that large data analysis was impossible for more detailed aspects of crossbow design. There was a sub-set of the overall data that was detailed enough to allow for a more specific examination of some aspects of crossbow design. These aspects were: the thickness and width of crossbow lathes, and a discussion of the distance from lathe to lock and how it related to draw distance. In total, 31 crossbows were included in the following analysis, composed of eighteen fifteenth-century composite crossbows and thirteen sixteenth-century steel crossbows.⁴³⁶ Many of the measurements for these crossbows were taken by the author.

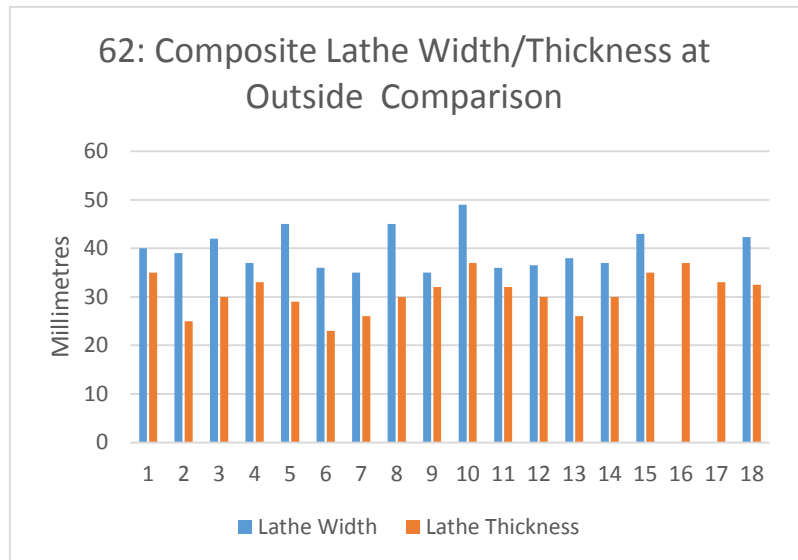
The different methods of constructing composite lathes is a subject in need of further study. While Holger Richter's *Die Horgenarmbrust* offered a very thorough and enlightening study of this weapon, the sheer amount there is to learn about composite crossbows means that much remains a mystery. Richter, along with Josef Alm, has documented the composition of the insides of surviving composite lathes, but the effect the differences in composite lathe construction would have had on performance remains a mystery. The contribution this thesis offers is a comparison of the lathe dimensions of the eighteen composite crossbows in this detailed data set. **Graph 61** shows a comparison of the width and thickness of the composite crossbows at their centre, where the lathe attached to the tiller. **Figure 63** clarifies what is meant in this analysis by the terms 'width' and 'thickness' in this context. What stood out first and foremost was how thick these lathes were. As a point of comparison, the grip sections of the *Mary Rose* longbows were on average between 30 and 35 mm thick and the thickest grip was 36.7

⁴³⁶ For Composite lathes see Appendix I, pp. 254, 256, 258-60, 261-3, 265-9.
For Steel lathes see Appendix I, pp. 270, 274-5, 280-1, 290-1, 295, 302, 304-5.

mm thick. The *Mary Rose* bows were by and large the thickest longbows and those grip sections were designed to add power to the weapon.⁴³⁷ In comparison, over half of the crossbow lathes were over 40 mm thick, and the largest was 51 mm thick. While the two technologies were quite different, this comparison does give an idea of the scale of these composite lathes. The lathes were all wider than they are thick but the degree of difference varies between lathes. The smallest difference was 7.2 mm, the median was 13.5 mm, and the greatest difference was 20 mm. It



Composite lathe dimensions measured near the tiller. Data from Appendix I.



Composite lathe dimensions measured near the nocks. Data from Appendix I.

is difficult to know how significant these differences were. When it came to the power of a bow, generally speaking, the thickness generated power, while the width distributed the strain of drawing the weapon to prevent breakages, usually with a detrimental effect on efficiency. Composite lathes were a more complex technology, though, and so how true this general structural rule was, when it came to their design, is currently a mystery. These lathes cannot be spanned now to test their draw weights, so historians are left to

⁴³⁷ See Chapter 2.

Tim Baker, "Bow Design and Performance", pp. 74-6.

Paul Bourke and David Whetham, "A report of the Defense Academy warbow trials Part I Summer 2005", *Arms and Armour* 4:1 (2007). pp. 54-6.

simply speculate about them.

Graph 62 shows a comparison of the same lathes' widths and thicknesses at their limbs on the outside. The outside, for purposes of this study, is the section of the crossbow lathe just before the nocks. Only one side of the crossbow was measured in each case since the sides are uniformly symmetrical. The only times when the two dimensions would not have been uniform is in cases of damage to one of the limbs. Numbers sixteen and seventeen did not have their outer widths measured by their

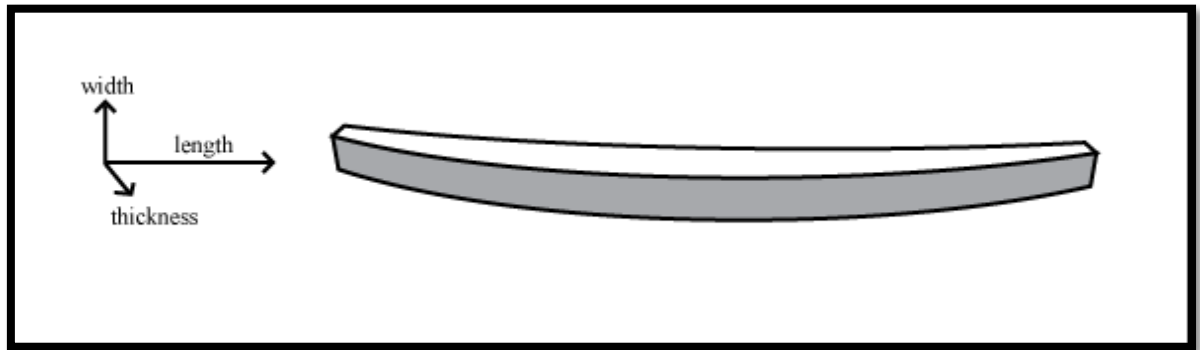


Figure 63: Crossbow Lathe Dimensions, Figure by Emily Neenan, commissioned by author.

museums, but their thicknesses are included for sake of completeness.⁴³⁸ What is most interesting about this graph is how it mirrors **Graph 61**. All of the numbers are slightly smaller, but the ratios are very similar, although in a few cases the differences were slightly less at the limbs than they were in the centre of the lathe. This suggests that composite lathes narrowed uniformly from the centre out toward their nocks, with the decrease in width being mirrored in decreases in thickness. While this trend is almost obvious when one looks at a composite lathe, it is good to know that it is reflected in the measurements of these lathes.

One interesting design feature, which is shown in **Graph 64**, is how the thickness of the lathe at its centre is very similar to its width near its nocks. While there are some differences in size, they are usually no more than 5 mm in either direction. This could be indicative of a general design trend of composite lathes. There could be a ratio these weapons were made with for optimal performance. Why this would be the case is not readily apparent and probably cannot be full understood without a greater understanding of the physics behind how composite lathes operated and some experimentation with replica medieval composite crossbows.

⁴³⁸ Appendix I, pp. 254, 256, 258-63, 265-9.

A similar study of steel lathes shows just how fundamentally different these two technologies were. The following analysis used detailed lathe measurements for eleven steel crossbows.⁴³⁹ There were two additional crossbows where detailed measurements have been taken, but since their lathes were likely later restorations and not medieval, they have been

excluded.⁴⁴⁰ **Graphs**

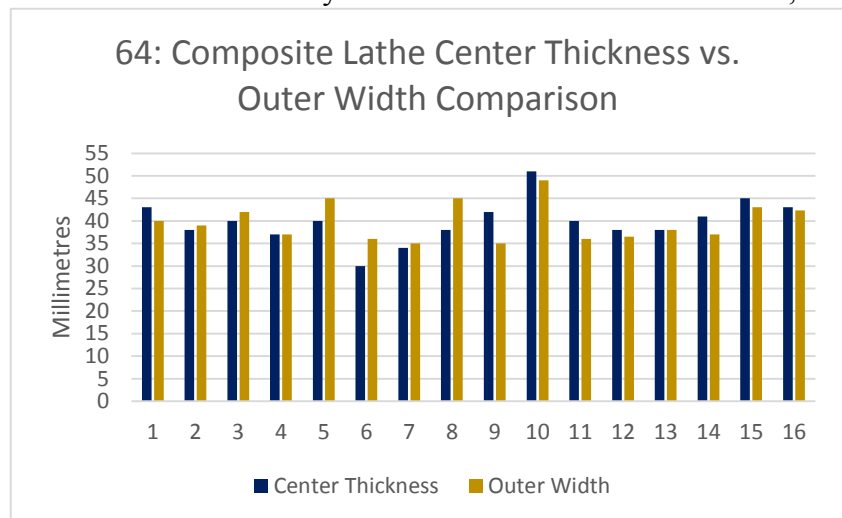
65 and **66** show the dimensions of these steel crossbow lathes; at the centre of the lathe near the tiller, and at the ends just before the nocks,

respectively. It should be noted that the last two crossbows on

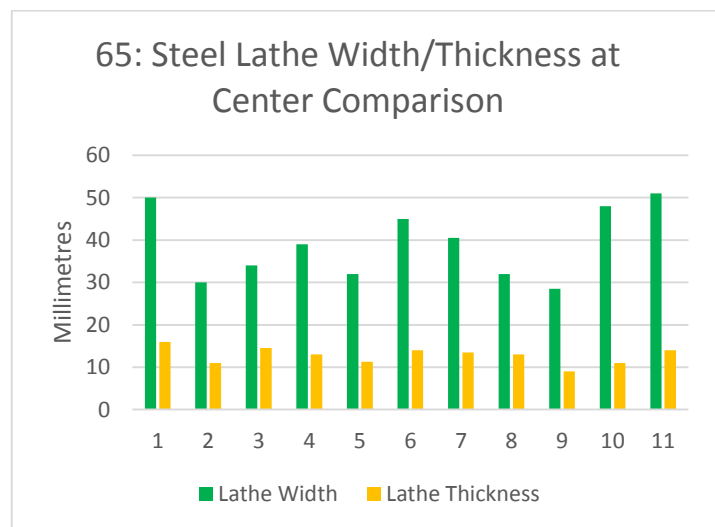
both graphs, numbers 10 and 11, were both heavy-steel crossbows. They have been included here for the sake of completeness, but it should be remembered that they could have been later weapons, and were generally of a different style to the rest of the weapons

in the graph.⁴⁴¹ The most obvious trend in these graphs, which should

be of no surprise to anyone who has seen a steel crossbow lathe before, is that the difference between width and thickness was typically very large. In several cases the difference was greater than 30 mm. The widths of these lathes, especially at the centre, resembled the composite lathes. Both types were between 30 and 50 mm wide, but the steel tillers were on average smaller. While most of the composite lathes were over 40



Comparison of composite lathe thickness at tiller versus the width of the same lathe near its nocks. Data from Appendix I.

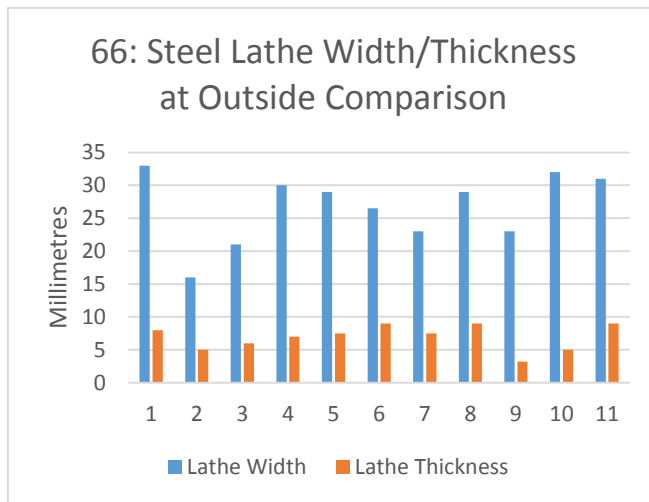


Steel lathe dimensions near the tiller. Data from Appendix I.

⁴³⁹ Appendix I, pp. 270, 274-5, 280-1, 290-1, 295, 302, 304-5.

⁴⁴⁰ Appendix I, pp. 270.

⁴⁴¹ Appendix I, pp. 254, 256, 258-63, 265-6, 268-70, 275, 280-1, 290-1, 295, 302, 304-5.



Steel lathe dimensions near the nocks. Data from Appendix I.

mm wide at the centre, only five of the steel lathes were of a similar width. The outer dimensions mirror their centre dimensions, but on a smaller scale, for both types of lathes. The ratio of width to thickness remained relatively constant as the steel lathes narrowed. Just how thin these lathes were was also a testament to the impressive amount of power a steel spring can generate. Steel crossbows

could easily equal, and often exceed, the power of composite crossbows, and yet these weapons had a tiny fraction of the thickness of their composite counterparts.⁴⁴² This also suggests that a few mm of difference in a steel lathe's thickness was much more significant to the weapon's power than a similar difference would have been in a composite crossbow. The relative difference between steel lathes was much greater than for composite lathes. For example, the difference between a lathe that was nine millimetres thick and one that was sixteen millimetres thick was almost double the size. By comparison, a composite lathe that was 50 mm thick compared to one that is 40 mm thick was only one quarter thicker. Even though the difference in thickness between the two extremes of the steel crossbow data was only eight millimetres, these lathes should not be treated as if they were generally uniform in thickness. The difference in thickness between them was in one way very minor – the absolute differences are not very large – but the impact on the crossbow's performance these small differences could have had was significant. Like with the composite lathes, without further study and a better understanding of how these weapons worked, it is not possible to convert these trends into estimates of how powerful these weapons were. While the sixteen millimetre thick lathe was almost twice as thick as the nine millimetre one, that does not mean it was almost twice as powerful. Crossbow power does not scale linearly, especially when the loss in efficiency from having a heavier lathe is accounted for.⁴⁴³

⁴⁴² Josef Alm, *European Crossbows*, pp. 34-7.

⁴⁴³ Appendix I, pp. 254, 256, 258-63, 265-6, 268-70, 275, 280-1, 290-1, 295, 302, 304-6.

W.F. Paterson, *A Guide to the Crossbow*, (Oldland, 1990). pp. 31-2.

Egon Harmuth, *Die Armbrust* (Graz, 1975). pp. 125-36

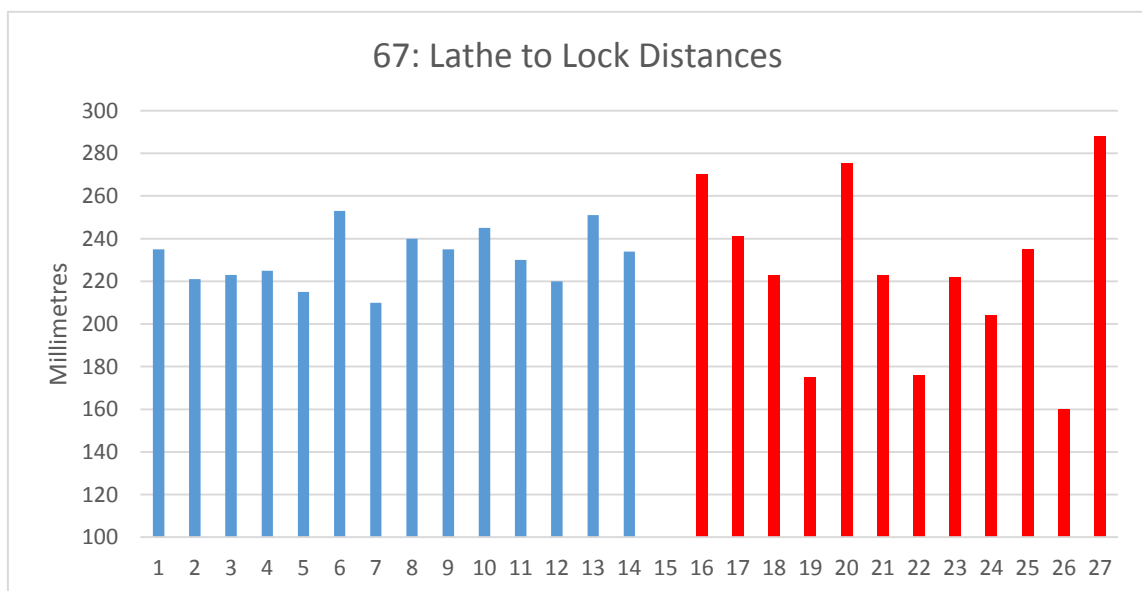
The 'lathe to lock' distance was the section of the tiller from the crossbow nut to the part of the edge of the lathe. Sometimes it was measured to the edge of the lock, which was the area that holds the nut. Other times it was measured to the middle of the nut, where the string would have rested when the crossbow was spanned. Due to this difference, all of the measurements for this section should be treated as if they have a length plus or minus five millimetres. This measurement was essentially a substitution for draw distance. In theory, the draw distance of a crossbow could always be accurately measured, since the string was always drawn back to the nut, but in practice, given the state of many crossbow lathes, this was not possible. The problem is that if the lathe was no longer in its original shape, then the resting position of the string cannot be determined, so it was impossible to determine how far the string would move when the crossbow was spanned. The lathe to lock distance was fixed, however, regardless of the state of the lathe. These problems were significantly more prevalent in composite crossbows, as opposed to steel crossbows, since steel lathes keep most of their curve even when unstrung. Lathe to lock distance could give some insight into the draw distance of these crossbows, but the lathe to lock distance was longer than the draw distance would have been. This is not necessarily an insurmountable problem, however. For one thing, the extra distance covered under string length contributed slightly to a crossbow's power. A crossbow lathe was already under pressure when it was strung, it had to be bent to be strung in the first place, so the power required to draw the weapon was greater due to this initial bend. However, since the string stopped when it reached its original resting position this extra stored power was not transferred to the bolt so the energy was mostly 'lost'.⁴⁴⁴ **Graph 67** shows the lathe to lock distances of both the composite and steel crossbows in this data set.⁴⁴⁵ The gap in the graph, along with the colour change, marks the shift from composite crossbows to steel crossbows. What stood out the most in this data set was how much greater the variation was in the steel crossbows than the composite ones. The greatest difference between two lathe to lock distances for the composite crossbows was 40 mm. By comparison, the greatest difference for the steel crossbows was 128 mm. There appears to have been a greater level of standardisation with the composite crossbows than there was for the steel

Erhard Franken-Stellamans, "A Mathematical Method for Determination of the Appropriate Draw Length for a Given Steel Bow", pp. 92-4.

⁴⁴⁴ Tim Baker, "Bow Design and Performance", in *The Traditional Bowyer's Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). pp. 1:48-65.

⁴⁴⁵ Appendix I, pp. 254, 256, 258-63, 265-6, 268-70, 275, 280-1, 290-1, 295, 302, 304-5.

crossbows. These distances on their own were not very informative but they did represent a key component to understanding the power of these weapons. In general, larger lathe to lock distances were probably indicative of greater power. There were, however, some complications with this relationship due to differences in where the string would rest before spanning. There was only a 5% difference between the median lathe to lock distances for the two types of crossbow. The median for steel crossbows was 223 mm while for composites it was 232 mm. Steel crossbows had a much wider range of lengths. Additionally, while greater distance was broadly indicative of greater power the lathe design was significantly more important. If two lathes were identical, then the greater lathe to lock distance would indicate greater power, but two lathes were never actually identical so this measurement was still only a secondary indicator of crossbow power.



Crossbow lathe to lock distances. Blue bars represent composite crossbows, red bars represent steel crossbows. Data from Appendix I.

Spanish Crossbows

Medieval European crossbows survive in greatest numbers from two regions: Spain and Central Europe, with the latter being the significantly larger category. The reason why these two areas had most of the surviving crossbows is not clear. For the purposes of this thesis, Central Europe has been defined as modern day Austria, Switzerland, and Germany. The more specific places of origin of these crossbows have been replaced with the broader category of Central Europe for three reasons. Firstly, many collections were not entirely confident in their classification of a crossbow as from

a specific region within Central Europe. Secondly, where a crossbow was found was not necessarily where it was made. Thirdly, these distinctions reflected modern borders of modern countries that either did not exist or were not as distinct when these weapons were made.⁴⁴⁶ There are some crossbows that survived from outside these areas. This thesis also includes crossbows from: England, Sweden, Poland, Italy, and the Low Countries. The crossbows from these regions were too few to make a robust data set for comparison, though. There were also quite a few crossbows whose origin was unknown or unclear. This made any detailed regional analysis of crossbows very difficult.

The only two regions with enough crossbows for comparison were Central Europe and Spain. There were, however, several problems with comparing Central European crossbows with Spanish crossbows. Spanish crossbows were exclusively made with steel lathes while many crossbows identified as Central European had composite lathes. Comparing two crossbows with different types of lathe while looking for regional differences is not a practical method of study. The next significant difference between the two regions was the placing of the lathe. Central European steel crossbows had their lathe mounted at the end of the tiller, the same as composite lathes.⁴⁴⁷ Spanish crossbows had their lathes mounted inside the tiller. The end of the tiller extended beyond the lathe for at least 10 mm, sometimes much more.⁴⁴⁸ While the evidence was limited, it seems that only Spanish crossbows had this design feature, at least in the Middle Ages. This type of lathe mounting became standard in early modern crossbows and was also present in the heavy-steel crossbows that could be medieval but were likely early modern.⁴⁴⁹ The final immediately apparent difference between Spanish and Central European crossbows was their size. As **Image 68** should make apparent, the Spanish crossbows were made with sleek design; they had thin tillers and lathes. Their Central European counterparts were bulky in comparison.⁴⁵⁰ These last two design differences were fundamental to historians' understanding of these weapons, but were also not captured well in the data available in this thesis. As a result of these problems, this thesis will take a slightly different approach to these regional differences than a direct comparison. Instead of examining the two regions side-by-side, this section will study the more unusual crossbow style, that is to say that of the Spanish crossbows, in detail, and compare it

⁴⁴⁶ Mario Scalini, *L'Armeria Trapp de Castel Coira*, pp. 211.

⁴⁴⁷ Appendix I, pp. 271-2, 287-91, 297-9.

⁴⁴⁸ Appendix I, pp. 271-2, 287-91, 297-9.

⁴⁴⁹ Josef Alm, *European Crossbows*, pp. 60, 65-8.

⁴⁵⁰ Appendix I, pp. 271-2, 287-91, 297-9.

back to the more general data, to see how it stands out from what could be considered the 'normal' design of steel crossbows.

A closer study of the Spanish crossbows, and how they fitted in with the broader



data, can inform historians on what differences in crossbow design looked like on a small scale. There were fourteen Spanish crossbows in the data set. Two were from the fifteenth century,

Image 68: Grandson B199, a small Spanish target crossbow currently in Grandson Castle, photo by author

one was transitional, and the remaining eleven were from the sixteenth century.⁴⁵¹ The string lengths and total lengths of these crossbows have been measured. Two have also had their lathe lengths measured and a further four had their tiller lengths measured. This latter measurement was difficult to interpret, however, since the tiller extended beyond the lathe in Spanish crossbows, and it was not clear if the tiller length of these crossbows was considered to have been the distance from the lathe to the butt of the crossbow, or if it was the entire tiller, with only the spanning ring or stirrup excluded. This complication, combined with the small number, means that this analysis will focus only on total lengths. **Graph 69** shows the string and total lengths of the Spanish crossbows. The variation in lengths that was present in the steel crossbows more generally is clearly also present in the Spanish crossbows. This is to be expected if these differences in size were representative of crossbows built for different purposes. If the demand for the same types of crossbows was present in Spain it would stand to reason that they would have produced those same crossbows but in their unique Spanish style. The string lengths nearly exactly mirrored those of the overall sixteenth-century steel crossbows. The only difference was that the longest Spanish crossbows did not quite equal the extremes of the sixteenth-century steel crossbows. The longest Spanish lathe was 820 mm long, and the shortest was 390 mm long. For the overall data the longest was 950 mm long and the shortest was 280 mm long. The box section of the Spanish string length graph was nearly

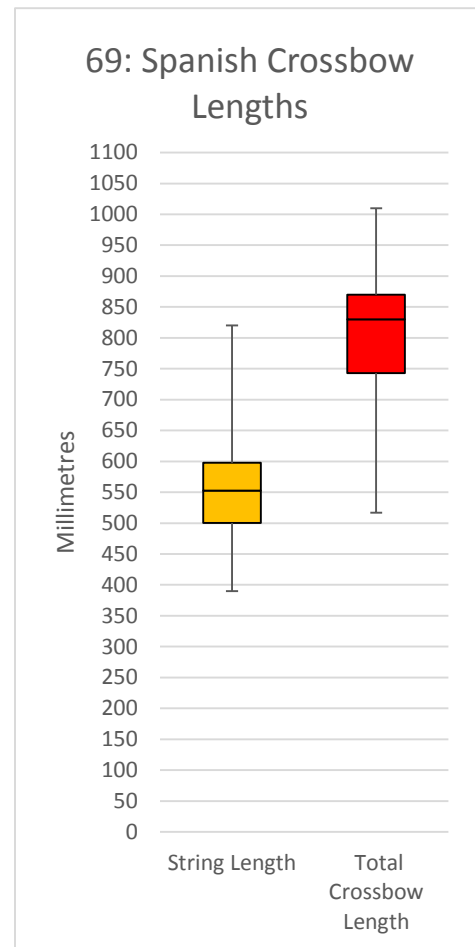
⁴⁵¹ Appendix I, pp. 271-2, 287-91, 297-9.

identical to that of the overall data. The differences between the ends of the two data boxes is less than 10 mm total. Only two of the Spanish lathes had more detailed information on their cross-sections or lathe lengths. The widths and thicknesses of these two can be seen in **Graphs 65** and **66**. The Spanish lathes are numbers two and three on those graphs.⁴⁵² They were on the smaller end of the data, especially their outer cross-sections, but only slightly. This suggests that Spanish lathes were on average smaller, and possibly narrowed more significantly as they reached their nocks. However, with such a small sample, this is hardly definitive and more evidence would need to be collected.

The Spanish crossbows showed a significant difference when it came to their tillers. They were much longer on average than the rest of the data. The median length of the Spanish tillers was 830 mm, while the median for steel crossbows in general was 645 mm. Only two of the Spanish tillers were shorter than 700 mm. The fact that they had an extra section of tiller extending beyond the front of their lathe could explain the difference in tiller lengths, but might not be the sole explanation. On the three crossbows that measurements are available for, the distance from lathe to their stirrup was never more than 25 mm.

While not every Spanish crossbow necessarily follows this trend, the bulk of the Spanish crossbows were over 50 mm longer than the average for steel crossbows in general. That is a difference that is only half covered by the extra tiller sections.

A final topic of consideration for the Spanish crossbow is their weight. Dirk Breiding has argued that by and large Spanish crossbows were lighter than Central European crossbows.⁴⁵³ Breiding's study only contained a handful of Spanish crossbows, though, so a wider study of Spanish crossbows should be done to see if his assertions are

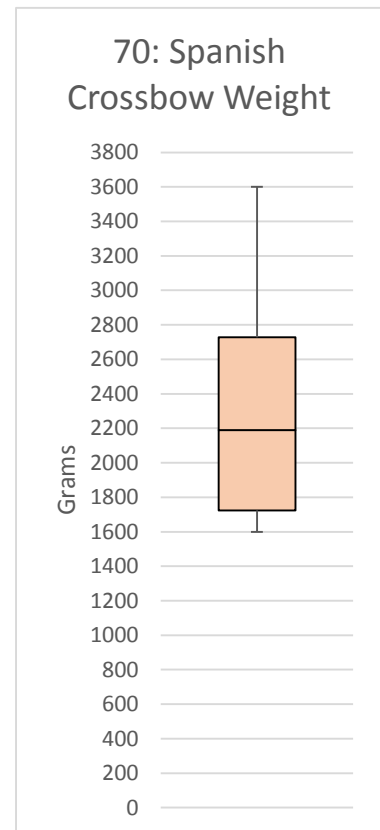


String lengths of Spanish steel crossbow lathes alongside total crossbow length. Data consists of 14 crossbows for both graphs. Data from Appendix I.

⁴⁵² Appendix I, pp. 271-2, 287-91, 297-9.

⁴⁵³ Dirk Breiding, *A Deadly Art*, pp. 30-4.

backed up by the evidence. Unfortunately only eight of the Spanish crossbows in the data have been weighed so this topic had a much smaller data pool than the preceding analysis.⁴⁵⁴ **Graph 70** shows the distribution of weights of the Spanish crossbows. When compared to the steel crossbow weights in **Graph 59**, the Spanish crossbows did appear to be on average lighter. The Spanish data lacked the extremes seen in the overall steel crossbow data but they did have a substantial amount of overlap. That said, all but one of the Spanish crossbows weighed less than the median weight of the overall data. That is very strong evidence for Spanish crossbows being lighter, at least on average, than those from other regions. This difference could probably be explained by the overall narrow tiller dimensions that Spanish crossbows seem to have had. Unfortunately, with such limited data available on these crossbow dimensions more generally, it was impossible to prove a connection between the shape of Spanish crossbows and the fact that on average they weighed less than other steel crossbows.



Spanish crossbow weight for 8 examples. Data from Appendix I.

Conclusion

In total, 140 different crossbows were included in the analysis conducted in this chapter. This sample drew on crossbows from across at least three centuries, but primarily focused on the fifteenth and sixteenth centuries. Wooden crossbow lathes were covered only briefly, as necessitated by the limited archaeological evidence. Most of the analysis concentrated on composite and steel crossbows. What data there were from the fourteenth century suggested that composite crossbows became shorter in the transition from the fourteenth to the fifteenth centuries. No similar change happened at the start of the sixteenth century, when the composite crossbow stopped being made. There seemed to be some standardisation in the dimensions and design of composite crossbows in the fifteenth and sixteenth centuries, but that does not mean that there was no diversity. The extremes of the data were significant outliers from the majority of composite crossbow

⁴⁵⁴ Appendix I, pp. 271-2, 287-91, 297-9.

lathes and could indicate that distinct types of crossbows were made during the Later Middle Ages. Alternatively, they could be indicative of different regional, temporal, or even workshop preferences for how the weapons were made.

The differences in composite crossbow design were negligible compared to those found in steel crossbows. The fifteenth-century steel crossbows were generally of a similar size and shape to their contemporary composite crossbows, but by the sixteenth century they had diversified to an extraordinary degree. The shortest lathes in the entire sample are from this data set, along with some of the longest. The lightest and the heaviest crossbows are from this same data set, although many of the latter are very difficult to date. There were clearly many different methods of crossbow design in place by the sixteenth century. So many types, in fact, that it may be an oversimplification to classify “steel crossbows” as a single category. This diversity is not the whole story, however, or even representative of the majority of the data. Overall what this data suggests is that historians’ concept of “the crossbow” as a single uniform weapon to be compared to another weapon, such as the longbow, is in fact far too simple an idea.

Chapter Six

Crossbow Spanning Devices

Initially crossbows would have been spanned by hand, using the power of the archer alone. A crossbow was spanned when its string is pulled from its initial resting position to the nut. As crossbows developed, crossbow-makers were able to build more powerful crossbows that could not practically be spanned by human power alone. As a result several devices were designed to help with spanning a crossbow. These devices were improved upon and expanded over several hundred years. The complexity and power of these devices varied significantly. The crossbow, especially in the Later Middle Ages, was not an isolated technology. Just as it would be a mistake to discuss guns without including gunpowder, no discussion of the medieval crossbow is complete without some mention of spanning devices. This chapter will first provide a general overview of the primary crossbow spanning devices, before moving on to an examination of the archaeological evidence for those same devices, and what they can tell historians about both the power and use of crossbows. It will conclude with a discussion of artistic images of spanning devices and what they can tell historians about how these devices were used by medieval archers.

Types of Spanning Device

The most basic development to assist with spanning a crossbow, which could barely even be called a device, was the addition of a stirrup to the front of the crossbow. This feature became standard in almost all medieval crossbows, although the specific shapes would differ. These helped the archer to hold the crossbow steady while they pulled the string back with their hands. It also prevented any damage to the lathe that might result from the previous habit of standing on the bow while pulling the string back.⁴⁵⁵ Exactly when the stirrup became a standard feature of crossbow design is not clear. Since very little is known about the early design and development of crossbows, and there are no surviving complete European crossbows from before the fourteenth century, it will likely remain a mystery. Crossbows certainly had stirrups by the thirteenth century, if not before.⁴⁵⁶

The first device independent of the crossbow itself, ‘the belt hook’, was

⁴⁵⁵ Ralph Payne-Gallwey, *The Crossbow: Its Military and Sporting History, Construction and Use*, (1903, repr. London, 1995). pp. 57-61.

⁴⁵⁶ David S. Bachrach, “Crossbows for the King: The Crossbow During the Reigns of John and Henry III of England”, *Technology and Culture*, 45:1, (2004). pp. 109-13.

Josef Alm, *European Crossbows: A Survey*, ed. and trans. G.M. Wilson and H. Bartlett Wells, (1994, repr. Dorchester, 1998). pp. 20-3.

Nicole Pétrin, “Philological notes on the crossbow and related missile weapons”, *Greek, Roman and Byzantine studies* 3:;3 (1992). pp. 280-91.

developed at approximately the same time as the stirrup. The belt hook was a metal hook that hung from the crossbowman's belt. Some belt hooks had only one hooked prong while others were two-pronged. A crossbow was spanned by putting the string on the hook and the archer's foot in the stirrup. There were two different methods of actually spanning the crossbow when using a belt hook. One method was to crouch when hooking the string and then pull the string back into place by standing up with one foot in the crossbow's stirrup. The other method was to balance on one foot with the other in the stirrup. The archer would then push down with the foot in the stirrup forcing the string back as it was held in place in the belt hook. There are contemporary images that are indicative of both of these methods, but the latter method appears more often. The belt hook was already in use by the thirteenth century and continued to be used throughout the Middle Ages.⁴⁵⁷

A later device that functioned on similar physical principles as the belt hook was the *krihake*. The *krihake* was a hook with an attached pulley which was mounted on a rope. The rope was attached to the archer's belt on one end, and had a loop of metal on the other. The metal loop was placed around a metal stud or hook on the crossbow and the hook attached onto the bowstring. This was done with the archer leaning over with their foot in the crossbow's stirrup. Then when the archer straightened their back the rope on their belt would pull the string and span the bow. This method was superior to the older belt hook, because the pulley and rope system used allowed for the archer to more efficiently use their force to either span a heavier crossbow or span a lighter crossbow with less effort. Despite the relative technological simplicity of the *krihake*, especially compared to some of the devices discussed later in this chapter, one should not assume that it was invented almost contemporary to the belt hook. *Krihakes* were probably first introduced in the fourteenth century and became fairly common in the fifteenth and sixteenth centuries.⁴⁵⁸ There was ample artistic evidence of its use from the fifteenth century, for example, two were being used by archers in Piero de Pollaiuolo's *Martyrdom of St Sebastian* from c. 1475 [Plate 39].

Crossbows with the highest draw weights required more force to span than could

⁴⁵⁷ Jens Sensfelder, "A Gothic Spanning-Belt Hook", *Journal of the Society of Archer-Antiquaries* 43 (2000). pp. 27-8.

Josef Alm, *European Crossbows*, pp. 20-3.

⁴⁵⁸ *Ibid.* 40-1.

A. G. Credland, "The Crossbow in the Far North", *Journal of the Society of Archer-Antiquaries*, 26 (1983). pp. 13-4.

Ralph Payne-Gallwey, *The Crossbow*, pp. 73-80.

Dirk Breiding, *A Deadly Art, 1250-1850*, (New York, 2014). p. 92-3.

be generated by human power alone, so devices were made to span them instead. There were two devices suited to crossbows of this type. They were sometimes associated with specific regions, although the accuracy of this association is not entirely clear.⁴⁵⁹ The first of these devices was the windlass. The windlass, which was sometimes called English windlass, was a system of ropes and pulleys connected to a winch. It was attached to the end of the crossbow. Sometimes it was built into the crossbow tiller but often it was just temporarily secured. It had two hooks which were attached to the bowstring. The archer would then turn the handles on either side of the winch which would pull the string back into position. The windlass required continuous cranking on the winch for it to work. If the archer stopped, the string would snap back into its original position. The windlass is generally thought to have been introduced into Europe sometime during the thirteenth century. There were mentions of it in a text written for Saladin by Al-Tarsusi in the late twelfth century and in Western Europe the windlass was often linked to Richard I's return from the Third Crusade (1189-92).⁴⁶⁰ Richard I (r. 1189-1199) was certainly a proponent of the crossbow but there was little evidence for him being connected to introducing the windlass as a new technology. The first clear evidence for the windlass in an English context is from the reign of Henry III, but it was likely in use well before then. The windlass continued to be used well into the early modern period.⁴⁶¹

The second spanning machine intended for use on heavy crossbows was the *cranequin*. The *cranequin* was sometimes associated with Germany or, more generally, Central Europe.⁴⁶² The *cranequin* was secured to the crossbow by means of a metal hook, or loop, which wrapped around the tiller and secured it to the top of the crossbow. Several *cranequins* can be seen in **Image 71**. The mechanism that did the work of spanning the crossbow was a group of gears in a case that were turned by a handle. These gears would move a ratched bar. The bottom of the ratched bar had a hook that was attached to the string, so that when the handle was cranked, the string would slowly be

⁴⁵⁹ Josef Alm, *European Crossbows*, pp. 39-40

⁴⁶⁰ David S. Bachrach, "Crossbows for the King, Part II: The Crossbow During the Reign of Edward I of England (1272-1307)", *Technology and Culture*, 47:1, (2006). pp. 83-5.

Anne-Marie Eddé, *Saladin*, trans. Jane Marie Todd, (Cambridge, 2011). pp. 281-2.

W.F. Paterson, *A Guide to the Crossbow*, (Oldland, 1990). pp. 34-5.

⁴⁶¹ David S. Bachrach, "Crossbows for the King: The Crossbow During the Reigns of John and Henry III of England", pp. 113-117.

Ralph Payne-Gallwey, *The Crossbow*, pp. 121-5.

Arthur Graves Credland, "Crossbow Remains (Part 2)", pp. 11-2.

Dirk Breiding, *A Deadly Art*, pp. 93

⁴⁶² Josef Alm, *European Crossbows*, pp. 39-40.

pulled back in stages. The majority of surviving examples were from the late fifteenth century and later, although it was difficult to date early *cranequins* so some of these examples could have been older. *Cranequins* from the late fifteenth, sixteenth and later centuries were more likely to have identifiers like maker's marks or coat of arms on them which makes it easier to date them accurately. Early *cranequins* had only one hook to attach to the string, while later ones had two hooks as well as a flap of metal that helped to ensure the archer lined the device up exactly on the center of the string. The *cranequin* likely came into use around the fourteenth century and continued to be used well into the early modern period. By the sixteenth century it had largely eclipsed the windlass. Many early modern *cranequins* had detailed images and decorations carved into them, sometimes inlaid with gold, that were likely indicative of noble ownership.⁴⁶³

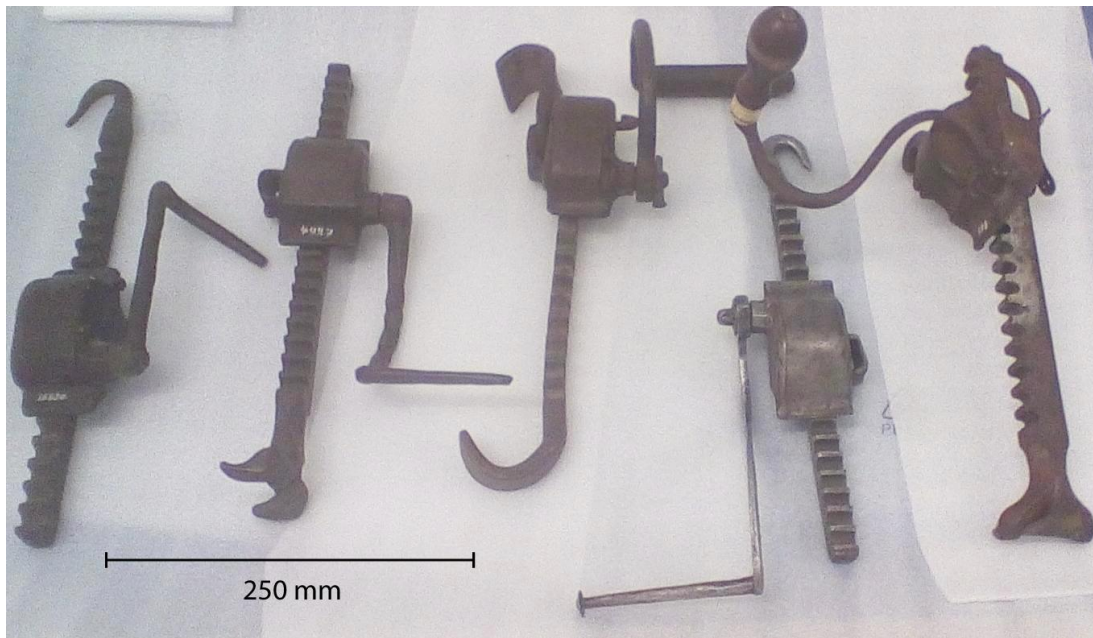


Image 71: A range of cranequins dating from the fifteenth and sixteenth centuries, currently in the Bernisches Historisches Museum, photo by author

The key difference in use between these devices was that the windlass was used in one smooth motion which required constant turning while the string was being winched back while the *cranequin* pulled the string back in stages. The devices also differed greatly in how they were made. The windlass was made of metal, ropes, and usually some wood while the *cranequin* was entirely made of metal, excluding any

⁴⁶³ Ralph Payne-Gallwey, *The Crossbow*, pp. 140-4.

Josef Alm, *European Crossbows*, pp. 38-40.

Sven Ekdal, "Horses and Crossbows: Two Important Warfare Advantages of the Teutonic Order in Prussia" in *The Military Orders: Volume 2 Welfare And Warfare*, ed. Helen Nicholson, (Aldershot, 1998). pp. 143-7.

Dirk Breiding, *A Deadly Art*, p. 94-5.

decorations.⁴⁶⁴ Both devices were quite slow to attach to the crossbow and operate, which meant that these heavy crossbows were slow to reload. The most commonly cited reload time for a powerful crossbow being operated by a trained archer is between thirty and sixty seconds per shot.⁴⁶⁵

The final spanning device that saw frequent use in the Later Middle Ages was the goats-foot lever. The goats-foot lever was composed of two metal claws and a handle. This device was used by hooking one claw over the string and the other end either hooked on to or braced against metal lugs in the crossbow's tiller. The handle could then

be used as a lever to pull the string into place. **Image 72** shows an example of this in action. There were some examples of crossbows with very small hand sized stirrups and lugs for a goats-foot lever that suggest that the device may sometimes have been used with a stirrup for stabilizing the crossbow.⁴⁶⁶ Where exactly it fit into the chronology of the history of crossbows was not clear, nor was it clear exactly how powerful a crossbow would have been to require its use. Many surviving goats-foot levers had rings or nobs of some sort on the end of their handles that would have allowed them to hang from a saddle, or possibly a belt, for ease of use.⁴⁶⁷ Like the *cranequin* the goats-foot lever remained popular well into the early modern period. It may have been primarily intended for hunting rather than warfare.⁴⁶⁸

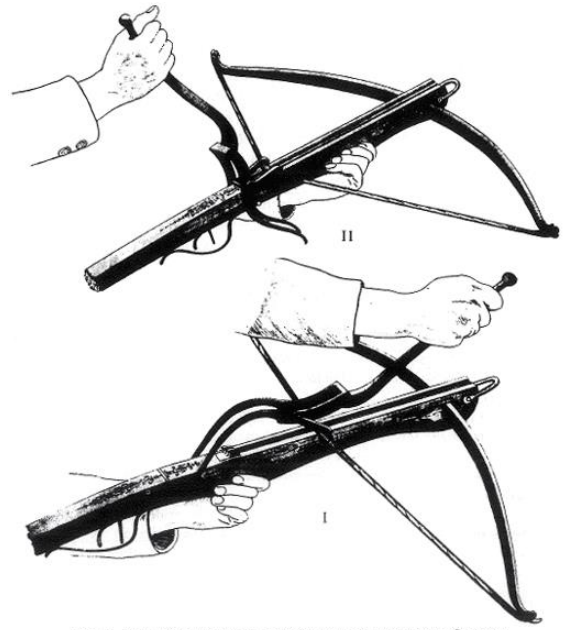


Image 72: A Goats-Foot Lever in Use, from Payne-Gallwey, The Crossbow, p. 85

Determining what kind of spanning method was used with a given crossbow can often be more difficult than might be expected. This seems like it would be relatively easy since there were several noticeable design features that indicated what type of spanning mechanism was used on a crossbow. Windlasses, *cranequins*, *krihakes*, and

⁴⁶⁴ Ibid. pp. 94-5; 103-11.

⁴⁶⁵ Ralph Payne-Gallwey, *The Crossbow*, pp. 121-125, 140-144.

Josef Alm, *European Crossbows*, pp. 38-40.

⁴⁶⁶ Josef Alm, *European Crossbows*, p.40.

⁴⁶⁷ Ibid. p.28.

⁴⁶⁸ Ibid. pp. 27-29.

Ralph Payne-Gallwey, *The Crossbow*, pp. 84-91.

goats-foot levers all attached to the crossbow in different ways, and the various lugs and hooks that these machines used can still be identified on many crossbows. Many collections have not mentioned these features in their descriptions, however, so one must either see the crossbow in person or hope that the collection had high quality photographs. The type of stirrup could help to narrow the range of possible spanning methods a crossbow would have used. A hook or windlass based system for spanning required a stirrup large enough to place a foot inside. In contrast the goats-foot lever or *cranequin* could be used with either the aforementioned kind of stirrup or else a stirrup only large enough for a hand, to merely stabilize the crossbow.⁴⁶⁹ The main problem for historians attempting this kind of analysis was the fact that crossbows were not only used in the time they were made. Some crossbows continued to be used for decades after they were first made. Sometimes, in the twilight years of their use, these crossbows would be modified by their owners to use a different spanning device. For example **Image 73** shows crossbow B2 from Grandsom Castle, which was been dated to the fifteenth century and had a *cranequin* lug which was definitely a later addition.⁴⁷⁰ For one thing, it was not very well inserted, it was not perpendicular to the tiller. It also penetrated and damaged the horn inlay decoration. The original crossbow-maker would almost certainly have made sure the lug was oriented correctly and definitely would not have so obviously damaged the decoration by adding the lug after the horn inlays were in place. Additionally, there is a hook on the top of the tiller that was clearly designed for a

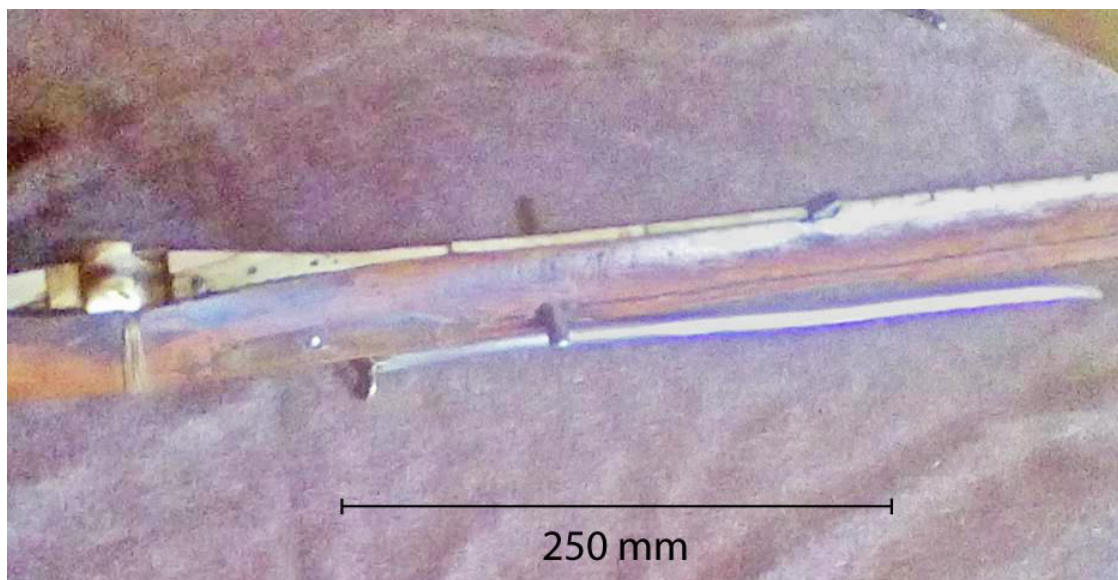


Image 73: Close up of Grandsom Crossbow B2 showing both its original krihake hook as well as the cranequin lug which was added later; photo by author

⁴⁶⁹ Dirk Breiding, *A Deadly Art*, pp. 92-6

⁴⁷⁰ Appendix I, p. 262.

krihake and probably represented the original spanning method intended for the crossbow. This was not the only example of this practice and many others involved less obvious modifications, so it can be hard for historians and curators to determine whether a spanning method was original to the crossbow or a later addition.⁴⁷¹

The Archaeological Record

The archaeological record for spanning devices lacked some of the complexity and depth when compared to that of the crossbows they were used with. While these devices were quite complex, the individual variations between them were not as obviously significant. That does not mean they did not raise any interesting questions. The lack of significant variation made it easier to discuss broader trends in the technology with a smaller data set, which was useful, since besides a few noticeable outliers, most types of the spanning devices frequently did not survive. *Cranequins* were the most likely to survive, especially from the fifteenth century and later, with goats-foot levers from the same time being the second most likely. Other devices were remarkably rare from any time before the early modern period. The *cranequin* and goats-foot lever were best suited to broad data analysis, since they both survived intact with relative frequency and were generally either mostly or totally complete.⁴⁷² When attempting to determine what was significant about the design of a spanning device, its use by the archer was considered first and foremost. It could have been used by an archer in the field, either while hunting or in battle, or it could have been intended exclusively for siege or some other kind of primarily stationary action. The difficulty in carrying the device, either due to its weight or due to it just having been otherwise cumbersome, could point historians towards a likely intended use for it. It was also worth considering that the device would be attached to the crossbow when it was in use, so the device's weight would temporarily have been added to that of the crossbow. In the case of very heavy spanning devices this could mean it was intended to have been used in a siege, but it could still have been intended for the hunt. Hunting would have required less frequent reloading than battle, and in the case of nobles hunting there could easily be more than one individual in charge of transporting or using the pieces of crossbow equipment for the hunter. The more specific cases for each of the spanning devices will be considered with their respective data, but these are the broad questions to keep in mind when

⁴⁷¹ Ian Ashdown, pers. comm. [20/2/15]

⁴⁷² Appendix II, pp. 309-324 for examples.

looking at the data collected on medieval spanning devices.

Belt hooks have very rarely survived but thankfully were not entirely absent from the archaeological record. Belt hooks can be difficult to accurately identify since they were essentially a simple metal hook. Determining whether such a hook was intended for spanning a crossbow or another use is not easy. One example of a surviving belt hook is currently in the German Hunting and Fishing Museum in Munich.⁴⁷³ This hook was excavated during a dig in Silesia, and has been identified by the museum's curators as being Gothic in style due to the techniques used by the blacksmith who created it. It was forged from a single piece of iron and is approximately 355 mm long. The hooked section was only about 114 mm long. The rest of the length was composed of the loop through which the hook was attached to the belt and a tongue that was presumed to have been used to stabilize the hook while it was in use. The tongue would likely have been enclosed in the belt which would explain why it is not visible in medieval images showing archers using belt hooks. The inside of the hook was flattened and smoothed out to reduce wear on the string while it was in use. There are a further two probable belt hooks currently in Grandson Castle.⁴⁷⁴ These two hooks, dated to the fifteenth century, were only probable belt hooks because they could be hooks for *krihakes* instead. The iron they are made from was quite corroded, and so it is not possible to determine if they were meant to have pulleys. It was more likely that they were belt hooks, though. These two differ noticeably in design from the one in Munich. They were much shorter: both were only 88 mm long. They both had two hooks, but in one case the hooks were less than a third of the total length of the device, while in the other they composed more than half the total length. These three items only represented a fraction of the likely surviving belt hooks, but were representative of the diversity that existed within the technology. There were probably a wide range of belt hook designs that were used in the Middle Ages. The device's simplicity means it would have been easy to change it to suit regional or personal preferences while still retaining its core function.

Krihakes have rarely survived in their entirety, especially those from before the sixteenth century, but the pulleys have survived relatively frequently. One near complete example from the sixteenth century was in the Swedish Royal Armouries.⁴⁷⁵ In the museum catalogue it was identified as a Samson Belt, another common name for the

⁴⁷³ Jens Sensfelder, "A Gothic Spanning-Belt Hook", pp. 20-2.

Appendix II, p. 326.

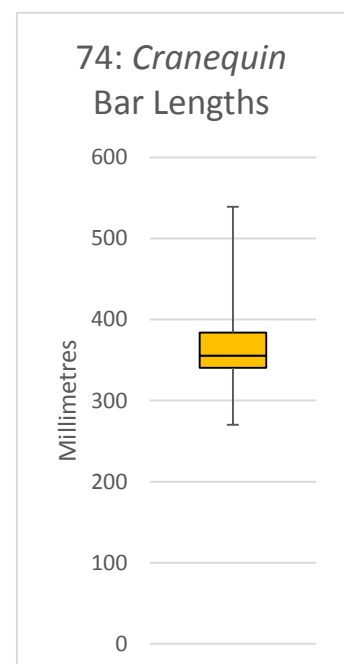
⁴⁷⁴ Appendix II, pp. 325-6.

⁴⁷⁵ Appendix II, p.324.

krihake. This example consisted of a belt, the pulley, and the ropes that would have been used to connect the two. It was a double pulley *krihake*, which means it had two hooks and two pulleys. The two pulleys were connected by a metal bar. The belt was 1600 mm long and 120 mm wide. The pulley was 86 mm long, but its width was not included in the description. The entire 'Samson Belt' weighed only 615 g. The data for this thesis includes three examples of surviving pulleys without the belt or ropes: two more in the Swedish Royal Armouries and one in the Metropolitan Museum of Art (Met). All of these examples were double pulleys. The second Swedish pulley was 86 mm long, 92 mm wide, and weighed 302 g. The final Swedish pulley was 107 mm long and had no other information published about it. The Met pulley was 177 mm long and was 77 mm wide and weighed 224 g.⁴⁷⁶ This small data set suggested that while there was noticeable variation in the size of *krihake* pulleys, generally they were quite small and would likely not have been cumbersome tools for the archer to use.

The *cranequin* was the spanning device that survived in the greatest number from the Middle Ages. There were two primary styles of *cranequin*. The difference was primarily determined by the placement of the crank handle and the orientation of the ratched bar. One, called Spanish by Dirk Breiding, had the crank handle mounted on the side of the *cranequin* case, meaning it would have been vertical when the *cranequin* was in use, while the other, called German by the same author, had the crank mounted on top of the case.⁴⁷⁷ The orientation of these mountings was relative to how they would have been when the *cranequin* was attached to the crossbow. The data set in this thesis consisted of 41 *cranequins*, including twenty with detailed measurements, many of these were taken by the author.⁴⁷⁸ Nine of the *cranequins* were dated to the fifteenth century while the remaining 32 *cranequins* were from the sixteenth century.

The length of a *cranequin* was measured as the length



Lengths of the bar sections of cranequins. Data consists of 41 examples. Data from Appendix II.

⁴⁷⁶Dirk Breiding, *A Deadly Art*, p. 97.

Appendix II, pp. 325-6.

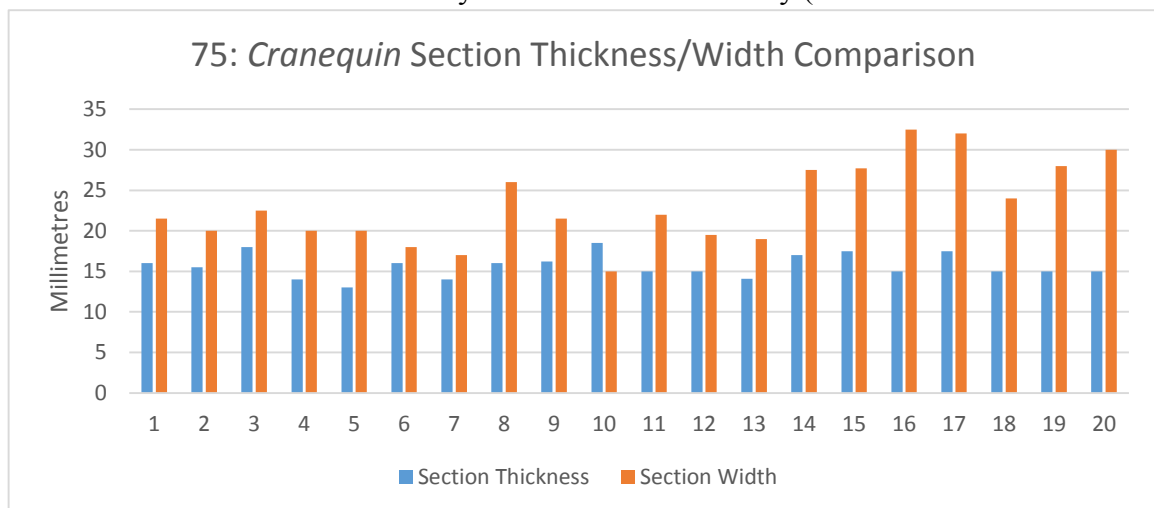
⁴⁷⁷Dirk Breiding, *A Deadly Art*, pp. 94-5.

Josef Alm, *European Crossbows*, p. 40.

⁴⁷⁸Appendix II, pp. 307-322.

of its ratched bar, including the hook at the end that attached to the string. The shortest *cranequin* in the data set was 270 mm long while the longest was 539 mm long.⁴⁷⁹ These two measurements were outliers from the general data though. As **Graph 74** shows that the bulk of the *cranequins* were between 300 and 400 mm long. Ian Ashdown, one of the curators of Grandson Castle, also described the 539 mm long *cranequin* as the longest he had ever seen, suggesting it was a significant outlier.⁴⁸⁰ In general fifteenth-century *cranequins* appear to have been shorter than their later counterparts. No fifteenth-century *cranequin* was longer than 400 mm and only one was less than 300 mm long.⁴⁸¹ In contrast, seven of the sixteenth-century *cranequins* were over 400 mm long and none were shorter than 300 mm.⁴⁸²

Graph 75 shows the dimensions of a section of the *cranequin* ratched bars. The section was measured to include the teeth, meaning it represents the widest section of bar. The graph was ranged chronologically from left to right and represents a slow transition from mid-fifteenth century to mid-sixteenth century (number 8 is the first



Dimensions of the cranequin bar, measured at the bar's widest point. Data from Appendix II.

sixteenth century *cranequin* in the graph). The graph showed that, while section thickness remained relatively constant, section width seemed to have had a noticeable increase. It should be noted that *cranequin* number 10, the only one whose thickness was greater than its width, was actually a misleading data point.⁴⁸³ It was a Spanish *cranequin* and the entire ratched bar was orientated ninety degrees off from other

⁴⁷⁹ Appendix II, pp. 309, 313.

⁴⁸⁰ Ian Ashdown, pers. comm. [20/2/15]

⁴⁸¹ Appendix II, pp. 307-10.

⁴⁸² Appendix II, pp. 310-22.

⁴⁸³ Josef Alm, *European Crossbows*, p. 40.
Dirk Breiding, *A Deadly Art*, p. 94.

cranequins. This means that while the measurements taken suggested that *cranequin* number 10 was an anomaly, in practice this was simply a difference in how the gear was mounted and the device would function the same as any other *cranequin*. One aspect of *cranequin* design that these numbers did not show was the actual length of the gears on the ratched bar. While some bars had gears along nearly their entire length, others were only partially a gear section, the rest of the bar was a simple metal arm. **Image 71** showed how these devices differed substantially in ways the numbers do not show.⁴⁸⁴

Cranequin cases, the section that covered the gears, were consistently longer than they were wide, and generally only a fraction of the overall length of the *cranequin*. In the detailed data the widest case was 121 mm wide. This also happened to be the longest case at 165 mm long. It was a significant outlier, however. While many cases - thirteen in total - were over 100 mm long, and none were shorter than 90 mm, only two cases were over 100 mm wide, and three were less than 50 mm wide.⁴⁸⁵ The implications of case size, however, was not clear. It did not show any obvious correlation with the *cranequin's* advantage, an aspect of design that will be discussed later, so it did not seem like larger cases were designed to create more powerful *cranequins*. It was very possible that the size differences were largely decorative. In general, fifteenth-century *cranequins* appear to have had smaller cases - over half were less than 100 mm long and only one was over 70 mm wide - but some sixteenth-century *cranequins* had equally small cases.⁴⁸⁶ If larger cases were primarily decorative, it could be that sixteenth-century *cranequins* had larger cases to accommodate more decoration.

Cranequins were heavy, which was likely their greatest single flaw as a spanning device. There was a significant variation in the weights of individual examples, though. The data set for *cranequin* weight included nine fifteenth-century *cranequins* and 29 sixteenth-century *cranequins*, for a total data set of 38 *cranequins*.⁴⁸⁷ The lightest *cranequin* in the data set weighed 1280 g while the heaviest weighed 5180 g.⁴⁸⁸ This latter *cranequin* weighed significantly more than the average crossbow in this study, but also represented an extreme outlier. The next heaviest *cranequin* weighed 3400 g, which, while still heavier than many crossbows, was over a kilogram lighter than the previous example. The fifteenth-century *cranequins* tended towards the lighter end of the

⁴⁸⁴ See Appendix II, pp. 307-22.

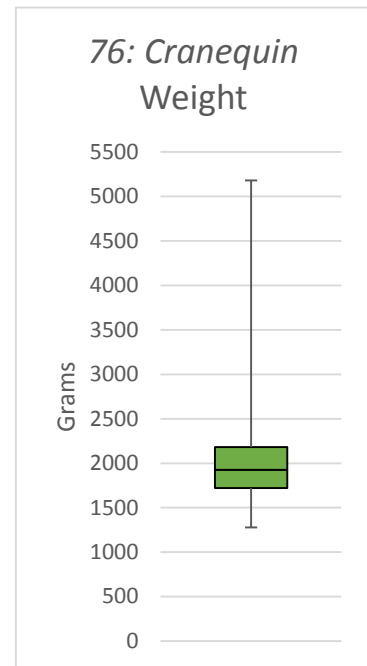
⁴⁸⁵ Appendix II, pp. 307-22.

⁴⁸⁶ Appendix II, pp. 307-22..

⁴⁸⁷ Appendix II, pp. 307-22..

⁴⁸⁸ Appendix II, pp. 312, 319.

spectrum. Only three fifteenth-century *cranequins* weighed more than 2000 g and the heaviest weighed 2285 g. That is not to say that light *cranequins* disappeared entirely in the sixteenth century, there were fourteen sixteenth-century *cranequins* that weighed less than 2000 g. In fact, as **Graph 76** shows, the vast majority of *cranequins* hovered around 2000 g in weight. The median weight was only 1945 g. Even still, most of the time a *cranequin* would have increased the weight of a crossbow it was attached to by at least half of that crossbow's weight, if not more.⁴⁸⁹ These devices would probably have required the crossbow to be braced against something - possibly the ground with the aid of a stirrup - to use. Supporting a crossbow with the extra weight of the device would have been exhausting. Just carrying a *cranequin* would have been a significant extra burden. While nowhere near the weight of a suit of armour, adding two or more kilograms to an archer's equipment load would likely not have been insignificant.⁴⁹⁰ It is not outside the realm of reasonable speculation to suppose that fatigue from frequent *cranequin* use over the course of a battle would have been significant, and could have had a negative impact on reloading speeds.



Cranequin weights, including both fifteenth and sixteenth century examples. Graph includes 38 cranequins. Data from Appendix II.

The windlass may have been the most mechanically complex spanning method used in the Middle Ages. Unfortunately, it was also one of the least likely to survive in its entirety. Due to its reliance on ropes, which frequently did not survive from the Middle Ages, complete windlasses have almost never survived, and even when they did it was likely that the ropes were a later restoration.⁴⁹¹ Crank handles have survived with some frequency, but were limited in what they showed of how the device worked. Only a few windlasses were included in this study, and many of them were still attached to their crossbows which made getting specific information about them difficult. The Wallace Collection had a sixteenth-century windlass handle. The handle was 210 mm wide and weighed 1340 g.⁴⁹² That made it smaller and lighter than the *cranequins* discussed above,

⁴⁸⁹ Appendix II, pp. 307-22.

⁴⁹⁰ Claude Blair, *European Armour circa 1066 to circa 1700* (London, 1958). pp. 191-2.

⁴⁹¹ Dirk Breiding, *A Deadly Art*, p. 97.

⁴⁹² Appendix II, p. 326.

but it was only one part of the original windlass. It is hard to guess how much bulk or weight the ropes and hooks would have added to the handle; it is probably safe to assume that it would have weighed no less than an average weight *cranequin*. The extra ropes and hooks would likely have been cumbersome to transport.

In the several cases of surviving windlasses that were attached to a crossbow, information was usually only available on the whole weapon, and not on the windlass and crossbow separately. One of these crossbows - Bern W1982 - can be seen in **Image 47**. The combined weight of this crossbow and its windlass was 9165 g.⁴⁹³ This crossbow, which was already discussed in the preceding chapter, was likely not used in battle, but instead was intended either for use from a fortified position or for target archery.⁴⁹⁴ As the included image showed, the windlass covered nearly the same distance as the crossbow's lathe and had several very large pulleys. This device would likely have weighed at least a kilogram, if not more, when independent of the crossbow. The exact weight was impossible to determine since the windlass was damaged and could not safely be detached from the crossbow. The Polish Military Museum had more crossbows with attached windlasses, but the available information on them was limited. Only one had been weighed and the entire crossbow, with windlass, weighed 1015 g.⁴⁹⁵ Crossbow F31 in Grandson Castle had an attached windlass and Jens Sensfelder published information on its properties separately from those of the crossbow.⁴⁹⁶ Unfortunately, the measurements for the dimensions of the windlass differed from those taken by the Wallace Collection, which has made comparison difficult. The Grandson windlass' mechanism was 77 mm wide while the handles were 225 mm long. The windlass weighed 2380 g. This data pool was far too small to make any solid conclusions from but the general trend it suggested was that at least by the sixteenth century the average windlass was probably roughly the same weight as the average *cranequin*.

The goats-foot lever was the other medieval spanning device, besides the *cranequin*, to survive both as whole devices and in significant numbers. Goats-foot levers were broadly uniform in design, but featured minor stylistic differences. In the six examples in the data set, the ranged in length from 466 to 568 mm long and in width from 53 to 80 mm wide. Three goats-foot levers had two main parts of the device - the fork and the handle – measured and in all cases the two sections were almost equal in

⁴⁹³ Appendix I, pp. 274-5.

⁴⁹⁴ See Chapter 5.

⁴⁹⁵ Appendix I, pp. 271-6.

⁴⁹⁶ Appendix I, pp. 304-5.

length. The greatest difference between parts was a fork that was 62 mm longer than its lever. All but one of the goats-foot levers in the data set weighed less than 1000 g. The exception weighed only 1070 g while the lightest was a mere 548 g. Goats-foot levers had sleek designs which helped to explain how light they were. The goats-foot lever was also designed to fold up into a more compact shape, which would suggest that it was significantly more portable than the *cranequin* or the windlass. The downside of the goats-foot lever, however, was that the mechanism was simply a lever, so the archer still had to do a large portion of the work to span the crossbow. For lighter crossbows this would not have been a problem, a lever is a very efficient simple machine, but for the more powerful crossbows this may have made the Goats-Foot Lever an impractical spanning device. This impracticality likely explains why other spanning devices were still used at the same time as the light and portable goats-foot lever.⁴⁹⁷

The power of spanning devices was measured by their advantage, which was the extent to which the energy the user puts into the device was increased by the device's operation. Unfortunately, advantage was very rarely determined for medieval spanning devices. The only widely available calculations of advantage were done by Jens Sensfelder and included exclusively *cranequins*. Sensfelder calculated the advantage of ten *cranequins* from the fifteenth and sixteenth centuries, three from the Royal Netherlands Armoury and seven from Grandson Castle.⁴⁹⁸ Three of these were definitely from the fifteenth century, two were from c. 1500, and five were from the sixteenth century. The least advantage provided by a *cranequin* Sensfelder measured was 1/57, meaning that the force pulling the string back was 57 times greater than the force required to rotate the handle of the *cranequin*. The greatest advantage was 1/342. The sixteenth-century *cranequins* generally had greater advantage, but with a data set this small it was hardly definitive. Advantage was a useful metric for examining the power of crossbows, since *cranequins* with very large advantages would only have been built if there were crossbows that needed that kind of power to span them. They could also give an indication of the range of crossbows available to medieval archers. *Cranequins* with lesser advantages would likely have been used to span weaker crossbows. The fifteenth-century *cranequins* had a wide range of advantages which started at the already mentioned 1/57 but include 1/138 and 1/143. This suggested that there was already a

⁴⁹⁷ Dirk Breiding, *A Deadly Art*, pp. 112-7.

Appendix I, pp. 274-5;

Appendix II, pp. 323-4.

⁴⁹⁸ Appendix II, pp. 308, 311-5; 318-9.

distinction between light and heavier crossbows towards the end of the fifteenth century. The existence of the extremely powerful 1/342, 1/273, and 1/271 *cranequins* in the sixteenth century pointed to the existence of some very powerful crossbows in that era. These advantages suggested that crossbows with a range of draw weights during the fifteenth and sixteenth centuries were all spanned by *cranequins*. It also gave a good idea of just how powerful these crossbows could have been, and how skilled contemporary engineers were at making devices to span them⁴⁹⁹

Artistic Representations of Spanning Devices

The problems inherent in using artistic evidence as a substitution for archaeological evidence was already explored extensively in Chapter Three. However, that chapter was also exclusively focused on the topic of bows in art, and something should be said about the many images of crossbows in medieval art. This section will not attempt to restate the argument from earlier in this thesis, the points made there are as applicable to the crossbow in art as they were to the bow. Instead this section will focus on a few images of crossbows in art from the thirteenth through sixteenth centuries and what, if anything, they might tell historians about how this weapon was used. In particular, medieval art provided one of the best insights historians could have into how spanning devices were used. While it was largely impossible to determine relative length with sufficient accuracy due to the stylised qualities of medieval art, the existence of certain technologies in images was a reliable indicator that the technology was invented sometime before the creation of the image. However, this was only useful when it came to trying to establish the chronology of a technology. It was problematic to try to reverse engineer the form these technologies would have taken, or how they worked, based solely on an artist's drawing of them. When examined in combination with surviving archaeological examples, however, they were a very useful source.

For thirteenth-century artistic depictions of crossbows, the greatest examples were found in the *Morgan Picture Bible*. Several crossbows were included in the battle scenes. These images were not clear on if the crossbows were intended to be wooden or composite. The tips of the crossbows seem to have been slightly reflexed, but that does not necessarily prove that one material was used over the other. The crossbows were most commonly depicted in scenes of sieges, such as in 'Hai Defeats the Israelites'⁵⁰⁰ and

⁴⁹⁹ Appendix II, pp. 308, 311-5; 318-9.

⁵⁰⁰ New York City, Pierpont Morgan Library, Ms M. 638, f. 10

'David Sends a Letter to Joab' [Plate 20].⁵⁰¹ In this latter scene crossbows were shown being used by both the attackers and the defenders. The crossbows all had metal rings on their front, probably indicative of a stirrup. These stirrups were almost circular but circular stirrups are generally considered to have become common only in the Later Middle Ages. The stirrups in the image were likely just an artistic decision and not an attempt to show actual circular stirrups. This was reinforced by the fact that one of the crossbowmen in 'David Sends a Letter to Joab' clearly had a belt hook. The belt hook would have required a stirrup large enough to accommodate a foot to use, and circular stirrups were almost always too small to use with a foot.

Crossbowmen reloading their weapons were frequently included in fourteenth-century marginalia images. *The Lutrell Psalter* had an image of a figure spanning a crossbow with a belt hook [Plate 32]⁵⁰², while the *Queen Mary's Psalter* had a pair of crossbowmen, one who was firing his crossbow and while his companion spanned a second crossbow [Plate 21].⁵⁰³ Both images were interesting since they showed how the belt hook was used in practice. Both of the figures engaged in reloading their weapons were illustrated balancing on one foot with the other foot placed in the crossbow's stirrup. Presumably they would then push the crossbow down with their foot while the belt hook would hold the string in place, thus spanning the weapon. A border figure in a fourteenth-century copy of the *Romance of Alexander* now in the Bodleian Library [Plate 36], was an interesting contrast with the two previous images. This image showed two archers, one with a bow and one with a crossbow.⁵⁰⁴ The crossbowman was spanning his weapon but seemed to be crouching down to do so, rather than balancing on one foot. However, the image was difficult to interpret. It could be argued that he had simply just finished spanning his crossbow, and that is why his feet appeared to both be resting on the ground. There was no clear spanning hook shown on his belt, either. That said, the most likely interpretation is that he was using an alternative spanning method to the one used by the figures in the *Lutrell* and *Queen Mary's Psalters*. These images showed two different methods for how to span a crossbow using a belt hook and so provided a valuable insight into how these devices would have been used during the Middle Ages.

There were two scenes of crossbows being used to hunt in a fifteenth-century

⁵⁰¹ New York City, Pierpont Morgan Library, Ms M. 638, f. 42

⁵⁰² London, British Library, Royal 2 B VII, f. 162v.

⁵⁰³ London, British Library, Add MS 42130, f. 56.

⁵⁰⁴ Oxford, Bodleian Library, MS Bodley 264, fol 51v

copy of Gaston Phoebus' *Livre de Chasse*.⁵⁰⁵ One of these crossbowmen was in an image already discussed in Chapter Three [Plate 23].⁵⁰⁶ His crossbow was remarkably similar in design to the bows being used by his companions but how to interpret that was not clear.⁵⁰⁷ The other image was much more interesting, as it showed three crossbowmen on the hunt, including one who was reloading his weapon.⁵⁰⁸ All of the crossbowmen in these images were illustrated with belt hooks, which was a strong indication of how this technology continued to be popular even in the Later Middle Ages. The crossbowman who was reloading his weapon was doing so in a manner virtually identical to that of the figure in the *Lutrell Psalter*.⁵⁰⁹ What these images showed was a continuity of practice in the technology and methods used to reload crossbows in medieval Europe. Spanning technology was not simply a linear progression, the invention of the *cranequin* and the *krihake* did not completely replace the simpler belt hook, for example. Simple and reliable spanning devices still had their place in medieval society, even if they could not span the most powerful crossbows of the Later Middle Ages.

An illumination of the battle of Crécy (1346) from a fifteenth-century copy of Froissart's *Chronicles* was one of the best medieval illustrations of the operation of a windlass [Plate 26].⁵¹⁰ The image included a Genoese crossbowman spanning his crossbow with a windlass. He had a stirrup to hold the weapon steady and did not crouch as he cranked both of the handles on the windlass. Whether the windlass was detachable or not was not clear, as this crossbow was the only one in the image whose end was clearly visible. The fact that one of the crossbowman was shown aiming his crossbow, and probably resting it against his shoulder, suggests that the windlass was removable. The relative size of the windlass was quite impressive, and while the crank handles might have been an exaggeration, based on evidence from surviving examples they could actually have been that large. This illustration was also evidence of the windlass's continued use and popularity in the fifteenth century since that was when the image was made.

In much the same way as it was true of bows, images of the martyrdom of St Sebastian were an invaluable source for images of crossbows in the Later Middle Ages. The detail on these works was often quite impressive. There was a lot to be taken from

⁵⁰⁵ Paris, Bibliothèque Nationale de France, MS fr. 616, f. 11v.

⁵⁰⁶ See Chapter 3.

⁵⁰⁷ See Chapter 3.

⁵⁰⁸ Paris, Bibliothèque Nationale de France, MS fr. 616, f. 116r.

⁵⁰⁹ London, British Library, Add MS 42130, f. 56.

⁵¹⁰ Paris, Bibliothèque Nationale de France, Fr 2643, f. 165v

what they showed of how medieval and early modern weapons were used. Albrecht Dürer's woodcut of the martyrdom featured a man in the foreground squatting down to use a *cranequin* on his crossbow [Plate 30].⁵¹¹ His crossbow had a stirrup and he was using it to aid his spanning, but he was not balancing on one foot like the characters using belt hooks from the *Lutrell* or *Queen Mary's Psalters*. The *cranequin* was mounted on top of the crossbow which, along with Dürer's own nationality, suggests it was intended to be a German *cranequin*. Of particular interest was just how small the crossbow was in comparison to the wielder. Dürer's human figures were accurately proportioned, so the usual medieval artist's distortion cannot explain away the size. What was more likely was that Dürer meant to depict a very small crossbow. That a small crossbow would use a *cranequin* to span it was interesting since it was usually associated with large, powerful crossbows.⁵¹² The data on advantage discussed earlier in this chapter showed how some of these devices were much weaker than others, and it this could be supporting evidence for that hypothesis.

In a fifteenth-century martyrdom, by Master der Heiligen Sippe [Plate 29], one archer was spanning a crossbow with a *cranequin* in much the same way as the Dürer martyrdom.⁵¹³ However, in this case the crossbow was turned so that the *cranequin* faced towards the archer. This difference was intriguing and suggested that, like with the belt hook, there were different methods for using the *cranequin*. The crossbow in this work appeared to be steel, based on the lathe's thickness and colour. The crossbow was also significantly larger in comparison to the archer than the crossbow in the Dürer piece was. Since both works were German in origin they made an interesting comparison. They showed how different styles of crossbow and spanning device existed within a region. These images showed similar pieces of spanning technology being used in a subtly different ways on very different types of crossbow.

One of the most famous Martyrdom of St Sebastian images was Piero de Pollaiuolo's painting, dating to c.1475 [Plate 39].⁵¹⁴ Two of the archers in the painting, both standing in the foreground, were painted while spanning their crossbows. Both crossbows appeared to have had steel lathes with pronounced curves. Unlike the German images discussed above, these archers were using *krihakes* rather than *cranequins*. This

⁵¹¹ Albrecht Dürer, Martyrdom of St. Sebastian, c. 1495, British Museum, London..

⁵¹² Josef Alm, *European Crossbows*, p. 40-1.

Dirk Breiding, *A Deadly Art*, pp. 93-5.

⁵¹³ Meister der Heiligen Sippe d. J, Martyrdom of St. Sebastian, c.1480, Bildarchiv & Wallraf-Richartz Museum, Cologne.

⁵¹⁴ Piero de Pollaiuolo, Martyrdom of St. Sebastian, c. 1475, National Gallery, London.

work was one of the best examples showing how the *krihake* was used by medieval archers. The difference between these archers and the fourteenth-century figures who used belt hooks was especially interesting, as the technologies they used were so similar. The fact that the *krihake* was mounted on a piece of rope hanging from the archer's belt allowed the archer to bend over slightly, rather than forcing them to either crouch down to a kneeling, or nearly kneeling, position or balance on one foot. Of particular interest in this depiction was the placement of the crossbow lathe. The lathes passed between the archer's legs and appeared to press up against their left calf muscles. Since both archers were doing this, it suggested that this was part of a technique for using the *krihake*. In the background a figure was painted aiming his crossbow at St Sebastian. An archer in the foreground obscured his waist so it was not clear if he also had a *krihake* around his waist. What was most interesting about this background figure was that his weapon showed how short the draw distance of the crossbows in the painting were. Based on the figure's stance, and where the resting place of the string probably was, the draw distance of these crossbows could not have been more than approximately a hundred millimetres in total. This was made especially clear by the starting position of the strings on the crossbows the archers in the foreground had only just begun to span. Images like this one were invaluable, since a device like the *krihake* did not have a single, obvious method of use that could be determined based solely on its design. While the design of the *cranequin* suggested how it was best used, details of the *krihake*'s use, such as bracing the crossbow between one's legs, were definitely not obvious and were only really made apparent by images such as this one.

The Martyrdom of St Sebastian remained a popular subject in the early sixteenth century. Two different images of the martyrdom were examined for this chapter. The first was a triptych by Hans Holbein the Elder from 1516 which depicted St Sebastian in the center image [Plate 37].⁵¹⁵ In the foreground he included a crossbowman in much the same pose as was seen in Albrecht Dürer's earlier martyrdom. The man was kneeling down to span his crossbow with a *cranequin* and had a bolt clenched in his teeth. The *cranequin* looked like the handle was meant to be side mounted *cranequin*, as opposed to the top mounted example seen in Dürer. This was not entirely clear because this impression could be the result of a perspective error on the artist's part, but side mounted handles were relatively common in the sixteenth century, even if they were usually associated with Spain and not Germany. It stands to reason that this could have been a

⁵¹⁵ Hans Holbein the Elder, Martyrdom of St. Sebastian, 1516, Alte Pinakothek, Munich.

Spanish *cranequin*. There were two other crossbowmen who were painted pointing their weapons at St Sebastian. All three crossbows were small, close in size to the one in the Dürer image, and appeared to have steel lathes. This was further evidence for small crossbows in the early sixteenth century which, when combined with the archaeological evidence from chapter 6, suggested that there was a type of small crossbow that was popular in the sixteenth century.⁵¹⁶

Pietro Perugino's *Martyrdom*, completed in 1505 [Plate 38], had a crossbowman who was holding his crossbow in a manner different to any of the archers discussed so far.⁵¹⁷ The front of the crossbow, which included a stirrup, was resting against his thigh and he had both hands on the far end of the tiller. It was not entirely clear what he was trying to accomplish in doing this. The most likely explanation was that he was intended to be spanning the crossbow with a goat's-foot lever, but it is hard to see if he was actually holding one or not. The strange method of holding the crossbow suggests that there were several possible spanning techniques for each spanning device. This technique was quite different from that shown in **Image 72**. Testing the various different spanning methods depicted in medieval art presents an interesting possible avenue for future experimental archaeology.

Conclusion

Spanning devices can help historians better understand the use and power of crossbows. By examining the dimensions of these devices, as well as how they were attached to the crossbow, historians could gain insight into the conditions crossbowmen would have been under when using their weapons. The lightweight and compact goat's-foot lever would have been used differently than either the heavier *cranequin*, or the large and heavy windlass. In this chapter, how these weapons were used was studied both from what the devices' design suggested and from what depictions of spanning devices in medieval art suggested about their use.

The modifications to crossbows to suit different spanning methods, usually exemplified by the addition of a *cranequin* lug, showed how the popularity of certain spanning devices changed over time. Crossbows were modified to suit the spanning device their new owner preferred, rather than continuing to use their original device. Examining spanning device's advantage can give historians an idea of the different types

⁵¹⁶ Chapter 6.

⁵¹⁷ Pietro Perugino, *Martyrdom of St. Sebastian*, 1505, Church of St. Sebastian, Panicale.

of crossbows that were in use at the time those devices were made. Spanning devices had to be made to use with a certain crossbow, so a powerful spanning device was indicative of a powerful crossbow. So far advantage has been determined for only a few spanning devices, all of them *cranequins*, but this evidence could prove to be very important and more data should be gathered on the advantage of spanning devices. This chapter has served to only give a brief discussion of this subject, and there is much more room for future analysis and discussion. The preceding pages have hopefully shown the possible benefits of this kind of analysis and shown how an understanding of crossbow spanning devices is necessary to understand crossbows.

Chapter Seven

Comparing Bows and Crossbows

The bow and the crossbow have so far been dealt with separately in this thesis and, while that was easier from a methodological point of view, it has neglected the historical reality of the complicated relationship between these two weapons. To fully understand either the bow or the crossbow, it is necessary to at least have some idea of how they related to each other. This is difficult, however, because the current state of research on these two weapons is quite different. There has been ample scholarship published on the history of the longbow, with rather extensive debates on its power and design, and when it was first adopted. In contrast, the state of crossbow research has so far been focused on establishing the facts of the history of the weapon. There has been little disagreement or debate about the crossbow, and most works published on it were still outlining its chronological development and use across various European kingdoms. The fact that there have been very few surviving medieval longbows, and only a handful of clear textual references, has probably helped the scholarship move on relatively quickly from simply discussing the evidence to debating its significance. In comparison, crossbow scholarship has been working through the abundance of data on the medieval crossbow, and this has likely contributed to the lack of spirited debate about the weapon's significance in a broader context. This uneven scholarship has limited the possible avenues of discussion in this chapter. This chapter will focus on already established areas of debate. The development of these two weapons will be discussed, before moving on to their performance in battles versus their performance in sieges. This chapter will then move on to cover their relative powers and the training requirements of these two weapons, before concluding with a brief discussion of their underlying similarities.

Bows and crossbows fulfilled very similar purposes in human society. They were both ranged weapons that could be used by a single individual and, usually, shot projectiles that resembled small spears. While there was almost certainly never a moment in history where a monarch sat down and consciously planned out which weapon he preferred, there was still an element of choice in the adoption of one of these weapons. England's primary use of the longbow from the thirteenth century through the sixteenth century was a clear sign of preference. In a similar vein, Genoese mercenaries were known for their use of the crossbow so anyone who hired the Genoese – like the French King for example – was, to some extent, showing a preference for the crossbow.⁵¹⁸

⁵¹⁸ Jean Froissart, *Chronicles*, trans. Geoffrey Brereton, (1968, repr. London, 1978). pp. 88-9. Matthew Strickland and Robert Hardy, *The Great Warbow: From Hastings to the Mary Rose*, (2005, repr.

Sometimes an individual's preference for a certain weapon has been shown the source material; the Holy Roman Emperor Maximilian I (r.1486-1519) was recorded as having shown an interest in the practice of archery for example. That interest did not always result in the weapon's adoption, though, as was the case with Maximilian, who never employed the longbow on the same scale as the English did.⁵¹⁹ While using one of these weapons did not exclude the use of the other, they did fill very similar roles in both warfare and hunting. There must have been a reason behind a region, city, or kingdom favouring one over the other. These reasons were probably numerous and included: the cost of the weapons, difficulty in acquiring materials to make them, and quality of craftsmen available to make those weapons. It is also reasonable to suppose that at least some element of the weapons design would have had an impact. This chapter will primarily be focussing on how the differences between these weapons could have impacted on their performance in a variety of situations, and on past individuals' preference for one or the other of these weapons.

Weapon Development

An interesting difference between bows and crossbows is that the crossbow continued to develop during the course of the Middle Ages, while the bow remained relatively static. While the bows of the *Mary Rose* showed an impressive increase in size from the bows of previous centuries, they were not the result of a revolutionary development in longbow technology. They were large yew staves made in the usual style and shape that yew bows had been carved into for centuries. The only difference was the size. There was evidence of experimentation in longbows in the past, but this experimentation primarily took place in the prehistoric era. Bows of different shapes and woods were already fading out by the time the Iron Age Danish bows were being made.⁵²⁰ By the High and Later Middle Ages, the yew longbow was standard and already had a nearly universal design.⁵²¹

In contrast to the longbow, the crossbow was continually developing and changing throughout the Middle Ages. The most significant change in crossbow

Somerset, 2011). pp. 114-5; 227-8.

⁵¹⁹ Holger Riesch, "Archery in Renaissance Germany," *Journal of the Society of Archer-Antiquaries* 38 (1995). pp. 63-6.

Matthew Strickland and Robert Hardy, *The Great Warbow*, p. 391.

⁵²⁰ J.G.D. Clarke, "Neolithic Bows from Somerset, England, and the Prehistory of Archery in Northwestern Europe", pp. 59-70.

⁵²¹ Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 34-40.

Andrew Halpin, "Archery Material" in *Late and Viking Age Medieval Waterford: Excavations 1986-92*, ed. M.F. Hurley, O.M.B. Scully, and S.W.J. McCutcheon (Waterford, 1997). pp. 546-52.

technology during this period was the invention of the steel lathe.⁵²² Wood had been used for both bows and crossbows since those technologies were first invented. Composite materials had been used in bows since pre-history, and in crossbow lathes since at least the early thirteenth century.⁵²³ In contrast, steel only began to be relatively common sometime in the Early Middle Ages, and the techniques required to make the quality of steel required for a lathe were discovered much later.⁵²⁴ The steel lathe was a major change because it used an inorganic material in a role that for centuries had been filled only by organic materials. This new material allowed for new types of lathes to be made, possibly by different craftsmen than had traditionally made crossbows. There were several other changes to crossbow technology over the course of the Middle Ages. New spanning devices were invented and, in the fifteenth and sixteenth centuries, new triggers began to be developed. Crossbows were clearly a work in progress, with extensive experimentation and alteration being performed by the craftsmen responsible for making them.⁵²⁵

There were several reasons why the bow remained so static over the Middle Ages while the crossbow changed so significantly, but the most fundamental was that the crossbow had more parts to change. Crossbows had many components, and many of them lent themselves well to alteration and improvement. Triggers, tillers, nuts, and lathes were all different parts of the crossbow that allowed for varying degrees of experimentation. The developments in spanning technology also meant the crossbow was not dependent on human strength to span it, which in turn meant lathe materials that might be impossible for humans to bend without mechanical assistance could be experimented with. The crossbow was also a relatively recent weapon compared to the longbow, so it should not be a surprise that it was still developing.⁵²⁶

⁵²² Josef Alm, *European Crossbows: A Survey* ed. and trans. G.M. Wilson and H. Bartlett Wells, (1994, repr. Dorchester, 1998). pp. 34-6

⁵²³ J.G.D. Clarke, "Neolithic Bows from Somerset, England, and the Prehistory of Archery in Northwestern Europe", *The Proceedings of the Prehistoric Society* 29:3 (1963). pp. 50-54

Gad Rausing, *The Bow: Some Notes on its Origin and Development* (Manchester, 1967). pp. 38-47.

David S. Bachrach, "Crossbows for the King: The Crossbow During the Reign of John and Henry III of England", *Technology and Culture* 45:1 (2004). pp. 108-9.

⁵²⁴ Alan Williams, "The Metallurgy of Medieval Arms and Armour" in *A Companion to Medieval Arms and Armour*, ed. David Nicolle (Woodbridge, 2002). pp. 45-46.

Claude Blair, *European Armour circa 1066 to circa 1700*, (London, 1958). pp. 62-6.

Kelly, Francis, "A Knight's Armour of the Early XIV Century Being the Inventory of Raoul de Nesle", *The Burlington Magazine for Connoisseurs* 6:24 (1905). pp. 457-60.

Josef Alm, *European Crossbows*, pp. 34-5.

Matthew Strickland and Robert Hardy, *The Great Warbow*, p. 122.

⁵²⁵ Josef Alm, *European Crossbows*, pp. 55-60.

⁵²⁶ W.F. Paterson, *A Guide to the Crossbow*, (Oldland, 1990). pp. 58-63.

This possibility for continuous development and experimentation could have been part of the crossbow's appeal. The weapon had the promise of being even better in the future, and as a result presented an enticing option for investment for rulers. The search for superior weapons to those of one's opponents was a core aspect of warfare, and it stands to reason that some medieval rulers might have seen promise in the crossbow's continuing development. It is also worth bearing in mind that development came with its own costs. To start with, experimentation was not free and it did not guarantee success. A new weapon design could have been no better – or could even have been worse – than an existing design, and thereby have provided no return on the investment of time and money that was required to produce it. An established, successful technology represented a safer bet, which might explain England's preference for the longbow. The longbow did not present the promise of future development, but any commander leading an army equipped with longbows knew what that weapon did and what to expect from it, and may have preferred that security above risking the outcome of a battle on new technology that may not have performed as hoped. While it is useful to think about what role these design elements might have played in the decisions made by medieval armies and their rulers, one should be very hesitant before making the leap to believing that those same individuals actually did make those decisions for these reasons. For example, it is useful to consider that Henry V (r.1413-22) might have preferred the longbow because it delivered a consistent performance over the centuries of its use in English armies, but it is problematic to then conclude that this line of argument proves that Henry V must have chosen the longbow for these reasons and not for others.

Battle Weapon versus Siege Weapon

One of the most popular and prominent arguments about the difference between the bow and the crossbow is the idea that the bow was a weapon for winning battles, while the crossbow was best suited to siege warfare. This idea was found in David Green's recent book on the Hundred Years War (1337-1453), as well as in Matthew Strickland and Robert Hardy's impressive treatise on the longbow.⁵²⁷ While the subject of the longbow's performance in battle has been very thoroughly studied, most recently and best by Strickland and Hardy, the subject of siege warfare has generally received significantly less academic attention. As a result, just how superior the crossbow would

⁵²⁷ David Green, *The Hundred Year's War: A People's History*, (Padstow, 2014). p. 136
Matthew Strickland and Robert Hardy, *The Great Warbow*, pp.113-4, 123-4, 134-5.

have been in this type of warfare has generally been a matter of speculation. It is also worth noting that most studies of the longbow's performance in battle have, unsurprisingly, focused on battles where the English used the longbow, often against an army equipped with the crossbow. This has neglected warfare where the longbow was absent entirely, for example, battles where the English were not involved. Overall, this has been a somewhat narrow depiction of medieval warfare. It was not the aim of this thesis to suggest a total re-imagining of the state of medieval warfare. Instead, the following sections will discuss complexities and complications in the current understanding of these weapons and their use to present future avenues of research and discussion.

The current most widely accepted theories on the respective advantages and disadvantages of these technologies could be boiled down to the following arguments. Longbows had a superior rate of fire to crossbows and were famous for their success in battles, particularly during the Hundred Years War. Crossbows had a slow reload time and were often on the losing side of the battles in Hundred Years War. This trend suggested that longbows were superior in battle. In contrast, longbows were large and not suited to firing out of arrow loops or from castle battlements. Crossbows, on the other hand, could be held loaded until a prime shot presents itself, and the protection of a fortified position negated most of the problems with their slow reload times. The following sections will examine aspects of this debate. When discussing battles, the issue of these weapons' rate of fire will be the primary focus, since that has generally been seen as the greatest advantage of the longbow.⁵²⁸ The topic of the bow and crossbow as used in siege warfare will be considered more broadly, as that subject has, in general, received less attention and could benefit from a wider discussion.⁵²⁹ Finally, the respective power of these weapons, and the significance of their differing levels of power, will be briefly discussed. It should first be stated, however, that since most of the debate has been on the subject of warfare from c.1300-c.1500, that period will be the focus of this analysis. While the crossbow was widely used before c.1300, including in English armies, there is less evidence from, and debate focused on, those centuries and, in general, this thesis has focused on the Later Middle Ages.⁵³⁰

⁵²⁸ Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 123; 134.

Robert Hardy, *Longbow A Social and Military History*, 3rd ed. (1978, Fort Worth, 1993). pp. 68-72.

⁵²⁹ Bernard S. Bachrach, "Medieval Siege Warfare: A Reconnaissance", *The Journal of Military History* 58:1 (1994). pp. 119-23.

⁵³⁰ Robert Hardy, *Longbow*, pp. 7-10.

Peter N. Jones, and Derek F. Renn, "The military effectiveness of arrow loops. Some experiments at White

Rate of Fire

In general the longbow had a superior rate of fire to the crossbow, but this fact has obscured some of the complexity inherent in determining a weapon's rate of fire. While it was definitely true that the longbow could be shot much faster than the crossbow, there are complicating factors to this discussion that are worthy of consideration.⁵³¹ To start with, crossbows came in many different types, with a range of different methods of reloading them. The *cranequin* and windlass certainly would be slow to use when reloading a crossbow, but the *krihake*, belt hook, and goats-foot lever would not have been nearly as slow. While experimental archaeology is not without its methodological complications and problems, this is an area where it would be of great use and has sadly been very limited. What estimates there are put the *cranequin* and windlass as having taken between thirty seconds and a minute to reload a crossbow.⁵³² The author has made some use of modern crossbow reloading devices which are very similar to the *krihake* – the difference with the modern equivalent is the use of handles instead of a belt, but the general principle is the same – and the author's experience indicated that a modern crossbow can be reloaded in fifteen to twenty five seconds with only minimal practice. Based on this experience, a crude estimate might put the faster systems at maybe fifteen to thirty seconds to use, depending on skill. Longbows are generally considered to have taken between six and ten seconds to reload and shoot.⁵³³ So even at their fastest, crossbows were still much slower than skilled longbow archers.

However, longbows probably were not usually shot at maximum speed. Arrows were not in infinite supply on campaign and at the fastest rate of fire, the longbow archers would have run out of arrows in short order. While exact arrow counts were absent for much of the Middle Ages, there exists some information from the early modern period. An inventory of the ships of the Henry VIII, unfortunately taken after the sinking of the *Mary Rose*, included the number of arrows and longbows present on each ship in his fleet. Jonathan Davies conducted an estimate based on the number of bows and the estimated rate of fire of the longbow, and found that, if the archers shot at maximum speed, the ships would have run out of arrows in a matter of minutes.⁵³⁴ While

Castle", *Château Gaillard* 9-10 (1982). pp. 445-7.

⁵³¹ Jim Bradbury, *The Medieval Archer*, pp. 8-10

⁵³² Ralph Payne-Gallwey, *The Crossbow: Its Military and Sporting History, Construction and Use*, (1903, repr. London, 1995). p. 7.

W.F. Paterson, *A Guide to the Crossbow*, pp. 32-4.

⁵³³ Andrew Ayton, "Arms, Armour, and Horses" in *Medieval Warfare* ed. Maurice Keen, (Oxford, 1999). pp. 203-5.

⁵³⁴ Jonathan Davies, "Military Archery and the Inventory of King Henry VIII", *The Journal of the Society*

this was not a perfect example – early modern ship warfare was not a direct stand in for the fields of medieval France – it was still a useful one. This was especially true given how readily historians have applied information learned from the *Mary Rose* back to the Middle Ages. Even if more arrows were present on a major English campaign than on a warship, it would have taken a staggering number of arrows to sustain a six-arrow-per-minute rate of fire for the several hours a medieval battle would have lasted. Matthew Strickland's analysis of England's use of the longbow in battle certainly suggested that archers were still firing hours into the battle, most famously at Poitiers (1356).⁵³⁵ While they sometimes ran out of arrows, as at Agincourt (1415), it was after several hours of fighting, so either the armies regularly brought hundreds of thousands of arrows with them on campaign, a very real possibility in some cases, or archers shot fewer than six arrows a minute.⁵³⁶

It is also important to consider whether the average English archer could have undergone the physical strain of firing a longbow at six arrows a minute for any extended period of time. It seems likely, almost inevitable, that the rate of fire of the longbow would have slowed as a battle progressed, due to exhaustion. In contrast, the crossbow was spanned primarily with machinery, which would have greatly reduced battlefield fatigue. It is impossible to know for certain the exact impact this would have had, but experimental archaeology could at least begin to give some kind of indication of how much energy would have been required to perform the herculean task of firing a longbow at maximum speed for an hour. If circumstance dictated that, in practice, archers shot slower than their maximum theoretical rate of fire, this would then mean that the difference between crossbow and longbow rate of fire would be less than generally supposed. When this is considered, alongside the fact that crossbows would have varying rates of fire depending on what type of spanning device was used, it is clear that, while longbows could, and likely sometimes did, have a greater rate of fire than crossbows, the gap between these two weapons was probably not as significant as it has often been believed to be. There were many variables involved in determining a weapon's rate of fire in a given context. Accurately determining how quickly a weapon was typically shot in a battle is very different from determining how quickly that same weapon could have

of Archer-Antiquities 44, (2001). pp.

⁵³⁵ Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 235-8.

⁵³⁶ *Ibid.* pp. 334-5.

Michael Prestwich, *Armies and Warfare in the Middle Ages: The English Experience*, (1996, repr. Hong Kong, 2006). pp. 139-41.

been shot at maximum speed.

In an interesting – if mostly speculative – article, Russell Mitchell actually attempted to perform a case study on the possible importance of rate of fire in medieval warfare. Specifically he examined the famous “duel” between the Genoese crossbowmen and English archers at Crecy (1346). His argument was rather more specific than the one outlined above but still worth examining in some detail. The article opened with a discussion of the battle itself and a general narrative of the events, before venturing into the realm of “what ifs”. Essentially, his argument was that the English could have maintained a very high rate of fire so long as they were only required to maintain a minimum level of accuracy. If they were firing into a packed formation of Genoese soldiers, then accuracy would be of minimal importance. This was effective at Crecy, possibly, because the Genoese did not have any of their protective equipment with them. Mitchell argued that, had the Genoese brought out their *pavises* as well as their helmets and other armour, the massed volley of arrows would have been ineffective, since the inaccurate shots would likely not have been lethal or disabling, or even particularly wounding. In response, the English would have had to take better aim with each of their shots to ensure accuracy in order to be effective, which would have greatly reduced their rate of fire. While definitely mostly speculation, Mitchell's article did make some good points about how modern scholars have often emphasised the advantage of the longbow's rate of fire over the crossbow, at the cost of fully examining other factors, such as accuracy, that would have had an impact on the relative effectiveness of both weapons in battle. He also made a respectable attempt at rehabilitating the Genoese crossbowmen's rather poor reputation among the historical community. The article's most useful contribution was how Mitchell showed just how many factors would have been in play during the battle. The complexity he illustrated points out just how problematic a simplistic narrative of the battle could be.⁵³⁷

One thing Mitchell did not mention was how difficult it would have been to aim a powerful longbow. The powerful bows of this period did not lend themselves to aiming. Holding the bow fully drawn while taking aim would have put severe strain on an archer's muscles and certainly would not have been possible for every shot for several hours over the course of a battle.⁵³⁸ Instead, an archer would have to have aimed in an

⁵³⁷ Russell Mitchell, “The Longbow-Crossbow Shootout at Crecy (1346): Has the 'Rate of Fire Commonplace' Been Overrated?” in *The Hundred Years War (Part II) Different Vistas* ed. L.J. Andrew Villalon and Donald J. Kagay, (Leiden, 2008). pp. 235-49.

⁵³⁸ Jennifer Coughlan and Malin Holst, “Health Status” in *Blood Red Roses: The Archaeology of a Mass*

instant, which was not impossible to do, but required a very high level of skill, only attainable through rigorous training and practice. It could be assumed that medieval archers were capable of instant aim, based on the English victories in the Hundred Years War, however, that would be a somewhat teleological explanation. If exclusive credit for these victories is to be given to the English longbowmen, then it does become necessary to assume those archers had staggeringly high levels of skill. Matthew Strickland argued that the average English archer was likely a semi-professional yeoman, at least during the later fourteenth and fifteenth centuries. He made the concession that not every archer would have been semi-professional, and so there would have been significant variation in the skills of individual English archers.⁵³⁹ The exact skill disparity in individual English archers is impossible to know for certain, but some attempt must be made to account for it in discussions of the longbow's rate of fire. It is possible that experimental archaeology could offer some insight into how the longbow would have performed in the hands of archers of varying skill and physical condition.

Siege Warfare

Siege warfare was the primary method of waging war of the Middle Ages, and so one would expect weapons designed for siege warfare to have been among the most prominent used at that time.⁵⁴⁰ The traditional narrative has assigned to crossbows the superior role in siege warfare for a few reasons, both positive and negative; the crossbow seemed particularly well suited to the siege, for both the besieged and the besieger, and the situations of siege warfare mitigated the crossbow's flaws. As the previous section has already mentioned, the crossbow had a slower rate of fire than the longbow, but the fortified positions associated with the siege, as well as the longer time frame of siege warfare, meant that a lower rate of fire was less of a disadvantage. Furthermore, the crossbow's ability to remain loaded before being shot was ideal for guards waiting on battlements, or in fortified camps, for an enemy to step out into the open. There was also some limited evidence to suggest that arrow loops were better suited to use by the crossbow. This latter situation could just be the result of many castles and fortifications being designed to accommodate crossbows because they were the dominant weapons of

Grave from the Battle of Towton AD 1461 ed. Veronica Fiorato, Anthea Boylston, and Christopher Knüsel, 2nd ed. (2000, Oxford, 2007). pp. 71-4.

Christopher Knüsel, "Activity-Related Skeletal Change" in *Blood Red Roses: The Archaeology of a Mass Grave from the Battle of Towton AD 1461* ed. Veronica Fiorato, Anthea Boylston, and Christopher Knüsel, 2nd ed. (2000, Oxford, 2007). pp. 108-9, 116.

⁵³⁹ Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 202-10

⁵⁴⁰ Bernard S. Bachrach, "Medieval Siege Warfare: A Reconnaissance", pp. 119-23.

the region they were built in, rather than being an inherent quality of the crossbow or the arrow loop.⁵⁴¹ This is the general outline of the argument for the crossbow's superiority in siege warfare, but it is a simplistic argument. The following paragraphs aim to examine the complexities of siege warfare with a particular focus on the possible role and performance of both the bow and the crossbow.

The first obstacle to this discussion was the fact that siege warfare has received only a fraction of the scholarly attention that the battles and campaigns of the Middle Ages have, so there was not nearly as large a body of work to use for this analysis. Bernard Bachrach pointed out as long ago as 1994 that siege warfare had gone almost entirely neglected by the major figures of medieval military history, with less than a handful of books written on the subject. Two books were written around the time of Bachrach's article and, more recently, Peter Purton published an impressive two volume history of medieval siege warfare.⁵⁴² Of these books, only Purton's contained any discussion of the crossbow and its role in siege warfare, and even that was mostly devoted to discussing arrow loops.⁵⁴³ Matthew Strickland included a section on the crossbow's use in sieges, which also covered the longbow to some extent, in *The Great Warbow*. This section was the most thorough discussion of the subject, but it was still only a cursory study, covering a period of several centuries. While its analysis of arrow loops and garrison supplies was excellent, it could only do so much to situate crossbows within the broader context of siege warfare, especially given that the *The Great Warbow* was a book primarily about the longbow and its use in battle.⁵⁴⁴ While each of these books was a valuable piece of scholarship, they did not compose a vast body of work. As a result, the following discussion is highly speculative and is focused mostly on noting the limitations of the current knowledge of medieval siege warfare and suggesting possible future avenues of research.

To begin with, it was not immediately apparent whether the either the bow or the crossbow was even a significant contributing factor to the outcome of a siege. While the crossbow seems to have been the superior weapon in a siege, based on a logical comparison of its properties to those of the longbow, that would be a moot point if neither weapon made a significant contribution to sieges in general. The minimal

⁵⁴¹ Peter N. Jones, and Derek F. Renn, "The military effectiveness of arrow loops. Some experiments at White Castle", pp. 445-7.

⁵⁴² Bernard S. Bachrach, "Medieval Siege Warfare: A Reconnaissance", pp. 123, 128-9.

⁵⁴³ Peter Purton, *A History of the Early Medieval Siege c.450-1200*, (Woodbridge, 2009). pp. 376-9.

⁵⁴⁴ Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 123-33.

scholarly attention paid to the bow and crossbow in sieges, especially compared to the attention paid to siege weapons, has made any detailed analysis difficult. Sieges came in many different forms at different times during the Middle Ages, and it lies outside the scope of this thesis to examine every possible permutation. However, some broad trends could be considered. The most important method of distinguishing between types of personal ranged weapons in a siege context is determining the role they would have played during an assault on the fortified position versus over the course of a prolonged siege.

During an assault, the role these weapons would have played is fairly obvious; enemies would be consistently placing themselves in the archer's field of fire and the massed volleys of arrows or bolts could have contributed greatly to the defence of a castle or town. Certainly there is evidence of archers holding back attacking forces. For example, in 1404 Caernarfon withstood a siege by Owain Glyndŵr even though the garrison was vastly outnumbered.⁵⁴⁵ That said, assaults on fortified positions were relatively rare in medieval warfare. It was far more common either to destroy the fortified walls or simply to wait until the garrison surrendered. Causing a breach in the wall, combined with the threat of brutal massacre if the city or castle was taken, certainly encouraged surrender as well.⁵⁴⁶ However, that does not rule out the possibility that the threat of deadly projectiles could primarily have been used to dissuade possible assaults. If there were no defending archers, assaults could have been significantly more common. It is also worth considering that the longbow might actually have been the superior weapon for driving off an assault. The generally greater rate of fire would have allowed for a more effective performance during the battle-like conditions of an assault. That said, the greater power of the crossbow could have been more important, as soldiers attacking a fortified position were likely to have brought some defensive equipment with them to try to ward off incoming missiles. The crossbow's greater penetrating force, along with the fact that the crossbow could be held in place to aim while loaded, waiting for the perfect shot against an opening in the enemy's defences, could have been more important factors than rate of fire.

The role of archers in a prolonged siege is a subject of greater complexity. While the support archers provided – attacking opposing soldiers from range – was the same as in a battle, a long-term siege was more complex than a straightforward assault. Archers

⁵⁴⁵ Ibid. p. 133.

Peter Purton, *A History of the Late Medieval Siege 1200-1500* (Woodbridge, 2010). pp. 218-20.

⁵⁴⁶ Jim Bradbury, *The Medieval Siege* (1992, repr. Woodbridge, 2002). pp. 78-88.

would also have fulfilled very different purposes depending on if they were part of the besieging army or the defending garrison. Three possible roles that garrison archers could have fulfilled will be considered, before moving on to the possible roles played by archers outside the walls.

One possible benefit of archers in a besieged fortification would have been to provide harassing shots against enemy patrols. There were several accounts of individuals being wounded by missiles shot by archers while patrolling the walls of the castle they were besieging. Most famously, Richard I died of a crossbow bolt received in such circumstances.⁵⁴⁷ However, it is not clear how common this was. One presumes that any besieging force would have camped out of range of the fortified archers, so these sort of opportunities to shoot would have been relatively few. While useful, it would hardly have required more than a handful of archers in a fortification to achieve this kind of threat. In this case, the crossbow would certainly have been the superior weapon, as it would have allowed the archer to sit and wait for the perfect shot when the target's guard was down. It would also have been better for taking a shot the moment the opportunity appeared. In this kind of situation, bows and crossbows would both have been superior to siege weaponry, due to the speed with which they could go from rest to firing and their accuracy in targeting a single individual.

Having a garrison of archers could also have forced the enemy to camp further from the fortified walls. This could have made it easier to resupply the fortification, especially important in the case of a city, by making it more difficult to completely encircle. The crossbow would likely have been better again in this situation since its greater power and heavier bolts would have meant the bolts probably flew farther and had more of an impact when they hit, thanks to gravity's greater effect on the heavier bolt.⁵⁴⁸ That said, the longer arrow, with its more sophisticated fletching, could possibly have flown farther than a bolt, as the effects of lift and drag would have made a more significant contribution. While these arrows could fly farther, their power at impact at those extreme distances could have been less than that of a heavier crossbow bolt. Anna Crowley's study on the longbow arrow's flight suggested that it retained much of its power on impact but there has been no comparative study of the crossbow bolt to suggest

⁵⁴⁷ Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 121, 286.

⁵⁴⁸ W.F. Paterson, *A Guide to the Crossbow*, pp. 32-4

Ralph Payne-Gallwey, *The Crossbow*, pp. 16-9.

Anna B. Crowley, "Appendix" in *The Great Warbow: From Hastings to the Mary Rose*, by Matthew Strickland and Robert Hardy (2005, repr. Somerset, 2011). pp. 411-4.

Josef Alm, *European Crossbows*, pp. 29-30, 42-3, 51-4.

which was the better weapon for this type of shooting.⁵⁴⁹

A third possible role for archers in a siege situation would have been taking part in an offensive sortie, either independently or alongside a relief army. Especially in the Later Middle Ages, when archers were a large part of medieval armies, it would have made sense for any garrison that could have been used in a sortie to resemble in composition the type of army that would have been used in a battle. In this case, the bow would likely have been the superior weapon, assuming one accepted that the bow was the superior battlefield weapon. Sorties were, almost by definition, nearly guaranteed to result in battle, and the rate of fire of the longbow could prove to have been more useful in battle conditions. However, if Kelly DeVries argument that the longbow's role in warfare was primarily to provoke an attack on a defensive position, then it would not have been very useful in a sortie situation, since the sortie would have been, nearly by definition, the attacking force.⁵⁵⁰ In general, this situation was more like a battle than a siege, so the previous discussion of the bow and crossbow's roles in battle are applicable to this situation as well.

To examine the role of archers from the attacker's perspective, it seems unlikely that the attacking archers would have simply approached a fortified position to shoot on its defenders. While experiments at White Castle showed that it was quite possible to shoot into an arrow loop consistently, doing so required the archer be quite close to the walls and easily within range of return shots. Another set of experiments published in *The Great Warbow* suggested that being in an elevated position with a longbow would have greatly increased the effective range of the weapon, and this effect would equally have applied to the crossbow.⁵⁵¹ This would mean that any archer trying to attack a fortified position would likely have been on the receiving end of a greater number of shots than they would have been able to loose. Given the existence of long range siege weaponry such as trebuchets and gunpowder artillery, it seems unlikely that much would have been gained by sending archers to shoot on a fortified position.⁵⁵²

Taking shots at soldiers on the walls of a fortified position may have been an activity promising little reward at the cost of great risk, but there was still a reason

⁵⁴⁹Ibid. pp. 29-30; 42-3;51-4.

Anna B. Crowley, "Appendix", pp. 411-4.

⁵⁵⁰ Kelly DeVries, "Catapults Are Not Atomic Bombs: Towards a Redefinition of 'Effectiveness' in Premodern Military Technology", *War in History* 4:4 (1997). pp. 462-4.

⁵⁵¹ Anna B. Crowley, "Appendix", pp. 411-4.

⁵⁵² For a more detailed discussion of these powerful siege weapons see:

Jim Bradbury, *The Medieval Siege*, pp. 250-70.

Peter Purton, *A History of the Early Medieval Siege*, pp. 357-88.

archers might do so during a siege. Archers could have provided covering fire against an enemy fortified position while siege engineers advanced to undermine the walls. While the archers would have been unlikely to score many lethal hits on enemies doing this, they could have provided significant protection for the siege engineers who had to advance close to the walls to do their job.⁵⁵³ Enemy archers would have been less likely to take a shot at an approaching siege engineer if it involved risking being shot themselves. In this situation, it seems likely that the longbow would actually have been the superior weapon, as its higher rate of fire could have created a continuous hail of arrows falling on the enemy position. However, a large enough force of crossbowmen staggering their shots, in order to ensure that they were not all reloading at the same time, could have had the same effect. This latter situation would have required more crossbowmen with a higher level of training, but would have avoided the possible problem of the archers becoming exhausted before the siege engineers had finished their work.

Another use for archers during a siege would have been to reinforce the besieging army against a possible battle. Whether due to an attack by a sortie from the fortifications or one by a relief army, sieges could frequently end in battles. Having a force that was able to win that battle, or possibly even to make sending a relief army an unattractive option, would have been an important aspect of a successful siege. In this case, one would expect longbows to be the superior weapon, as the outcome would have been a battle from a defensive position, which DeVries described as the ideal situation for the longbow. However, once again the longbow's advantages might not have been necessary. A relief army was nearly guaranteed to attack the besieging army, so the longbow may not have been necessary to provoke an assault. That said, DeVries argument also stressed that the longbow was useful for damaging the strength of an attacking army's initial charge, so the longbow would certainly still have been useful.⁵⁵⁴

The current dichotomy of crossbows for sieges and longbows for battles was also not reliably represented in surviving medieval evidence. For example, Henry V (r. 1413-22) likely had some five thousand archers in his army at the siege of Harfleur (1415).⁵⁵⁵

⁵⁵³ Jim Bradbury, *The Medieval Siege*, pp.270-4.

⁵⁵⁴ Kelly DeVries, "Catapults Are Not Atomic Bombs: Towards a Redefinition of 'Effectiveness' in Premodern Military Technology", pp. 462-4.

⁵⁵⁵ Jim Bradbury, *The Medieval Archer*, pp. 118-22.

Harris Nicolas, *History of the Battle of Agincourt and of The Expedition of Henry the Fifth into France in 1415; To Which is Added The Roll of the Men At Arms in the English Army*, 3rd edition (1827, London, 1833). pp. 332-86.

Edward III (r.1327-77) besieged Calais with the army with which he had won the Battle of Crecy (1346), although Edward was resupplied over the course of that lengthy siege, which would likely have changed the composition of his army. Edward also focused on a starvation siege, meaning his army was likely intended to fight off any relieving forces rather than to take the city in an assault.⁵⁵⁶ Charles VII (r. 1422-61) recruited large numbers of longbowmen for his campaigns at the end of the Hundred Years War (1337-1453), many of which focused on reclaiming English castles and towns in Normandy and Gascony rather than on battling opposing armies. While Charles' extensive use of gunpowder artillery – in both siege and battle – meant that it was more complicated to rate the role of the longbow in these campaigns, he likely did not see it as the inferior weapon for siege based warfare.⁵⁵⁷

This discussion did not really answer the question of whether the bow or the crossbow was superior in siege warfare. The ability to stay loaded at all times was a great advantage, and the presence of fortifications to protect the archer as he reloaded certainly played to the crossbow's strengths. On the other hand, the longbow was hardly useless in a siege. It is not even clear if the minor differences between bows and crossbows were noticeable during a siege. What seemed most likely, and was suggested by Purton, was that both weapons were used, sometimes simultaneously, to defend fortified positions in the Middle Ages.⁵⁵⁸ While it is possible to argue the theoretical benefits and drawbacks of each weapon, both were clearly used in siege warfare and there was no surviving evidence for a clear preference among medieval garrisons for one weapon over the other. For example, while England was famed as the land of the longbow, the crossbow was not entirely excluded from their armies. In fact, crossbows were frequently recorded being sent between garrisons in medieval England. The *Calendar of Documents Relating to Scotland* had a plethora of entries concerning this very topic, and Paul Holmer has shown something similar with the garrison at Calais.⁵⁵⁹ Henry V took both crossbow and longbow archers with him to the siege of Harfleur, although the crossbowmen were clearly in the minority. According to *Sloane MS 6400*, there were only 98 crossbowmen compared to over 7,000 longbowmen.⁵⁶⁰ Elsewhere in Europe, the crossbow was the

⁵⁵⁶ Peter Purton, *A History of the Late Medieval Siege*, pp. 121-2.

⁵⁵⁷ Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 353-6.

⁵⁵⁸ Peter Purton, *A History of the Early Medieval Siege*, pp. 376-9.

⁵⁵⁹ *Calendar of Documents Relating to Scotland: Preserved in Her Majesty's Record Office London*, ed. Joseph Bain, 4 vols. (Edinburgh: H. M. General Register House, 1881-1888). p. 2:40, 4:347, 4:419
Paul Holmer, "The Military Crossbow in Yorkist England," *Journal of the Society of Archer-Antiquaries* 22, (1979). pp. 11-3.

⁵⁶⁰ Jim Bradbury, *The Medieval Archer*, pp. 118-9.

dominant weapon for both kinds of warfare. The French made extensive use of crossbowmen, both their own and hired mercenaries, and the Teutonic Order shared their preference for the crossbow.⁵⁶¹ The dichotomy of crossbow versus longbow, and their respective merits in types of warfare, was an oversimplification that does not reflect medieval warfare as it was fought. Instead, historians would be better served examining where and how these weapons were used by contemporary armies, and attempting to see if a pattern of use emerges from the evidence.

Weapon Power

A detailed discussion of draw weights and weapon power has already been included in Chapter 1, and there is no reason to repeat those same arguments here. In general, crossbows seemed to have had a much higher draw weight than longbows, but crossbows also had a much lower efficiency, meaning the power gap between the two weapons was lower than their draw weights alone would have suggested. Crossbows came in a wide variety of sizes and designs. The available evidence on crossbow draw weights was based on only a handful of weapons, so it was hard to determine the average power of medieval crossbows. The limited data, combined with the diversity of medieval crossbows, meant that it has been impossible to accurately get a general idea of the weapon's power. Still, even if more research would be necessary to fully determine the crossbow's power, it did appear to have been generally the more powerful weapon, compared to the longbow. This greater power came at the cost of the slower rate of fire discussed above. This section will discuss some of the possible the benefits of a powerful weapon.

The advantage of a more powerful weapon was that it was more likely to deliver fatal or crippling blows against an enemy, which seemed to have indeed been true of the crossbow. If an army wished to win by killing or maiming its enemies from afar, then the crossbow was clearly the superior weapon. It is once again worth bearing in mind Kelly

Peter Purton, *A History of the Late Medieval Siege*, pp. 248-51.

Harris Nicolas, *History of the Battle of Agincourt*, pp. 375, 381, 386

⁵⁶¹ Holger Riesch, "Yew Exploitation and Long-Bow Trade in the 16th Century", *Journal of the Society of Archer-Antiquaries* 39 (1996). pp. 5-8.

Sven Ekdahl, "Horses and crossbows: two important warfare advantages of the Teutonic Order in Prussia" in *The Military Orders: Volume 2 Welfare And Warfare*, ed. Helen Nicholson, (Aldershot, 1998). pp. 148-51.

Sven Ekdahl, "Die Armbrust in Deutschordensland Preussen zu Beginn des 15. Jahrhunderts", *Fasciculi Archaeologiae Historicae* 5 (1992). pp. 44-48.

Andrzej Abratowski, "The Bow in Poland", *Journal of the Society of Archer-Antiquities* 44 (2001). pp. 15-8.

DeVries' argument that the longbow was best suited to a role as a support weapon, rather than being relied on to deliver killing blows. The English definitely did not want their weapon to be harmless – the arrow shots had to pose some threat – but it did not have to be consistently delivering deadly blows to simply hinder or confuse the armies of the French.⁵⁶² While it certainly would not have been a disadvantage to have had a weapon that was better at injuring opposing soldiers, the later medieval English Kings clearly preferred the tactical advantage of the longbow over that of the crossbow, even if the latter was more likely to deliver lethal projectiles.

It is possible that the choice between the crossbow and the longbow represented more basic strategic decisions. If the longbow's primary purpose was as a support weapon then it had to be included as part of a holistic army strategy. In contrast, the crossbow's killing potential could have been added on to an already established army strategy to enhance it. For example, the crossbow's lethal potential could in theory have been used to kill or maim enemy soldiers before the main body of the army charged into them. This would have been a more offensive tactic than the tactic of forcing the enemy army to charge using longbow shots. Of course the failure of a tactic very much like this at Crecy distinctly points out many of its limitations. This line of thinking may be going too far towards technological determinism. It was more likely that the French and English commanders had a strategy in mind for their armies, and chose the weapon better suited to fulfilling that strategy, while considering other factors such as weapon cost and training requirements, than that these weapons had a single optimal method of use that had to be discovered by medieval generals. What does seem likely was that, while the differences between these weapons may be overstated, the crossbow's greater power and the longbow's greater rate of fire were influential on the tactics used by the armies that employed them.

Training Requirements

Longbows and crossbows have sometimes been compared in terms of the training required for a soldier to become competent with the weapon. The usual argument, present from at least as early as the turn of the twentieth century, was that the longbow took significantly more skill to use than the crossbow.⁵⁶³ Anyone could have picked up and used a crossbow with minimal training, while a longbow took years of practice to

⁵⁶² Kelly DeVries, “Catapults Are Not Atomic Bombs: Towards a Redefinition of 'Effectiveness' in Premodern Military Technology”, pp. 462-4.

⁵⁶³ Ralph Payne-Gallwey, *The Crossbow*, p. 9

become competent with. This argument has in turn been used to suggest that longbows were not widely adopted because of the effort required in putting together an army of archers using them. This can have the, sometimes intentional, side effect of making the English seem superior to their, often French, opponents, since by this line of argument, they had the more skilled soldiers. This line of thinking could lead to the argument that the longbows' greater training requirement meant that longbow archers were superior in other areas, such as accuracy or discipline. This argument is rather simplistic, though, and in need of exploration in greater depth to try and understand what difference these training requirements would have had on the users of these weapons.⁵⁶⁴

Longbows, assuming modern assessments of their draw weights were correct, were very difficult weapons to use, but that does not necessarily mean that everyone who used them was highly skilled. A distinction should be made here between skill and difficulty. Skill implies that the individual was capable of engaging in the activity in question with frequent success. Difficulty was the challenge required to do the activity at all. To put it in more specific terms: skill with a longbow implied that an archer was able to shoot quickly and accurately. The difficulty of the longbow was that drawing it at all required for the archer to have had sufficient strength. A longbow that draws over 100 lbs at 28 in was a very difficult weapon to use, but much of that difficulty was due to the sheer strength required to draw it. A medieval archer expected to shoot a bow like that for an entire battle would have to have been very strong, and that kind of strength took deliberate training to achieve and maintain. Most archers would likely have reached an acceptable level of accuracy just through the sheer number of hours they would have spent shooting. However, so long as an archer stayed physically fit enough to draw and shoot their bow they could have been considered 'trained'. The distinction here is that the descriptor of 'trained' lacks specifics; it does not follow that English archers who were 'trained' could have shot their bows accurately and quickly just because they had the physical ability to draw them.

What little contemporary evidence there was for the practice of archery has not provided a clear picture of the standards of training. An ordinance to the sheriff of Kent made during the reign of Edward III, which was re-issued up to the fifteenth century,

⁵⁶⁴ Robert Hardy, *Longbow*, pp. 76-8.

Jim Bradbury, *The Medieval Archer*, pp. 160-4.

H.D.H. Soar, "Some General Notes on the Drilling and Exercising of Archers", *Journal of the Society of Archer-Antiquaries* 43 (2000). pp. 56-59

required individuals to practice with their bows on feast days.⁵⁶⁵ This could have indicated that English archers practised regularly with their bows, but the existence of this ordinance suggests that archers were not maintaining the level of training expected by the king. This same ordinance banned other sports that the king thought were distracting the archers, including football, cock fighting, and the hurling of stones.⁵⁶⁶ This could suggest that the English were fighting a losing battle to maintain the training required to make the longbow an effective weapon. Starting with Edward III's mandatory training and continuing through Roger Ascham's (1515-1568) attempt to reclaim past glory with *Toxophilus* (1545), the longbow was a weapon whose continued use was not guaranteed. Each generation appeared to struggle with the problem of how to keep a trained body of archers ready for war.⁵⁶⁷ While the struggle to maintain archery training existed during the reign of Edward III, some of the English archer's greatest successes were achieved under Henry V, over fifty years after that first ordinance, so it could not have been in continuous decline from 1363. While the quality of English archers did reach a low point in the sixteenth century, a fact much bemoaned by John Smythe and others of his time, it would be an oversimplification to argue that the longbow was a weapon in decline from 1363 to 1590.⁵⁶⁸ It was far more likely that maintaining a trained body of archers was difficult but medieval English monarchs were still largely successful in maintaining enough trained archers to be successful in war. It is also worth mentioning that the aforementioned ordinance in Kent included permission to practice “bullets and bolts” alongside the practice of bows and arrows, which shows that, even at this time, England continued to use the crossbow alongside the longbow.⁵⁶⁹

The sport of Popinjay Shooting was popular in Central Europe and promoted skill with a crossbow. In this sport, a large pillar would have been erected in a town square with a small metal bird, the popinjay, on top. The first archer to successfully hit the target won a trophy.⁵⁷⁰ Other archery practices were common too; target competitions were popular across the European continent. This is not to say that crossbowmen were the

⁵⁶⁵ Jim Bradbury, *The Medieval Archer*, pp. 163-4.
Calendar of the Close Rolls Preserved in the Public Office, Edward III, 14 vols. (London, 1896-1913). pp. 11:534-5

⁵⁶⁶ *Ibid.* pp. 11:534-5

⁵⁶⁷ Ascham, Roger, *Toxophilus*, ed. Edward Arber (London, 1868). pp. 95-8.
 Jim Bradbury, *The Medieval Archer*, pp. 163-4.

⁵⁶⁸ Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 405-6.

Thomas Esper, “The Replacement of the Longbow by Firearms in English Army”, *Technology and Culture* 6:3 (1965). pp. 383-5

⁵⁶⁹ *Calendar of the Close Rolls Preserved in the Public Office, Edward III*, pp. 11:534-5

⁵⁷⁰ Josef Alm, *European Crossbows: A Survey*, pp. 31-2.

more highly trained archer. These examples show that Archery practice was emphasised across Western Europe and, while the minimum strength threshold for firing a longbow was significantly higher than that of a crossbow, that does not necessarily mean that the use of the longbow guaranteed superior archers.

The rediscovery of the *Mary Rose* and the skeletons aboard it has enabled some study of the possible skeletal damage a life as an archer could have entailed. While the exact reason why this damage happened cannot be known for certain, there has been a growing body of work arguing in favour of archery practice as a probable cause of the damage that was seen on some of the skeletons. Specifically, the scapula, a part of the shoulder blade, was not attached to the rest of the bone on several of the bodies.⁵⁷¹ This research has been enhanced by studies of the bodies from a mass grave from the Battle of Towton (1461), which had similar signs of damage. Some of these latter skeletons also showed signs of damage to their elbows consistent with damage from the frequent and repeated use of a bow.⁵⁷² (Some of the *Mary Rose* skeletons also had signs of spine compression, but A.J. Stirland has argued that this was most likely the result of operating the gunpowder artillery on the *Mary Rose*, and was not due to archery.⁵⁷³) This evidence tied in with the idea that archery practice was fairly common and quite rigorous in medieval England. However, it also demonstrated how damaging this practice could have been to the human skeleton over a long period of time. The people buried at Towton were on average older than those who died on the *Mary Rose* and this suggests that archery practice would not have necessarily forced an individual's military career to end early. However, the Towton graves would not have included anyone who had been forced to retire due to damage suffered from archery practice since anyone who had retired would not have been fighting in the Battle of Towton. It is possible that individual archers suffered worse injuries than those shown in the Towton or *Mary Rose* bodies.⁵⁷⁴ This line of research is still fairly new and limited to only a handful of case studies. Further research into medieval skeletons could hopefully provide some more insight into how much of the damage seen in Towton or the *Mary Rose* was common for the time, and how much was likely the result of military training and practice.

These skeletons highlighted the long term damage a person could suffer from

⁵⁷¹ A.J. Stirland, *The Men of the Mary Rose Raising the Dead*, 2nd ed. (2000, Sparkford, 2005). pp. 118-130.

⁵⁷² Christopher Knüsel, "Activity-Related Skeletal Change", pp. 108-9, 116.

⁵⁷³ A.J. Stirland and T. Waldron, "Evidence for the Activity Related Markers in the Vertebrae of the Crew of the *Mary Rose*", *Journal of Archaeological Science* 24 (1997). pp. 329-335.

⁵⁷⁴ Christopher Knüsel, "Activity-Related Skeletal Change", pp. 103, 116

extensive training with a longbow, but what they did not show was the frequency of short term damage, or the problems with maintaining peak physical condition for archers. An army on campaign usually could not have spared an entire day every week to let its archers practice shooting, and, with a fixed amount of arrows, it would have been some risk to lose a large number of them, even if many could likely have been retrieved, albeit at a greater cost of time.⁵⁷⁵ A commander could hope that his archers remained in a fit enough state to shoot their bows, but likely doing so would require training them to be stronger than necessary for the bows they were equipped with or possibly bringing weaker longbows on campaign, so the archers could still shoot after weeks on the march with little practice. The bodies at Towton have been compared to those of professional athletes, and that is an apt comparison when considering these problems.⁵⁷⁶ Minor injuries, such as pulled muscles or torn tendons, have always been common in athletes and could have been a problem with medieval archers, especially if they trained more intensely before going on campaign, and particularly as they wouldn't have had the same technological and medical support that modern athletes can rely on to minimise injuries and facilitate quick healing.⁵⁷⁷ This is not to say that historians should doubt that English archers were in great physical condition and capable of firing their powerful longbows. Instead, it is to point out that there were numerous logistical and societal problems with creating and maintaining an elite body of archers that have to be considered. It is also important to remember that not every archer in a large English army would have been at peak physical condition, and the best case scenario for English archers and longbows should not be treated as the likely norm during an actual battle.

The longbow had a high minimum strength requirement for effective use and a very high skill level for optimal use, meaning that an archer could almost always improve their ability to use a longbow effectively with more practice. In comparison, the crossbow had a low minimum strength threshold to use, but did have a skill level equal to that of the longbow. In practice, though, one should not assume theoretical high points were actual historical reality. It is impossible to know the practical level of training the average archer had in the Middle Ages. There would likely have been a noticeable variance between individual archers, and it should not be unquestioningly assumed that the majority of archers in a given army were at the maximum skill level that was possible with their weapons.

⁵⁷⁵ Michael Prestwich, *Armies and Warfare in the Middle Ages*, pp. 136-41.

⁵⁷⁶ *Ibid.* pp. 103, 116.

⁵⁷⁷ Jennifer Coughlan and Malin Holst, "Health Status", pp.71-4.

Weapon Development

The sixteenth century marked the final decline of both the bow and the crossbow as weapons of war but, while this eventually spelled the death of the longbow outside of use by small numbers of enthusiasts in later eras, it sparked several developmental changes in the crossbow. The longbow stayed in use in the English army up until 1595, but it was in decline throughout the sixteenth century. Even though the greatest archaeological deposit of longbows came from the *Mary Rose*, the weapon was well past its military zenith when that ship set sail.⁵⁷⁸ While the longbow has enjoyed popular revivals since then, both as a target shooting weapon in Victorian England and among certain groups of modern day hunters, its days as the battle-deciding war bows of the Hundred Years War are well and truly finished.⁵⁷⁹ The crossbow underwent a similar decline as a weapon of war, although pointing to a definitive end date is complicated by its wider use than the longbow, as it continued to develop and change over the centuries. In fact, the crossbow became a technology of ever increasing complexity. Josef Alm described the crossbow as reaching the “pinnacle of its development” during the sixteenth century.⁵⁸⁰ Its popularity both as a target shooting weapon and as a hunting weapon remained high from the sixteenth century through to the modern era. In that time, it underwent significant technological improvements and alterations. For example, more complex triggers that improved the quality of the bolt release were developed in the late fifteenth century, and these became increasingly elaborate in later centuries.⁵⁸¹ Crossbows even saw some interesting, strange, and short-lived developments, such as the wheel-lock gun-crossbow combination weapons of the mid-sixteenth century.⁵⁸²

While one could always dwell on the specific technological or strategic differences between these weapons, this decline and transformation of the weapons perhaps showed the single greatest division between these two technologies. The longbow was a weapon invented in early pre-history, but in many ways it was rooted in the Middle Ages. Its dominance began in the High Middle Ages and its 'death' was at the start of the early modern period. In contrast, the crossbow was possibly invented as late as the High Middle Ages and has gone through several developmental stages.⁵⁸³ It

⁵⁷⁸ Thomas Esper, “The Replacement of the Longbow by Firearms in English Army”, pp. 383-5

⁵⁷⁹ Robert Hardy, *Longbow*, pp.150-6,173-83.

Jay Massey, “Why Traditional?” in *The Traditional Bowyers Bible*, ed. Jim Hamm, 4 vols. (Guilford, 1992). pp. 1:16-18.

⁵⁸⁰ Josef Alm, *European Crossbows*, p. 55.

⁵⁸¹ W.F. Paterson, *A Guide to the Crossbow*, pp. 34-5.

⁵⁸² Breiding, Dirk, *A Deadly Art: European Crossbows, 1250-1850* (New York, 2014). pp. 80-7.

⁵⁸³ Nicole Pétrin, “Philological notes on the crossbow and related missile weapons”, *Greek, Roman and*

changed from being a weapon that dominated wars to a weapon of sport shooters and hunters. The reason for this difference in development stemmed from their most basic difference: the longbow as a technology has had little room for innovation or transformation, while the crossbow was a device ripe for improvement and alteration. The fact that artisans could add new features to a crossbow meant that it had room to grow as a technology to meet the demands of each new era. The crossbow's tiller also presented a perfect opportunity for artistic decoration and embellishment; carving or altering a bow's limbs could have damaged the weapon's performance but the crossbow's tiller could have been decorated as much as the artist, or his patron, desired. The crossbow could have been transformed to suit what its contemporaries wanted it to be, while the longbow has always been the longbow.

Bow and Crossbow Similarities

So far this chapter has focused on differences between these two weapons. It is important to remember that these weapons also had similarities, as they fulfilled similar roles as the primary personal projectile weapons of the High and Later Middle Ages. They were also governed by the same principles of physics in their design and operation, and eventually replaced by the same advances in gunpowder weaponry. The following paragraphs will undertake an exploration of the similarities between bows and crossbows, emphasising both how they were affected by the context of the Later Middle Ages, and how they were used in similar manners during that same time.

In general, the Later Middle Ages had more powerful types of bow and crossbow than the Early or High Middle Ages. While the High Middle Ages did not see a radical technological shift in the development of the longbow, the longbows of the *Mary Rose* were larger, more powerful weapons than those used in earlier centuries. Certainly, late medieval longbows were more powerful than early medieval longbows. New types of crossbow were made in the Later Middle Ages that were more powerful than the crossbows that had preceded them. New, more powerful spanning methods were introduced in the Later Middle Ages, which were indicative of an increase in power. The technology expanded from exclusively crossbows that could be spanned by hand to include crossbows that required the assistance of powerful machinery to be spanned.⁵⁸⁴ Designs of the weapons themselves changed over the same period, generally trending

Byzantine studies 33:3 (1992). pp. 280-91.

⁵⁸⁴ Josef Alm, *European Crossbows: A Survey*, pp. 35-7.

towards greater levels of power. Crossbows became more complex in addition to becoming more powerful, while longbows appear to have increased in size and power. Unfortunately, no craftsmen responsible for making these weapons has left any kind of personal records describing the reasons for these changes. Any explanation must be predicated on the limited evidence available and a healthy helping of speculation.

The development of new kinds of armour almost certainly had an impact on weapons and the individuals who made them. Plate armour first began appearing around the turn of the fourteenth century, roughly the same time that the longbow came to prominence in England, and it is certainly tempting to see them as related.⁵⁸⁵ It is unlikely that the invention of plate armour caused an increase in the power of ranged weapons, or vice versa, but new developments in armour almost certainly encouraged new developments in weapons. While the suit of full plate was the most iconic result of plate armour's re-introduction to European warfare, it was likely only worn by a handful of noble warriors. The initial cost of such armour would have been very high and suits of full plate were not mass produced in the Middle Ages.⁵⁸⁶ Unfortunately, a comprehensive study of what armour was worn, and by whom, during this time period has yet to be undertaken, so what the common soldier wore is still a matter of some speculation.⁵⁸⁷ While the cost of plate armour seemed to generally have gone down over the centuries after it was first introduced, the rate of its cost reduction, and its uptake among the common soldiery, is still not known. The introduction of the coat-of-plates, which was a cheaper, simpler suit of armour more likely to be worn by the common soldier, probably had a more immediate impact on the types of weapons armies were equipping their soldiers with than full plate did. The coat-of-plates was a coat, or sometimes just a vest, with strips of iron – or steel in higher quality examples – sewn into it. Coats-of-plates came in many styles and shapes, but their major advantage was that they were a cheaper way for an individual to wear armour made primarily of plates of metal.

The impact this would have had on weapon development was a demand for an increase in the power of the weapons, as soldiers, and their employers, would want their

⁵⁸⁵ Claude Blair, *European Armour circa 1066 to circa 1700*, pp. 62-6.

Kelly, Francis, "A Knight's Armour of the Early XIV Century Being the Inventory of Raoul de Nesle", pp. 457-60.

R. Ewart Oakeshott, *The Archaeology of Weapons Arms and Armour from Prehistory to the Age of Chivalry*, (1960, repr. London, 1996). pp. 282-8.

⁵⁸⁶ Alan Williams, *The Knight and the Blast Furnace: a history of the metallurgy of armour in the Middle Ages & the early modern period*, (Leiden, 2003). pp. 53-8.

⁵⁸⁷ *Ibid.* pp. 46-8.

weapons to be able to threaten armoured enemy soldiers.⁵⁸⁸ This would have applied equally to ranged weapons as it would have to melee weapons. While the exact success of this increase in power has been the topic of some debate⁵⁸⁹, the increase in power did correlate strongly with the increase in the quality of armour worn by soldiers. This argument was not exactly a new revelation, though, and was also not without its problems. The longbow entered widespread use in the English army before the invention of full plate armour, and the windlass likely dates to the mid-thirteenth century, if not earlier. There were even references to what could be a windlass in a text written by Al-Tarsusi for Saladin (1137/8-1193) during the twelfth century.⁵⁹⁰ However, the presence of powerful bows and crossbows before the invention of plate armour did not negate the possibility that these technologies impacted each other. It did not even preclude the likely situation that both longbows and crossbows continued to increase in power as the Middle Ages progressed. What was not clear was how exactly weapons and armour would have impacted each other. Weapons capable of delivering lethal blows despite the presence of armour would likely be a motivating factor to develop better armour. In the same way, armour capable of preventing lethal attacks would encourage the development of more powerful weapons. These two factors were also not in a vacuum; other factors constrained or discouraged the development of these technologies. For example, if all that mattered was that soldiers needed a weapon to penetrate plate armour then gunpowder technology should have been developed much sooner. However, the cost and complexity of innovating in gunpowder weapons were more important factors in determining the speed with which the technology developed than the need for them in warfare was.⁵⁹¹ That is to say nothing of the time required for medieval commanders to first determine gunpowder's importance and then understand how it could have been used effectively. What seems likely is that, among other factors, developments in armour encouraged the pursuit of advances in weapons technology, and vice versa. The fact that these technologies were encouraged to develop does not necessarily mean that new, more advanced versions of them were made. The desire to develop new weapons and armour does not mean that it was always possible to improve upon existing designs and materials. As the eventual adoption of gunpowder showed, bows and crossbows were not

⁵⁸⁸ Claude Blair, *European Armour circa 1066 to circa 1700*, pp. 55-56, 58-59.

⁵⁸⁹ See the Experimental Archaeology section of Chapter 1.

⁵⁹⁰ Anne-Marie Eddé, *Saladin*, trans. Jane Marie Todd, (Cambridge, 2011). pp. 281-2.

W.F. Paterson, *A Guide to the Crossbow*, pp. 34-5.

⁵⁹¹ Alan Williams, *The Knight and the Blast Furnace*, pp. 850-5.

able to keep up with advances in armour and were eventually replaced as a result.⁵⁹²

Conclusion

The primary purpose of this chapter was not to provide answers but rather to outline the complexity of analysing the bow and crossbow's roles in medieval warfare. Bows and crossbows had clear differences in design and usage, but the impact of these differences has been difficult to determine. While, at a glance, the longbow seemed to have been the superior weapon for battle and the crossbow the weapon better suited to siege warfare, a closer examination of medieval warfare showed how complex their relationship actually was. In battle, the longbow's superior rate of fire gave it an advantage, but the exact value of this advantage is unknown. Siege warfare was an area that has received limited scholarly attention, and warrants further exploration. The argument over which weapon was better suited to siege warfare was complicated immediately by the question of how important these weapons were in general to either the besieging or defending forces. In a mode of warfare that featured starvation tactics and massive siege engines, it has not been immediately obvious what difference a few dozen crossbows could have made to the outcome. Even beyond that, siege warfare came in many different forms and different sieges involved very different tactics so establishing a general rule for an entire form of warfare, especially across the entire Middle Ages, quickly becomes impossibly complex. If this chapter was condensed to a single point, it is that these topics are complicated and warrant greater study and consideration than they have often been given. While the longbow and its use in battle has been the subject of several detailed studies – most recently Strickland and Hardy's *The Great Warbow* – the way it was used in sieges, as well as how the crossbows was used in warfare generally, have not received a comparable amount of study. There is still much that historians do not know about how these weapons were used, and a greater understanding of both these weapons and the tactics associated with them has the promise to greatly enhance the understanding of medieval warfare more generally. Understanding medieval warfare is essential to understanding the Middle Ages in general since it played a central role in, and had a major impact on, nearly every aspect of medieval life.

⁵⁹² Alan Williams, *The Knight and the Blast Furnace*, pp. 842-57.

Conclusion

The words 'bow' and 'crossbow' have usually been used to refer to a diverse range of weapons that shared several important qualities, but also had a plethora of nuanced and significant differences. Frequently these differences have been ignored, or at least not properly accounted for, when these weapons have been included as part of a discussion on a broader aspect of military history. This simplification is understandable; it is, for example, easier to discuss the crossbow as if it was a single type of weapon with a uniform design than it is to engage with all the nuance and the complications of the weapon. However, a degree of detail and analysis has been lost when the crossbow was simplified. Even the three generally accepted broad categories of crossbow – wooden, composite and steel crossbows – still contained a significant variety of crossbow shapes, sizes, and designs within their respective groups. Similarly, longbow discussions have too often focused only on the length of the bows and have not examined the other important aspects of longbow design. From the basic mechanics of archery to the variety in design, these weapons warrant a greater, more in-depth discussion than they have generally received. This work will not be the final word on the crossbow or the bow. Instead, it has been a declaration that these weapons are deserving of more attention and consideration, while providing examples of how a simplistic understanding of them cannot hope to fully encapsulate either weapon.

A general understanding of the physics behind archery must form the foundation of a study of the bow and the crossbow, to appreciate the complexity and significance of the design and operation of these weapons. While a good grasp of these principles is essential to undertaking any experimental archaeology, and interpreting the results of those experiments, that is not the sole reason this information is valuable. The physics of archery informs historians how these weapons worked, how they were designed, and how they would have been used. To have a full understanding of the bow and the crossbow in the Middle Ages, one must understand the principles which governed them. However, the mechanics of archery are of such complexity that a thorough understanding of them is essentially unattainable for historians unless they are first willing to get a Ph.D. in physics.⁵⁹³ While this complexity precludes an understanding of the performance of bows and crossbows based in mathematical analysis, this does not mean that a general grasp of the overall principles is impossible. This general understanding is far easier to acquire and in many ways almost as useful. For example, a bow gains much

⁵⁹³ Mark Denny, *Their Arrows Will Darken the Sun: A Guide to the Evolution and Science of Ballistics*, (Baltimore, 2011). pp. 7-15

of its power from its thickness so, when comparing bows, a historian who understands that will correctly identify that a thicker bow was likely to be more powerful.⁵⁹⁴ While it is not possible to say how much more powerful one bow is than another without having undertaken many complicated calculations and measurements, that level of detail is not always necessary to draw valid conclusions. While some level of understanding of the mechanics of archery is necessary to any discussion of the performance and design of bows and crossbows, that level need not be more than a general survey of the subject.

The fact that the bow and crossbow operated with near identical physical mechanics means that there is an interesting, and generally unexplored, relationship between the two weapons. The earliest crossbow lathes made of wood were essentially shorter versions of the longbows found in the *Mary Rose*. The two surviving examples of wooden crossbow lathes were made of yew and had draw weights in the region of 150 lbs.⁵⁹⁵ The difference between these and the *Mary Rose* longbows was that the former were half the length of the *Mary Rose* longbows. Despite this difference in length, the crossbow lathes achieved draw weights in only eight to ten inches that it took 28 to 30 in draw for the *Mary Rose* longbows to reach.⁵⁹⁶ While this difference in draw length underlined many of the differences in these technologies, the core design of these weapons – meaning thick staves of yew – were similar. This similarity raised interesting questions about how knowledge of medieval technology was shared and retained. If crossbow makers could have made weapons out of yew that achieved the power of the *Mary Rose* bows – something that no one seems to dispute – then it would seem unlikely that bowyers could not have achieved similar results when making longbows during those same centuries unless the two groups of craftsmen never shared information. There has been little study of bowyers or crossbow makers during the High Middle Ages so possible links or divisions between the two remain entirely speculative for the moment.⁵⁹⁷ The two groups of craftsmen, as well as the wooden weapons they made, are both deserving of wider and more in-depth study. One possible benefit of this research is

⁵⁹⁴ Tim Baker, “Bow Design and Performance” in *The Traditional Bowyers Bible*, ed. Jim Hamm, 4 vols. (Guilford, 1992). pp. 65-74.

⁵⁹⁵ Robert C. Brown, “Observations on the Berkhamstead Bow”, *Journal of the Society of Archer-Antiquaries* 10 (1967). p. 17

G.M. Wilson, “Notes on Some Crossbows in the Collection of Glasgow Museum and Art Gallery”, (Unpublished Notes, 2006). pp. 3-7.

⁵⁹⁶ Matthew Strickland and Robert Hardy, *The Great Warbow: From Hastings to the Mary Rose*, (2005, repr. Somerset, 2011). pp. 12-3, 17-8.

Robert C. Brown, “Observations on the Berkhamstead Bow”, p. 17.

⁵⁹⁷ For an example of what research has been done so far see:

David Bachrach, “Origins of the Crossbow Industry in England”, *Journal of Medieval Military History* 2 (2004). pp. 73-88.

that a better understanding of the few high medieval yew lathes that have survived could provide new insights into the longbow during a time when no archaeological evidence of the latter weapon has survived. While yew lathes – like the Berkhamsted Bow – were generally considered normal for the twelfth and thirteenth centuries, if not earlier, there has been an ongoing debate as to whether the longbows of that same period were even longbows at all.⁵⁹⁸ This lack of comparison and discussion could be the result of the division in the scholarship of the longbow and crossbow. Most scholarly works have focused on only one of either the crossbow or the longbow, so this similarity could have simply gone unnoticed.

One example of the importance of understanding the physics of archery can be seen by examining how discussions about the longbow have been framed. The longbow's very name implies that its most significant feature was that it was a bow that was longer than other, 'normal', bows. However, this was a misleading description. While the longbow may have been longer than other bows – although the evidence suggests that it was instead the shorter bows that were the deviation from the norm – length was not the most important feature of the longbow's design. While a greater length did usually correspond to a greater power in a bow, it was not the only way to make a powerful bow, and it was not even the most efficient way to do so. Longer bows were generally more inefficient, which reduced the overall impact of their increase in draw weight. The thickness of a bow was a much greater indicator of its power, and in studying that thickness it was possible to get a much better impression of the progression of bow power over time.⁵⁹⁹ For example, the impressive selection of bows that have survived from prehistory were almost all well over a metre and a half long and some were even two metres long.⁶⁰⁰ However, these bows would almost certainly had draw weights much lower than the bows from the *Mary Rose*, as a result of their different designs. This was especially true of those weapons made in the diamond bow shape.⁶⁰¹ These weapons

⁵⁹⁸ Clifford Rogers, "The development of the longbow in late medieval England and 'technological determinism'", *Journal of Medieval History*, 37:3 (2011). pp. 322-3.

Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 34-8.

⁵⁹⁹ Tim Baker, "Bow Design and Performance", pp. 65-74.

⁶⁰⁰ Paul Comstock, "Ancient European Bows" in *The Traditional Bowyer's Bible* ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). pp. 2:86-96.

J.G.D. Clarke, "Neolithic Bows from Somerset, England, and the Prehistory of Archery in North-western Europe", *The Proceedings of the Prehistoric Society* 29:3 (1963). pp. 89-95.

J.N. Lanting, B.W. Kooi, W. A. Casparie and R. van Hinte, "Bows from the Netherlands", *Journal of the Society of Archer-Antiquaries* 42 (1999). pp. 7-8.

⁶⁰¹ Tim Baker, "Bow Design and Performance" in *The Traditional Bowyers Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). pp. 1:66-71.

Paul Comstock, "Other Bow Woods" in *The Traditional Bowyer's Bible*, ed. Jim Hamm, 4 vols. (1992,

meet the length requirement to be considered 'longbows', but they do not have the power that many scholars would expect from a bow with that name.

The greatest question in the study of the English longbow has been whether the bows from the *Mary Rose* were essentially identical to those used during the Hundred Years War (1337-1453) and earlier, or whether they were representative of a new kind of bow that was developed sometime during the High Middle Ages. The current debate has primarily focused on the issue of length, which ignored several important features in the development of medieval and prehistoric bows. It was the other aspects of the longbow's design that this thesis has focused on. The role of thickness in determining a bow's power has already been discussed in the previous paragraph, but a study of thickness can contribute to the debate on the longbow's development in more ways than by just identifying similarities between crossbow lathes and *Mary Rose* bows. There were only five mostly complete European high medieval longbows to survive to the modern day: four twelfth-century bows excavated at Waterford City and one bow excavated at Balinderry Crannóg in Meath. These bows were closer in date to the wars of Edward I (r.1272-1307) and the Battle of Crecy (1346) than the *Mary Rose* bows were, and provided a glimpse into the weapon's stage of development leading up to those events. They represented a minimum level the technology had achieved before its famous victories. Bows contemporary to the Irish bows may have been more powerful, but historians can be confident that high medieval bowyers were at least capable of making bows equal to those found in Ireland. This has made them a very useful point of comparison for the weapons from the *Mary Rose* and yet for some reason they have often been ignored, or discussed only in passing. *The Great Warbow* contained only a brief mention of the Balinderry Bow and no mention of the Waterford Bows, while Clifford Rogers' recent article discussed only the Waterford Bows and not the Balinderry Bow.⁶⁰² Even when they have been mentioned, these weapons have been used only to support an already established hypothesis rather than being considered on their own merits.

While this thesis included discussions of prehistoric and early medieval bows, the primary focus was on the comparison between high medieval bows from Ireland and the longbows from the *Mary Rose*. The prehistoric and early medieval bows were included

repr. Guilford, 2000). pp. 1:149-55.

See Chapter 1.

⁶⁰² Matthew Strickland and Robert Hardy, *The Great Warbow*, p. 40.

Clifford Rogers, "The development of the longbow in late medieval England and 'technological determinism'", pp. 333-5.

to provide context to the weapon's development; it was these latter two categories of bows that presented the most interesting and significant comparison. The Balinderry Bow was the closest in size to the bows from the *Mary Rose*.⁶⁰³ The Balinderry Bow's length would have been on the shorter end of the scale for a *Mary Rose* bow but it would not have been the shortest. Its thickness was also on the lower end of the *Mary Rose* spectrum, while its width was nearly the same as most of the *Mary Rose* bows. The Waterford Bows were much shorter than the *Mary Rose* bows, but they were five millimetres thinner than their counterparts in the sixteenth century. However, the Waterford Bows suffered extensive decay and were originally thicker than they were when they were measured after excavation, meaning the real difference in size between the two was less than it now appears.⁶⁰⁴ In general, the Irish bows were smaller than the *Mary Rose* bows, and as a result would have been weaker weapons. This means that Strickland and Hardy's assertion that high medieval longbows were functionally identical to the *Mary Rose* bows was not backed up by the archaeological evidence.⁶⁰⁵ However, Clifford Rogers' argument that these earlier bows represented some transitional technology, bridging the gap between the short bow and *Mary Rose* style longbow, was also not backed up by the archaeological evidence.⁶⁰⁶ The Balinderry Bow showed that longbows of the length seen in the *Mary Rose* definitely existed during the High Middle Ages. The Waterford bows showed how searching for a middle-length bow missed an important aspect in longbow design. A bow that was of 'middle-length' could have been nearly as powerful as one that was much longer, if it was thick enough. While the capability to make *Mary Rose* style bows was present during the High Middle Ages, weapons identical to those same bows were not made because there was no demand for bows that powerful. Instead, bowyers made weapons that suited the time and people who were going to be using them, resulting in bows like those found in Balinderry and Waterford.

⁶⁰³ H. O'Neill Hencken, Gwyneth Harrington, H. L. Movius, Jr., A. W. Stelfox and Geraldine Roche, "Ballinderry Crannog No. 1", *Proceedings of the Royal Irish Academy. Section C: Archaeology, Celtic Studies, History, Linguistics, Literature* 43 (1935 – 1937). pp. 133, 139.

⁶⁰⁴ Andrew Halpin, "Archery Material" in *Late and Viking Age Medieval Waterford: Excavations 1986-92*, ed. M.F. Hurley, O.M.B. Scully, and S.W.J. McCutcheon (Waterford, 1997). pp. 546-52.

Andrew Halpin, "Military Archery in Medieval Ireland: Archaeology and History", *Military Studies in Medieval Europe –Papers of the 'Medieval Europe Brugge 1997' Conference* 11 (1997). pp. 54.

Bartlett, Clive, Chris Boyton, Steve Jackson, Adam Jackson, Douglas McElvogue, Alexandra Hildred and Keith Watson, "The Longbow Assemblage" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). pp. 2:596-9.

⁶⁰⁵ Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 34-5, 39-43

⁶⁰⁶ Clifford Rogers, "The development of the longbow in late medieval England and 'technological determinism'", pp. 322-8.

The use of medieval art as a substitute for gaps in the archaeological record has long been an appealing methodology and has gained support from some academics currently working in the field of medieval archery.⁶⁰⁷ This practice and the methods associated with it are not without their problems, however. To begin with, artistic images were usually only reliably informative on general elements of weapon design. Comparing bow thickness or the nuances of crossbow design was more difficult than comparing how long the bows appear in a given image; while longbow thickness differences were usually only the matter of a few millimetres, and thus too detailed to detect in medieval images; length could be a variation of hundreds of millimetres, and thus much easier to see. This sort of approach neglected the often important nuances of weapon design, by focussing too much on the more obvious differences in weapon appearance. Medieval art has been an invaluable resource for historians to study but it has also been a difficult subject to engage with and required a careful approach. Medieval art was not created with the goal of complete realism in mind and contained many stylistic flourishes. Treating medieval art as if it were a literal and realistic representation of medieval life is an inherently flawed approach. Figures were depicted as varying greatly in size within a single work, and the same was true of their surroundings.⁶⁰⁸ Expecting a universal scale to apply to a work of medieval art will result in disappointment and flawed conclusions. Even variations in length, which seem so obvious to the casual observer, might not be significant. Medieval artists were often anonymous and their reasons for creating their image the way they did will forever remain obscured from historians. A smaller weapon in an image could be reflective of reality, but it could just as easily be a stylistic choice, or simply a part of the image that the artist was not particularly interested in. What is now of great interest to modern scholars was not necessarily the most important part of the image to the medieval artist who made it. This is not to say that medieval art should not be included in the study of medieval archery, or medieval warfare more generally. While the images have not provided a level of detail sufficient to draw nuanced conclusions from them about weapon design, they could be used to indicate weapon usage. The types of weapons shown in an image could indicate when and where those weapons were used. Similarly, images of archers stringing their bows or using a spanning device on a crossbow provides insight into how these weapons would have been operated by medieval archers.

⁶⁰⁷ Ibid. pp. 336-40.

⁶⁰⁸ Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 44-6. See Chapter 3.

Often the crossbow has been treated as if it was a single weapon of uniform design and function but this is a misleading conceptualisation of the weapon. Crossbows were made in a variety of styles, with several different types of lathes, and the crossbow changed significantly across the centuries of its use. In an attempt to better understand the diversity of crossbows present during the Later Middle Ages, this thesis collected and compared data on 140 crossbows from the thirteenth through sixteenth centuries.⁶⁰⁹ This approach focused on the archaeological record of the crossbow and set out to establish what, if any, style of crossbow represented the 'standard' crossbow for a given century. Crossbows were examined by lathe type and by century, with trends compared between centuries. Most of the analysis focused on composite and steel crossbows, since this thesis contained data on only two medieval wooden crossbow lathes. What this research showed is that expecting a single standard crossbow for a given period in time is a flawed approach, as crossbows came in a vast range of sizes and designs even within a region and century.

Composite crossbows changed significantly in the transition from fourteenth to fifteenth centuries, but then remained fairly consistent in size through the sixteenth century. The data for this initial change were unfortunately quite limited, since there were only two composite crossbows that dated to the fourteenth century.⁶¹⁰ What set these two crossbows apart was the length of their lathes. The fourteenth-century composite lathes were among the longest of any century, only shorter than the wooden lathes of the same time period. No later composite lathe even approached these in size. There was a gap of over 100 mm separating the longest fifteenth-century lathe from the shortest fourteenth-century lathe.⁶¹¹ Unfortunately, a sample size of just two lathes means that any conclusion drawn from this deviation is necessarily a tentative one, since there always remains the possibility that these two were outliers. However, the size of the gap, and the fact that no other composite or steel crossbows from any century even approached these in length does suggest that this difference was significant, despite the small sample. Hopefully more fourteenth-century composite crossbows will be found to provide some more context in the future. For the time being, the data suggested that composite crossbows underwent a significant change in the transition from the fourteenth to the fifteenth century.

Fifteenth-century composite crossbows were remarkably consistent in their

⁶⁰⁹ See Appendix I, pp. 254-306.

⁶¹⁰ See Appendix I, pp. 255-6.

⁶¹¹ See Appendix I, pp. 255-70.

dimensions, in both the lengths of their lathes and their tillers. The handful of examples from the sixteenth century were nearly identical, fitting in perfectly with the data from the previous century. The composite lathe faded out of use in the sixteenth century and the lack of change in design could have been a reflection of this decline. While there was a general consistency to the weapon during this period, that does not mean that there was no variety at all. The data in this thesis suggested that most of the crossbows in these two centuries were of an approximately similar build. However, this cluster spanned a wide enough range of dimensions that it is likely that distinct styles existed within the group. There also existed outliers from this cluster that probably represented different styles, or possibly unique examples, that broke from the contemporary norm.⁶¹² For example, there was a two kilogram weight difference between the lightest and heaviest fifteenth-century composite crossbows. The lightest composite crossbow was less than 2 kg in weight, so the heaviest one was over twice as heavy.⁶¹³ These extremes represented crossbow types that were probably less popular, which is why there were fewer like them in the data. Even within the more clustered data, there was significance to the data spread. To return to the weight example, most of the data were clustered into a group, wherein the lightest crossbow was approximately 1000 g lighter than the heaviest. A kilogram in weight was not an insignificant difference. Similar trends could be seen in the lathe and tiller lengths for these crossbows. With the data currently available, it was not possible to determine where in this cluster possible further sub-groups or unique designs existed. However, it was likely that there did exist significant differences between crossbows, even when they were comparatively similar in size and shape. The difficulty lay in understanding when differences in dimensions were simply the result of different craftsmen working with different tools and materials, and when the differences were the result of clear, significant, and intentional decisions in weapon design. The first step to resolving this question was in determining what differences in dimensions and design would have had a clear impact on weapon performance and which had a negligible or non-existent effect. The data in this thesis suggested that there was a dominant style of composite crossbow during the fifteenth and sixteenth centuries that, while not the only style at the time, was the clear preference of Western European crossbowmakers and the individuals who bought from them. However, further research will be necessary to understand these weapons to an even greater degree of detail, to see if within this dominant group there

⁶¹² See Chapter 5.

⁶¹³ See Appendix I, pp. 277-304.

were further sub-groups that may point to new trends in the crafting and use of crossbows.

Steel crossbows had a wide variety of shapes, sizes, and designs across their centuries of use. These different types became more common as the centuries progressed. The exact date when the steel crossbow was introduced to Europe has been a topic of some debate to the present day, but it was definitely in use by the fifteenth century at the very latest.⁶¹⁴ The data in this thesis were compiled from a collection of steel crossbows dating from the fifteenth century up to the middle of the sixteenth century. Surviving steel crossbows were relatively scarce in the fifteenth century, but by the sixteenth century they had survived in such numbers that they were the single largest group in the data. The handful of fifteenth-century steel crossbows were similar in size to their composite counterparts.⁶¹⁵ They were very close in lathe length and had only slightly longer tillers. While the lathes were designed very differently as a result of the different material they were made from, the similarity in length presents an intriguing idea. The similarity suggested that in the fifteenth-century steel crossbows were being modelled after composite crossbows which were the dominant style of crossbow at the time. Alternatively, the weapons' similarity could have been the result of external factors shaping the development of both weapons. Steel crossbows in this century require the same type of research as their composite counterparts. There are very likely sub-groups within steel crossbows that could be identified with a greater understanding of steel crossbows as a technology, along with closer examination of the surviving examples.

The diversity of the steel crossbows made in the sixteenth century was greater than that of any previous century. The data collected on just the first half of this century, with a few crossbows that could possibly date to a later decade, clearly showed a technology that was undergoing significant change. The smallest crossbow from any century was found alongside some of the largest in this group, as were both the lightest and the heaviest crossbows.⁶¹⁶ While these were generally outliers from the bulk of the data there was still more variation within the core of the data than there was in any other type of medieval crossbow in any century.⁶¹⁷ A possibly explanation for this variation

⁶¹⁴ Josef Alm, *European Crossbows: A Survey*, ed. and trans. G.M. Wilson and H. Bartlett Wells, (1994, repr. Dorchester, 1998). pp. 34-6.

Ralph Payne-Gallwey, *The Crossbow: Its Military and Sporting History, Construction and Use*, (1903, repr. London, 1995). pp. 9-10.

⁶¹⁵ See Appendix I, pp. 270-6.

See Chapter 5.

⁶¹⁶ See Appendix I, pp. 277-304.

⁶¹⁷ See Chapter 5.

was the crossbow's decline in relevance as a weapon of war. New demands – of target shooting, hunting, and other sports – began to replace the old demands of war. While some war crossbows continued to be produced in the first half of the century they were increasingly in the minority.⁶¹⁸ What these data showed is that the crossbow was far from a technology on the verge of dying out, and instead was a technology diversifying to find a new purpose in a changing society. Dividing the available data into a range of crossbow types could provide a fascinating glimpse into the transformation of a weapon of war into a weapon for sport, as well as providing insight into how medieval society shifted into early modern society. A broad survey of the data suggested more questions than answers, however, as the crossbow was clearly being pulled in many directions at once. Some of the weapons in this century were so different from each other that it seems almost misleading to refer to them simply as 'crossbows'. They shared the same core properties of the weapon, but were different in nearly every nuanced detail of design and shape.

The complexity of the crossbow means that it should be thought of as a broad weapon-type rather than as representing a specific single weapon. To encourage this, there must be a change in terminology, which first requires determining which method of classification would be best for the crossbow. One system would be to use “crossbow” to mean the overall category of weapons, and then determine more specific terms for types of crossbow. This would be comparable to the label of polearms, where “polearm” is the term for the group of weapons that are attached to long poles, such as halberds, bills, spears, and pikes.⁶¹⁹ This system is the simplest option, but would require the creation of several new terms as well as the creation of descriptive qualities to aid in the classification of a given crossbow into the correct category. The current three categories, based on the lathe types, are too broad to be a complete system in and of themselves. Within a single lathe type there was significant and important variety, certainly on the scale of centuries but also on the scale of decades. For example, even within the relatively narrow category of steel crossbows from the first half of the sixteenth century, there was significant variation in type and design.⁶²⁰ A single label of 'steel crossbow' or even 'sixteenth-century steel crossbow' is far too broad to be a truly useful labelling

⁶¹⁸ Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 399-400.

Josef Alm, *European Crossbows: A Survey*, pp. 56-7.

⁶¹⁹ R. Ewart Oakeshott, *The Archaeology of Weapons Arms and Armour from Prehistory to the Age of Chivalry*, (1960, repr. London, 1996). pp. 259-61.

⁶²⁰ See Chapter 5.

system. Even within the fifteenth-century composite crossbows, a category of remarkable similarity in general, a single label would be an oversimplification of the weapon. Instead, more specific descriptions and types must be determined and labelled to make for a useful classification system for crossbows.

A second option, which could work in tandem with the previous one, would be to create a typology for crossbows. The Oakeshott typology for medieval swords is an example of a system of this type.⁶²¹ This would allow for individual aspects of the crossbow's design to be described separately. For example, tiller shape could be classified into a series of types which would be entirely independent from lathe shapes. This would allow for changes in the design of lathes to be examined without any need to reference changes in tillers. The greatest problem with this approach is that it would increase the complexity required to discuss the crossbow. In a typology system, a given crossbow would be a combination of several types rather than belonging to a single category. For example, a crossbow might be a Type 6 lathe attached to a Type VII tiller with a Type C nut.⁶²² This would make creating general categories of crossbows quite difficult since any category would have to include several different types of lathes, tillers, and nuts. It may be worth adopting a complex system such as this over a simpler and more intuitive system if the data warrant this level of complexity to be properly described. Another problem with this approach would be the amount of time required to create a typology. Many different qualities compose a typology, and these qualities must be determined and described based on the available evidence. The numerical data approach taken in this thesis cannot on its own create this kind of typology. Detailed descriptions of existing crossbows, including design features and shapes, not just raw dimensions, are necessary to creating a typology. This would require visiting many more collections than was possible in this thesis and making detailed observations, in addition to measurements, of dozens of the weapons. This type of research would be time consuming, expensive, and taxing for anyone undertaking it. With that in mind, it would have to offer something that made it sufficiently worthwhile to justify the cost and effort of the research.

It is in support of such research that this thesis is arguing: complexity is good. There are times when it is necessary to simplify a topic and many reasons to do so. These include, but are not limited to: external restrictions on the length of a work, lack of time to realistically research a subject to its fullest, or because there is no need for the reader

⁶²¹ R. Ewart Oakeshott, *The Archaeology of Weapons*, pp. 132-4, 202-7, 232-4, 303-4, 313-5.

⁶²² Typology names are hypotheticals, but based on those used by Oakeshott.

to have a deep understanding of a subject to understand the writer's general argument. Much of the time complexity is not feasible, or not strictly necessary, but that does not mean that historians should not strive for a highly complex understanding of the subject of their scholarship. For example, while the majority of general histories of the Crusades do not devote chapters to the vast amount of scholarly work that has been done on the complex manuscript histories of the chroniclers of the Crusades, those books are certainly better and more informative because that research exists.⁶²³ In a similar vein, while the majority of late medieval histories do not need to discuss in detail the complexities of longbow or crossbow design, that does not mean that a greater understanding of them would not improve that field of research. The study of the equipment and technology available to medieval soldiers has much promise for giving historians a better understanding of the ways warfare was waged, and the reasons behind the outcomes of its campaigns and sieges. Similar promise lies in the understanding of the types of equipment that existed at a given time and a deeper understanding of its design.

The longbow and the crossbow were two of the most important weapons of their age and a failure to understand how they were designed, made, and used must on some level represent a failure in our understanding of late medieval warfare in Western Europe. The consistency in the longbow's design over the High and Later Middle Ages made it easier to examine its use over that time period.⁶²⁴ In contrast, the crossbow was a weapon of great diversity, and if this diversity is not understood then it becomes increasingly difficult to understand the equipping of armies with those weapons. Simply identifying whether a given unit was equipped with steel or composite crossbows is not enough. While textual sources rarely included specific details of crossbow design, a good understanding of crossbow design, combined with a careful reading of these sources, could lead to a better understanding of how the crossbow was designed and used.⁶²⁵ Similarly, the context of a campaign, combined with textual evidence and evidence from crossbow design, could offer a fuller understanding of military pursuits than was previously possible.

⁶²³ For example see:

Peter Frankopan *The First Crusade: The Call from the East* (2012, repr. London, 2013). Which makes little mention of western Christian sources, but benefits significantly from other scholar's in-depth research on them in addition to Frankopan's deep understanding of the *Alexiad*.

⁶²⁴ See Chapter 2.

⁶²⁵ David S. Bachrach "Crossbows for the King, Part II: The Crossbow During the Reign of Edward I of England (1272-1307)", *Technology and Culture* 47:1 (2006). pp. 86-8.

While this thesis has attempted to provide new information on the development of the crossbow over the course of the Later Middle Ages, its result has been pointing out just how little is known about this weapon. The longbow has been widely studied and has a fairly clear path of development, with only some dissenting historians opposing the narrative. In comparison, the crossbow has only been covered in broad, general terms.⁶²⁶ The nuance and detail of the crossbow's development is important, since it gives insight into the creation and design of an important medieval weapon. While some aspects of the crossbow's design will inevitably remain a mystery lost to time, there is much more historians could learn about the weapon, and a detailed study, and classification system, are important first steps along a path to greater understanding of not just the crossbow, but of late medieval warfare in general.

⁶²⁶ Matthew Strickland and Robert Hardy, *The Great Warbow*, pp. 34-8.
Clifford Rogers, "The development of the longbow in late medieval England and 'technological determinism'", pp. 322-3.

Appendix I: Crossbow Data

The following is an appendix of all of the crossbows consulted as part of this thesis. They have been laid out in a semi-chronological order within which they are sorted by type. Most of the details are self descriptive but some require a bit of extra explanation. When dimensions are given for lathes in the form of Y x Z, Y represents the height or width of the lathe while Z is the thickness. The category “source” is where the numbers in this data were gathered from and not a comprehensive list of every publication where a given crossbow might have been mentioned. The crossbows from the Bernisches Historisches museum have two catalog numbers, separated by a forward slash, because the official museum inventory numbers and the numbers used in Rudolf Wegeli's catalog of the same are different. Both have been given here, the one with a W preceding it is the Wegeli number.

Crossbow ID: Berkhamsted Bow

Lathe Type: Wood (yew)

Lathe Length: 1235 mm

String Length: n/a

Tiller Length: n/a

Total Length: n/a

Weight: n/a

Date: 13th - 14th centuries

Origin: English

Location: British Museum, London

Source:

Brown, Robert C., “Observations on the Berkhamstead Bow”, *Journal of the Society of Archer-Antiquaries* 10 (1967). pp. 12-17.

Credland, Arthur Graves, “Crossbow Remains (Part 2)”, *Journal of the Society of Archer-Antiquaries* 24 (1991). p. 9.

Wilson, G.M., “Notes on Some Crossbows in the Collection of Glasgow Museum and Art Gallery”, (Unpublished Notes, 2006).

Crossbow ID: Glasgow E. 1939.65.en

Lathe Type: Wood (yew)

Lathe Length: 1099 mm

String Length: n/a

Tiller Length: n/a

Total Length: n/a

Weight: n/a

Date: 14th - 15th centuries

Origin: n/a

Location: Kelvingrove Art Gallery, Glasgow

Source:

Wilson, G.M., "Notes on Some Crossbows in the Collection of Glasgow Museum and Art Gallery", (Unpublished Notes, 2006). pp. 2-8.

Crossbow ID: Rustkammer Dresden U 110

Lathe Type: Composite
Lathe Length: 1018 mm
String Length: 745 mm

Tiller Length: n/a
Total Length: n/a

Weight: n/a
Date: 14th - 15th centuries
Origin: n/a

Location: Rustkammer Dresden

Source:

Richter, Holger, *Die Horgenarmbrust*, (Ludwigshafen, 2006). pp. 70-3.

Crossbow ID: Cologne W1109

Lathe Type: Composite
Lathe Length: 946 mm
String Length: 720 mm

Tiller Length: 875 mm
Total Length: n/a

Weight: 2000 g
Date: 14th - 15th centuries
Origin: German

Location: City Museum of Cologne

Source:

Harmuth, Egon, "Concerning the One-Foot Crossbow of the High Gothic", *Journal of the Society of Archer-Antiquaries* 28 (1985). pp. 9-10

Richter, Holger, *Die Horgenarmbrust*, (Ludwigshafen, 2006). pp. 26-31.

Crossbow ID: Schloss Grandson B33

Lathe Type: Composite
Lathe Length: 735 mm
String Length: 735 mm

Lathe Cross-Section Middle: 49x38 mm
Lathe Cross-Section Outside: 36.5x30 mm
Lathe to Lock Distance: 245 mm

Tiller Length: 893 mm
Total Length: 1010 mm

Weight: 2560 g
Date: Early 15th century

Origin: German(?)

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Crossbow ID: MET 29.158.647

Lathe Type: Composite

Lathe Length: n/a

String Length: 755 mm

Tiller Length: n/a

Total Length: 956 mm

Weight: 3989 g

Date: c.1425-75

Origin: Central Europe

Location: Metropolitan Museum of Art, New York City

Source:

Breiding, Dirk, *A Deadly Art: European Crossbows, 1250-1850* (New York, 2014). pp. 21-2

Crossbow ID: Netherlands Cat. No. 19

Lathe Type: Composite

Lathe Length: 712 mm

String Length: 631 mm

Lathe Cross-Section Middle: 50.2x43 mm

Lathe Cross-Section Outside: 42.3x32.5 mm

Lathe to Lock Distance: n/a

Tiller Length: 742 mm

Total Length: 836 mm

Weight: 2890 g

Date: c.1425-75

Origin: Central Europe

Location: Royal Netherlands Army Museum, Delft

Source:

Sensfelder, Jens, *Crossbows in the Royal Netherlands Army Museum*, (Delft, 2007). pp.154-5.

Crossbow ID: MET 04.3.36

Lathe Type: Composite

Lathe Length: n/a

String Length: 650 mm

Tiller Length: n/a

Total Length: 712 mm

Weight: 2972 g
Date: c. 1460

Location: Germany
Source:

Breiding, Dirk, *A Deadly Art: European Crossbows, 1250-1850* (New York, 2014). pp. 23-6.

Crossbow ID: M138 Ontario Museum

Illustration 1: M138 Ontario Museum, photo from museum

Lathe Type: Composite
Lathe Length: n/a
String Length: 673 mm

Tiller Length: 800 mm
Total Length: 838 mm

Weight: n/a
Date: c.1475-85
Origin: Germany or Austria



M138 Ontario Museum, photo from museum

Location: Royal Ontario
Museum, Toronto
Source:

Keeble, K. Corey, *European Crossbows in the Royal Ontario Museum*, (Toronto, 2008). pp. 36-9.

Crossbow ID: MET 25.42

Lathe Type: Composite
Lathe Length: n/a
String Length: 609 mm

Tiller Length: n/a
Total Length: 737 mm

Weight: 2284 g
Date: c. 1489
Origin: Central Europe (Vienna?)

Location: Metropolitan Museum of Art, New York City
Source:

Breiding, Dirk, *A Deadly Art: European Crossbows, 1250-1850* (New York, 2014). pp. 26-9.

Crossbow ID: Bern W1977

Lathe Type: Composite
Lathe Length: n/a
String Length: 725 mm

Tiller Length: 760 mm

Total Length: 865 mm

Weight: 3120 g

Date: c.1450-1500

Origin: Swiss(?)

Location: Historisches Museum, Bern

Source:

Wegeli, Rudolf, *Inventar der Waffensammlung des Bernischen Historischen Museums in Bern*, (Bern, 1948). pp. 22-3.

Crossbow ID: Bern W1978 / 915

Lathe Type: Composite

Lathe Length: 675 mm

String Length: 669 mm

Lathe Cross-Section Middle: 50x30 mm

Lathe Cross-Section Outside: 36x23 mm

Lathe to Lock Distance: 225 mm

Tiller Length: 676 mm

Total Length: 790 mm

Weight: 2535 g

Date: c.1450-1500

Origin: Swiss(?)



Bern W1978, photo by author

Location: Historisches Museum, Bern

Source:

Wegeli, Rudolf, *Inventar der Waffensammlung des Bernischen Historischen Museums in Bern*, (Bern, 1948). p. 23.

Measurements collected by author.

Crossbow ID: Bern W1979 / 914

Lathe Type: Composite

Lathe Length: 661 mm

String Length: 655 mm

Lathe Cross-Section Middle: 45x34 mm

Lathe Cross-Section Outside: 35x26 mm

Lathe to Lock Distance: 215 mm

Tiller Length: 702 mm

Total Length: 720 mm



Bern W1979, photo by author

Weight: 2825 g
Date: c. 1450-1500
Origin: Swiss(?)

Location: Historisches Museum, Bern

Source:

Wegeli, Rudolf, *Inventar der Waffensammlung des Bernischen Historischen Museums in Bern*, (Bern, 1948). pp. 23-4.

Measurements collected by author.

Crossbow ID: Luzern HMLU 00281

Lathe Type: Composite

Lathe Length: 694 mm

String Length: 665 mm

Lathe Cross-Section Middle: 55x43 mm

Lathe Cross-Section Outside: 40x35 mm

Lathe to Lock Distance: 235 mm

Tiller Length: 682 mm

Total Length: 831 mm



Luzern HMLU 00281, photo by author

Weight: n/a

Date: c.1450-1500

Origin: Swiss(?)

Location: Historisches Museum, Luzern

Source:

Measurements collected by author.

Crossbow ID: Luzern HMLU 00282

Lathe Type: Composite

Lathe Length: 715 mm

String Length: 715 mm

Lathe Cross-Section Middle: 51x38 mm

Lathe Cross-Section Outside: 39x25 mm

Lathe to Lock Distance: 221 mm

Tiller Length: 656 mm

Total Length: 700 mm



Luzern HMLU 00282, photo by author

Weight: n/a

Date: c.1450-1500

Origin: Swiss(?)

Location: Historisches Museum, Luzern

Source:

Measurements collected by author.

Crossbow ID: Luzern HMLU 00285.1

Lathe Type: Composite

Lathe Length: 700 mm

String Length: 696 mm

Lathe Cross-Section Middle: 59x40 mm

Lathe Cross-Section Outside: 45x29 mm

Lathe to Lock Distance: n/a



Luzern HMLU 00285.1, photo by author

Tiller Length: n/a

Total Length: n/a

Weight: n/a

Date: c.1450-1500

Origin: Swiss(?)

Location: Historisches Museum, Luzern

Source:

Measurements collected by author.

Crossbow ID: Schloss Grandson B132-a (bow)

Lathe Type: Composite

Lathe Length: n/a

String Length: 670 mm

Lathe Cross-Section Middle: 58x42 mm

Lathe Cross-Section Outside: 35x32 mm

Tiller Length: n/a

Total Length: n/a

Weight: 560 g

Date: c.1460-80

Origin: n/a

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Crossbow ID: Schloss Grandson B132-a (tiller)

Lathe Type: n/a

Lathe Length: n/a

String Length: n/a

Lathe to Lock Distance: c.210 mm

Tiller Length: 674 mm
Total Length: n/a

Weight: 880 g
Date: c.1460-80
Origin: n/a

Location: Grandson Castle, Switzerland
Source:
Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Crossbow ID: Worcester Art Museum 2014.57
Lathe Type: Composite
Lathe Length: 720 mm
String Length: 720 mm

Tiller Length: n/a
Total Length: 910 mm

Weight: 3572 g
Date: c.1475
Origin: German

Location: Worcester Art Museum, Massachusetts
Source:
Worcester Art Museum Digital Catalog:
<http://vqs61.v3.pair.com:8080/emuseum/view/objects/asitem/items@:47881> [Accessed 20/7/15].

Crossbow ID: Cleveland Museum of Art 1725
Lathe Type: Composite
Lathe Length: n/a
String Length: 745 mm

Tiller Length: n/a
Total Length: 870 mm

Weight: 3740 g
Date: c.1460-70
Origin: German

Location: Cleveland Museum of Art
Source:
Communication with museum.



Cleveland Museum of Art 1725, photo by collection

Crossbow ID: Schloss Grandson B2
Lathe Type: Composite
Lathe Length: 695 mm
String Length: 695 mm

Lathe Cross-Section Middle: 50x40 mm
Lathe Cross-Section Outside: 36x32 mm
Lathe to Lock Distance: 235 mm

Tiller Length: 766 mm
Total Length: 795 mm

Weight: 2660 g
Date: c.1460-80
Origin: German

Location: Grandson Castle,
Switzerland
Source:
Sensfelder, Jens,
“Dokumentation Schloß
Grandson”, (Unpublished
Catalog, 2007/08).



Schloss Grandson B2, photo by author

Crossbow ID: Luzern HMLU 00283

Lathe Type: Composite
Lathe Length: 698 mm
String Length: 698 mm

Lathe Cross-Section Middle: 55x40 mm
Lathe Cross-Section Outside: 42x30 mm
Lathe to Lock Distance:
223 mm

Tiller Length: 675 mm
Total Length: n/a

Weight: n/a
Date: 15th century
Origin: Swiss(?)

Location: Historisches
Museum, Luzern
Source:
Measurements collected
by author.



Luzern HMLU 0028, photo by author

Crossbow ID: Luzern HMLU 00284

Lathe Type: Composite
Lathe Length: 700 mm
String Length: 685 mm

Lathe Cross-Section Middle: 54x37 mm
Lathe Cross-Section Outside: 37x33 mm
Lathe to Lock Distance: n/a



Luzern HMLU 00284, photo by author

Tiller Length: n/a

Total Length: n/a

Weight: n/a

Date: 15th century

Origin: Swiss(?)

Location: Historisches Museum, Luzern

Source:

Measurements collected by author.

Crossbow ID: Glasgow E.1939.65.tc

Lathe Type: Composite

Lathe Length: 737 mm

String Length: n/a

Tiller Length: 866 mm

Total Length: n/a

Weight: n/a

Date: 15th century

Origin: German

Location: Kelvingrove Art Gallery, Glasgow

Source:

Wilson, G.M., "Notes on Some Crossbows in the Collection of Glasgow Museum and Art Gallery", (Unpublished Notes, 2006).

Crossbow ID: Glasgow E.1939.65.sz

Lathe Type: Composite

Lathe Length: 692 mm

String Length: n/a

Tiller Length: 826 mm

Total Length: n/a

Weight: n/a

Date: 15th century

Origin: German

Location: Kelvingrove Art Gallery, Glasgow

Source:

Wilson, G.M., "Notes on Some Crossbows in the Collection of Glasgow Museum and Art Gallery", (Unpublished Notes, 2006).

Crossbow ID: Glasgow E.1939.65.sf.[1]

Lathe Type: Composite

Lathe Length: 743 mm

String Length: n/a

Tiller Length: 826 mm

Total Length: n/a

Weight: n/a

Date: 15th century

Origin: German

Location: Kelvingrove Art Gallery, Glasgow

Source:

Wilson, G.M., "Notes on Some Crossbows in the Collection of Glasgow Museum and Art Gallery", (Unpublished Notes, 2006).

Crossbow ID: Glasgow E.1939.65.sr

Lathe Type: Composite

Lathe Length: 686 mm

String Length: n/a

Tiller Length: 848 mm

Total Length: n/a

Weight: n/a

Date: 15th century

Origin: German

Location: Kelvingrove Art Gallery, Glasgow

Source:

Wilson, G.M., "Notes on Some Crossbows in the Collection of Glasgow Museum and Art Gallery", (Unpublished Notes, 2006).

Crossbow ID: Glasgow (no ID)

Lathe Type: Composite

Lathe Length: 813 mm

String Length: n/a

Tiller Length: 902 mm

Total Length: n/a

Weight: n/a

Date: 15th century

Origin: n/a

Location: Kelvingrove Art Gallery, Glasgow

Source:

Wilson, G.M., "Notes on Some Crossbows in the Collection of Glasgow Museum and Art Gallery", (Unpublished Notes, 2006).

Crossbow ID: Bern W1980 / Bern 4085

Lathe Type: Composite

Lathe Length: 698 mm

String Length: 685 mm

Lathe Cross-Section Middle: 55x38 mm

Lathe Cross-Section Outside: 38x26 mm

Illustration 11: Bern W1980, photo by author

Lathe to Lock Distance: n/a



Bern W1980, photo by author

Tiller Length: n/a

Total Length: n/a

Weight: 1335 g

Date: 15th century

Origin: Swiss(?)

Location: Historisches Museum, Bern

Source:

Wegeli, Rudolf, *Inventar der Waffensammlung des Bernischen Historischen Museums in Bern*, (Bern, 1948). p. 24.

Measurements collected by author.

Crossbow ID: Zamkowe Pszczynie MP/S/3168

Lathe Type: Composite

Lathe Length: 825 mm

String Length: 825 mm

Tiller Length: n/a

Total Length: 995 mm

Weight: n/a

Date: 15th century

Origin: Polish(?)

Location: Pszczyna Castle Museum

Source:

Kruczek, Jan, *Kusze Katalog Zbiorów*, (Pszczyna, 2002). pp.13-15

Crossbow ID: Schloss Grandson 60 C

Lathe Type: Composite

Lathe Length: 740 mm

String Length: 674 mm

Lathe Cross-Section Middle: 55x38 mm

Lathe Cross-Section Outside: 45x30 mm

Lathe to Lock Distance: 253 mm

Tiller Length: 750 mm

Total Length: 875 mm

Weight: 2400 g

Date: 15th century

Origin: Central Europe (?)

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Crossbow ID: Jagd und Fischereimuseum 2250

Lathe Type: Composite

Lathe Length: 740 mm

String Length: 672 mm

Tiller Length: 897 mm

Total Length: n/a

Weight: n/a

Date: 15th century

Origin: n/a

Location: German Hunting and Fishing Museum, Munich

Source:

Sensfelder, Jens, "Crossbows in the Hunting & Fishing Museum in Munich", *Journal of the Society of Archer-Antiquaries* 43 (2000). 6-11.

Richter, Holger, *Die Horgenarmbrust*, (Ludwigshafen, 2006). pp. 38-41.

Crossbow ID: Schweizerisches Landesmuseum LM 6010

Lathe Type: Composite

Lathe Length: 655 mm

String Length: 595 mm

Tiller Length: 820 mm

Total Length: 970 mm

Weight: n/a

Date: 15th century

Origin: Central Europe

Location: Landesmuseum, Zurich
Source:
Communication with museum.

Crossbow ID: Schweizerisches Landesmuseum 5748

Lathe Type: Composite
Lathe Length: 650 mm
String Length: n/a

Tiller Length: 815 mm
Total Length: 965 mm

Weight: n/a
Date: 15th century
Origin: n/a

Location: Landesmuseum, Zurich
Source:
Communication with museum.

Crossbow ID: Ratisches H 1970.978

Lathe Type: Composite
Lathe Length: 701 mm
String Length: n/a

Tiller Length: 812 mm
Total Length: n/a

Weight: n/a
Date: 15th century
Origin: Central Europe

Location: Ratisches Museum,
Chur
Source:
Communication with museum.

Crossbow ID: MET 29.16.14

Lathe Type: Composite
Lathe Length: 754 mm
String Length: 570 mm

Lathe Cross-Section Middle: 57x48 mm
Lathe Cross-Section Outside: ?x33 mm



Ratisches H 1970.978, photo from collection

Lathe to Lock Distance: 251 mm

Tiller Length: 833 mm

Total Length: 950 mm

Weight: 2380 g

Date: 15th century

Origin: German

Location: Metropolitan Museum of Art, New York City

Source:

Measurements taken by author.



MET 29.16.14, photo by author

Crossbow ID: MET 14.25.1575a

Lathe Type: Composite

Lathe Length: 722 mm

String Length: 692 mm

Lathe Cross-Section Middle: 63x47 mm

Lathe Cross-Section Outside: ?x37 mm

Lathe to Lock Distance: 180 mm

Tiller Length: 756 mm

Total Length: 823 mm

Weight: 3457 g

Date: late 15th century

Origin: German(?)

Location: Metropolitan Museum of Art, New York City

Source:

Measurements taken by author.



MET 14.25.1575a, photo by author

Crossbow ID: Schloss Grandson F1

Lathe Type: Composite

Lathe Length: 725 mm

String Length: 725 mm

Lathe Cross-Section Middle: 58x45 mm

Lathe Cross-Section Outside: 43x35 mm

Lathe to Lock Distance: 220 mm

Tiller Length: 790 mm

Total Length: 895 mm

Weight: 3360 g

Date: late 15th century

Origin: German(?)

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Crossbow ID: Schloss Grandson B244

Lathe Type: Composite

Lathe Length: 715 mm

String Length: 715 mm

Lathe Cross-Section Middle: 51x41 mm

Lathe Cross-Section Outside: 37x30 mm

Lathe to Lock Distance: 230 mm

Tiller Length: 720 mm

Total Length: 835 mm

Weight: 2600 g

Date: late 15th century

Origin: German(?)

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Crossbow ID: CH 293

Lathe Type: Composite

Lathe Length: 600 mm

String Length: n/a

Tiller Length: 670 mm

Total Length: n/a

Weight: 1785 g

Date: c.1450-1500

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996).

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: MWP 56

Lathe Type: Composite

Lathe Length: 785 mm
String Length: 785 mm

Tiller Length: n/a
Total Length: 910 mm

Weight: 3250 g
Date: 15th century
Origin: Polish(?)

Location: Polish Military Museum,
Warsaw

Source:
Communication with museum.



MWP 56, photo from collection

Crossbow ID: Schloss Grandson B111
Lathe Type: Steel (probably a later addition)
Lathe Length: n/a
String Length: 596 mm

Lathe Cross-Section Middle: 42.5x12.5 mm
Lathe Cross-Section Outside: 30x6 mm
Lathe to Lock Distance: 223 mm

Tiller Length: 668 mm
Total Length: 715 mm

Weight: 3140 g
Date: Late 15th century
Origin: German(?)

Location: Grandson Castle,
Switzerland

Source:
Sensfelder, Jens, "Dokumentation
Schloß Grandson", (Unpublished
Catalog, 2007/08).



Schloss Grandson B111, photo by author

Crossbow ID: Wallace Collection A1032

Lathe Type: Steel
Lathe Length: n/a
String Length: 596 mm

Tiller Length: n/a
Total Length: 720 mm

Weight: 4400 g
Date: c.1450-70
Origin: Central Europe



Wallace Collection A1032, photo from collection

Location: Wallace Collection, London

Source:

Wallace Collection Digital Catalog:

<http://wallacelive.wallacecollection.org/eMuseumPlus> [Accessed 23/7/15]

Crossbow ID: Armeria de Alava 0478

Lathe Type: Steel

Lathe Length: n/a

String Length: 600 mm

Tiller Length: n/a

Total Length: 870 mm

Weight: n/a

Date: 15th century

Origin: Spanish

Location: Armoury Museum of Alava, Spain

Source:

Communication with museum.

Crossbow ID: Armeria de Alava 0479

Lathe Type: Steel

Lathe Length: n/a

String Length: 710 mm

Tiller Length: 830 mm

Total Length: n/a

Weight: n/a

Date: 15th century

Origin: Spanish

Location: Armoury Museum of Alava, Spain

Source:

Communication with museum.

Crossbow ID: MWP 57

Lathe Type: Steel

Lathe Length: n/a

String Length: 800 mm

Tiller Length: 1320 mm

Total Length: 1340 mm

Weight: 6110 g

Date: 15th century

Origin: Italian

Location: Polish Military Musuem, Warsaw

Source:

Communication with museum.

Crossbow ID: MWP 58/1

Lathe Type: Steel

Lathe Length: n/a

String Length: 780 mm

Tiller Length: 910 mm

Total Length: 1350 mm (includes windlass)

Weight: n/a

Date: 15th century(?)

Origin: n/a

Location: Polish Military Museum, Warsaw

Source:

Communication with museum.



MWP 58/1, photo from collection

Crossbow ID: Philadelphia Museum of Art 1977-167-1001

Lathe Type: Composite

Lathe Length: 715 mm

String Length: n/a

Tiller Length: 799 mm

Total Length: n/a

Weight: n/a

Date: c.1470-1500

Origin: Central Europe

Location: Philadelphia Museum of Art, Philadelphia

Source:

<http://www.philamuseum.org/collections/browse.html?sort=Artist&packID=2085>

Crossbow ID: Schlossmuseum Wernigerode K XII Bla 3

Lathe Type: Composite

Lathe Length: 690 mm

String Length: 600 mm

Tiller Length: 695 mm

Total Length: n/a

Weight: n/a

Date: 15th - 16th centuries

Origin: n/a

Location: Schlossmuseum Wernigerode

Source:

Richter, Holger, *Die Horgenarmbrust*, (Ludwigshafen, 2006). pp. 67-9.

Crossbow ID: Armeria de Alava 0471

Lathe Type: Steel
Lathe Length: n/a
String Length: 820 mm

Tiller Length: 990 mm
Total Length: n/a

Weight: n/a
Date: 15th - 16th centuries
Origin: Spanish

Location: Armoury Museum of Alava, Spain
Source:
Communication with museum.

Crossbow ID: MET 14.25.1572a

Lathe Type: Steel
Lathe Length: n/a
String Length: 624 mm

Tiller Length: n/a
Total Length: 737 mm

Weight: 3000 g
Date: 15th - 16th centuries
Origin: Central Europe (German?)

Location: Metropolitan Museum of Art, New York City
Source:
Breiding, Dirk, *A Deadly Art: European Crossbows, 1250-1850* (New York, 2014). pp. 35-6.

Crossbow ID: MWP 59/1-2

Lathe Type: Steel
Lathe Length: n/a
String Length: 830 mm

Tiller Length: n/a
Total Length: 830 mm

Weight: n/a
Date: 15th - 16th centuries(?)
Origin: n/a

Location: Polish Military Museum, Warsaw
Source:
Communication with museum.

Crossbow ID: MWP 59/1

Lathe Type: Steel
Lathe Length: n/a



MWP 59/1-2, photo from collection

String Length: 830 mm

Tiller Length: n/a

Total Length: 830 mm (excl. Windlass)

Weight: n/a

Date: 15th - 16th centuries (?)

Origin: n/a

Location: Polish Military Museum, Warsaw

Source:

Communication with museum.



MWP 59/1, photo from collection

Crossbow ID: MWP 60

Lathe Type: Steel

Lathe Length: n/a

String Length: 530 mm

Tiller Length: n/a

Total Length: 920 mm

Weight: 10150 g

Date: 15th - 16th centuries(?)

Origin: n/a

Location: Polish Military Museum, Warsaw

Source:

Communication with museum.



MWP 60, photo from collection

Crossbow ID: MWP 52641

Lathe Type: Steel

Lathe Length: n/a

String Length: 725 mm

Tiller Length: n/a

Total Length: 1165 mm

Weight: n/a

Date: 15th - 16th centuries(?)

Origin: n/a

Location: Polish Military Museum, Warsaw

Source:

Communication with museum.

Crossbow ID: Bern W1982 / 3875

Lathe Type: Steel

Lathe Length: 890 mm

String Length: 711 mm

Lathe Cross-Section Middle: 48x11 mm

Lathe Cross-Section Outside:
32x5 mm
Lathe to Lock Distance: n/a

Tiller Length: 938 mm
Total Length: 990 mm

Weight: 9165 g
Date: 15th - 16th centuries(?)
Origin: Central Europe

Location: Historisches Museum,
Bern
Source:
Wegeli, Rudolf, *Inventar der
Waffensammlung des Bernischen
Historischen Museums in Bern*,
(Bern, 1948). p. 25.
Measurements by author



Crossbow ID: Schloss Grandson B132-b
(lathe)

Bern W1982, photo by author

Lathe Type: Composite
Lathe Length: n/a
String Length: 712 mm

Lathe Cross-Section Middle: 65x51 mm
Lathe Cross-Section Outside: 49x37 mm

Tiller Length: n/a
Total Length: n/a

Weight: 1380 g
Date: c. 1500
Origin: n/a

Location: Grandson Castle, Switzerland
Source:
Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Crossbow ID: Schloss Grandson B132-b (Tiller)

Lathe Type: n/a
Lathe Length: n/a
String Length: n/a

Lathe to Lock Distance: c.240 mm

Tiller Length: 672 mm
Total Length: n/a

Weight: 860 g

Date: c. 1500

Origin: n/a

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Crossbow ID: MWP 58/1-2

Lathe Type: Steel

Lathe Length: n/a

String Length: n/a

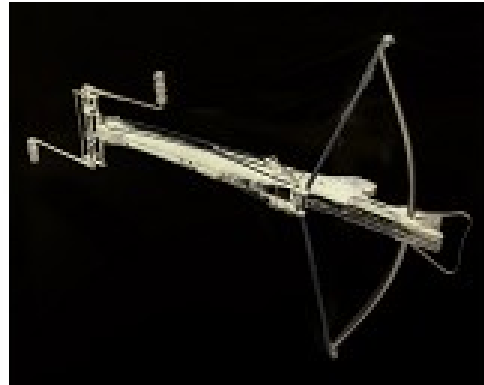
Tiller Length: n/a

Total Length: 910 mm(?)

Weight: n/a

Date: 15th century

Origin: n/a



MWP 58/1-2, photo from collection

Location: Polish Military Museum

Source:

Communication with museum.

Crossbow ID: RA XI.104

Lathe Type: Composite

Lathe Length: n/a

String Length: 660 mm

Tiller Length: n/a

Total Length: 710 mm

Weight: n/a

Date: c.1500

Origin: Central Europe

Location: Royal Armouries, Leeds

Source:

Communication with Museum.

Crossbow ID: Wallace Collection A1034

Lathe Type: Composite

Lathe Length: n/a

String Length: 637 mm

Tiller Length: n/a

Total Length: 725 mm

Weight: 2170 g

Date: c. 1520

Origin: Central Europe



Wallace Collection A1034, photo from collection

Location: Wallace Collection, London

Source:

Wallace Collection Digital Catalog:

<http://wallacelive.wallacecollection.org/eMuseumPlus> [Accessed 23/7/15]

Crossbow ID: Swedish Royal Armoury 26690

Lathe Type: Composite

Lathe Length: 790 mm

String Length: 790 mm

Tiller Length: 930 mm

Total Length: 930 mm

Weight: n/a

Date: c. 1500

Origin: n/a

Location: Swedish Royal Armoury, Stockholm

Source:

Royal Armoury Digital Catalog:

<http://emuseumplus.lsh.se/eMuseumPlus> [Accessed 22/7/15]

Crossbow ID: Swedish Royal Armoury 17136 (2406)

Lathe Type: Composite

Lathe Length: 700 mm

String Length: n/a

Tiller Length: 665 mm

Total Length: n/a

Weight: n/a

Date: Early 16th century

Origin: Central Europe

Location: Swedish Royal Armoury,

Stockholm

Source:

Royal Armoury Digital Catalog:

<http://emuseumplus.lsh.se/eMuseumPlus> [Accessed 22/7/15]

Crossbow ID: CH 294

Lathe Type: Steel

Lathe Length: n/a

String Length: n/a

Tiller Length: 665 mm

Total Length: n/a

Weight: 1125 g

Date: c. 1500



Swedish Royal Armoury 26690, photo from collection



Swedish Royal Armoury 17136 (2406), photo from collection

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 264-5.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 295

Lathe Type: Steel

Lathe Length: n/a

String Length: 560 mm

Tiller Length: 710 mm

Total Length:n/a

Weight: 2250 g

Date: c. 1500

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 264-5.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 296

Lathe Type: n/a

Lathe Length: n/a

String Length: n/a

Tiller Length: 650 mm

Total Length: n/a

Weight: 1140 g

Date: c. 1500

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 264-5.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 297

Lathe Type: Steel

Lathe Length: n/a

String Length: 580 mm

Tiller Length: 650 mm

Total Length: n/a

Weight: 2890 g
Date: c. 1500
Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 264-5.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 298

Lathe Type: Steel

Lathe Length: n/a

String Length: 500 mm

Tiller Length: 640 mm

Total Length: n/a

Weight: 1785 g

Date: c. 1500

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 264-5.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 299

Lathe Type: Steel

Lathe Length: n/a

String Length: 490 mm

Tiller Length: 630 mm

Total Length: n/a

Weight: 1800 g

Date: c. 1500

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 264-5.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: Wallace Collection A1033

Lathe Type: Steel

Lathe Length: n/a

String Length: 458 mm

Tiller Length: n/a
Total Length: 1000 mm

Weight: 2640 g
Date: c. 1500
Origin: Central Europe

Location: Wallace Collection, London

Source:

Wallace Collection Digital Catalog:

<http://wallacelive.wallacecollection.org/eMuseumPlus> [Accessed 23/7/15]

Crossbow ID: CH 301

Lathe Type: Steel
Lathe Length: n/a
String Length: 590 mm

Tiller Length: 670 mm
Total Length: n/a

Weight: 3077 g
Date: c. 1510-5
Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 266-7.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: Netherlands Cat. No. 20

Lathe Type: Steel
Lathe Length: 555 mm
String Length: 510 mm

Lathe Cross-Section Middle: 28.5x9 mm
Lathe Cross-Section Outside: 23x3.2 mm
Lathe to Lock Distance: 160 mm

Tiller Length: 525 mm
Total Length: 560 mm

Weight: 1610 g
Date: 1528
Origin: Central Europe

Location: Royal Netherlands Army Museum, Delft

Source:

Sensfelder, Jens, *Crossbows in the Royal Netherlands Army Museum*, (Delft, 2007). pp.160-2.

Crossbow ID: Schloss Grandson F2

Lathe Type: Steel

Lathe Length: 634 mm

String Length: 585 mm

Lathe Cross-Section Middle: 39x13 mm

Lathe Cross-Section Outside: 30x7 mm

Lathe to Lock Distance: 223 mm

Tiller Length: 638 mm

Total Length: 715 mm

Weight: 3580 g

Date: Early 16th century

Origin: German

Location: Grandson Castle,
Switzerland

Source:

Sensfelder, Jens,

“Dokumentation Schloß
Grandson”, (Unpublished
Catalog, 2007/08).

Measurements by author.



Schloss Grandson F2, photo by author

Crossbow ID: Zamkowe Pszczynie MP/S/1143

Lathe Type: Steel

Lathe Length: n/a

String Length: 620 mm

Tiller Length: n/a

Total Length: 635 mm

Weight: 3380 g

Date: 1542

Origin: Central Europe

Location: Pszczyna Castle Museum

Source:

Kruczek, Jan, *Kusze Katalog Zbiorów*, (Pszczyna, 2002). pp. 17-9.

Crossbow ID: CH 300

Lathe Type: Steel

Lathe Length: n/a

String Length: 570 mm

Tiller Length: 640 mm

Total Length: n/a

Weight: 2085 g

Date: c. 1500-1550

Origin: n/a

Location: Churburg Caslte, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 264-5.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 302

Lathe Type: Steel

Lathe Length: n/a

String Length: 560 mm

Tiller Length: 680 mm

Total Length: n/a

Weight: 2780 g

Date: c.1500-1550

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 266-7.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 303

Lathe Type: Steel

Lathe Length: n/a

String Length: 500 mm

Tiller Length: 640 mm

Total Length: n/a

Weight: 3180 g

Date: c.1500-1550

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 266-7.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 304

Lathe Type: Steel

Lathe Length: n/a

String Length: 540 mm

Tiller Length: 640 mm

Total Length: n/a

Weight: 2537 g

Date: c.1500-1550

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 268-9.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 305

Lathe Type: Steel

Lathe Length: n/a

String Length: 540 mm

Tiller Length: 640 mm

Total Length: n/a

Weight: 2500 g

Date: c.1500-1550

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 268-9.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 306

Lathe Type: Steel

Lathe Length: n/a

String Length: 560 mm

Tiller Length: 640 mm

Total Length: n/a

Weight: 2585 g

Date: c.1500-1550

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 268-9.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 307

Lathe Type: Steel
Lathe Length: n/a
String Length: 530 mm

Tiller Length: 640 mm
Total Length: n/a

Weight: 2400 g
Date: c.1500-1550
Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 268-9.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 308

Lathe Type: Steel
Lathe Length: n/a
String Length: 570 mm

Tiller Length: 650 mm
Total Length: n/a

Weight: 3135 g
Date: c.1500-1550
Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 268-9.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 309

Lathe Type: Steel
Lathe Length: n/a
String Length: 560 mm

Tiller Length: 650 mm
Total Length: n/a

Weight: 3000 g
Date: c.1500-1550
Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 268-9.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 310

Lathe Type: Steel

Lathe Length: n/a

String Length: 580 mm

Tiller Length: 630 mm

Total Length: n/a

Weight: 3000 g

Date: c.1500-1550

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 268-9.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 323

Lathe Type: Steel

Lathe Length: n/a

String Length: 430 mm

Tiller Length: 580 mm

Total Length: n/a

Weight: 515 g

Date: c.1500-1550

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 272-3.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 324

Lathe Type: Steel

Lathe Length: n/a

String Length: 280 mm

Tiller Length: 500 mm

Total Length: n/a

Weight: 260 g

Date: c.1500-1550

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 272-3.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 325

Lathe Type: Steel

Lathe Length: n/a

String Length: 395 mm

Tiller Length: 465 mm

Total Length: n/a

Weight: 367 g

Date: c.1500-1550

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 274-5.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 327

Lathe Type: Steel

Lathe Length: n/a

String Length: 380 mm

Tiller Length: 495 mm

Total Length: n/a

Weight: 382 g

Date: c.1500-1550

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 274-5.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 328

Lathe Type: Steel

Lathe Length: n/a

String Length: 390 mm

Tiller Length: 565 mm

Total Length: n/a

Weight: 449 g

Date: c.1500-1550

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 274-5.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 329

Lathe Type: Steel

Lathe Length: n/a

String Length: 350 mm

Tiller Length: 510 mm

Total Length: n/a

Weight: 487 g

Date: c.1500-1550

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 274-5.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: Met 27.160.19a

Lathe Type: Steel

Lathe Length: n/a

String Length: 546 mm

Tiller Length: n/a

Total Length: 829 mm

Weight: 2726 g

Date: c.1540

Origin: Spanish

Location: Metropolitan Museum of Art, New York City

Source:

Breiding, Dirk, *A Deadly Art: European Crossbows, 1250-1850* (New York, 2014). pp. 37-8.

Crossbow ID: CH 326

Lathe Type: Steel

Lathe Length: n/a

String Length: 365 mm

Tiller Length: 490 mm

Total Length: n/a

Weight: 354 g
Date: 1540
Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 274-5.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: RA XI.10

Lathe Type: Steel

Lathe Length: n/a

String Length: 587 mm

Tiller Length: n/a

Total Length: 663 mm

Weight: 3430 g

Date: c. 1550

Origin: Central Europe

Location: Royal Armouries, Leeds

Source:

Communication with Museum.

Crossbow ID: RA XI.31

Lathe Type: Steel

Lathe Length: n/a

String Length: 559 mm

Tiller Length: n/a

Total Length: 921 mm

Weight: 2380 g

Date: c.1550

Origin: Spanish

Location: Royal Armouries, Leeds

Source:

Communication with Museum.

Crossbow ID: Wallace Collection A1035

Lathe Type: Steel

Lathe Length: n/a

String Length: 501 mm

Tiller Length: n/a

Total Length: 870 mm

Weight: 2730 g

Date: c.1550
Origin: Spanish

Location: Wallace Collection, London

Source:

Wallace Collection Digital Catalog:

<http://wallacelive.wallacecollection.org/eMuseumPlus> [Accessed 23/7/15]

Crossbow ID: Glasgow (no ID)

Lathe Type: Steel

Lathe Length: 578 mm

String Length: n/a

Tiller Length: 578 mm

Total Length: n/a

Weight: n/a

Date: mid 16th century

Origin: German

Location: Kelvingrove Art Gallery, Glasgow

Source:

Wilson, G.M., "Notes on Some Crossbows in the Collection of Glasgow Museum and Art Gallery", (Unpublished Notes, 2006).

Crossbow ID: Glasgow E.1939.65.tz

Lathe Type: Steel

Lathe Length: 457 mm

String Length: n/a

Tiller Length: 686 mm

Total Length: n/a

Note: Tiller is a later restoration, likely c. 1600

Weight: n/a

Date: mid-16th century

Origin: English

Location: Kelvingrove Art Gallery, Glasgow

Source:

Wilson, G.M., "Notes on Some Crossbows in the Collection of Glasgow Museum and Art Gallery", (Unpublished Notes, 2006).

Crossbow ID: Glasgow E.1939.65.uc[1]

Lathe Type: Steel

Lathe Length: 762 mm

String Length: n/a

Tiller Length: 737 mm

Total Length: n/a

Weight: n/a
Date: mid-16th century
Origin: German

Location: Kelvingrove Art Gallery, Glasgow

Source:

Wilson, G.M., "Notes on Some Crossbows in the Collection of Glasgow Museum and Art Gallery", (Unpublished Notes, 2006).

Crossbow ID: Schloss Grandson F14

Lathe Type: Steel

Lathe Length: n/a

String Length: 525 mm

Lathe Cross-Section Middle: 32x11.3 mm

Lathe Cross-Section Outside: 29x7.5 mm

Lathe to Lock Distance: 176 mm

Tiller Length: 583 mm

Total Length: 605 mm

Weight: 2300 g

Date: mid-16th century

Origin: German

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Crossbow ID: Schloss Grandson B284-a

Lathe Type: Steel

Lathe Length: 900 mm

String Length: 723 mm

Lathe Cross-Section Middle:

34x14.5 mm

Lathe Cross-Section Outside:

21x6 mm

Lathe to Lock Distance: 275

mm

Tiller Length: 985 mm

Total Length: 1010 mm

Weight: 3600 g

Date: mid-16th century

Origin: Spanish



Schloss Grandson B284-a, photo by author

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Measurements by author.

Crossbow ID: Schloss Grandson B199

Lathe Type: Steel

Lathe Length: 460 mm

String Length: 390 mm

Lathe Cross-Section Middle: 30x11 mm

Lathe Cross-Section Outside: 16x5 mm

Lathe to Lock Distance: 175 mm

Tiller Length: 724 mm

Total Length: 724 mm

Weight: 1630 g

Date: mid-16th century

Origin: Spanish

Location: Grandson

Castle, Switzerland

Source:

Sensfelder, Jens,

“Dokumentation Schloß

Grandson”, (Unpublished Catalog, 2007/08).

Measurements by author.



Schloss Grandson B199, photo by author

Crossbow ID: CH 311

Lathe Type: Steel

Lathe Length: n/a

String Length: 490 mm

Tiller Length: 620 mm

Total Length: n/a

Weight: 2585 g

Date: c.1525-1575

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 270-1.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 312

Lathe Type: Steel

Lathe Length: n/a

String Length: 610 mm

Tiller Length: 660 mm

Total Length: n/a

Weight: 3690 g
Date: c.1525-1575
Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 270-1.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 313

Lathe Type: Steel

Lathe Length: n/a

String Length: 590 mm

Tiller Length: n/a

Total Length: 670 mm

Weight: 3430 g

Date: c.1525-1575

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 270-1.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 314

Lathe Type: Steel

Lathe Length: n/a

String Length: 610 mm

Tiller Length: 670 mm

Total Length: n/a

Weight: 3125 g

Date: c.1525-75

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 270-1.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 315

Lathe Type: Steel

Lathe Length: n/a

String Length: 580 mm

Tiller Length: 640 mm
Total Length: n/a

Weight: 3440 g
Date: c.1525-1575
Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 270-1.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 316

Lathe Type: Steel
Lathe Length: n/a
String Length: 580 mm

Tiller Length: 700 mm
Total Length: n/a

Weight: 3580 g
Date: c.1525-1575
Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 270-1.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 317

Lathe Type: Steel
Lathe Length: n/a
String Length: 495 mm

Tiller Length: 615 mm
Total Length: n/a

Weight: 2520 g
Date: c.1525-1575
Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 270-1.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 318

Lathe Type: Steel
Lathe Length: n/a
String Length: 505 mm

Tiller Length: 660 mm
Total Length: n/a

Weight: 1855 g
Date: c.1525-1575
Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 272-3.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 319

Lathe Type: Steel
Lathe Length: n/a
String Length: 505 mm

Tiller Length: 640 mm
Total Length: n/a

Weight: 1780 g
Date: c.1525-75
Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 272-3.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 320

Lathe Type: Steel
Lathe Length: n/a
String Length: 505 mm

Tiller Length: 640 mm
Total Length: n/a

Weight: 1835 g
Date: c.1525-75
Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 272-3.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 321

Lathe Type: Steel

Lathe Length: n/a

String Length: 520 mm

Tiller Length: 620 mm

Total Length: n/a

Weight: 1905 g

Date: c.1525-75

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 272-3.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: CH 322

Lathe Type: Steel

Lathe Length: n/a

String Length: 440 mm

Tiller Length: 850 mm

Total Length: n/a

Weight: 1755

Date: 16th century

Origin: n/a

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 272-3.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 211-2.

Crossbow ID: Bern W1986 / 585

Lathe Type: Steel

Lathe Length: 840 mm

String Length: 795 mm

Lathe Cross-Section Middle: 50x16 mm

Lathe Cross-Section Outside: 33x8 mm

Lathe to Lock Distance: 241 mm

Tiller Length: 715 mm

Total Length: 740 mm

Weight: 7780 g

Date: 16th century

Origin: n/a

Location: Historische Museum,
Bern

Source:

Wegeli, Rudolf, *Inventar der
Waffensammlung des Bernischen
Historischen Museums in Bern*,
(Bern, 1948). pp. 27-9.

Measured by author.

Crossbow ID: Bern W 1987

Lathe Type: Steel

Lathe Length: n/a

String Length: 570 mm

Tiller Length: 600 mm

Total Length: 620 mm

Weight: 3620 g

Date: 16th century

Origin: n/a

Location: Historische Museum, Bern

Source:

Wegeli, Rudolf, *Inventar der Waffensammlung des Bernischen Historischen Museums in
Bern*, (Bern, 1948). pp. 27-9.

Crossbow ID: Bern W 1989

Lathe Type: Steel

Lathe Length: n/a

String Length: 585 mm

Tiller Length: 740 mm

Total Length: 785 mm

Weight: 4535 g

Date: 16th century

Origin: n/a

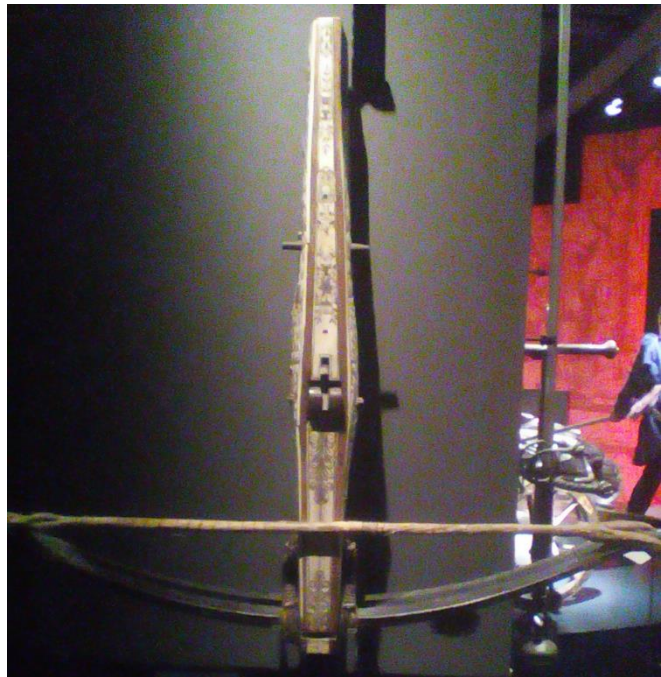
Location: Historische Museum, Bern

Source:

Wegeli, Rudolf, *Inventar der Waffensammlung des Bernischen Historischen Museums in
Bern*, (Bern, 1948). pp. 29-30.

Crossbow ID: Bern W 1988

Lathe Type: Steel



Bern W1986, photo by author

Lathe Length: n/a
String Length: 560 mm

Tiller Length: 630 mm
Total Length: 670 mm

Weight: 3910 g
Date: 16th century
Origin: n/a

Location: Historische Museum, Bern

Source:

Wegeli, Rudolf, *Inventar der Waffensammlung des Bernischen Historischen Museums in Bern*, (Bern, 1948). p.30

Crossbow ID: Armeria de Alava 0472

Lathe Type: Steel
Lathe Length: n/a
String Length: 520 mm

Tiller Length: n/a
Total Length: 800 mm

Weight: n/a
Date: 16th century
Origin: Spanish

Location: Armoury Museum of Alava, Spain

Source:

Communication with museum.

Crossbow ID: Armeria de Alava 0473

Lathe Type: Steel
Lathe Length: n/a
String Length: 500 mm

Tiller Length: n/a
Total Length: 830 mm

Weight: n/a
Date: 16th century
Origin: Spanish

Location: Armoury Museum of Alava, Spain

References:

Communication with museum.

Crossbow ID: Armeria de Alava 0474

Lathe Type: Steel
Lathe Length: n/a
String Length: 540 mm

Tiller Length: n/a
Total Length: 610 mm

Weight: n/a
Date: 16th century
Origin: Central Europe

Location: Armoury Museum of Alava, Spain
Source:
Communication with museum.

Crossbow ID: Armeria de Alava 0475
Lathe Type: Steel
Lathe Length: n/a
String Length: 610 mm

Tiller Length: n/a
Total Length: 580 mm

Weight: n/a
Date: 16th century
Origin: Central Europe

Location: Armoury Museum of Alava, Spain
Source:
Communication with museum.

Crossbow ID: Armeria de Alava 0476
Lathe Type: Steel
Lathe Length: n/a
String Length: 590 mm

Tiller Length: n/a
Total Length: 700 mm

Weight: n/a
Date: 16th century
Origin: Spanish

Location: Armoury Museum of Alava, Spain
Source:
Communication with museum.

Crossbow ID: Armeria de Alava 0480
Lathe Type: Steel
Lathe Length: n/a
String Length: 670 mm

Tiller Length: n/a
Total Length: 820 mm

Weight: n/a
Date: 16th century
Origin: Central Europe

Location: Armoury Museum of Alava, Spain
Source:
Communication with museum.

Crossbow ID: Armemuseum Stockholm Inv. No. 23418

Lathe Type: Steel
Lathe Length: 560 mm
String Length: n/a

Tiller Length: n/a
Total Length: 920 mm

Weight: 3740 g
Date: 16th century
Origin: Swedish(?)

Location: Swedish Army
Museum, Stockholm
Source:
Communication with
museum.



Armemuseum Stockholm Inv. No. 23418. photo from collection

Crossbow ID: Swedish Royal Armoury 6815 (4698)

Lathe Type: Steel
Lathe Length: 746 mm
String Length: n/a

Tiller Length: n/a
Total Length: 463 mm

Weight: 3150 g
Date: 16th century
Origin: n/a

Location: Swedish Royal
Armoury, Stockholm
Source:
Royal Armoury Digital Catalog:



Swedish Royal Armoury 6815 (4698), photo from collection

<http://emuseumplus.lsh.se/eMuseumPlus> [Accessed 22/7/15]

Crossbow ID: Swedish Royal Armoury 6817 (4699)

Lathe Type: Steel
Lathe Length: 563 mm
String Length: n/a

Tiller Length: n/a
Total Length: 463 mm

Weight: 3150 g
Date: 16th century
Origin: Central Europe(?)

Location: Swedish Royal Armoury,
Stockholm
Source:
Royal Armoury Digital Catalog:



Swedish Royal Armoury 6817 (4699), photo from collection

<http://emuseumplus.lsh.se/eMuseumPlus> [Accessed 22/7/15]

Crossbow ID: Swedish Royal Armoury 6818 (4696)

Lathe Type: Steel
Lathe Length: 740 mm
String Length: n/a

Tiller Length: n/a
Total Length: 680 mm

Weight: 5250 g
Date: 16th century
Origin: Central Europe(?)

Location: Swedish Royal Armoury,
Stockholm
Source:
Royal Armoury Digital Catalog:



Swedish Royal Armoury 6818 (4696), photo from collection

<http://emuseumplus.lsh.se/eMuseumPlus> [Accessed 22/7/15]

Crossbow ID: Swedish Royal Armoury 26597 (4698)

Lathe Type: Steel
Lathe Length: 745 mm
String Length: n/a

Tiller Length: n/a
Total Length: 600 mm

Weight: n/a
Date: 16th century
Origin: Sweden(?)

Location: Swedish Royal Armoury,
Stockholm
Source:



Swedish Royal Armoury 26597 (4698), photo from collection

Royal Armory Digital Catalog: <http://emuseumplus.lsh.se/eMuseumPlus> [Accessed 22/7/15]

Crossbow ID: Swedish Royal Armoury 6843 (5059)

Lathe Type: Steel
Lathe Length: 645 mm
String Length: n/a

Tiller Length: n/a
Total Length: 880 mm

Weight: 3400 g
Date: 16th century
Origin: n/a

Location: Swedish Royal Armoury, Stockholm

Source:

Royal Armory Digital Catalog: <http://emuseumplus.lsh.se/eMuseumPlus> [Accessed 22/7/15]



*Swedish Royal Armoury 6843 (5059),
photo from collection*

Crossbow ID: Swedish Royal Armoury 6789 (4697)

Lathe Type: Steel
Lathe Length: 600 mm
String Length: n/a

Tiller Length: n/a
Total Length: 612 mm

Weight: 3885 g
Date: 16th century
Origin: German(?)

Location: Swedish Royal Armoury, Stockholm

Source:

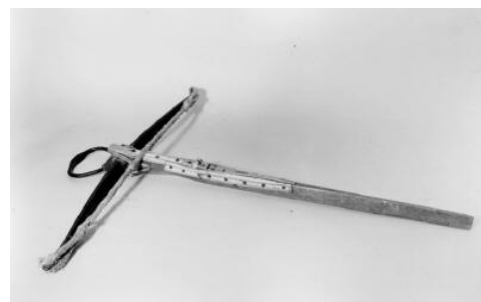
Royal Armory Digital Catalog: <http://emuseumplus.lsh.se/eMuseumPlus> [Accessed 22/7/15]

Crossbow ID: Swedish Royal Armoury 6846 (2431)

Lathe Type: Steel
Lathe Length: 815 mm
String Length: n/a

Tiller Length: n/a
Total Length: 1150 mm

Weight: 3650 g
Date: 16th century
Origin: Nordic(?)



*Swedish Royal Armoury 6846 (2431), photo
from collection*

Location: Swedish Royal Armoury, Stockholm

Source:

Royal Armory Digital Catalog: <http://emuseumplus.lsh.se/eMuseumPlus> [Accessed 22/7/15]

Crossbow ID: Swedish Royal Armoury 6816 (20:51)

Lathe Type: Steel

Lathe Length: 390 mm

String Length: n/a

Tiller Length: n/a

Total Length: 522 mm

Weight: 1460 g

Date: 16th century

Origin: n/a

Location: Swedish Royal Armoury, Stockholm

Source:

Royal Armory Digital Catalog: <http://emuseumplus.lsh.se/eMuseumPlus> [Accessed 22/7/15]

Crossbow ID: Swedish Royal Armoury 20507 (5787:3)

Lathe Type: Steel

Lathe Length: 870 mm

String Length: n/a

Tiller Length: n/a

Total Length: 1100 mm

Weight: n/a

Date: 16th century

Origin: Nordic(?)

Location: Swedish Royal Armoury, Stockholm

Source:

Royal Armory Digital Catalog:
<http://emuseumplus.lsh.se/eMuseumPlus> [Accessed 22/7/15]

Crossbow ID: Schloss Grandson F8

Lathe Type: Steel

Lathe Length: n/a

String Length: 620 mm

Lathe Cross-Section Middle: 32x13 mm

Lathe Cross-Section Outside: 29x9 mm

Lathe to Lock Distance: 235 mm

Tiller Length: 661 mm

Total Length: 700 mm



Swedish Royal Armoury 20507 (5787:3), photo from collection

Weight: 4520 g
Date: 16th century
Origin: German

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Crossbow ID: MWP 24639

Lathe Type: Steel

Lathe Length: n/a

String Length: 950 mm

Tiller Length: n/a

Total Length: 750 mm

Weight: n/a

Date: 16th century

Origin: n/a

Location: Polish Military Museum, Warsaw

Source:

Communication with museum.

Crossbow ID: MWP 24741

Lathe Type: Steel

Lathe Length: n/a

String Length: 500 mm

Tiller Length: 490 mm

Total Length: 517 mm

Weight: 1600 g

Date: 16th century

Origin: Spanish

Location: Polish Military Museum, Warsaw

Source:

Communication with museum.

Crossbow ID: MWP 50349

Lathe Type: Steel

Lathe Length: n/a

String Length: 580 mm

Tiller Length: n/a

Total Length: 600 mm

Weight: n/a

Date: 16th century

Origin: n/a

Location: Polish Military Museum, Warsaw

Source:

Communication to museum.

Crossbow ID: MWP 53022

Lathe Type: Steel

Lathe Length: n/a

String Length: 750 mm

Tiller Length: n/a

Total Length: 740 mm

Weight: n/a

Date: 16th century

Origin: German

Location: Polish Military Museum, Warsaw

Source:

Communication with museum.

Crossbow ID: MWP 59219

Lathe Type: Steel

Lathe Length: n/a

String Length: 590 mm

Tiller Length: n/a

Total Length: 620 mm

Weight: n/a

Date: 16th century

Origin: n/a

Location: Polish Military Museum, Warsaw

Source:

Communication with museum.

Crossbow ID: Schloss Grandson F31

Lathe Type: Steel

Lathe Length: n/a

String Length: 775 mm

Lathe Cross-Section Middle: 51x14 mm

Lathe Cross-Section Outside: 31x9 mm

Lathe to Lock Distance: 288 mm

Tiller Length: 850 mm

Total Length: 990 mm

Weight: 6120 g

Date: c.1550-1750
Origin: Flemish

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Crossbow ID: Schloss Grandson F10

Lathe Type: Steel

Lathe Length: n/a

String Length: 567 mm

Lathe Cross-Section Middle: 45x14 mm

Lathe Cross-Section Outside: 26.5x9 mm

Lathe to Lock Distance: 222 mm

Tiller Length: 582 mm

Total Length: 620 mm

Weight: 4080 g

Date: c.1568

Origin: German(?)

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Crossbow ID: Schloss Grandson F11

Lathe Type: Steel

Lathe Length: n/a

String Length: 565 mm

Lathe Cross-Section Middle: 40.5x13.5 mm

Lathe Cross-Section Outside: 23x7.5 mm

Lathe to Lock Distance: 204 mm

Tiller Length: 643 mm

Total Length: 663 mm

Weight: 3580 g

Date: 4567

Origin: German

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Crossbow ID: MWP 24775

Lathe Type: Steel

Lathe Length: n/a

String Length: 580 mm

Tiller Length: 590 mm
Total Length: 616 mm

Weight: 2000 g
Date: 16th - 17th centuries
Origin: Spanish

Location: Polish Military Museum, Warsaw
Source:
Communication with Museum.

Crossbow ID: Bern 1983
Lathe Type: Steel (later restoration to crossbow)
Lathe Length: n/a
String Length: n/a

Lathe to Lock Distance: 270 mm

Tiller Length: 760 mm
Total Length: 760 mm

Weight: 2955 g
Date: late 16th century
Origin: n/a



Location: Historische Museum,
Bern

Bern 1983, photo by author

Source:

Wegeli, Rudolf, *Inventar der Waffensammlung des Bernischen Historischen Museums in Bern*, (Bern, 1948). pp. 25-6.

Measurements by author.

Appendix II: Spanning Devices

Cranequins

Collection ID: CH 335

Bar Length: 396 mm

Section Thickness: n/a

Section Width: n/a

Case Length: n/a

Case Width: n/a

Crank Length: n/a

Weight: 2285 g

Advantage: n/a

Date: c.1450-1500

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 279.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 212.

Collection ID: CH 336

Bar Length: 384 mm

Section Thickness: n/a

Section Width: n/a

Case Length: n/a

Case Width: n/a

Crank Length: n/a

Weight: 1945 g

Advantage: n/a

Date: c.1450-1500

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 279.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 212.

Collection ID: Grandson C63

Bar Length: 335 mm

Section Thickness: 16 mm

Section Width: 21.5 mm

Case Length: 119 mm

Case Width: 73 mm
Crank Length: 194 mm

Weight: 2040 g
Advantage: 1 to 143
Date: c.1475-1500

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Collection ID: Grandson F76

Bar Length: 310 mm
Section Thickness: 15.5 mm
Section Width: 20 mm

Case Length: 93 mm
Case Width: 60 mm
Crank Length: 108 mm

Weight: 1620 g
Advantage: 1 to 57
Date: c.1475-1500

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson",
(Unpublished Catalog, 2007/08).

Collection ID: Grandson F75

Bar Length: 335 mm
Section Thickness: 18 mm
Section Width: 22.5 mm

Case Length: 104 mm
Case Width: 64 mm
Crank Length: 172 mm

Weight: 1720 g
Advantage: 1 to 138
Date: Late 15th century

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson",
(Unpublished Catalog, 2007/08).

Collection ID: CH 345

Bar Length: 390 mm
Section Thickness: n/a
Section Width: n/a



Grandson F76, photo by author



Grandson F75, photo by author

Case Length: n/a
Case Width: n/a
Crank Length: n/a

Weight: n/a
Advantage: n/a
Date: c.1450-1500

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 281.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 212.

Collection ID: Bern W2007 / 15820

Bar Length: 336 mm
Section Thickness: 14 mm
Section Width: 20 mm

Case Length: 103 mm
Case Width: 64 mm
Crank Length: 120 mm

Weight: 1630 g
Advantage: n/a
Date: 15th century

Location:
Historisches
Museum, Bern

Source:

Wegeli, Rudolf,
Inventar der

Waffensammlung des Bernischen Historischen Museums in Bern, (Bern, 1948). p. 35.



Bern W2007, photo by author

Collection ID: Bern W2008 / 15419

Bar Length: 270 mm
Section Thickness: 13 mm
Section Width: 20 mm

Case Length: 95 mm
Case Width: 63 mm
Crank Length: 160 mm

Weight: 2065 g
Advantage: n/a
Date: 15th century



Bern W2008, photo by author

Location: Historisches Museum, Bern

Source:

Wegeli, Rudolf, *Inventar der Waffensammlung des Bernischen Historischen Museums in Bern*, (Bern, 1948). p. 35.

Collection ID: Bern W2004 / 4927

Bar Length: 341 mm

Section Thickness: 16 mm

Section Width: 18 mm

Case Length: 90 mm

Case Width: 52 mm

Crank Length: 160 mm

Weight: 1720 g

Advantage: n/a

Date: 15th century



Bern W2004, photo by author

Location: Historisches Museum, Bern

Source:

Wegeli, Rudolf, *Inventar der Waffensammlung des Bernischen Historischen Museums in Bern*, (Bern, 1948). p. 34-5.

Collection ID: Bern W2005 / 17475

Bar Length: 320 mm

Section Thickness: 14 mm

Section Width: 17 mm

Case Length: 99 mm

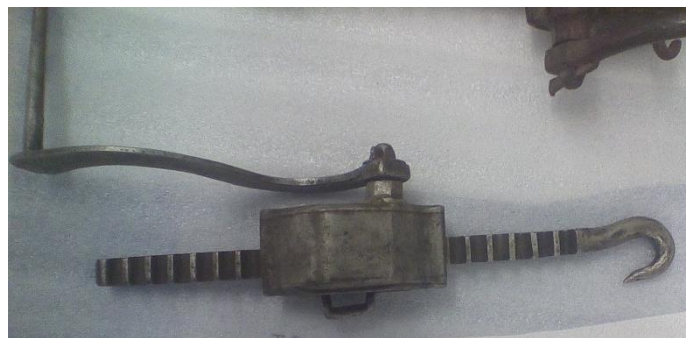
Case Width: 50 mm

Crank Length: 202 mm

Weight: 1380 g

Advantage: n/a

Date: 15th century



Bern W2005, photo by author

Location: Historisches Museum,
Bern

Source:

Wegeli, Rudolf, *Inventar der Waffensammlung des Bernischen Historischen Museums in Bern*, (Bern, 1948). p. 35.

Collection ID: CH 337

Bar Length: 374 mm

Section Thickness: n/a

Section Width: n/a

Case Length: n/a

Case Width: n/a

Crank Length: n/a

Weight: 2866 g
Advantage: n/a
Date: c.1500

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 280.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 212.

Collection ID: CH 338

Bar Length: 380 mm

Section Thickness: n/a

Section Width: n/a

Case Length: n/a

Case Width: n/a

Crank Length: n/a

Weight: n/a

Advantage: n/a

Date: c.1500

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 280.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 212.

Collection ID: Grandson F124

Bar Length: 380 mm

Section Thickness: 16 mm

Section Width: 26 mm

Case Length: 116.5 mm

Case Width: 77 mm

Crank Length: 216 mm

Weight: 1840 g

Advantage: 1 to 271

Date: c. 1500

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Collection ID: Netherlands cat. no. 40

Bar Length: 353 mm

Section Thickness: 16.2 mm

Section Width: 21.5 mm



Grandson F124, photo by author

Case Length: 98 mm
Case Width: 68 mm
Crank Length: 147.5 mm

Weight: 1910 g
Advantage: 1 to 103
Date: c. 1500

Location: Royal Netherlands Army Museum, Delft

Source:

Sensfelder, Jens, *Crossbows in the Royal Netherlands Army Museum*, (Delft, 2007).
p.242.

Collection ID: MET 2012.4

Bar Length: 377 mm
Section Thickness: n/a
Section Width: n/a

Case Length: n/a
Case Width: 160 mm(?)
Crank Length: n/a

Weight: 1435 g
Advantage: n/a
Date: c.1505-19

Location: Metropolitan Museum of Art, New York City

Source:

Breiding, Dirk, *A Deadly Art: European Crossbows, 1250-1850* (New York, 2014). pp.
99-100.

Collection ID: Grandson B202-b

Bar Length: 384 mm
Section Thickness: 18.5 mm
Section Width: 15 mm

Case Length: 91 mm
Case Width: 44 mm
Crank Length: 140 mm

Weight: 1280 g
Advantage: 1 to 98
Date: c.1500-33

Location: Grandson
Castle, Switzerland

Source:

Sensfelder, Jens,
“Dokumentation Schloß
Grandson”, (Unpublished Catalog, 2007/08).



Grandson B202-b, photo by author

Collection ID: Grandson B346

Bar Length: 539 mm
Section Thickness: 15 mm
Section Width: 22 mm

Case Length: 99 mm
Case Width: 64 mm
Crank Length: c.130 mm
Weight: n/a
Advantage: n/a
Date: c.1520



Grandson B346, photo by author

Location: Grandson
Castle, Switzerland
Source:
Measurements by author.

Collection ID: Netherlands cat. no. 41

Bar Length: 445 mm
Section Thickness: 15 mm
Section Width: 19.5 mm

Case Length: 97.5 mm
Case Width: 49 mm
Crank Length: 190 mm

Weight: 1770 g
Advantage: 1 to 166
Date: c. 1500-25

Location: Royal Netherlands Army Museum, Delft
Source:
Sensfelder, Jens, *Crossbows in the Royal Netherlands Army Museum*, (Delft, 2007).
p.246.

Collection ID: Grandson F77

Bar Length: 348 mm
Section Thickness: 15.5
mm
Section Width: 29 mm

Case Length: 123 mm
Case Width: 85 mm
Crank Length: 222 mm
Weight: 1900 g
Advantage: 1 to 232
Date: c.1532



Grandson F77, photo by author

Location: Grandson Castle, Switzerland

Source:
Measurements by author.

Collection ID: CH 339
Bar Length: 322 mm
Section Thickness: n/a
Section Width: n/a

Case Length: n/a
Case Width: n/a
Crank Length: n/a

Weight: 1682 g
Advantage: n/a
Date: c.1500-50

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 280.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 212.

Collection ID: CH 340
Bar Length: 345 mm
Section Thickness: n/a
Section Width: n/a

Case Length: n/a
Case Width: n/a
Crank Length: n/a

Weight: 1550 g
Advantage: n/a
Date: c.1500-50

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 280.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 212.

Collection ID: CH 341
Bar Length: 345 mm
Section Thickness: n/a
Section Width: n/a

Case Length: n/a
Case Width: n/a
Crank Length: n/a

Weight: 2100 g

Advantage: n/a
Date: c.1500-50

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 280.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 212.

Collection ID: CH 342

Bar Length: 340 mm

Section Thickness: n/a

Section Width: n/a

Case Length: n/a

Case Width: n/a

Crank Length: n/a

Weight: 1815 g

Advantage: n/a

Date: c.1500-50

Location: Churburg Castle, Italy

Source:

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 280.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 212.

Collection ID: Netherlands cat. no. 42

Bar Length: 430 mm

Section Thickness: 14.1 mm

Section Width: 19 mm

Case Length: 98.5 mm

Case Width: 49 mm

Crank Length: 148 mm

Weight: 1610 g

Advantage: 1 to 178.8

Date: c.1500-50

Location: Royal Netherlands Army Museum, Delft

Source:

Sensfelder, Jens, *Crossbows in the Royal Netherlands Army Museum*, (Delft, 2007). p. 248.

Collection ID: Netherlands cat. no. 43

Note: This *cranequin* has been modified from its original condition

Bar Length: 390 mm

Section Thickness: 17 mm

Section Width: 27.5 mm

Case Length: 139 mm
Case Width: 81 mm
Crank Length: 213 mm

Weight: 2210 g
Advantage: n/a
Date: 1540

Location: Royal Netherlands Army Museum, Delft

Source:

Sensfelder, Jens, *Crossbows in the Royal Netherlands Army Museum*, (Delft, 2007).
p.250.

Collection ID: Netherlands cat. no. 44

Bar Length: 364 mm
Section Thickness: 17.5 mm
Section Width: 27.7 mm

Case Length: 134 mm
Case Width: 86 mm
Crank Length: 250 mm

Weight: 2070 g
Advantage: n/a
Date: c.1525-1550

Location: Royal Netherlands Army Museum, Delft

Source:

Sensfelder, Jens, *Crossbows in the Royal Netherlands Army Museum*, (Delft, 2007). p.
254.

Collection ID: Worcester Art Museum 2014.582

Bar Length: 354 mm
Section Thickness: n/a
Section Width: n/a

Case Length: n/a
Case Width: n/a
Crank Length: n/a

Weight: 2013 g
Advantage: n/a
Date: c.1530

Location: Worcester Art Museum, Massachusetts

Source:

Worcester Art Museum Digital Catalog:

<http://vqs61.v3.pair.com:8080/emuseum/view/objects/asitem/items@:49856> [Accessed
30/7/15].

Collection ID: MET 48.149.36b

Bar Length: 359 mm

Section Thickness: n/a

Section Width: n/a

Case Length: n/a

Case Width: 88 mm

Crank Length: n/a

Weight: 2343 g

Advantage: n/a

Date: c.1500-50

Location: Metropolitan Museum of Art, New York City

Source:

Breiding, Dirk, *A Deadly Art: European Crossbows, 1250-1850* (New York, 2014). pp.101-2.

Collection ID: Wallace Collection A1054

Bar Length: 374 mm

Section Thickness: n/a

Section Width: n/a

Case Length: n/a

Case Width: n/a

Crank Length: n/a

Weight: 2460 g

Advantage: n/a

Date: 1545

Location: Wallace Collection,
London

Source:

Wallace Collection Digital Catalog:

<http://wallacelive.wallacecollection.org/eMuseumPlus> [Accessed 23/7/15]



© The Wallace Collection

Wallace Collection A1054, photo from collection

Collection ID: Swedish Royal Armoury 9816
(06:4247)

Bar Length: 378 mm

Section Thickness: n/a

Section Width: n/a

Case Length: n/a

Case Width: n/a

Crank Length: 199 mm

Weight: 1870 g

Advantage: n/a

Date: c.1550



Swedish Royal Armoury 9816 (06:4247), photo from collection

Location: Swedish Royal Armoury, Stockholm

Source:

Royal Armory Digital Catalog: <http://emuseumplus.lsh.se/eMuseumPlus> [Accessed 22/7/15]

Collection ID: Worcester Art Museum 2104.581

Bar Length: 404 mm

Section Thickness: n/a

Section Width: n/a

Case Length: n/a

Case Width: 73 mm

Crank Length: n/a

Weight: 1842 g

Advantage: n/a

Date: c.1550

Location: Worcester Art Museum, Massachusetts

Source:

Worcester Art Museum Digital Catalog:

<http://vqs61.v3.pair.com:8080/emuseum/view/objects/asitem/items@:47991> [Accessed 30/7/15].

Collection ID: Grandson F80

Bar Length: 348 mm

Section Thickness: 15 mm

Section Width: 32.5 mm

Case Length: 139 mm

Case Width: 108 mm

Crank Length: 262 mm

Weight: 2220 g

Advantage: 1 to 342

Date: mid-16th century



Grandson F80, photo by author

Location: Grandson Castle,
Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Collection ID: Wallace Collection A1055

Bar Length: n/a

Section Thickness: n/a

Section Width: n/a

Case Length: n/a
Case Width: n/a
Crank Length: n/a

Weight: 5180 g
Advantage: n/a
Date: c.1560

Location: Wallace Collection, London

Source:

Wallace Collection Digital Catalog:

<http://wallacelive.wallacecollection.org/eMuseumPlus> [Accessed 23/7/15]



Wallace Collection A1055, photo from collection

Collection ID: Grandson C64

Bar Length: 348 mm
Section Thickness: 15 mm
Section Width: 32.5 mm

Case Length: 165 mm
Case Width: 121 mm
Crank Length: 261 mm

Weight: 3220 g
Advantage: 1 to 273
Date: c.1575-1600

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Collection ID: Met 14.25.1575b

Bar Length: 431 mm
Section Thickness: n/a
Section Width: n/a

Case Length: n/a
Case Width: 58 mm
Crank Length: n/a

Weight: 1638 g
Advantage: n/a
Date: 16th century

Location: Metropolitan Museum of Art, New York City

Source:

Breiding, Dirk, *A Deadly Art: European Crossbows, 1250-1850* (New York, 2014). p. 98.

Collection ID: Swedish Royal Armoury 9558 (5550)

Bar Length: 429 mm
Section Thickness: n/a
Section Width: n/a

Case Length: n/a
Case Width: n/a
Crank Length: 235 mm

Weight: 3400 g
Advantage: n/a
Date: 16th century

Location: Swedish Royal Armoury, Stockholm
Source:
Royal Armory Digital Catalog:
<http://emuseumplus.lsh.se/eMuseumPlus> [Accessed 22/7/15]

Collection ID: CH 343
Bar Length: 325 mm
Section Thickness: n/a
Section Width: n/a

Case Length: n/a
Case Width: n/a
Crank Length: n/a

Weight: 1755 g
Advantage: n/a
Date: 16th century

Location: Churburg Castle, Italy
Source:
Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 281.
Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 212.

Collection ID: CH 344
Bar Length: 325 mm
Section Thickness: n/a
Section Width: n/a

Case Length: n/a
Case Width: n/a
Crank Length: n/a

Weight: 2050 g
Advantage: n/a
Date: 16th century

Location: Churburg Castle, Italy
Source:



*Swedish Royal Armoury
9558 (5550), photo from
collection*

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996). p. 281.

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996). pp. 212.

Collection ID: Bern W2009 / 598

Bar Length: 350 mm
Section Thickness: 15 mm
Section Width: 24 mm

Case Length: 109 mm
Case Width: 71 mm
Crank Length: 180 mm



Bern W2009, photo by author

Weight: 1960 g
Advantage: n/a
Date: 16th century

Location: Historisches Museum, Bern

Source:

Wegeli, Rudolf, *Inventar der Waffensammlung des Bernischen Historischen Museums in Bern*, (Bern, 1948). p. 35-6.

Collection ID: Bern 17474

Bar Length: 359 mm
Section Thickness: 15 mm
Section Width: 28 mm

Case Length: 130 mm
Case Width: 86 mm
Crank Length: 260 mm



Bern 17474, photo by author

Weight: n/a
Advantage: n/a
Date: 16th century

Location: Historisches Museum, Bern

Source:

Measurements by author.

Collection ID: Bern W2010

Bar Length: 357 mm
Section Thickness: n/a
Section Width: n/a

Case Length: 135 mm
Case Width: 75 mm
Crank Length: n/a

Weight: 2605 g
Advantage: n/a

Date: 16th century

Location: Historisches Museum, Bern

Source:

Wegeli, Rudolf, *Inventar der Waffensammlung des Bernischen Historischen Museums in Bern*, (Bern, 1948). p. 36.

Collection ID: Bern W2014

Bar Length: 335 mm

Section Thickness: n/a

Section Width: n/a

Case Length: 135 mm

Case Width: 72 mm

Crank Length: n/a

Weight: 2040 g

Advantage: n/a

Date: 16th century

Location: Historisches Museum, Bern

Source:

Wegeli, Rudolf, *Inventar der Waffensammlung des Bernischen Historischen Museums in Bern*, (Bern, 1948). p. 38.

Collection ID: HMLU 00286

Bar Length: 354 mm

Section Thickness: 15 mm

Section Width: 30 mm

Case Length: 143 mm

Case Width: 97 mm

Crank Length: 223 mm

Weight: n/a

Advantage: n/a

Date: 16th century

Location: Historisches

Museum, Luzern

Source:

Measurements by author. *HMLU 00286, photo by author*



Goat's Foot Levers

Collection ID: MET 14.25.1609

Total Length: 498 mm

Fork Length: n/a

Lever Length: n/a

Max Breadth: 72 mm

Weight: 713 g

Date: c.1450-1550

Location: Metropolitan Museum of Art, New York City

Source:

Breiding, Dirk, *A Deadly Art: European Crossbows, 1250-1850* (New York, 2014). pp. 112-3.

Collection ID: MET 27.160.19b

Total Length: 466 mm

Fork Length: n/a

Lever Length: n/a

Max Breadth: 67 mm

Weight: 548 g

Date: c.1525-75

Location: Metropolitan Museum of Art, New York City

Source:

Breiding, Dirk, *A Deadly Art: European Crossbows, 1250-1850* (New York, 2014). p. 114.

Collection ID: Grandson Bonhams 254-b

Total Length: 512 mm

Fork Length: 287 mm

Lever Length: 225 mm

Max Breadth: 55 mm

Weight: 720 g

Date: 16th century

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Collection ID: Grandson
B2362

Total Length: 541 mm

Fork Length: 299 mm

Lever Length: 242 mm

Max Breadth: 66 mm

Weight: 660 g

Date: 16th century



Grandson B2362, photo by author

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Collection ID: Grandson B284-b

Total Length: c.568 mm

Fork Length: 273 mm

Lever Length: c.295 mm

Max Breadth: 53 mm

Weight: 1070 g

Date: 16th century

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Collection ID: Swedish Royal Armoury 9819 (2446)

Fork Length: 535 mm

Lever Length: n/a

Max Breadth: n/a

Weight: 812 g

Date: 1400-1600



Location: Swedish Royal Armoury,
Stockholm

Source:

Royal Armory Digital Catalog:

*Swedish Royal Armoury 9819 (2446), photo from
collection*

<http://emuseumplus.lsh.se/eMuseumPlus> [Accessed 22/7/15]

Belt Hooks, *Krihakes*, and Windlass Handles

Collection ID: Swedish Royal Armoury 23745 (5787: 9)

Belt Length: 1600 mm

Belt Width: 120 mm

Hook Width: n/a

Hook Length: 89 mm

Weight: 615 g

Date: 16th century

Type: Double Hook *Krihake*



Location: Swedish Royal Armoury,
Stockholm

Source:

Royal Armory Digital Catalog: <http://emuseumplus.lsh.se/eMuseumPlus> [Accessed 22/7/15]

*Swedish Royal Armoury 23745 (5787: 9), photo from
collection*

Collection ID: Swedish Royal Armoury 24415 (14:50)

Hook Width: n/a

Hook Length: 107 mm

Weight: n/a

Date: 16th century

Type: Double Hook Pulley

Location: Swedish Royal Armoury, Stockholm

Source:

Royal Armoury Digital Catalog:

<http://emuseumplus.lsh.se/eMuseumPlus> [Accessed 22/7/15]



Swedish Royal Armoury 24415 (14:50), photo from collection

Collection ID: Swedish Royal Armoury 26618 (25:185)

Hook Width: 92 mm

Hook Length: 86 mm

Weight: 302 mm

Date: 16th century

Type: Double Hook Pulley

Location: Swedish Royal Armoury, Stockholm

Source:

Royal Armoury Digital Catalog:

<http://emuseumplus.lsh.se/eMuseumPlus> [Accessed 22/7/15]



Swedish Royal Armoury 26618 (25:185), photo from collection

Collection ID: MET 14.25.1611

Hook Width: 77 mm

Hook Length: 177 mm

Weight: 224 g

Date: c.1475-1525

Type: Double Hook Pulley

Location: Metropolitan Museum of Art, New York City

Source:

Breiding, Dirk, *A Deadly Art: European Crossbows, 1250-1850* (New York, 2014). p. 97.



Collection ID: Grandson 4061

Hook Width: 60 mm

Hook Length: 88 mm

Weight: n/a

Date: c.1400-50

Type: Two Hooked Belt Hook

Location: Grandson Castle, Switzerland

Grandson 4061, photo by author

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Collection ID: Grandson B290

Hook Width: 49 mm

Hook Length: 88 mm

Weight: n/a

Date: 15th century

Type: Two Hooked Belt Hook

Location: Grandson Castle, Switzerland

Source:

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).



Grandson B290, photo by author

Collection ID: Jagd und Fischereimuseum,
(catalog number unknown).

Total Length: 355 mm

Hook Length: 114 mm

Weight: n/a

Date: Gothic(?)

Type: Single Hook Belt Hook

Location: German Hunting and Fishing Museum, Munich

Source:

Jens Sensfelder, "A Gothic Spanning-Belt Hook", *Journal of the Society of Archer-Antiquaries* 43 (2000). pp. 20-21.

Collection ID: Wallace Collection A1059

Total Windlass Width: 1340 mm

Handle Length: 210 mm

Weight: 1340 g

Date: 16th century

Type: Windlass Handle

Location: Wallace Collection,
London

Source:

Wallace Collection Digital
Catalog:



© The Wallace Collection

Wallace Collection A1059, photo from collection

<http://wallacelive.wallacecollection.org/eMuseumPlus> [Accessed 23/7/15]

Collection ID: Bern W1983, 3675

Windlass Mechanism Width: 245 mm

Handle Length: 241 millimeter

Weight: n/a

Date: 16th century?

Type: Windlass

Location: Historisches Museum, Bern

Source:

Wegeli, Rudolf, *Inventar der Waffensammlung des Bernischen Historischen Museums in Bern*, (Bern, 1948). p. 25.



Bern W1983, photo by author

Appendix III: Glossary

Archer: A soldier who wields either a bow or a crossbow as their primary weapon. While archer is often used to only refer to soldiers using bows, crossbowman being the alternative term, this thesis will use the term archer to refer to soldiers using either weapon. In some situations it could be used to refer to soldiers using one of the weapons but those will be determined by context, i.e. in a chapter on the longbow the term archer will refer primarily to soldiers using longbows.

Bow: A simple projectile weapon, usually made with wood, and powered by pulling back on a string that is attached to either end of the bow. A bow is composed of several components. The bows grip is the area in the middle where the archer holds it. The bows limbs are the working parts of the bow, they bend when the bow-string is pulled back. The bow nocks are where the string attaches to the bow. The bow is divided into its belly and its back. The belly of the bow is the side that, when the bow is held and ready to loose, faces the archer. The back is the side of the bow that faces away from the archer in the same circumstances.

Longbow: What length makes a bow a longbow is a difficult problem since it requires historians to draw a line marking 'long' from 'short'. While Jim Bradbury made an argument for rejecting longbow as a term entirely in favor of 'ordinary wooden bow'⁶²⁷ this thesis will continue to use it because as a term it conjures an image in our mind that grants immediate understanding of what the author means when he uses it. For the purposes of this thesis the Longbow is a wooden bow of European origin whose length exceeds at least four feet.

Self Bow: A bow carved from a single piece of wood.

Composite Bow: A bow made from several different materials. It can be used to mean a bow made of two different types of wood glued together but in this thesis it is used to mean bows made of horn, sinew, and wood used primarily in Asia and North Africa.

Compass Bow: A bow where the entire bow, including the grip, contributes to the force of the weapon when drawn. The opposite is a bow whose grip does not bend when the bow is drawn and the work is done entirely by the bow's limbs.

Recurve: The bow shape where, when unstrung, a bows limbs curve forward beyond the grip rather than settling into a relatively straight bow stave.

Reflex: The shape of bow nocks where they are curved forward, away from the archer.

Siyah: The limbs of a composite bow, usually used to refer to the upper limbs but can be used to refer to the limbs in general.

Draw Weight: The measurement of a bow's, or crossbow's, power. Described in terms of pounds of force at a specified distance it represents how much force is required to pull the bow string back to that same distance.

⁶²⁷ Jim Bradbury, *The Medieval Archer*, (Woodbridge, 1985). pp. 12-4.

Crossbow: A weapon primarily composed of a bow mounted horizontally onto a wooden tiller used for holding it. While there is some debate as to whether a crossbow requires a trigger to be a crossbow, a similar weapon without a trigger would be a bow guide, all weapons of this type had triggers during the time period this thesis covers so the question is a moot one.⁶²⁸ A crossbow is composed of a lathe, tiller, string, nut, and trigger. It may also have other attachments on its tiller to aid in the spanning of the weapon.

Lathe: The bow part of the crossbow. While the term bow could be used instead of lathe this thesis is using lathe to avoid possible confusion with the longbow.

Tiller: The wooden grip of the crossbow that the lathe is attached to. The tiller also houses the crossbow's trigger.

Nut: The rotating piece, usually made of horn, that holds the string in place when the crossbow is spanned. The trigger is used to release the nut, which allows the weapon to shoot.

Span: The act of drawing a crossbow's string back so that it rests in the crossbow's nut. When a crossbow's string is resting in its nut it has been spanned.

Cranequin: A powerful method for spanning a crossbow which uses a crank and a gear shaft to pull the crossbow string into place. See Appendix II for examples.

Case: The box on a *cranequin* that contains the gears.

Ratched Bar: The bar section of a *cranequin*.

Krihake: A pulley on a rope attached to a belt that is used to span crossbows. See Appendix II for examples.

Windlass: A powerful method for spanning a crossbow that uses a winch-like system to pull the string back into place. See Appendix II for examples.

Goats-Foot Lever: A complex lever that is used to span crossbows. See Appendix II for examples.

⁶²⁸ Nicole Pétrin, "Philological notes on the crossbow and related missile weapons", *Greek, Roman and Byzantine studies* 33;3 (1992). pp. 280-91.

Bibliography

Primary Sources

Accounts of the Lord High Treasurer of Scotland, ed. Thomas Dickson, Sir James Balfour Paul and C. T. McInnes, 13 vols. (Edinburgh, 1877-1978).

Angelucci, Angelo, *Catalogo della armeria reale: illustrato con incisioni in legno* (Torino, 1890).

Anglo-Saxon Chronicle trans. G. N. Garmonsway, (1953, repr. London, 1972).

Arab Archery, trans. Nabih Amin Faris and Robert Potter Elmer (Princeton, 1945).

Ascham, Roger, *Toxophilus*, ed. Edward Arber (London, 1868).

Calendar of Documents Relating to Scotland: Preserved in Her Majesty's Record Office London, ed. Joseph Bain, 4 vols. (Edinburgh, 1881-1888).

Calendar of the Close Rolls Preserved in the Public Office, Edward III, 14 vols. (London, 1896-1913).

Crooke, Juan Bautista, *Catálogo Histórico-descriptivo De La Real Armería De Madrid* (Rivadeneira, 1898).

Curry, Anne, *The Battle of Agincourt: Sources and Interpretations*, (2000, repr. Woodbridge, 2009).

Enguerrand de Monstrelet, *The Chronicles of Enguerrand de Monstrelet*, trans. Thomas Johnes (London, 1840).

Franzoi, Umberto, *Armour of the Doges Palace in Venice*, (Venice, 1966).

Froissart, Jean, *Chronicles*, trans. Geoffrey Brereton, (1968, repr. London, 1978).

Giraldus Cambrensis, *The Itinerary and Description of Wales*, trans. Richard Colt Hoare, (1809, repr. London, 1908).

Giraldus Cambrensis, *Expugnatio Hibernica*, trans. Thomas Forester, (London, 1905)

Graf Trapp, Oswald, *The Armoury of the Castle of Churburg*, trans. James Gow Mann (1929, repr. Udine, 1996).

Kelly, Francis, "A Knight's Armour of the Early XIV Century Being the Inventory of Raoul de Nesle", *The Burlington Magazine for Connoisseurs* 6:24 (1905). 457-459, 462-469.

Kruczek, Jan, *Kusze Katalog Zbiorów*, (Pszczyna, 2002).

Nicolas, Harris, *History of the Battle of Agincourt and of The Expedition of Henry the*

Fifth into France in 1415; To Which is Added The Roll of the Men At Arms in the English Army, 3rd edition (1827, London, 1833).

Phoebus, Gaston, *The Hunting Book of Gaston Phébus : Manuscrit Français 616, Paris, Bibliothèque Nationale* ed. Marcel Thomas, François Avril and Wilhelm Schlag, (London, 1998).

Scalini, Mario, *L'Armeria Trapp de Castel Coira*, (Udine, 1996).

Select Charters and Other Illustrations of English Constitutional History From the Earliest Times to the Reign of King Edward the First ed. William Stubbs and H.W.C. Davis, 9th ed. (1870, London, 1913).

Sensfelder, Jens, *Crossbows in the Royal Netherlands Army Museum*, (Delft, 2007).

Sensfelder, Jens, "Dokumentation Schloß Grandson", (Unpublished Catalog, 2007/08).

Wegeli, Rudolf, *Inventar der Waffensammlung des Bernischen Historischen Museums in Bern*, (Bern, 1948).

Wilson, G.M., "Notes on Some Crossbows in the Collection of Glasgow Museum and Art Gallery", (Unpublished Notes, 2006).

Electronic Sources

The Art of Archery, ed. Henri Gallace and trans. H. Walrond (London, 1903).
<http://www.archerylibrary.com/books/gallice/> [Accessed 11/4/13]

Royal Armoury, Stockholm, digital catalog. <http://livrustkammaren.se/en> [Accessed 1/7/15]

Wallace Collection, London, digital catalog.
<http://www.wallacecollection.org/thecollection/collections/armsandarmour> [Accessed 7/1/15]

Encyclopedia Britannica, <http://www.britannica.com/> [Accessed 23/9/15]

Historical Sources

Abratowski, Andrzej, "The Bow in Poland", *Journal of the Society of Archer-Antiquities* 44 (2001). 15-21.

Alm, Josef, *European Crossbows: A Survey*, ed. and trans. G.M. Wilson and H. Bartlett Wells (1994, repr. Dorchester, 1998).

Asbridge, Thomas, *The Crusades The War for the Holy Land*, (London, 2010).

Ascani, Enrico and Francesco Gorgo, "A Technical Study of the Fresco in the 'St. Sebastian Chapel', Celle Macra, Italy", *Journal of the Society of Archer-Antiquaries* 42 (1999). 86-88.

- Atex, Wayne, and G. Menes, "The Omnogov Bow", *Journal of the Society of Archer-Antiquaries* 38 (1995). 71-5
- Ayton, Andrew, "Arms, Armour, and Horses" in *Medieval Warfare* ed. Maurice Keen, (Oxford, 1999). 186-208.
- Bachrach, Bernard S., "Medieval Siege Warfare: A Reconnaissance", *The Journal of Military History* 58:1 (1994). 119-133.
- Bachrach, David S., "Origins of the Crossbow Industry in England", *Journal of Medieval Military History* 2 (2004). 73-88.
- Bachrach, David S., "Crossbows for the King: The Crossbow During the Reign of John and Henry III of England", *Technology and Culture* 45:1 (2004). 102-119.
- Bachrach, David S., "Crossbows for the King, Part II: The Crossbow During the Reign of Edward I of England (1272-1307)", *Technology and Culture* 47:1 (2006). 81-90.
- Baker, Tim, "Bow Design and Performance" in *The Traditional Bowyers Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). 1:43-116.
- Bartlett, Clive, Chris Boyton, Steve Jackson, Adam Jackson, Douglas McElvogue, Alexzandra Hildred and Keith Watson, "The Longbow Assemblage" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). 2:594-618.
- Benini, Stefano, "The Bow in Medieval Ferrara", *Journal of the Society of Archer-Antiquaries* 36 (1993). 31
- Benini, Stefano, "The Bow in Italy", *Journal of the Society of Archer-Antiquaries* 36 (1983). 7-13.
- Bennett, Matthew, "The Myth of the Military Supremacy of Knightly Cavalry" in *Armies, chivalry and warfare in medieval Britain and France: proceedings of the 1995 Harlaxton Symposium*, ed. Matthew Strickland (Stamford, 1998) 1-20.
- Bergman, C.A., McEwen, E. and Miller, R., "Experimental Archery: Projectile Velocities and Comparison of Bow Performances", *Antiquity* 62:237 (1988). 658-670.
- Blair, Claude, *European Armour circa 1066 to circa 1700* (London, 1958).
- Blair, Claude, "Early Firearms" in *Pollard's History of Firearms*, ed. Claude Blair (Feltham, 1983). 25-32.
- Boie, Achim and Bader, H.D., "Bows used by the 'Huns'", *Journal of the Society of Archer Antiquaries*, 38 (1995). 28-32.
- Bourke, Paul, and David Whetham, "A Report of the Findings of the Defence Academy Warbow Trials", *Arms and Armour* 4:1 (2007). 53-75.

Boylston, Anthea, Malin Holst, and Jennifer Coughlan, "Physical Anthropology" in *Blood Red Roses: The Archaeology of a Mass Grave from the Battle of Towton AD 1461* ed. Veronica Fiorato, Anthea Boylston, and Christopher Knüsel, 2nd Ed. (2000, Oxford, 2007). 45-59.

Bradbury, Jim, *The Medieval Archer* (Woodbridge, 1985).

Bradbury, Jim, *The Medieval Siege* (1992, repr. Woodbridge, 2002).

Breiding, Dirk, *A Deadly Art: European Crossbows, 1250-1850* (New York, 2014).

Brown, Robert C., "Observations on the Berkhamstead Bow", *Journal of the Society of Archer-Antiquaries* 10 (1967). 12-17.

Burns, Robert, "100,000 Crossbow Bolts for the Crusader King of Aragon", *Journal of Medieval Military History* 2 (2004).159-164.

Burns, Robert, "The Medieval Crossbow as Surgical Instrument: an Illustrated Case History", *Bulletin of the New York Academy of Medicine* 48 (1972). 983-989.

Caldera, Massimiliano, Fulvio Cervini, Giorgio Dondi, Enrico Ricchiardi, Alessandro Guerrini, Federico Barello, and Clara Vitulo, *L'Armeria Reale La Biblioteca Reale*, (Turin, 2008).

Carminati, Franco, "Piedmontese Archery", *The Journal of the Society of Archer-Antiquaries* 36 (1993). 49-50.

Cenni, Alessio, "Wooden Bows in Medieval Italy", *Journal of the Society of Archer-Antiquaries* 39 (1996). 50-51.

Cenni, Alessio, "Late Medieval Quivers", *Journal of the Society of Archer-Antiquaries* 43 (2000). 27-34.

Cenni, Alessio, "Crossbow-Making in Venice During the 13th Century", *Journal of the Society of Archer-Antiquaries* 47 (2004). 34-43.

Clarke, J.G.D., "Neolithic Bows from Somerset, England, and the Prehistory of Archery in Northwestern Europe", *The Proceedings of the Prehistoric Society* 29:3 (1963). 50-98

Clear, R.M., M.F. Hurley and E. Shee Twohig, *Skiddy's Castle and Christ Church: Cork Excavations 1974-77*, (Cork, 1997).

Comstock, Paul, "Other Bow Woods" in *The Traditional Bowyer's Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). 1:149-64.

Comstock, Paul, "Ancient European Bows" in *The Traditional Bowyer's Bible* ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). 2:80-112.

Comstock, Paul, "Bending Wood" in *The Traditional Bowyer's Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). 2:155-66

Cotterell, Brian, and Johan Kamminga, *Mechanics of Pre-Industrial Design* (Cambridge, 1990).

Coughlan, Jennifer and Malin Holst, "Health Status" in *Blood Red Roses: The Archaeology of a Mass Grave from the Battle of Towton AD 1461* ed. Veronica Fiorato, Anthea Boylston, and Christopher Knüsel, 2nd Ed. (2000, Oxford, 2007). pp. 71-5.

Credland, Arthur Graves, "Crossbow Remains", *Journal of the Society of Archer-Antiquaries* 23 (1980). 12-19

Credland, Arthur G., "The Medieval War Arrow", *Journal of the Society of Archer-Antiquaries* 25 (1982). 28-35.

Credland, Arthur, "Crossbow Remains (pt. 3)", *Journal of the Society of Archer-Antiquaries* 25 (1982). 16-21.

Credland, A. G., "The Crossbow in the Far North", *Journal of the Society of Archer-Antiquaries* 26 (1983). 12-23.

Credland, Arthur, "Notes on the Crossbow Spanning Bench", *Journal of the Society of Archer-Antiquaries* 33 (1990). 13-22.

Credland, Arthur Graves, "Crossbow Remains (Part 2)", *Journal of the Society of Archer-Antiquaries* 24 (1991). 9-16.

Crossley, D.W., "Medieval Iron Smelting" in *Medieval Industry* ed. D.W. Crossley (London, 1981). 29-41.

Crowley, Anna B., "Appendix" in *The Great Warbow: From Hastings to the Mary Rose*, by Matthew Strickland and Robert Hardy (2005, repr. Somerset, 2011). 408-414.

Davies, Jonathan, "Military Archery and the Inventory of King Henry VIII", *The Journal of the Society of Archer-Antiquities* 44, (2001). 31-38.

Davies, Jonathan, *Gunpowder Artillery 1267-1603*, (Bristol, 2003).

Denny, Mark, "Bow and Catapult Internal Dynamics", *European Journal of Physics* 24 (2003). 367-378.

Denny, Mark, *Their Arrows Will Darken the Sun: A Guide to the Evolution and Science of Ballistics* (Baltimore, 2011).

DeVries, Kelly, *Infantry Warfare in the Early Fourteenth century: Discipline, Tactics, and Technology* (Woodbridge, 1996).

DeVries, Kelly, "Catapults Are Not Atomic Bombs: Towards a Redefinition of 'Effectiveness' in Premodern Military Technology", *War in History* 4:4 (1997). 454-470

DeVries, Kelly, "Gunpowder Weaponry and the Rise of the Early Modern State", *War in History* 5:2 (1998). 127-145.

DeVries, Kelly, "The Forgotten Battle of Bevershoutsveld, 3 May 1382: Technological Innovation and Military Significance" in *Armies, chivalry and warfare in medieval Britain and France: proceedings of the 1995 Harlaxton Symposium* ed. Matthew Strickland (Stamford, 1998). 289-303

DeVries, Kelly, "Gunpowder and Early Gunpowder Weapons" in *Guns and Men in Medieval Europe, 1200-1500* ed. Kelly DeVries, (Aldershot, 2002).121-135.

DeVries, Kelly, "The Use of Chronicles in Recreating Medieval Military History", *Journal of Medieval Military History* 2 (2004). 1-15.

DeVries, Kelly, David Whetham and Paul Bourke, "Comments", *Arms and Armour* 4:1 (2007). 75-81..

DeVries, Kelly, "The Introduction and use of the Pavise in the Hundred Years War", *Arms and Armour* 4:2 (2007). 93-100.

Eddé, Anne-Marie, *Saladin*, trans. Jane Marie Todd, (Cambridge, 2011).

Ekdahl, Sven, "Die Armbrust in Deutschordensland Preussen zu Beginn des 15. Jahrhunderts", *Fasciculi Archaeologiae Historicae* 5 (1992). 17-48.

Ekdahl, Sven, "Horses and crossbows: two important warfare advantages of the Teutonic Order in Prussia" in *The Military Orders: Volume 2 Welfare And Warfare*, ed. Helen Nicholson, (Aldershot, 1998). 119-151.

Esper, Thomas, "The Replacement of the Longbow by Firearms in English Army", *Technology and Culture* 6:3 (1965). 382-393.

Featherstone, Donald, *The bowmen of England: the story of the English longbow*, (New York, 1967).

Fliegel, Stephen N., "The Art of War: Thirteenth Century Arms and Armour" in *The Book of Kings: Art, War, and the Morgan Library's Medieval Picture Bible*, ed. William Noel and Daniel Weiss (Baltimore, 2002). 83-97.

Foley, Vernard, George Palmer and Werner Soedel, "The Crossbow", *Scientific American*, 252;1 (1984). 104-110.

Frankopan, Peter, *The First Crusade: The Call from the East* (2012, repr. London, 2013).

Franken-Stellamans, Erhard, "A Mathematical Method for Determination of the Appropriate Draw Length for a Given Steel Bow", *Journal of the Society of Archer-Antiquaries* 47 (2004). 92-97.

Fritze, Robin, *New Worlds: The Great Voyages of Discovery 1400-1600*, (Westport, 2002)

George, Hereford B., "The Archer's at Crecy", *The English Historical Review* 10:40 (1895). 733-738.

Gendall, Janet E., "Archery Material in the Arundell MSS", *Journal of the Society of Archer-Antiquaries* 48 (2005). 91-94.

Gies, Frances and Joseph Gies, *Cathedra Forge and Waterwheel: Technology and Invention in the Middle Ages*, (New York, 1994).

Gravett, Christopher, *Knight: Noble Warrior of England 1200-1600*, (Oxford, 2008).

Grayson, Charles, "Composite Bows" in *The Traditional Bowyers Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). 2:113-154.

Green, David, *The Hundred Years War: A People's History*, (Padstow, 2014).

Haldane, Douglas, "The Fire-Ship of Al-Salih Ayyub and Muslim Use of 'Greek Fire'" in *The Circle of War in the Middle Ages* ed. Donald Kagay and Andrew Villalon (Woodbridge, 1999). 137-144.

Hall, Bert S., "The Corning of Gunpowder and the Development of firearms in the Renaissance" in *Gunpowder: The History of an International Technology* ed. Brenda Buchanan (Bath, 1996). 87-120.

Hall, Bert, "Weapons of War and Late Medieval Cities: Technological Innovation and Tactical Changes" in *Technology and Resource Use in Medieval Europe: Cathedrals, Mills and Mines* ed. Elizabeth Bradford Smith and Michael Wolfe (Aldershot, 1997). 185-208.

Halpin, Andrew, "Archery Material" in *Late and Viking Age Medieval Waterford: Excavations 1986-92* ed. M.F. Hurley, O.M.B. Scully, and S.W.J. McCutcheon (Waterford, 1997). 538-552

Halpin, Andrew, "Military Archery in Medieval Ireland: Archaeology and History", *Military Studies in Medieval Europe – Papers of the 'Medieval Europe Brugge 1997 Conference* 11 (1997). 51-60.

Halpin, Andrew, "Archery and Warfare in Medieval Ireland: A Historical and Archaeological Study" 2 vols. (unpublished Ph.D. Thesis, Trinity College Dublin, 1998).

Hamm, Jim, "Sinew Backing" in *The Traditional Bowyers Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). 1:213-32.

Hamm, Jim, "Tillering" in *The Traditional Bowyers Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). 1:257-86.

Hamm, Jim, "Recurves" in *The Traditional Bowyers Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). 2:167-186.

Hardcastle, Ron, "Cutting and Seasoning Wood" in *The Traditional Bowyer's Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). 1:19-42.

Hardy, Robert, *The Longbow: A Social and Military History*, 3rd ed. (1978, Fort Worth, 1993).

Hardy, Robert, "Longbows" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). 2:589-94.

Hardy, Robert, "Historical Importance and Assessment of the Longbow Assemblage" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). 2:586-89.

Hardy, Robert, J. Levy, P. Pratt, Roy King, S. Stanley, B.W. Kooi, D. Adams, and A. Crowley, "Assessment of the Working Capabilities of the Longbows" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). 2:622-32

Harmuth, Egon, *Die Armbrust* (Graz, 1975).

Harmuth, Egon, "Concerning the One-Foot Crossbow of the High Gothic", *Journal of the Society of Archer-Antiquaries* 28 (1985). 9-12.

Harris, P. Valentine, "From the Longbow to Crossbow and Back", *Journal of the Society of Archer-Antiquaries* 18 (1975). 9-12.

Hildred, Alexzandra, "Scope and Importance of the Assemblage" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). 2:578-579

Hildred Alexzandra, "Archery on Henry VIII's Vessels: Inventory Evidence" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). 2:579-582

Hildred, Alexzandra, "Distribution of the Assemblage" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). 2:583-584.

Hildred, Alexzandra, "Distribution of Archers Based on Associated Artefacts" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). 2:585-586

Hildred, Alexzandra and Roy King, "Horn Nock" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). 2:632-641.

Hildred, Alexzandra, "Longbow Chests" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). 2:641-644.

Hildred, Alexzandra, Keith Watson, Mark Hopkins, Adam Jackson, and John Waller, "Arrows" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). 2:665-677

Hildred, Alexzandra, "Arrow Spacers" in *Weapons of Warre: The Armaments of the Mary*

Rose, ed. Alexandra Hildred, *Archaeology of the Mary Rose 3*, 2 vols. (Portsmouth, 2011). 2:693-697.

Hildred, Alexzandra, and Ann Stirland, "The Identification of Archers from Skeletal Remains" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, *Archaeology of the Mary Rose 3*, 2 vols. (Portsmouth, 2011). 2:703-712.

Holmer, Paul, "The Military Crossbow in Yorkist England", *Journal of the Society of Archer-Antiquaries* 22, (1979). 11-16.

Holts Booth, Annette, "Crossbow Production at the Archbishop's Palace, Trondheim, Norway", *Journal of the Society of Archer-Antiquaries* 39 (1996). 94-100.

Insulander, Ragnar, "The Bow from Stellmoor – The Oldest in the World?", *Journal of the Society of Archer-Antiquaries* 42 (1999). 78-80.

Jones, Peter N., and Derek F. Renn, "The military effectiveness of arrow loops. Some experiments at White Castle", *Château Gaillard* 9-10 (1982). 445-456.

Jones, Peter N., "A Short History of the Attack of Armour", *Metallurgist and Materials Technologist*, 16:5 (1984). p. 247-50.

Jones, Peter N., "The Metallography and Relative Effectiveness of Arrowheads and Armor During the Middle Ages", *Materials Characterization* 29 (1992). 111-117.

Kaegi, Walter Emil, "The Contribution of Archery to the Turkish Conquest of Anatolia", *Speculum* 39:1 (1964). 96-108.

Kaiser, Robert E., "The Medieval English Longbow: Characteristics and Origin", *Journal of the Society of Archer-Antiquaries* 23 (1980). 21-29.

Karchenski, Walter J., "The Nuremburge *Stechzeuge* Armours", *The Journal of the Arms and Armour Society* 9:4 (1993). 181-203.

Karpowicz, Adam, "Ottoman Bows - An Assessment of Draw Weight, Performance and Tactical Use", *Antiquity* 81:313 (2007). 675-685.

Keeble, K. Corey, *European Crossbows in the Royal Ontario Museum*, (Toronto, 2008).

Keen, Maurice, *England in the Later Middle Ages*, (1973, repr. New York, 2000).

Keen, Maurice, "The Changing Scene: Guns, Gunpowder, and Permanent Armies" in *Medieval Warfare* ed. Maurice Keen, (Oxford, 1999). 273-92.

Klopsteg, Paul E., *Turkish Archery and the Composite Bow* (London, 1934).

Knüsel, Christopher, "Activity-Related Skeletal Change" in *Blood Red Roses: The Archaeology of a Mass Grave from the Battle of Towton AD 1461* ed. Veronica Fiorato, Anthea Boylston, and Christopher Knüsel, 2nd ed. (2000, Oxford, 2007).103-118.

Kooi, B.W., "On the Mechanics of Some Replica Bows", *Journal of the Society of*

Archer-Antiquaries 36 (1993). 14-18.

Kooi, B.W., "Functioning of the Ears and Set-Back at the Grip of Asiatic Bows", *Journal of the Society of Archer-Antiquaries* 39 (1996). 73-77.

Kramer, Gerhard, "Das Feuerwerkbuch: its Importance in the Early History of Black Powder" in *Gunpowder: The History of an International Technology* ed. Brenda Buchanan (Bath, 1996). 45-56.

Kruczek, Jan, *Kusze I Ich Twórcy*, (Pszczyna, 2013).

Lanting, J.N., B.W. Kooi, W. A. Casparie and R. van Hinte, "Bows from the Netherlands", *Journal of the Society of Archer-Antiquaries* 42 (1999). 7-10.

Lavin, James, "An Examination of Some Early Documents Regarding the Use of Gunpowder in Spain", *The Journal of the Arms and Armour Society* 4:9 (1964). 163-169.

Massey, Jay, "Why Traditional?" in *The Traditional Bowyers Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). 1:15-18.

McGlynn, Sean, "Myths of Medieval Warfare", *History Today* (January, 1994). 28-34.

McLeod, Wallace, "The Range of the Ancient Bow", *Phoenix* 19:1 (1965). 1-14.

Mitchell, Russ, "Archery versus Mail: Experimental Archaeology and the Value of Historical Context", *Journal of Medieval Military History* 4 (2006). pp. 18-28.

Mitchell, Russell, "The Longbow-Crossbow Shootout at Crecy (1346): Has the 'Rate of Fire Commonplace' Been Overrated?" in *The Hundred Years War (Part II) Different Vistas* ed. L.J. Andrew Villalon and Donald J. Kagay (Leiden, 2008). 233-57.

Morin, Marco, "The Earliest European Firearms" in *A Companion to Medieval Arms and Armour* ed. David Nicolle (Woodbridge, 2002). 55-62.

Morris, J.E., "The Archers at Crecy", *The English Historical Review* 12:47 (1897). 427-436.

Morris, J.E., *The Welsh Wars of Edward I*, (1901, repr. Stroud, 1996).

Musset, Lucien, *The Bayeux Tapestry*, trans. Richard Rex (Woodbridge, 2005).

Nickel, Helmut, "The Mutual Influence of Europe and Asia in the Field of Arms and Armour" in *A Companion to Medieval Arms and Armour* ed. David Nicolle (Cambridge, 2002).107-125.

Oakeshott, R. Ewart, *The Archaeology of Weapons Arms and Armour from Prehistory to the Age of Chivalry*, (1960, repr. London, 1996).

Oman, Charles, *The Art of War in the Middle Ages*, (Oxford, 1885).

Oman, Charles, *A History of the Art of War: The Middle Ages from the Fourth to the*

Fourteenth Century, (London, 1898).

O'Neill Hencken, H., Gwyneth Harrington, H. L. Movius, Jr., A. W. Stelfox and Geraldine Roche, "Ballinderry Crannog No. 1", *Proceedings of the Royal Irish Academy. Section C: Archaeology, Celtic Studies, History, Linguistics, Literature* 43 (1935 – 1937). 103-239.

Pan, Jixing, "The Origin of Rockets in China" in *Gunpowder: The History of an International Technology* ed. Brenda Buchanan (Bath, 1996). 25-32.

Partington, J.R., *A History of Greek Fire and Gunpowder*, (1960, repr. Baltimore, 1999).

Paterson, W.F., "Archers of Islam", *Journal of the Economic and Social History of the Orient* 9 (1966). 69-87.

Paterson, W.F., "'Mary Rose'- a Preliminary Report", *Journal of the Society of Archer-Antiquaries* 23 (1980). 29-34.

Paterson, W.F., "What is a Longbow?", *Journal of the Society of Archer-Antiquaries* 25 (1982). 36

Paterson, W.F., "A 'Mary Rose' Archery Symposium", *Journal of the Society of Archer-Antiquaries* 26 (1983). 49-51.

Paterson, W.F., "'Mary Rose' Archery Enigmas", *Journal of the Society of Archer-Antiquaries* 28 (1985). 7-8.

Paterson, W.F., *A Guide to the Crossbow*, (Oldland, 1990).

Paterson, W.F., "'Mary Rose'- A Second Report", *Journal of the Society of Archer-Antiquaries* 24 (1991). 4-6.

Pauli Jensen, Xenia and Lars Christian Nørbach, *Illerup Adal: Die Bogen, Pfeile und Axte 13* (Aarhus, 2009).

Pauli Jensen, Xenia, "Alliances and Power Structures in Southern Scandinavia during the Roman Iron Age", *Lund Archaeological Review* 17 (2011). 35-47.

Payne-Gallwey, Ralph, *The Crossbow: Its Military and Sporting History, Construction and Use*, (1903, repr. London, 1995).

Peterson, Jon, *Playing At the World: A History of Simulating Wars, People and Fantastic Adventures from Chess to Role Playing Games*, (San Diego, 2012).

Pétrin, Nicole, "Philological notes on the crossbow and related missile weapons", *Greek, Roman and Byzantine studies* 33:3 (1992). 265-291.

Phillips, Gervase, "Longbow and Hackbutt: Weapons Technology and Technology Transfer in Early Modern England", *Technology and Culture* 40:3 (1999). 576-93

Pierce, Ian, "Arms, Armour and Warfare in the Eleventh Century" in *Anglo Norman*

Studies X: Proceedings of the Battle Conference ed. Allen Brown (Woodbridge, 1987). 237-255.

Pierce, Ian, "The Knight, his Arms and Armour c. 1150-1250" in *Anglo Norman Studies XV: The Battle Conference* ed. Marjorie Chibnall (Woodbridge, 1992). 251-274.

Pratt, R.L., and Robert Hardy, "The Arrow found in Westminster Abbey in 1878", *Journal of the Society of Archer-Antiquaries* 18 (1975). 22-4

Prestwich, Michael, "Miles in Armis Strenuus: The Knight at War", *Transactions of the Royal Historical Society Sixth Series*, 5 (1995). 201-220.

Prestwich, Michael *The Three Edwards: War and State in England 1272-1377*, 2nd ed. (1980, New York, 2003).

Prestwich, Michael, *Armies and Warfare in the Middle Ages: The English Experience* (1996, repr. Hong Kong, 2006).

Purton, Peter, *A History of the Early Medieval Siege c.450-1200*, (Woodbridge, 2009).

Purton, Peter, *A History of the Late Medieval Siege 1200-1500*, (Woodbridge, 2010).

Rausing, Gad, *The Bow: Some Notes on Its Origin and Development* (Manchester, 1967).

Reid, William, "The Bowman's Thumb-Ring", *Royal Armouries Yearbook* 6 (2001). 150-161.

Richardson, Thom, "The Introduction of Plate Armour in Medieval Europe", *Royal Armouries Yearbook* 2 (1997). 40-45.

Richardson, Thom, "Ballistic Testing of Historical Weapons", *Royal Armouries Yearbook* 3 (1998). 50-52.

Richardson, Roland Thomas, "The Medieval Inventories of the Tower Armouries 1320-1410" (unpublished Ph.D. Thesis, University of York, 2012).

Richter, Holger, "Two Rare Crossbows in the 'Schwarzburger Zeughaus' Collection", *Journal of the Society of Archer-Antiquaries* 48 (2005). 95-97.

Richter, Holger, *Die Horgenarmbrust*, (Ludwigshafen, 2006).

Riesch, Holger, "Archery in Renaissance Germany", *Journal of the Society of Archer-Antiquaries* 38 (1995). 63-67.

Riesch, Holger, "Yew Exploitation and Long-Bow Trade in the 16th Century", *Journal of the Society of Archer-Antiquaries* 39 (1996). 5-12.

Rimer, Graeme, "Early Handguns", *Royal Armouries Yearbook*, 1 (1996). 73-78.

Smith, Robert D., "The Reconstruction and Firing Trials of a Replica of a 14th-Century Cannon", *Royal Armouries Yearbook*, 4 (1999). 86-94.

- Roesdahl, Else, *The Vikings*, (London, 1991).
- Rogers, Clifford, "The Military Revolutions of the Hundred Years' War", *The Journal of Military History* 57:2 (1993). 241-78.
- Rogers, Clifford, "The Efficacy of the English Longbow: A Reply to Kelly DeVries", *War In History* 5:2 (1998). 233-42.
- Rogers, Clifford, "The Age of the Hundred Years War" in *Medieval Warfare* ed. Maurice Keen, (Oxford, 1999). 136-62
- Rogers, Clifford, "The development of the longbow in late medieval England and 'technological determinism'", *Journal of Medieval History*, 37:3 (2011). 321-341.
- Rogers, R., *Latin Siege Warfare in the Twelfth Century*, (1992, repr. New York, 1997).
- Rohde, Fritz, "Concerning the Construction of the Crossbow in the Late Middle Ages" trans. T.M. Hamilton, *Journal of the Society of Archer-Antiquaries* 19 (1976). 17-20.
- Sensfelder, Jens, "Crossbows in the Hunting & Fishing Museum in Munich", *Journal of the Society of Archer-Antiquaries* 43 (2000). 6-11.
- Sensfelder, Jens, "A Gothic Spanning-Belt Hook", *Journal of the Society of Archer-Antiquaries* 43 (2000). 20-24.
- Sensfelder, Jens, "The 'Naked' Cranequin – An Example of the Artistic and Technical Skill in the 16th Century", *Journal of the Society of Archer-Antiquaries* 48 (2005). 23-27.
- Soar, Hugh, "Wristguards" in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). 2:644-51.
- Stirland, A.J., and T. Waldron "Evidence for Activity Related Markers in the Vertebrae of the Crew of the Mary Rose", *Journal of Archaeological Science* 24 (1997). 329-335.
- Stirland, A.J., *The Men of the Mary Rose Raising the Dead*, 2nd ed. (2000, Sparkford, 2005).
- Stone, John, "Technology, Society, and the Infantry Revolution of the Fourteenth Century", *Journal of Military History* 68:2 (2004). 361-380.
- Strickland, Matthew, and Robert Hardy, *The Great Warbow: From Hastings to the Mary Rose*, (2005, repr. Somerset, 2011).
- Strunk, John, "Yew Longbow" in *The Traditional Bowyer's Bible*, ed. Jim Hamm, 4 vols. (1992, repr. Guilford, 2000). 1:117-130.
- Thorne, P.F., "Clubs and Maces in the Bayeux Tapestry", *History Today* (October, 1982). 48-50.

Tout, T.F., “The Tactics of the Battles of Boroughbridge and Morlaix”, *The English Historical Review* 19:76 (1904). 711-715.

Tout, T.F., “Firearms in England in the Fourteenth Century”, *The English Historical Review* 26:104 (1911). 666-702.

Tylecote, R.F., J.N. Austin, and A.E. Wraith, “The Mechanism of the Bloomery Process in Shaft Furnaces”, *Journal of the Iron and Steel Institute* 209:5 (1971). 342-363.

Veek, Walther, *Der Alamannenfriedhof von Oberflacht*, (Stuttgart, 1924).

Watson, David R., *Iolo's First Book of the Crossbow*, 2nd ed. (1995, Austin, 2009).

Watson, Keith, “Estimating Longbow Weights from the Arrow Shaft Data” in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). 2:617-18.

Watson, Keith, “Statistical Analysis of the Longbow Data” in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). 2:618-22.

Watson, Keith, “Analysis” in *Weapons of Warre: The Armaments of the Mary Rose*, ed. Alexandra Hildred, Archaeology of the Mary Rose 3, 2 vols. (Portsmouth, 2011). 2:677-688.

Webb, Alf, “Those So-Called Bow-Pullers”, *Journal of the Society of Archer-Antiquaries* 36 (1993). 32-33.

Weiss, Daniel, “Portraying the Past, Illuminating the Present: The Art of the Morgan Library Picture Bible” in *The Book of Kings Art, War, and the Morgan Library's Medieval Picture Bible*, ed. William Noel and Daniel Weiss (Baltimore, 2002). 10-35.

Whetham, David, “The English Longbow: A Revolution in Technology?” in *The Hundred Years War (Part II) Different Vistas* ed. L.J. Andrew Villalon and Donald J. Kagay (Leiden, 2008). 213-232.

White, Lynn, “Kyeser's 'Bellifortis': The First Technological Treatise of the Fifteenth Century”, *Technology and Culture* 10:3 (1969). 436-441.

Williams, Alan, “Some Firing Tests with Simulated Fifteenth-Century Handguns”, *The Journal of the Arms and Armour Society* 8:1 (1974). 114-120.

Williams, Alan, “On the Manufacture of Armor in Fifteenth-Century Italy, Illustrated by Six Helmets in the Metropolitan Museum of Art”, *Metropolitan Museum Journal* 13 (1978). 131-142.

Williams, Alan, “Four Helms of the Fourteenth Century Compared”, *The Journal of the Arms and Armour Society* 10:3 (1981). 80-101.

Williams, Alan, “Augsburge Craftsmen and the Metallurgy of Innsbruck Armour”, *The Journal of the Arms and Armour Society*, 9:3 (1993). 121-146.

Williams, Alan, "Milanes Armour and its Metallurgy" in *Military Studies in Medieval Europe Papers of the Medieval Europe Brugge 1997 Conference* ed. Guy de Boe and Frans Verhaeghe, 2 vols. (Zellick, 1997). 2:61-70.

Williams, Alan, "Experiments with 'Medieval Steel' Plates", *The Journal of the Historical Metallurgy Society* 32:2 (1998). 82-86.

Williams, Alan, "The Metallurgy of Medieval Arms and Armour" in *A Companion to Medieval Arms and Armour*, ed. David Nicolle (Woodbridge, 2002). 45-54.

Williams, Alan, *The Knight and the Blast Furnace: a history of the metallurgy of armour in the Middle Ages & the early modern period* (Leiden, 2003).

Wilson, Guy, "Pavises in England", *Royal Armouries Yearbook* 2 (1997). 53-54.

Wylie, W.M., "The Graves of the Alemanni at Oberflacht in Suabia", *Archaeologia* 36 (1855). 129-160.

Zaky, A. Rahman, "Gunpowder and Arab Firearms in Middle Ages", *Gladius* 6 (1967). 45-58.

Zygulski, Z., "Oriental and Levantine Firearms" in *Pollard's History of Firearms* ed. Claude Blair (Feltham, 1983). 425-462.