Roman Imperial Artillery
ROMAN IMPERIAL ARTILLERY

OUTRANGING THE ENEMIES OF THE EMPIRE

Alan Wilkins
The ballista stone-thrower, reconstructed from Vitruvius’ text and Heron’s advice and diagram (Chapter 7). (photograph: Margery Wilkins).
‘...THE MISSILE IS LAUNCHED WITH SUCH FORCE THAT IT REACHES NOT LESS THAN TWICE THE RANGE OF A SHOT FROM A BOW ...’

6th century AD writer Procopius,
War against the Goths i.21.17,

describing the bolt launched from the metal frame arch strut catapult.

Greek torsion catapults, which used the energy stored in tensioned and twisted rope springs, were adopted and developed by the Roman army. They were the most powerful missile-projectors of their time in the western world, and had a considerable influence on events there from their invention in the fourth century BC. As bolt-shooters they are still recorded in use by Byzantine armies in the eleventh century AD. No other weapon launching heavy missiles has dominated western warfare for so long.
This research is dedicated to Margery, Ian and Helen, and to my mentors

Contents

List of Figures .......................................................................................................................... v

Acknowledgements ................................................................................................................. xi
  The First Edition .................................................................................................................. xi
  The Second and Third Editions ............................................................................................ xii
  The author .......................................................................................................................... xv

Preface ................................................................................................................................. xvi
  Archaeological discoveries and recent research ............................................................... xvii

Glossary ................................................................................................................................. xxiii

Weights and measures ......................................................................................................... xxv
  Weights and measures ........................................................................................................ xxv
  Vitruvius’ list of stone shot weights and corresponding spring-hole diameters
    (Based on Marsden 1971, 198-199) .............................................................................. xxv

Chapter 1. Introduction........................................................................................................... 1

Chapter 2. Greek origins ....................................................................................................... 4
  The gastraphetes (‘stomach-bow’): a semi-robotic archer ................................................ 6
  The introduction of the winch and stand ......................................................................... 8
  Torsion-powered artillery ................................................................................................. 11

Chapter 3. The menace of the new weapon ....................................................................... 14
  Sulla’s artillery in sieges: the Pompeii ‘target’ ............................................................... 16
  Caesar’s artillery ............................................................................................................... 19

Chapter 4. The bolt-shooter: accuracy, range and effects ................................................... 22
  Maiden Castle, Dorset ....................................................................................................... 22
  Hod Hill, Dorset. A bolt-shooters’ ‘target’ ................................................................ 24
  The palisaded enclosure and Huts 36a and 37 ............................................................. 26
  Which bolt-shooters were used? ...................................................................................... 26
  Vespasian’s battle plan ................................................................................................... 27
  The evidence of the boltheads ....................................................................................... 30
  Artillery platforms (tribunalia) at Hod Hill ................................................................... 32
  Accuracy ......................................................................................................................... 32
  Range .............................................................................................................................. 33

Chapter 5. Reconstructing the Roman bolt-shooter ............................................................ 38
  Archaeological evidence for the design of the Roman torsion bolt-shooter ............ 41
  The curious case of the Ampurias frame ...................................................................... 41
  The Caminreal iron frame plating ............................................................................... 42
Chapter 6. The new design: the metal frame arch strut cheiroballistra/\mantellustra\null

Eric Marsden’s identification of the machine ................................................................. 72
The transition from scorpion to \mantellustra\null ............................................................ 75
The cheiroballistra’s all-metal spring frame: appraisal of this radically different

design ................................................................................................................................. 76
Increase in power ............................................................................................................... 77
Improved field of view ...................................................................................................... 77
Faster speed of rewind and consequent increased rate of missile launch ................. 78
Elimination of ricocheting bolts ..................................................................................... 79
The new design of bolt, with aerodynamic and horrific wounding properties ... 80
The Cheiroballistra manuscripts ................................................................................... 82
Kanones duo (two boards) i.e. Case and Slider ............................................................. 82
Kleisis (trigger mechanism) ............................................................................................. 86
Kambestria (Field-frames) ............................................................................................... 87
Pittaria (Pi-brackets) ....................................................................................................... 88
The Field-frame Rings ..................................................................................................... 90
Kamarion (Arch) .............................................................................................................. 92
Klimakion (Ladder) ......................................................................................................... 94
Kulindrooi chalkoi (bronze Cylinders/Washers) and Kanonia (Bars) ......................... 96
Koneoeide duo (two cone-shaped parts) i.e. Arms ......................................................... 97
Missing parts ...................................................................................................................... 99
Ease of dismantling and repair ...................................................................................... 101
Winch and stand. Double ratchet handles .................................................................... 102
Tactical positioning of the *manuballista* ................................................................. 105
The protective metal spring-frame covers .............................................................. 106
The arm ‘sleeves’ .................................................................................................... 108
Did the arch strut design have inward swinging arms? The evidence of Trajan’s Column ............................................................................................................. 110

**Chapter 7. Deciphering the manuscripts: Vitruvius’ ballista** ......................... 113
The two half-spring frames .................................................................................... 115
The washers ........................................................................................................... 117
The framework holding the half-springs and the ‘inward-swinging arms’ theory ................................................................................................................ 117
The Ladder and the Table .................................................................................... 122
The trigger ............................................................................................................. 122
Bowstring problems .............................................................................................. 122
‘Building the Impossible’: the BBC *ballista* ...................................................... 125
The arms ............................................................................................................... 127
The stand and the angle of elevation .................................................................... 127

**Chapter 8. The stone missiles: range and effects** ............................................ 129
A *ballista* and sling ‘target’ on the Rhine frontier ............................................. 131

**Chapter 9. Masada AD 73-74** ........................................................................ 133

**Chapter 10. Qasr Ibrim: artillery in defence. Inscribed stone shot** ............... 136

**Chapter 11. Artillery in action in the field: Arrian’s battle plan** ...................... 145

**Chapter 12. Burnswark Roman camps and native hillfort, Dumfriesshire** ...... 147
Evidence for the abandonment of British hillforts .............................................. 151
The dating of the site’s features and evidence from the Nicholson and Reid excavations ........................................................................................................ 153
The missile bombardment .................................................................................... 158
The collapse/demolition of the hillfort’s rampart .............................................. 163
Occupation of the hillfort after the collapse/demolition of the ramparts .......... 164
Discoveries of sling bullets outside the South Camp ........................................ 164
Evidence suggesting that the camps were intended for repeated use .......... 165
The date(s) of the missile launchings ................................................................. 166
The Three Brethren as artillery platforms ........................................................... 166
Training in missile attack and in rapid assault under covering fire ................ 169
Covering fire ........................................................................................................ 170
Interpreting the missile bombardment .............................................................. 171
To summarise ...................................................................................................... 172
High Rochester *ballistaria*, Northumberland .................................................. 176

**Chapter 13. The last stone-throwers** ............................................................... 178
The one-arm catapult ............................................................................................ 178
The traction trebuchet ......................................................................................... 181
Chapter 14. The Hatra stone-thrower and the inward-swinging arms theory ................................................................. 183
  The Hatra catapult, the Vitruvian *ballista*’s successor? ......................................................................................... 184
  The inward-swinging arms theory ......................................................................................................................... 189
  The Morgan-Feeley Hatra quarter scale models as inward and outward swinging ......................................................... 192

Chapter 15. Survival .................................................................................................................................................. 197

Chapter 16. The Roman achievement ...................................................................................................................... 198

Chapter 17. Future search and research .................................................................................................................. 200

Appendix 1. The Roman origin of the mediaeval revolving-nut crossbow release ................................................................. 202

Appendix 2. Review of 2021 TV film on Burnswark Hill, *Massacre on Hadrian’s Wall* ......................................................... 205
  A programme for the American Smithsonian Channel and Channel Five in Britain ...................................................... 205

Sources and references to artillery ......................................................................................................................... 210
  Accounts of Roman artillery in action ..................................................................................................................... 211
  Select bibliography .................................................................................................................................................. 211
  Museums and sites .................................................................................................................................................... 216
    Museums ............................................................................................................................................................... 216
    Sites in Britain .................................................................................................................................................... 219
  Websites and TV programmes .............................................................................................................................. 220
  Where the reconstructed catapults described in this book can be seen ........................................................................ 221
List of Figures

Len Morgan, the author and Tom Feeley ................................................................. xiii
The dramatic display of the Xanten-Wardt and manuballista bolt-shooters at the Carvoran Roman Army Museum was opened by Tom’s widow Marian on February 6, 2017 (photograph: Margery Wilkins) ................................................................. xiv
Welcoming the delivery of the giant ballista and onager at Comlongon Castle........ xiv
The BBC one-talent ballista team (page 125) is dwarfed by the vast timbers (photograph: Margery Wilkins) ............................................................... xv
Figure 1 - Technical tests at Piddington Roman villa site .................................... xvi
Figure 2 - The combined crank handle and handspike from Elenovo, Bulgaria .... xx
Figure 3 - A line of ballista balls and the first complete scorpio bolt from the old bed of the Rhine at De Meern, in the Netherlands (Diagram and CT scan: Erik Graafstal)......... xxi
Figure 4 - The spring frame and arms of a reconstructed Xanten-Wardt scorpion bolt-shooter ............................................................................................... xxiv
Figure 5 - The author’s version of Dionysius of Alexandria’s polybolos ............ 2
Figure 6 - Schramm’s fine reconstruction of the polybolos (photo: Dietwulf Baatz) 3
Figure 7 - Scythian archer. Composite bows ...................................................... 5
Figure 8 - The stomach bow ............................................................................. 6
Figure 9 - Testing a gastraphetes ..................................................................... 7
Figure 10 - Codex P drawing of a gastraphetes (photograph: Wikipedia commons) 6
Figure 11 - Catapult winches ........................................................................ 8
Figure 12 - Marsden’s three-span torsion bolt-shooter (Photograph: Eric Marsden) 10
Figure 13 - The giant BBC ballista, the one talent stone-thrower created for the BBC programme ‘Building the Impossible’. ........................................ 13
Figure 14 - Carthage stone shot ..................................................................... 15
Figure 15 - Sulla’s artillery: the Pompeii ‘target’ (Mike Burns. From JRMES 14/15, 1-10) 17
Figure 16 - Sulla’s artillery ............................................................................. 18
Figure 17 - Alésia ............................................................................................ 20
Figure 18 - Missiles from Caesar’s siege found at Alésia (Mont Auxois in central France) ................................................................. 21
Figure 19 – Boltheads and sling bullets ............................................................ 21
Figure 20 - Artillery victim at Maiden Castle .................................................. 22
Figure 21 - Marsden’s three-span at Maiden Castle: a television first .......... 24
Figure 22 - Plan of boltheads targeting the chieftain’s huts and enclosure ...... 25
Figure 23 - Filming at Hod Hill for Channel 5, June 2012 ............................. 27
Figure 24 - Vespasian’s possible plan of attack – crossing the ditches ......... 29
Figure 25 - Reconstruction of an Iron Age hut ............................................... 29
Figure 26 - Vespasian’s plan of attack ............................................................. 30
Figure 27 - Scorpion and Hod Hill missiles .................................................... 31
Figure 28 - Close range impact with the Polybolos (photograph: the author) .... 33
Figure 29 - Bolt leaving a Xanten-Wardt scorpion .............................................................. 36
Figure 30 - Schramm demonstrating his ballista to the Kaiser (photograph: Saalburg Museum) ........................................................................................................................................... 39
Figure 31 - The Ampurias frame as published ...................................................................... 41
Figure 32 - The corrected Ampurias display ........................................................................ 42
Figure 33 - The Caminreal (Teruel) iron frame reconstructed ........................................... 43
Figure 34 - Catapult washers (diagrams after Dietwulf Baatz. Washer photograph: the author) ........................................................................................................................................... 44
Figure 35 - Vedennius’ scorpio and the Xanten-Wardt reconstruction .................................. 46
Figure 36 - Xanten-Wardt frame .......................................................................................... 46
Figure 37 - Xanten-Wardt missing parts (photographs: Maarten Dolmans) ....................... 48
Figure 38 - Operating Xanten-Wardt scorpions ................................................................. 50
Figure 39 - The Xanten-Wardt Report’s box support (after Schalles 2010, 175 Figure 5) ........................................................................................................................................... 50
Figure 40 - Reconstruction of the Xanten-Wardt scorpion .................................................. 51
Figure 41 - Carlisle catapult find .......................................................................................... 52
Figure 42 - Frame wedge system on a scorpio maior .......................................................... 55
Figure 43 - Scorpion case, slider and winch (photographs: the author) ............................... 57
Figure 44 - Catapult on the Altar of Zeus, Pergamon. Scorpion curved arms (photograph: Margery Wilkins) ......................................................................................................................... 58
Figure 45 - The Cremona battle-shield ................................................................................ 59
Figure 46 - Scorpion stand ................................................................................................... 60
Figure 47 - The complete number 211 bolt as conserved ................................................... 61
Figure 48 - Bolt 211 (top): narrow glue or paint bands at the rear end. Bolt 416 (bottom) with incomplete shaft ................................................................................................................................. 61
Figure 49 - Two scorpion reconstructions .......................................................................... 62
Figure 50 - Qasr Ibrim foreshaft and bolthead ....................................................................... 63
Figure 51 - Bolt damage to lorica segmentata ..................................................................... 64
Figure 52 - Bolt strike on chainmail and helmet .................................................................... 64
Figure 53 - Artillery boltheadsim ........................................................................................ 66
Figure 54 - William Newton’s version of the rope tensioning frame described by Vitruvius and Heron ......................................................................................................................... 68
Figure 55 - Catapult scene on Trajan’s Column, Rome (cast in the Victoria and Albert Museum, London) ................................................................................................................................. 69
Figure 56 - Victor Prou’s cheiroballistra (from Prou 1877 Figures 47 and 16) .................... 71
Figure 57 - Trajan’s Column catapults ................................................................................... 71
Figure 58 - Eric Marsden’s cheiroballistra .......................................................................... 72
Figure 59 - Two carroballistae on Trajan’s Column ............................................................ 73
Figure 60 - The author’s first interpretation of the Cheiroballistra manuscript, built in 1991 ......................................................................................................................................................... 74
Figure 61 - Aiming the three-span scorpio and the cheiroballistra (photographs: the author and Margery Wilkins) ......................................................................................................................... 78
Figure 62 - Misfire (still frame from video: the author) ........................................................ 79
Figure 63 - Dura Europos bolt replica ................................................................. 80
Figure 64 - The horrific strike effect of this bolt on ballistic gel simulating human or animal flesh ................................................................. 81
Figure 65 - Slow-motion film of a cheiroballistra bolt penetrating a large melon ....... 82
Figure 66a - The Cheiroballistra manuscript ....................................................... 83
Figure 66b - The Cheiroballistra manuscript ....................................................... 84
Figure 67 - Operating the cheiroballistra ................................................................ 85
Figure 68 - Cheiroballistra trigger mechanism .................................................... 86
Figure 69 - Field-frame replicas and Gornea example ........................................... 87
Figure 70 - Codex M’s Field-frames and Heron’s ballista diagram ....................... 88
Figure 71 - Junction of the Ladder tenons and the Field-frames (models and photographs: the author) ................................................................. 89
Figure 72 – Lyon and Orșova Field-frames ......................................................... 91
Figure 73 - The Elenovo Kambestrian (photographs: Kayumov and Minchev) ........ 91
Figure 74 - Kambestria from Elenovo and Sala (Morocco) .............................. 92
Figure 75 - Orșova iron Arch strut (photograph: Dietwulf Baatz) .............. 93
Figure 76 - The Cheiroballistra Arch .................................................................. 93
Figure 77 - Codex P Arch and Ladder diagram .................................................. 94
Figure 78 - Reconstruction of the main frame. The Ladder ................................ 95
Figure 79 - Codices M and V diagrams of the Arms (diagrams after Wescher) .... 98
Figure 80 - The Elenovo arm (photograph: Kayumov and Minchev) .............. 98
Figure 81 - Tom Feeley’s version of the alternative wood encased Arms (photograph: Tom Feeley) ................................................................. 99
Figure 82 - The position of the Ladder on the Field-frames. See text below (photograph: the author) ................................................................. 99
Figure 83 - Left hand end of the reconstructed cheiroballistra ........................... 101
Figure 84 - The author’s version of the cheiroballistra frame parts ................... 102
Figure 85 - The Cupid Gem .............................................................................. 103
Figure 86 - Reconstruction of the cheiroballistra .............................................. 103
Figure 87 - The Elenovo crank handle and handspike (illustration from Kayumov and Minchev 2010) ................................................................. 104
Figure 88 - Reconstruction of the Elenovo crank handle-handspike (photographs: Tom Feeley) ................................................................. 105
Figure 89 - Trajan’s Column: ballista on cart (photograph of the Column: the author) .... 106
Figure 90 - The Lyon size of arch strut catapult: Tom Feeley’s version ............. 107
Figure 91 - Adding extra torsion to Len Morgan’s Lyon size catapult (photograph: Margery Wilkins) ................................................................. 107
Figure 92 - The Arm ‘sleeves’ .......................................................................... 108
Figure 93 - Two reconstructions of the cheiroballistra (photographs: the author) .... 109
Figure 94 - Tom Feeley’s framework. Impact of bolt on lorica segmentata ........ 109
Figure 95 - Penetration tests of bolts (photographs: the author) ...................... 110
Figure 96 - Trajan’s Column: projections on the outside of the field-frame covers (photographs: the author) ................................................................. 111
Figure 97 - Trajan’s Column: forward projecting beams – the sliders ........................................ 112
Figure 98 - Len Morgan’s two *ballista* reconstructions .......................................................... 113
Figure 99 - *Ballista* half spring-frame ..................................................................................... 116
Figure 100 - Heron’s rhombus diagram ...................................................................................... 116
Figure 101 - Vitruvius’ plated washers ....................................................................................... 117
Figure 102 - Heron’s *ballista* diagram ...................................................................................... 118
Figure 103 - *Ballista* model made for Eric Marsden (photograph: the author) ...................... 119
Figure 104 - Crossbeams .......................................................................................................... 119
Figure 105 - Diagram of the *ballista* framework ...................................................................... 120
Figure 106 - The crossbars and the table .................................................................................... 122
Figure 107 - The author’s model *ballista* ................................................................................ 123
Figure 108 - Trigger and mounting plate .................................................................................... 124
Figure 109 - The bowstring belt .................................................................................................. 124
Figure 110 - Cross-section of table, ladder and slider ............................................................... 125
Figure 111 - The BBC one talent Vitruvian *ballista* (photograph: the author) ...................... 126
Figure 112 - The Morgan-Wilkins two *librae* catapult in action ............................................ 128
Figure 113 - Cutting a one talent stone ball ............................................................................... 129
Figure 114 - Philon’s defence against the one talent *ballista* .................................................... 131
Figure 115 - *Ballista* stones and sling shot in a long line on the former river bed close to the De Meern fort .............................................................................................................. 131
Figure 116 - Stone missiles at the Masada Exhibition (photograph: Eric Marsden) ................. 133
Figure 117 - Qasr Ibrim before the Aswan Dam ........................................................................ 136
Figure 118 - Map of the Nile. Airphoto of the site .................................................................... 138
Figure 119 - *Ballista* balls in South Rampart Street (photograph: McDonald Institute Cambridge) ..................................................................................................................................... 138
Figure 120 - Ink writing on *ballista* balls .................................................................................. 139
Figure 121 - Hans Barnard’s size analysis. The seven British Museum balls ......................... 140
Figure 122 - Clusters of *ballista* balls on the West Rampart .................................................. 141
Figure 123 - The Kandaxe ball and Message for Hitler on a WW2 shell .................................... 142
Figure 124 - Qasr Ibrim tanged boltheads. ................................................................................ 143
Figure 125 - Burnswark Hill from the SE, from close to the Eaglesfield crossing of the M74 (photograph: the author) ........................................................................................................ 147
Figure 126 - Burnswark hillfort and the Roman South Camp (Reproduced with the permission of Cambridge University Collection of Aerial Photography © Copyright reserved.) .................................................................................................................................. 147
Figure 127 - Burnswark hillfort and Roman camps, Dumfries and Galloway (from Jobey 1977-8 Figure 1) ................................................................................................................................. 149
Figure 128 - The Roman camps and hillfort from the north east (photograph: © Crown Copyright: HES) ........................................................................................................................................... 150
Figure 129. *Ballista* ball from the 2015 excavation Trench 2 ..................................................... 152
Figure 130 - The 2016 Trench 4 cut into the back of the South Camp’s north west rampart (photograph: Andrew Nicholson) .................................................................................................................... 154
Figure 131 - The southern Roman camp, Burnswark, looking south (photograph: © Crown Copyright: HES) ................................................................. 156
Figure 132 - Burnswark sling bullets, arrowheads and a Trajan’s Column stone thrower and slinger ......................................................................................................................................................... 157
Figure 133 - Burnswark missiles (photograph: John Reid) ...................................................................................................................................................... 158
Figure 134 - The Three Brethren and the 2016 trenches behind the rampart .............. 159
Figure 135 - Groups of lead sling bullets found in Trench 5 of the 2016 excavations and in the North Camp .................................................................................................................................................. 160
Figure 136 - Excavation trenches 1-5 and the distribution of lead signals from 2013 to 2017 .................................................................................................................................................... 161
Figure 137 - Carol van Driel-Murray at the centre one of the Three Brethren catapult mounds ........................................................................................................................................................................ 162
Figure 138 - Carol standing in the South Camp’s deep recut ditch west of the centre gateway .......................................................................................................................................................... 162
Figure 139. The 2015 excavations on Burnswark Hill ...................................................................................................................................................... 163
Figure 140 - Trajan’s Column Scene LXVI. An arch strut bolt-shooter on a log emplacement ....................................................................................................................................................... 167
Figure 141 - ‘Troops’ passing through the centre gateway, thirteen abreast. (photograph: John Reid) ................................................................................................................................. 169
Figure 142 - The BBC one talent ballista launching the final ball (photograph: Margery Wilkins) .......................................................................................................................................................... 170
Figure 143 - A two librae Vitruvian ballista being assembled by a team of legionaries (photograph: the Roman Military Research Society) .................................................................................................................................................. 175
Figure 144. High Rochester ballistaria inscription (after Richmond) ..................................................................................................................................................................................... 176
Figure 145 - Ms diagram of a one-arm stone-thrower on a siege tower ................................ 178
Figure 146 - Two modern reconstructions of the onager .......................................................................................................................................................................................... 180
Figure 147 - The Morgan-Wilkins onager ........................................................................ 181
Figure 148 - The Traction trebuchet (Wikipedia Commons) ............................................ 182
Figure 149 - Excavation photo of the Hatra catapult (photograph: W.I. Al-Salihi, Directorate-General of Antiquities, Baghdad.) ......................................................................................................................... 183
Figure 150 - Mosul Museum’s strange reconstruction of the Hatra catapult (photograph: Mary Desbruslais) .......................................................................................................................................................... 185
Figure 151 - Baatz’s diagram of the Hatra frame ................................................................ 186
Figure 152 - The author’s suggested spring-frame design of the Hatra catapult. The bronze washers. (photographs: Dieuwulf Baatz) ............................................................................................................. 187
Figure 153 - The Morgan-Wilkins outward swinging Hatra catapult .................................. 188
Figure 154 - Martin McAree’s graphs of the relative performances of inswinger and outswinger ..................................................................................................................................................... 191
Figure 155 - Mike Lewis’ models ..................................................................................... 192
Figure 156 - Hatra inswinging designs: (left) Aitor Iriarte’s two versions of the Hatra catapult. (right) Mike Lewis’ inswinging cheiroballista ........................................................................................................................................ 192
Figure 157 - Tom Feeley’s quarter-scale inward swinging Hatra catapult .......................... 193
Figure 158 - Tom Feeley's inswinging version in three positions (photographs: Mark Hatch) ......................................................................................................................... 194
Figure 159 - A battery of twelve bolt-shooting and one stone-throwing catapults, June 2013 .................................................................................................................................. 195
Figure 160 - The fragmentary Roman hunting relief from St Marcel .................. 202
Figure 161 - The Solignac hunting relief ................................................................. 203
Acknowledgements

The First Edition

The untimely death of Dr Eric Marsden in his late forties robbed the world of Greek and Roman studies of a brilliant mind. I have tried to keep up the momentum of his research, attempting fresh reconstructions based firmly on the manuscript evidence and archaeological finds. All those working in this field owe an immense debt to Marsden and to a long line of scholars and enthusiasts, outstanding among whom were the experimental archaeologist Erwin Schramm, and the text editor Carle Wescher. Professor Dr Dietwulf Baatz has long maintained an eagle-eyed watch on the discoveries of catapult parts, publishing them with exemplary clarity. I am very grateful to him for advice and for allowing me to reproduce some of his drawings and photographs. It is a great delight to acknowledge the considerable help and constant encouragement of Mrs Margaret Marsden and of Dr John Marsden, Eric’s son. I have benefited from correspondence or conversations with many people, notably Don Acklam, Lindsay Allason-Jones, the late John Anstee, Caroline Baillie, Hans Barnard, Mike Bishop, Duncan Campbell, Tom Feeley, Rex Harpham, Mark Hassall, Aitor Iriarte, Simon James, Lawrence Keppie, Carole Kirsopp, Gordon Macdonald, Christos Makrypoulias, Steve Ralphs, Pam Rose, David Sim, Digby Stevenson, and Carol van Driel Murray. The credit for undertaking the daunting challenge of building the one-talent ballista goes to producers Helen Thomas, George Williams and their BBC colleagues. I am grateful to Adam Hart-Davis and producer Martin Mortimore for challenging me to reconstruct Dionysius’ repeating bolt-shooter. My colleagues in the Roman Military Research Society and Paul and Christine Jones have helped with the field tests. Permission to use illustrations has been given by The Society of Antiquaries of London, Cambridge University Library of Air Photographs, Simon James, Len Morgan, Tom Feeley, the Ermine Street Guard, Dumfries Museum, Saalburg Museum, Staatliche Museum of Berlin. The Victoria and Albert Museum, London kindly allowed photography of the casts of Trajan’s Column. The staff of the British Museum were extremely helpful in allowing photography and weighing of the Qasr Ibrim stone shot.

It will be obvious that I owe a large and continuing debt to Len Morgan for realising my ideas so brilliantly. The superb quality of his reconstructions of the scorpio and cheiroballistra can be seen in the following pages and at the displays of the Roman Military Research Society. Sir Ian Richmond started my interest in the subject with the loan of Schneider’s book on Schramm’s reconstructions.
The Second and Third Editions

Several of the above have continued to contribute very valuable help or advice, most notably my engineer friends and collaborators Len Morgan and Tom Feeley, whose catapult construction has proceeded apace. I continue to owe an enormous debt to them. Unlike the general technicians who in the past built machines for previous researchers such as de Reffye, Dufour, Schramm and Marsden, Len and Tom already had an extensive knowledge of Roman technology and long experience of reconstructing Roman arms and armour before they linked into my research. Len has that special skill as a pattern-maker, and his superb replicas and reconstructions of armour and weapons are found in museums and displays all over the Roman Empire.

Very sadly, Tom died of cancer on 30 November 2015. The photographs of the machines which he made in conjunction with Len Morgan, confirm the staggering quality of his metalwork in particular. After a long and distinguished career in the oil industry, he had devoted many years to a study of the equipment of the Roman army, reproducing armour, weapons, furniture and so on with the highest skill and authenticity.

Len Morgan and I met in 1993, and displayed our first reconstruction of the *cheiroballistra* in 1995 at Leiden University. Over subsequent years we worked on the Vitruvian bolt-shooter and stone-thrower, based on my revised editions of Vitruvius’ text, the Spanish frames and the Cremona shield. In 2004 Tom joined our programme of catapult reconstructions. His tremendous drive, enthusiasm and determination to work through difficult challenges enabled him to solve numerous problems, such as how to create the ‘cans’ covering the spring frames of the *cheiroballistra*, including their projecting ‘sleeves’ (Figure 92), the soldering technique required to create the decorative edging of the Xanten-Wardt catapult’s bronze plates (Figure 40), and how to construct the eight-sided housing of the Elenovo crank-handles (Figures 2 and 88). He was the first person to solve the latter problem, with Len’s help, mounting a pair of these crank handles on the winch of his *carroballista* size arch strut catapult, and drawing important conclusions about how this design of handle speeded up loading time and therefore the rate of missile launch.

David Breeze continues to give me much valued support and is responsible for this Third Edition being published by Archaeopress. Our son Ian has always maintained a fine computer set up for me and has given vital help in preparing this edition for the publisher. My wife Margery has shown endless patience in allowing me to give priority to the Roman world, rather than to that of twenty-first century house maintenance. This book is for her and would never have happened without her support.
I recall with gratitude Karen Carruthers and Janet Watson’s early help in translating Baatz’s technical German. I also owe thanks to Mark Hatch and my colleagues in the Roman Military Research Society, Richard Abdy, Andrew and Barbara Birley, Hans Barnard, Mike Bishop, Dot Boughton, Salvador Busquets, The Dorset County Museum, Duncan Campbell, Mary Desbruslais, Maarten Dolmans, Carol van Driel-Murray, the Elder family, the Ermine Street Guard, Roy Friendship-Taylor, Adam Hart-Davis, Erik Graafstal, Maureen Guirdham, Bill Hanson, Rebecca Jones, Ildar Kayumov and Alexander Minchev, Ralph Jackson, Kay Kingstone, Carolina Rangel de Lima, Martin McAree, the Marsden family, Andrew Nicholson, Tim Padley, Graham Piddock, John Reid, Lucy Romeril, Pamela Rose, David Sim, John Smith and Marcus Brittain, Digby Stevenson, David Thomson and Teresa Church, Derek Welsby, Alexander Zimmerman and Jo Kempkens.

*Len Morgan, the author and Tom Feeley*

Our many years of friendship and enthusiastic cooperation are responsible for the catapult reconstructions recorded in this book. Tom left his Xanten-Wardt and *manuballista* boltshooters to the Carvoran Roman Army Museum on Hadrian’s Wall.
The dramatic display of the Xanten-Wardt and manuballista bolt-shooters at the Carvoran Roman Army Museum was opened by Tom’s widow Marian on February 6, 2017 (photograph: Margery Wilkins)

Welcoming the delivery of the giant ballista and onager at Comlongon Castle. The future custodians of our artillery, Teresa Church and Professor David Thomson, accepting delivery of the components of the ballista and the onager.
The author

Alan Wilkins studied Classics at Lancaster Royal Grammar School and read the subject at Emmanuel College, Cambridge, specialising in ancient history and archaeology under Professors Jocelyn Toynbee and A. G. Woodhead. He spent several years excavating on Roman military and civilian sites in Britain, and was a field assistant to Sir Ian Richmond for 17 years. He lectured on Greek and Roman Civilisation for Liverpool University’s Extra-Mural Department, and was one of the pioneers of the JACT evidence-based teaching of Greek and Roman history. After 30 years teaching Classics at Woodbridge School, Merchant Taylors School, Crosby and Annan Academy, he turned to the subject of Greek and Roman artillery, following the tragic early death of his friend Dr Eric Marsden. He has attempted to maintain the momentum of Eric’s research into the subject. He is a Fellow of the Society of Antiquaries of London.
This Third Edition has been extensively revised and updated, with more illustrations and new sections on the exciting finds of the first complete catapult shaft and bolthead and a line of ballista balls from the old bed of the Rhine at Utrecht (Figure 3), the film of the horrific wounding properties of a cheiroballistra bolt shot into ballistic gel Figure 64), and the two reliefs in France of Roman hunting crossbows which prove that they are the ancestors of mediaeval crossbows (Figures 160 and 161). I have completely rewritten the section on the Burnswark camps, offering decisive arguments for the site as the only known Roman army practice area.

The second edition covered the latest discoveries, the author’s revised editions of the texts of the Greek and Roman engineers, and full-size reconstructions of the bolt-shooting and stone-throwing catapults. Nearly all of the latter have been produced in collaboration with engineers Len Morgan and Tom Feeley, and are based firmly on the ancient texts, the archaeological finds, and evidence from Roman relief sculpture.

After tracing the Greek origins of torsion-powered catapults, this book describes the machines used from the time of Sulla and Caesar onwards, their dominance in the warfare of the western world for over a thousand years, and their importance in the history of technology. The exciting find of a nearly complete catapult frame at Xanten-Wardt in Germany allows the Roman army’s bolt-shooter to be reconstructed with a very high degree of accuracy. This type is identified as the one used extensively in the invasion of Britain; as a result, a modified scenario is suggested for Vespasian’s attack on the hill fort of Hod Hill, Dorset.

The author’s 2007 revised edition of the Latin text of Vitruvius’ description of the stone-throwing ballista replaces the 1917 unsatisfactory and misleading version. From it Len Morgan has built two impressive full-size ballistae which have proved successful in action. From Egypt a vivid picture has emerged of a small garrison of legionaries, isolated in enemy territory down the Nile, toiling to cut stone ammunition for these machines. The unique ink inscriptions on several of the stone balls tell the story of the rivalry between five centurions. At the siege of Masada in Israel large stone-throwers were a key part of the attack on the Jewish resistance fighters in Herod’s spectacular fortress, bringing the war against the Jews to an end.

The only surviving Roman battle plan by a Roman general, Arrian, shows how artillery was deployed in the field to halt an attack in Cappadocia (East Turkey) by a large force of the feared Sarmatian mounted spearmen. The technique was to put down such an ‘indescribable volume of missiles’ from the catapults, in combination with archers, slingers and spearmen, that the charging Sarmatians would never reach the legionary infantry line.
Technical tests, conducted in cooperation with David Sim, demonstrate the penetration power of bolt-shooters. The range and accuracy achieved by Roman catapults is discussed. All of this accounts for the superiority of torsion catapults over conventional weapons, and their ability to ward off most threats to the peace of the Roman world.

To attempt to settle the controversy as to whether the catapults with wide frames had inward swinging arms, my two colleagues constructed quarter-scale models of the Hatra catapult, one as an inswinger, the other as a conventional outswinger. The fascinating results of shooting and other technical tests are given towards the end of the book.

Archaeological discoveries and recent research

Major archaeological discoveries and many developments in research on Roman artillery have been made since the Shire publication of my *Roman Artillery* in 2003.

The most important new information is the detailed publication in 2010 of the nearly complete main frame of a bolt-shooting catapult of the mid first century AD, found at Xanten-Wardt in north west Germany. This exciting find has added enormously to our understanding of these machines, because not only have the metal plating and washers survived, but for the first time the wood of a catapult frame and the front end of the wooden case and slider have been preserved. This means that it is no longer necessary to estimate the possible details of this standard Roman bolt-shooting catapult. German and Dutch experts responsible for conserving and reconstructing the frame kindly sent a full set of one-to-one plans to enable my highly skilled engineer colleagues Len Morgan and Tom Feeley to make millimetre-accurate copies. I have prepared one of these for the British Museum’s 2024 Exhibition *Legion: Life in the Roman Army*.

From this discovery we have been able to confirm that two pieces of iron-bound ash, found in a Roman workshop during the Carlisle Millenium Excavations, are parts under construction for the same size and type of bolt-shooter as the Xanten-Wardt. This is the first hard evidence that standardised catapult plans were distributed to Roman army workshops throughout the Empire. The Carlisle objects are also the first parts of the framework of a catapult to be identified in Britain.

The fact that the rope springs of the Xanten-Wardt *scorpio* have the same height as those of the *cheiroballistra*, and have the same spring diameter, 45mm, as Eric Marsden’s corrected reading for the *Cheiroballistra* manuscript, producing a spring volume of 0.42litre, suggests that the designers of the *cheiroballistra* adopted the Xanten-Wardt springs, and throws further doubt on Aitor Iriarte’s non-winched version with 25.6mm diameter springs and a 0.13 litre spring volume.
During investigations into the sizes of catapult boltheads found on sites like Hod Hill and Vindolanda, I have found that the majority have an internal socket diameter of 10 – 12mm. This size is too small for a three-span, but exactly right for the Xanten-Wardt bolt-shooter, suggesting that this highly portable version was a very common field machine, probably producing a very effective battlefield performance from an economical amount of sinew rope. The Xanten-Wardt appears to be the Lee-Enfield or Mauser of its day.

Pamela Rose, Hans Barnard and I have published a detailed account of the brief Roman military occupation of Qasr Ibrim on the Nile, described by Strabo. Pamela Rose has described the excavations of the defences and pinpointed the positions of caches of ballista balls. The many hundreds of them surviving from excavations on the site have been weighed and analysed in great detail in a tour de force by Hans Barnard, the first large cache of Roman artillery balls of Imperial date to be fully published at the time. My decipherment of the unique ink inscriptions on 38 of the balls has shown that the garrison was under the command of five centurions, four of whom had assumed the famous names Pompey, Julius, Antony and Octavius. The inscriptions and the differing weights of the stone shot allow estimates of the sizes of stone-throwing ballistae used and other technical details of the machines.

The Proceedings of the VII Roman Military Equipment Conference, Zagreb contains the important report by Ildar Kayumov and Alexander Minchev on the military equipment ploughed up in 1962 in Southern Bulgaria. Three iron items are related to artillery, a kambestrion field-frame, a crank handle-handspike and a possible arm.

My 2007 edition of the Latin text by Vitruvius describing the stone-throwing ballista is the first radically revised edition to appear since the unsatisfactory and misleading version by Schramm and Diels in 1917. It confirms Eric Marsden's discovery that Schramm included 'a number of items that would seem never to have been in Vitruvius’ original', and disproves a recent claim that the Latin text is ‘badly mutilated’ and an invalid source for understanding the machine. My large model is based on this revised edition and the descriptions of Philon and Heron. Len Morgan has used it to construct two magnificent full-size versions of a two librae ballista.

The late Tom Feeley produced not only the first reconstruction of the protective covers on the arch strut catapults depicted on all the Trajan’s Column machines, but also, along with Len Morgan, the first reconstruction of the Lyon size of arch strut bolt-shooter, which was probably the size used as carroballistae. All Tom and Len’s carroballistae need are a cart and two mules!

We have collaborated with David Sim in live-firing field tests to calculate the actual penetration power and damage effects of Roman bolt-shooting catapults. The results have already modified some claims by writers on this subject.
David Sim has made the exciting discovery that the Roman army was using rolled iron plates of uniform thickness (variation of no more than 0.1mm), possibly importing them from India. I believe that there is a further possibility that the technique or even the supply of rolled plates actually originated from China along the Silk Road. These plates were used to produce the boltheads for catapults (Sim 1995, 1-3), and possibly for the plating on catapult frames. The first rolling mills are customarily stated to have appeared in Europe during the 18th century.

The arguments for the existence of catapults with inswinging arms have tended to become a theoretical exercise in vacuo, losing sight of the artillerymen’s battlefield priorities. Of course, when it is proposed that inswinging arms would have an arm arc of 100+° for the arch strut bolt-shooters, as opposed to the 70° of an outswinging version, the conclusion does indeed appear to be obvious, a ‘no brainer’ – inswingers should produce more power, which is, after all, the aim of catapult construction as defined by Philon and Heron. Practical tests are one valid approach, and Len Morgan and Tom Feeley completed quarter scale versions of two opposing interpretations of the Hatra catapult, as an inswinger and outswinger. The results, incorporating graphs of technical analysis, are described in Chapter 14.
Even before these tests, I pointed out that the additional time taken to wind back the inswinging arms through the extra 30° or so would have markedly reduced the rate of missile launch: no Roman artilleryman faced with a rapidly approaching enemy would thank you for that. Hadrian himself emphasises that the priority for archers was to practise to achieve faster speeds of shooting, (page 196).

One problem in particular, the shortness of the inswinger’s arms, means that as short levers they make the winding back of the extra 30° much harder and slower. The existence of two improved, faster rewind winch systems, the Cupid Gem twin handle ‘seesaw’ action and the Bulgarian crank handle-handspike, confirms that the Romans were intent on speeding up rewind to increase the volume of missiles. As to palintone catapults, my establishment of a Latin text of Vitruvius free of the Schramm-Diels ‘mutilations’, and Len Morgan’s resulting construction of two full-size Vitruvian ballistae have confirmed that Vitruvius’ and Heron’s palintone stone-throwers had outward swinging arms.

In his very important scholarly Hesperia article (Campbell 2011) Duncan Campbell warns against the damage to artillery research done by ‘blue-sky’ thinking (in the pejorative meaning of that phrase). ‘Schneider’s bold hypothesis, that the text labelled with the name of a catapult (for what else could a cheiroballistra be?) was, in fact, no such thing, effectively derailed the study of the iron-framed ballista and took it down a blind alleyway, where it remained for 60 years... It was only after the text was rescued by Eric Marsden that it was again taken seriously as a description of a catapult. If we are to maintain the rigor of our discipline we must be careful to rein in the kind of ‘blue-sky’ thinking that Schneider freely employed, or at least subject it to careful scrutiny.’ (Campbell 2011, 678). Similar damage has been done over the last 14 years by Aitor Iriarte’s Procrustean solution of the Cheiroballistra text: his dogged determination to retain the 25mm rope spring diameter of the ms reading has entailed forcing details to fit. He was, to his great

Figure 2 - The combined crank handle and handspike from Elenovo, Bulgaria
The 1962 find was identified by Kayumov and Minchev amongst a group of Roman military artefacts which include a catapult spring-frame and possible arm. (Photo: Kayumov and Minchev)
credit, honest enough to admit twice (Iriarte 2000, 58 and 62) that, ‘As Wilkins remarks, it is impossible to pass the tenons of the ‘ladder’, which are 3 d<actyls> apart, through the pitaria [pi-brackets] in the kambestria [field-frames]. I have no defence at this point...’ The actual ms measurements and the resulting relationship of tenons to pi-brackets are

Figure 3 - A line of ballista balls and the first complete scorpio bolt from the old bed of the Rhine at De Meern, in the Netherlands (Diagram and CT scan: Erik Graafstal)
See Chapter 5, page 60 and Figures 47 and 48 for the Rhine bolt, and Chapter 8, page 131 and Figure 115 for the line of ballista balls.
discussed in Section 7. Unfortunately, he then ignored this impossibility, ‘conjured up folds... to set the tenons apart enough’ and passed his tenons through the pi-brackets. As a consequence, all other reconstructions of which I am aware have followed his lead and forced the tenons through the pi-brackets; they are, unfortunately, invalid as interpretations of the Cheiroballistra ms. Other examples of desperate ‘blue-sky’ thinking are 1. Kayumov and Minchev’s explanation (2010, 339) that the beams protruding from the frames of the Trajan’s Column catapults cannot be sliders [which are moved forward at the start of the loading procedure in order to lock the trigger on the bowstring] because ‘a slider was a quite fragile element...A Roman artilleryman would hardly leave his engine in such a vulnerable state out of fear of accidental damage.’ 2. Iriarte’s belief (2000, 70) that the round ‘cans’ covering the field-frames and spring-cord and are stylized representations of them, leads him to explain the absence of the lower washers on the Column scenes by saying ‘Perhaps the chief sculptor thought that the upside down washers - such components would, ‘no doubt’, fall by their own weight - were a mistake in the cartoons and, subsequently, eliminated them.’

In conclusion, developments such as the publications of the Xanten-Wardt frame and the 1962 Bulgarian finds, plus the Morgan-Wilkins work on Vitruvius’ palintone ballista, and the Feeley-Morgan tests on inswinging and outswinging catapults, invite revised, constructive thoughts from all interested scholars. We look forward to reading them.