Roman Imperial Artillery

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Outranging the enemies of the empire

Alan Wilkins

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The *ballista* stone-thrower, reconstructed from Vitruvius' text and Heron's advice and diagram (Chapter 7). (photograph: Margery Wilkins).

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'…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

E.J.W.H., E.W.M., I.A.R., and J.M.C.T.

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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

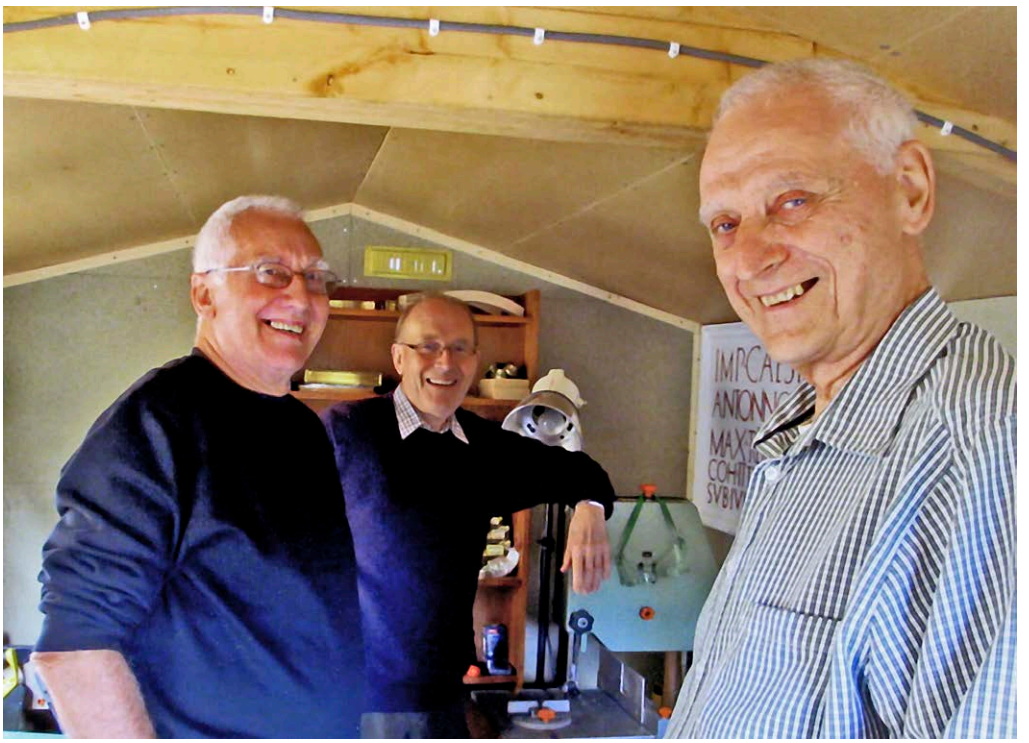
Several of the above have continued to contribute very valuable help or advice, most notably my engineer friends and collaborators Len Morgan and Tom Feeley, whose catapult construction has proceeded apace. I continue to owe an enormous debt to them. Unlike the general technicians who in the past built 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* bolt-shooters 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 BBC one-talent ballista *team (page 125) is dwarfed by the vast timbers (photograph: Margery Wilkins).*

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.

Preface

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.

Figure 1 - Technical tests at Piddington Roman villa site
A battery of 12 bolt-shooters and at the far end the Morgan-Wilkins stone-thrower. The bolts were shot at various types of replica armour. **Inset**: David Sim recording the hits on his group of hand-forged replica shield bosses.

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

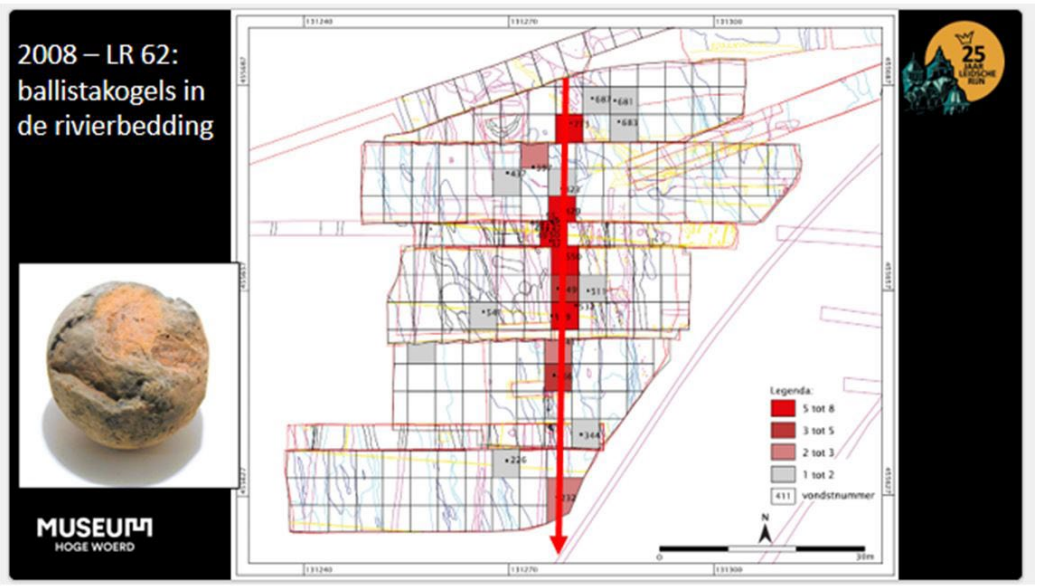


Figure 3 - A line of ballista *balls and the first complete* scorpio *bolt from the old bed of the Rhine at De Meern, in the Netherlands (Diagram and CT scan: Erik Graafstal)*
See Chapter 5, page 60 and Figures 47 and 48 for the Rhine bolt, and Chapter 8, page 131 and Figure 115 for the line of *ballista* 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 on all the Trajan's Column machines bear an '*enormous*' resemblance to the washers, 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.