Appendix I: The Efficiency of the English Longbow

A long standing debate in academia, which can place the realm and value of experimental archaeology into its proper context, is on the efficiency of the English Longbow. The debate itself is important in measuring whether or not it was as great a knight killer as the battles of Crecy, Poitiers and Agincourt seem to lay claim. Scholars have been divided heavily over this matter for decades, even centuries, with some claiming that a longbow could not possibly penetrate plate armour and others claiming it can penetrate armour with great ease. Other debates that have sprung from this have included the effectiveness of the longbow in comparison to the crossbow, using this as justification for a perceived supremacy of the longbow. This debate, like many others, has been argued for and challenged repeatedly but never fully died away. In recent years, however, the debate has been expanded with research into practical archaeology, and experimenting with replicas of historical warbows.

Some of the most prominent tests that have occurred in the last few decades have ranged far and wide in their scope. Five will be reviewed briefly here. Most of these have been based off studies on a surfeit of sixteenth century longbows that were discovered in 1982 on the shipwreck of the Mary Rose. Some have used direct replicas, attempting to get as close to a one to one ratio as possible. Others have used indirect replicas or experiments, or come to their conclusions using mathematical formulas. These will be reviewed in turn.

The Dr Williams test[1] (2004) tested arrow penetration against maille measured at 80 joules of force, and established that medieval arrows would not penetrate maille. However, there are several issues with this test. First, he only tested one arrow type, and as will be shown later, different arrow heads on the same bow can produce varying results. Second, he used a drop tester, which while accurate and repeatable does not show a difference between the different kinds of wood that were available to the medieval archer. This last point is important as different woods transfer energy differently, and can have widely varying energy outputs even when shot by the same bow and also, though a rare occurrence, can of course break. It also does not measure the variance that can occur if the armour is being struck at an angle and thus does not have the full weight of force behind it, thus measuring the propensity for glancing blows. Thus, while Dr Williams offered a wonderful and repeatable test, it is very limited in its scope.

[1]William, Alan, 2004, *The Archaeometallury of Armour*, University of Reading

Another test is the Hardy test.[2] Though he successfully measured that arrows could achieve partial penetration on plate armour, the tests were made only against 1.5mm mild steel which, as Hardy observed earlier in his work, is approximately the thickness of the thinnest parts of several fourteenth century bascinets. He also did not measure the total amount of body penetration, and as no padding material was used under the armour, total actual penetration is unknown.

A third test is the Soar tests. This test was meticulous in its attempts to achieve historical accuracy, placing historical evidence into its proper contexts, viewing and exploring as many sources as possible – going as far as forging the arrowheads themselves – and finally producing a range of well measured tests, including one series of tests against a target moving at 20 mph (9.7 yards per second) over a distance of 80 yards. However, though well researched, these tests fall short of historical use by the fact that all tests were performed at 15 yards, or, in the case of a moving target, under 100 yards from a charging destrier. These scenarios, all within seconds of melee, are situations that would rarely, if ever, have occurred on the battlefield. At such close ranges archers are more likely to have hidden behind other troops, changed weapons or fled from a charging enemy at that range and regardless, most arrows would have been fired via volley rather than at point blank. These tests therefore provide for us, at best, an upper limit of medieval capability under highly unusual circumstances.

A fourth test is the Bickerstaffe test,[3] which used a bow with a 160 lb. draw weight against replica breastplate, with all tests made at point blank range like the Soar tests. The result was the arrow easily punctured the breastplate exerting approximately 156 joules of force. However, the average poundage of Mary Rose bow staves were between 90-120 lbs. draw weight,[4] significantly less than the 160 lb. bow used. Thus the results achieved here do not accurately replicate the possible achievements of the medieval bow.

Over the last few decades several experiments of vastly varying intents have been conducted. On internet forums, one of the most frequently referenced documents of practical testing by a lay-historian on the English longbow is the Matheus Bane testing of 2006. Over the last six years it seems to have become a reference point for academics and amateurs alike. It has even made appearances in some scholarly journals. In this testing it was proven that an arrow from a longbow can penetrate

[2]Hardy, Robert, 1976, *Longbow – a Social and Military History*, Great Britain, Patrick Stephens

[3]

[4]Soar, Hugh, 2006, *Secrets of the English War Bow*, Yardly, Westholme p.15

through many different forms of armour, a table displaying a condensed summary of the results follows:

X The arrow penetrated and produced enough deformation to be fatal

/ The arrow penetrated but did not produce significant deformation to be fatal

D The arrow did not penetrate but caused enough deformation to be fatal

– The arrow failed to penetrate

NA This combination was not tested

Armour Type	Needle Bodkin	Short Bodkin	Broadhead	Type 16 Broadhead
Jack	X	–	X	X
Butted maille	X	X	X	X
Rivetted maile (Average quality)	X	X	X	NA
Rivetted maille (High quality)	X	D	X	X
Coat of plates	X	–	–	–
Plate armour	X	–	–	–

Though an interesting test, there are quite a few issues with it that must be addressed before it can be used as a source. First, we do not know whether the steel he used was hardened, mild or tempered, which is something other experimenters laboured hard to present. The density and hardness of the material can alter results considerably, especially in the mail tests where soft rings will absorb greater impact being more prone to bend than to break. Also, Bane has not taken into account that his measurements for 'probable' death are based on modern ballistics measurements, which penetrate the body in a very different way to the arrow, and deal a high measure of concussive force to organs. Many of the wounds deemed probably fatal on the basis of this and other evidence, are in fact very probably survivable.[5]

This debate perfectly encapsulates the value and problems that can be associated with experimental testing. As in the case of the Bickerstaffe or Williams test, the results can easily be skewed in one direction or another and even the most reliable of tests can have their faults. However, though these tests must be given a scientific eye, they do produce debatable results. The Bickerstaffe and Soar tests, for example, provide for us circumstances that the medieval archer could, or likely would not, have reached. Therefore we can lay these results as upper margins. Tests like Bane's, Hardy's and Williams, though laden with several of their own faults, raise a number of interesting comparisons, and between these tests we can begin making approximate, if limited, assessments.

[5]For an interesting and highly informative article on wounds and survivability in the medieval period, see (SPADA)

When coupled with historical documentation, arguments using these experiments are debatably more reliable than any based solely on eyewitness text. The reason for this is because eyewitness reports can only ever take from one solitary viewpoint, the author's own, are always of a particular bias, the author's filter, can be prone to exaggeration or understatement, and are limited in their scope to what the author, not historians, thought would be of interest. Like modern interpretations, eyewitness or later documented reports can simply be unreliable as testimony. On the other hand, without contemporary documentation, modern experiments have a very limited basis of comparison. Thus the debate on the efficiency of the longbow, and all other debates, will never be answered solely using one approach chosen from experimentation or the studying of documents, literature and archaeology, but requires a hand in each.

Appendix II: Historical Shields

Greek Aspis

Size: Approximately between 32”-42” in diameter.

Thickness: 2mm-3mm

Shape: Circular.

Curvature: Concave.

Handle: Leather strap located near the edge of the shield and a metal loop for the arm.

Boss: None

Materials: Wood, often with a thin sheet of bronze.

Roman Scutum

Size: Approximately 42” (106cm) by 26” (66cm) chord. Width with curve 34” (86cm)

Thickness: 5mm-6mm

Shape: Rectangular

Curvature: Concave.

Handle: Hand grip located in the centre of the shield.

Boss: Central metal (iron), domed boss located over handgrip to protect hand.

Materials: Wood, metal (iron) and leather.

Viking Round Shield/Target

Size: Approximately between 16”-42” in diameter. The 42” represents the largest medieval round shield found to date, and 16” represents a theoretical border between target style shield combat and buckler combat. The exact diameter differentiating a buckler from a target exists somewhere in the realm of 14”-16” diameter due to biomechanical and physical restrictions.

Shape: Circular.

Curvature: None.

Handle: Hand grip either wooden or metal (iron) often wrapped by leather located in the centre of the shield.

Boss: Central metal (iron), domed boss located over handgrip to protect hand.

Materials: Wood, metal (iron) and leather.

Talhoffer’s Duelling Shield

Size: 5’ by 2’

Shape: Oblong.

Curvature: None.

Handle: Almost Quaterstaff length handgrip, approx. 5’ running centre-vertically through the length of the shield.

Boss: Elongated central boss running vertically up the spine of the shield protecting the handgrip on the inside.

Materials: Wood, metal (iron) and leather.

Appendix III: Shield Archaeology

Archaeology Map LH I

The following map shows the areas where finds from the Middle Minoan and LH I-II period artefacts have been found. Time period, approximately between 1600 and 1500 BCE

Artefacts MM

The Following Artefacts date from the Middle Minoan period approximately 1600-1550 BCE

Fig 1. Sealstone, Knossos, Middle Minoan 1600-1550

Fig 2. Akrotiri Soldier, fresco, West House, North Wall, Room 5, Thera, 1600 BCE

Fig 3. Pottery, Akrotiri, Thera

Artefacts LH I - LH II, Mainland

The Following Artefacts date from the period between LH I and LH II, approximately 1600-1500 BCE

Fig 4-5. Siege Rhyton, Shaft Grave IV Circle A, Mycenae, LHIB 1550-1500

Fig 6. Sealstone, Shaft Grave III Circle A, Mycenae, LH I-LH II

Fig 7. Sealstone, Shaft Grave III Circle A, Mycenae, LH I-LH II

Fig 8. Lion Hunt Dagger, Shaft Grave IV Circle A, Mycenae, LHIB 1550-1500

Fig 9. “Battle of the Glen” (CMS I, No. 16) Gold Ring, Shaft Grave IV Circle A, Mycenae, LHIB 1550-1500

Fig 10. Battle Krater, Shaft Grave IV Circle A, Mycenae, LH IB 1550-1500 BCE

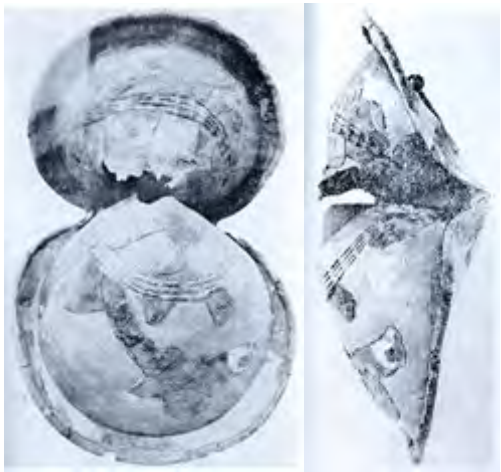

Fig 11. Votive Shield, Shaft Grave IV, Circle A

Fig 12. Gold Pendant, Pylos, LH II

Fig 13. Seal stone, Vafio, LH II

Fig 14. Fresco, Inner Forecourt of Old Palace, Tiryns

Fig 15. Stucco plaque, Tsountas' House, Mycenae

<u>Artefacts LM I – LM II, Aegean</u>

The Following Artefacts date from the period between LM I and LM II, approximately 1600-1500 BCE

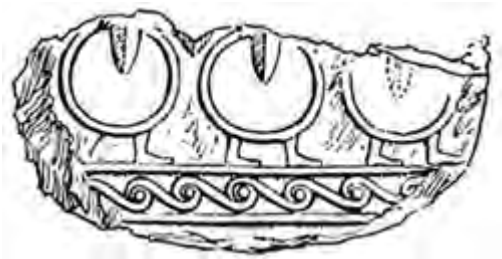

Fig 16. Seal Stone, Knossos, Crete, LM IB-LM II, 1550-1500 BCE

Fig 17. Pottery, Knossos, Crete, LM IB, 1500 BCE

Fig 18. Seal stone, Haghia Traida, Cyclades, LM IB-LM II, 1550-1500 BCE

Fig 19. Ivory Shield, Crete, LM II, 1500 BCE

Archaeology Map LH II – LH III

The following map shows the areas where finds from the LH II period artefacts have been found. Time period, approximately between 1500 and 1300 BCE

Artefacts LH II – LH III, Mainland

The Following Artefacts date from the period between LH II and LH III B2, approximately 1500-1250 BCE

Fig 20. Pottery, Tiryns, LH IIIB2, 1300-1250 BCE


Fig 21. Ivory shield, Mycenae, LH IIIA, 1300 BCE

Artefacts LM II – LM III, Aegean

The Following Artefacts date from the period between LM II and LM III, approximately 1500-1350 BCE

Fig 22. Seal, Zakros, Crete, LM II, 1500-1450 BCE

Fig 23. Pottery, Knossos, Crete, Second Palace Period, 1380 BCE

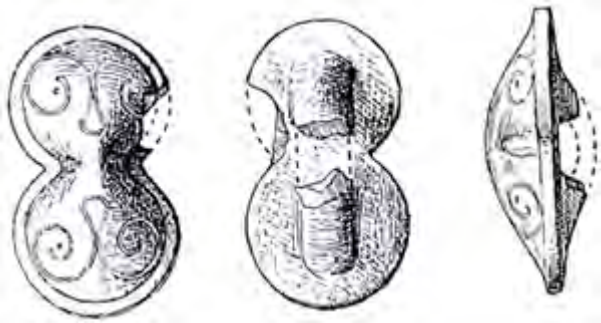

Fig 24. Pendant, Knossos, Crete, LM IIIA, 1370 BCE

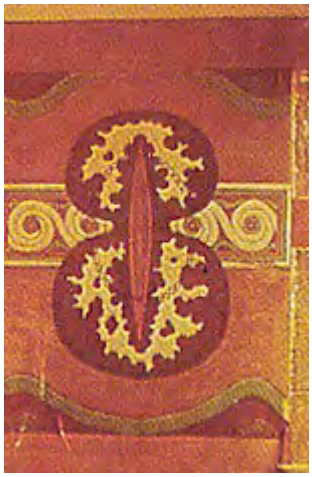

Fig 25. Wall painting, Knossos, Crete, LMII and LM IIIA1, 1500-1350 BCE

Fig 26. Ivory plate, Delos, LH IIIA-B, 1350 BCE

Fig 27. Seal, Knossos, Crete, LM II, 1500 BCE

Artefacts LM II – LM III, Cyprus and Palestine

The Following Artefacts date from the period between LM II and LM III, approximately 1500-1350 BCE

Fig 28. Necklace, Enkomi, Cyprus, Late Cypriote II, approx. 1450-1200 BCE

Fig 29. Necklace, Pyla-Kokkinokremos, Cyprus, Late Cypriote II, 1450-1200 BCE

Fig 30. Vase, Gezer, Palestine, TM IB and TM II-IIIA, 1500-1370 BCE

Other Evidence

Fig 31. The Warrior Vase, Mycenae accropolis, LHIIIB, ca. 1330 BCE

Appendix IV: Chronology

Relative and Absolute Chronologies of the Mycenaean period (after manning 2010: Table 2.2; Voutsaki 2010: Table 7.1)

Relative Date	Date BC
Middle Helladic III (MH III)	1800-1700
Late Helladic I (LH I)	1700/1675-1635/1600
LH IIA	**1635/1600-1480/1470**
LH IIB	**1480/1470-1420/1410**
LH IIIA:1	**1420/1410-1390/1370**
LH IIIA:2	**1390/1370-1330/1315**
LH IIIB	1330/1315-1200/1190
LH IIIC	1200/1190-1075/1050

Appendix V: The 2012 Experimental Trials

These trials were omitted from the thesis proper for not being of high enough standard. They are, however, included here for sake of completeness. Although they do not contradict the conclusions presented in the thesis, they have not been used to generate the conclusions presented in this thesis due to this low standard.

Construction

Two types of shields were constructed for this test. The first type was a simple wicker-weave using willow. The willow used was acquired through garden fencing stores and had to be thoroughly soaked and bent into shape.[6] These shields were not covered with hide and the straps were weaved in through the willow. These shields were made to be the approximate dimensions of the historic shields, however not all of them maintained their curvature during construction.

The second type was a pre-curved 12mm 5ply pinewood base, 60cm flat-width, fronted with between 2 and 3 layers of hide. The straps on these shields were nailed and later screwed into place.[7] The leather on the first two prototypes were respectively glued and stretched into place. The glued shield left ripples and minor contortions on the face after the hide had set. The stretched shield, once nailed, produced a much smoother and more consistent result. All subsequent shields of this type used stretched and stapled hides.

No figure-of-eight designs were used in these tests.

During construction of the pinewood type, it was noted by the shield builder that when nailing in the second layer of leather, the nails he lay on top of the shield rolled considerably, however when nailing in the third the vibrations of his hammer were almost completely absorbed by the two preceding layers. He tested this with the following shield built in this way and generated an almost identical result. This indicates a much higher level of absorption between two and three layers on top of the plank design. This property would not be reproduced using willow which has a lesser ability to absorb and spread impact.

Of the shields, a total of seven – three wicker four pinewood – were deemed suitable reconstructions for use. Another three were used only for formation purposes and were deliberately positioned

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[6] Due to the age of the willow, most snapped rather than bent during construction. Historically these would have been green and would not have snapped so easily.

[7] Historically these would most probably have been riveted.

during tests to limit their impact on results. A twelfth shield was used as target practice for spear thrusts prior to and during the tests.

First Day: Formation Tests

On the first day only five experimenters were present and so testing was limited. It was decided that it would be prudent to try various means of advancing in formation and various means of organized thrusting, including thrusting on the forward step and thrusting on the recovery step. It was found that thrusting on the forward step was considerably more efficient. After this, experimentation continued on potential ways the formation could be organised.

In these tests it was discovered that when arranged in two ranks the second rank could easily gain defence from the front rank with an enemy spear thrust sliding harmlessly through the ranks between the shields. It was also discovered that the ellipses shape on the top of the rectangular shields allowed the second rank a much greater field of vision, and in some positions allowed the second rank to rest their spears on the shields of the front rank, poised to thrust directly at anyone who attempted to penetrate the ranks. The experimenters felt confident that if someone advanced with a sword the spearman in the second rank could very easily impale the aggressor, thus keeping everyone safe.

In several attempts to penetrate the formation with a low spear thrust, it was found that the spear glanced harmlessly off the front rank's shields, and then off the shields of the second rank, passing ineffectively down a channel of shields. Only spear thrusts made from eye level were able to effective strike the second rank without constantly sliding down the inverted shield wall.[8] By the third rank, the attacking spear was completely useless as it could not be retrieved and the third rank was able to thrust into combat over the top of the first two ranks to stab the assailant.

Initial tests with spears raised at eye level showed that a marching formation could thrust quite well on the thrust, with front rank thrusting on the advance while second rank pulled back their spears and second rank thrusting on the next step while first rank pulled back their spears. This manoeuvre, dubbed a 'sewing machine' action, looked fairly effective, however it was doubted whether an entire regiment could perform this on the march once lines engaged, especially once psychological factors were taken into account.

[8] This could explain the high prevalence of head height thrusts evident in the imagery.

It was observed that warriors could easily turn their backs on their opponents, forming an almost complete shield wall for defence if required, then swivel at the hips to open out into thrust. This thrust was quite powerful as it made use of a considerable amount of bodily momentum. This rotation would keep them mostly safe, when not wishing to strike, however it did make the formation quite static as it was difficult to do this on the march. Only one angle was ever exposed at this time and only when on the thrust. However, later tests that evening showed that in compact formations this constant swivelling disrupted the aim of the second rank and the moving shield occasionally impacted other spearmen. It was also relatively unbalanced and in close quarters the shieldsman could be pushed over easily. It was concluded that only a small rotation of a few centimetres would be necessary to maximise a warrior's defence without hindering him or blocking his vision, and this would not adversely impact other spearmen in the ranks.

Second Day: Single Combat Tests

Only four experimenters made it this evening and the following observations were made.

1. The shields were actually not wide enough to give the full protection the experimenters wanted in combat, specifically their thighs and elbows were relatively unprotected. This was unsurprising as the shields they were using were 60cm wide rather than the 80cm originally proposed. It was abundantly clear to all experimenters that even just a few centimentres wider and it would provide almost perfect coverage for the underarm, thigh and elbow.
2. The exposed flank was incredibly vulnerable having no means of protecting their chests except by parrying with the spear. Similarly the defended flank had no clear way of attacking any aggressor that attacked their shielded side. This made the formation very vulnerable on both flanks.
3. Though the shield was cumbersome at first, everyone got used to it fairly quickly and agreed that so long as it was tailored correctly to the experimenter's size it wouldn't be too hard to fight or even run with them. One experimenter, who initially disliked the idea of wearing it over the back and attempted to wear it directly over one shoulder, however when he finally tried wearing it over his back, he reported that after a few minutes it ceased being uncomfortable and quite quickly found he could barely notice it at all.

These observations were then followed with the experimenters attempting to duel with spears, occasionally fighting with short swords and grapples. It was concluded universally by the experimenters that this shield must have been a formation shield. Try as they might, it was incredibly

difficult for experimenters to engage in effective single combat with them. If an opponent could get past their weapon or behind their shield there was almost nothing they could do to respond. If the opponent grabbed the shield they had almost full control of the combat, allowing the swordsman to easily stab over the shield or throw their opponent to the ground.[9] When knocked to the ground it was very difficult for the shieldsman to get up again. Essentially, once the distance had been closed, in one on one combat the shieldsman would die.

However, when the distance had not been closed, every experimenter reported that the shield did not interfere with their movement at all. All the shields were found to be almost completely without burden to the wearer, this included both the crudely constructed wicker frames, many of which were not even properly curved. Even those being worn by men far larger than the shields were designed for did not find them burdensome. It was noted by all experimenters how light the shields felt when worn on their back.

Second Day: Two on Two Tests

Attempts were tried at two vs two combat in order to view the difference between this and single warfare. These tests proved for a second time that while rotating on the spot was an effective defence, it was difficult to do in packed formations without cramping either the spearman beside them in rank. It also made the fighting considerably static and allowed for their opponent to simply wait and take opportune shots whenever his opponent successfully projected his opponent's rhythm.

Though the sparring was reported as 'fun', little from this test could be taken as conclusive evidence. Two things, however, did stand out as conclusive in all forms of formation combat. It was found to be incredibly easy to parry an opponent's thrust, even when a thrust was made at the inside line. Parrying the spear thrust was considerably less dangerous for allies as most of the time it bounced harmlessly into an ally's shield. More importantly, however, it was discovered that it was far easier to thrust at the man to the right of the soldier directly opposite in line. This was due to the fact that this man was more in line with a spear thrust, and at that angle was also exposed to attack at almost all times. This meant that formation fighting most likely happened at a diagonal angle with warriors striking at the enemy directly to across and to the right rather than directly in front.[10]

Third Day: Second Formation Test

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[9] Such a technique of grabbing the shield and thrusting over may be depicted in one of the Sealstones from Shaft Grave III, see Appendix III, Fig. 7

[10] A similar tactic was used by English troops with the bayonet in the 18th century during the Jacobite rebellion to get past the Scottish Targe.

These tests consisted of a total of thirteen experimenters. A variety of formations and drills were performed. The first tests involved comfort levels in how to wear the strap, with varying comments being raised about over which shoulder the strap should sit, and a repeat of which foot to advance with and how to hold the spear.

We discovered that when the strap sat over the left shoulder and under the right shoulder, if the left side was facing the opponent then the head was more exposed. On the other hand, when tests for kneeling were attempted, it was found this position to be more comfortable. When worn over the right shoulder and under the left shoulder, still with the left side facing forward. The shield offered greater protection to the head however it exposed the thigh considerably more as it could no longer sit vertically down the body. Six of the eleven experimenters commented that they could not notice a difference while wearing it, however everyone in the second rank commented that it was marginally easier to thrust when the front rank kept their shield over the right shoulder, but they felt marginally more defended when the shield was over the front rank's left. It was debated after completing the testing that they were most likely worn with the strap over the forward shoulder (in this case, the left shoulder) as it offered more protection to the leg and the warriors did wear helmets to protect the head. Other side benefits of this position that were raised was that there was slightly more cushioning from an opponent's shield charge when worn over the left shoulder due to the fact that the shield hung slightly further from the body on that side. Additionally on occasion a spear thrust that came on the inside of the shield worn over the right shoulder that missed the body could occasionally get trapped between the warrior and the inside facing of the shield. This was a potential hazard. On the other hand, when worn over the left shoulder there was an increased chance of self-strangulation when the strap pulled on the airways, particularly on a charge.[11] In conclusion, wearing the shield over the left shoulder offered marginally more benefits than wearing over the right,[12] though a warrior's personal preference could have been the case. The policy of warrior's preference was adopted in future tests.[13]

The second debate involved which leg to advance on. Assuming the left leg was forward, was it better to close step with the right foot then open out with the left, or better to open up with the left

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[11] It was not tested whether the two styles of strapping used in these experiments had an effect on shield position. The two styles were: integrating the leather strap within the weave and also nailing and riveting it into place.

[12] This would support Herodotus' statement that early shields were worn into battle without a grip over the left shoulder (*Histories* 1.171.4).

[13] The Lion Hunt dagger and Battle Krater each show the strap being worn over either shoulder, thus, if we assume that these images are accurate, it is likely that which shoulder was used altered either between warriors or battles.

foot and close distance with the right? Typically in martial combat, it is often better to step with the forward foot first as it retains greater balance and allows for more power to be generated from off the rear foot, however several experimenters thought it best to test this with the shields to see if it made any major difference. After testing both, it was concluded that it was still better to step with the forward leg first and the rear leg second. This was considered conclusive enough that it was adopted as the standard for all future tests.

The third debate was amounted to where the hands should be placed gripping the spear. Couched positions, alternating grips and even an attempt at a single handed grip were tried. In the end it was concluded that the two most comfortable positions were the following:

1. Holding the spear with both hands and gripping it with the palms facing outward, held up at head height.
2. Holding the spear with both hands and gripping it with the palms facing inward, held down at hip height.
3. Holding the spear with the forward hand gripping from underneath and palm facing inwards and the rear hand gripping from on top palm outward.
4. Holding the spear with the forward hand gripping from on top palm outward and the rear hand gripping from underneath, palm inward.

Though the second option allowed for a slightly greater variety of techniques and additional strength behind the thrusts, allowing for more muscle groups to be involved, the first option led to positions that seemed more akin to what is depicted in the ancient imagery. It was concluded that all options were viable and all were adopted alternately throughout the testing.

Once these tests had been performed, and the experimenters had a feel for the equipment, nine of the experimenters were divided across two ranks, one of five and one of four, and put through a series of tests. In total six formations were tried, these are listed here:

1. Both ranks had their spears raised to eye level.
2. Front rank lowered their spears to hip level, second rank remained raised.
3. Front rank kept their spears raised at eye level, second rank lowered spears to hip level.
4. Front rank knelt on the ground while second rank thrust over the top.

5. Crossweave formation, front rank aimed their spears to an enemy on their right while second aimed their spears directly forward or to the left.
6. Wedge formation

In each test the experimenters were asked to thrust for a minute at their own pace, and once for a minute in unison on a tenth experimenter's command in order to see what effect this had on the second rank. Experimenters were then made to march in formation. Each formation was then tested with another experimenter attempting to penetrate the formation with a spear or sword in order to find and expose weaknesses in the formation. The results of these experiments are reported below.

First Test

Prior to performing this test it was agreed that the rear rank had to thrust over the arms of the forward rank or risk getting their thrusts entangled. After testing both sporadic and simultaneous thrusting, experimenters in the second rank commented that they were not worried about accidentally getting hit in the head by the front rank at any point.

After the marching test attempts at penetration were tried. Penetrating to the first rank of spearmen was relatively easy, often by parrying the spears of the front rank it was easy to force them out of the way, however I was often stabbed by the second rank in the attempt. It was easy to penetrate on either flank as I could easily use my opponent's shield for cover and only ever one of my opponent's spears to worry about due to the difficulty for spearmen to change their combat angle.

Second Test

When the front rank lowered their spears, it was found that the spears naturally angled upwards in the thrust. In this position due to the shape of the shield it left the wielder slightly more exposed as they could no longer hide behind their shield as effectively by thrusting through the gap. This would be an advantage of the figure-of-eight design. Penetrating this proved to be more difficult than the first test as the lowered spears were slightly more manoeuvrable, though this advantage was only marginal and was significantly less frightening than the first. It exhibited the same practical weaknesses as were apparent in the first test.

Third Test

Due to the upward angle of the thrust from the hip level, discovered during the second test, it was established that the psychological advantage of the enemy having to fight through spears pointed at

their faces was certainly a factor. The positional advantage of having the second rank of spears thrusting at a different target than the front rank, combining the best of the previous tests was thus a more effective formation. However, it would be difficult to suddenly adopt this position in the midst of battle as two handed spears could not easily be lowered or lifted once fighting had begun. In experiments where the second rank had their spears lowered, the second rank ran the disastrous risk of losing the use of their spear whenever the warrior in front of them was killed as he often fell onto their spear shafts. It was concluded that if used, the front rank would have had their spears lowered and the second rank and beyond would have had spears lifted upwards.

Penetrating this formation was much the same as in previous tests, however the combination of a spear point in the face and the additional manoeuvrability of the lowered spears was considerably more daunting. The resulting psychological hesitation and flexibility did give the formation an advantage.

Fourth Test

This test was inspired by one seal stone in which the legs were splayed awkwardly behind the body.[14] It was believed that this may have been representative of a kneeling stance. In practice, it was discovered that this position left the front rank incredibly weakened and greatly restricted their ability to move their shields in defence. Further experimentation suggested that if performed against a charging enemy it kept the front rank completely safe against spears thrust from eyelevel and possibly allowed them to avoid the upward thrust of those at a low level. In this position, it still allowed the kneeling troops to impale their charging opponents in the torso or face.[15] It was not tested what would happen to the front rank if the enemy simply ran over the top of them.

This position was arguably difficult to penetrate from the front due to the tactical maneuverability of the lower spears. However with a sword they were also considerably easier to parry upwards so they couldn't harm anyone. This kneeling formation also did little for the flanks unless the entire formation intended to remain completely static and have the outside lines kneel.

Fifth Test [16]

In order to address the issue of the flanks, a crossweave formation of having the first rank of spears at a diagonal angle and the second rank facing forward was attempted. This formation proved the

[14] Appendix III, Fig. 9

[15] As one experimenter put it, they could easily stab their opponents "right in the face."

[16] Tests five and six were the inspiration of and organized by experimenter Mathew Evans, a martial arts instructor at the Melbourne Sword and Spear Association.

most interesting of the shield-wall formation tests. By placing the spears in this crossweave formation it not only allowed for multiple angles of attack, but also allowed for all spear points to create a sizeable psychological impact on attackers. It also increased the defensive capacity of the first rank as the shield was constantly at an angle to defend them from the enemy, with the spearmen in the second rank providing a defence against anyone who got past. When attempted with the first rank forward and second rank diagonal, it was found that while range was sharply reduced for the second rank it allowed for a fairly effective coverage that could be adopted at any point on the march, including the moment of impact.

When attempting to penetrate this formation, it proved increasingly difficult. In order to press forward I had to actively choose between one of two spear points and could not, as I had occasionally done to other formations, force one spear into another spear in order to create a complete opening. This formation also greatly increased the difficulty in attacking the exposed flank as there were always spears, often two or more, pointed directly at me. The shielded flank, however, was just as easy to assault as in previous tests.

Sixth Test

Our final test experimented with the prospect of a wedge formation using the shields.[17] In this formation, two warriors were positioned in the front rank facing each other so their shields faced outward. The resulting wall on either side became very difficult to attack from any angle. In subsequent tests, it was found that placing a swordsman directly behind the front two shieldsmen he was able to burst forward and take advantage of any break in the opponent's line. When attempting to counter-charge this formation, there was invariably between two and three spears assaulting an assailant at any point in the wedge, making it horridly effective on both offense and defence. It was, however, impossible for us to test this formation on the charge due to a lack of opposing numbers.

Weapon Tests

It was decided that the shields would not provide useful results for weapons testing. However, after much discussion among experts, it was decided that they would provide useful results in grappling tests. A number of tests were tested and it was found that the shield was a detriment in this kind of combat.

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[17] A wedge formation is a triangular type formation with the front rank only being one or two men deep with each subsequent rank adding additional men on either side.

For the first tests, the combatant experimenters were a shieldsman with tower shield and long spear and a swordsman armed only with a short sword.[18] Assuming the swordsman could get past the spear, it was found that in close quarters the swordsman would consistently win against the shieldsman if he took control of the shield. Grabbing any part of the shield allowed the swordsman almost complete control of both the shield and the shieldsman. By pulling down and back he could force the shield against the inside of the shieldsman's knees, forcing him to the ground. If he pushed the shield away from him he could force the shieldsman to rotate with it and expose his chest to a sword thrust. In turn if he pulled the shield toward him he could not only force the shieldsman to rotate, permitting the swordsman a strike at the back of his neck, but he could now actively use his opponent's shield to defend himself against other enemy strikes. In almost all of these tests the shieldsman was very easily thrown to the ground.

No matter which direction the swordsman moved the shield, the shield operated the shieldsman's body. By pushing or pulling the shield it pushed against the back of the shieldsman's knees and pulled the strap against the shoulder, pulling the shieldsman off balance and making it very difficult for the shieldsman to either manoeuvre or resist. In such a bind, it was impossible for the shieldsman to strike back with either his spear or a secondary sword as his body was contorted. Though several attempts were made to allow the shieldsman to grapple back, it was virtually impossible for him to gain an effective fighting position as quickly as the swordsman.

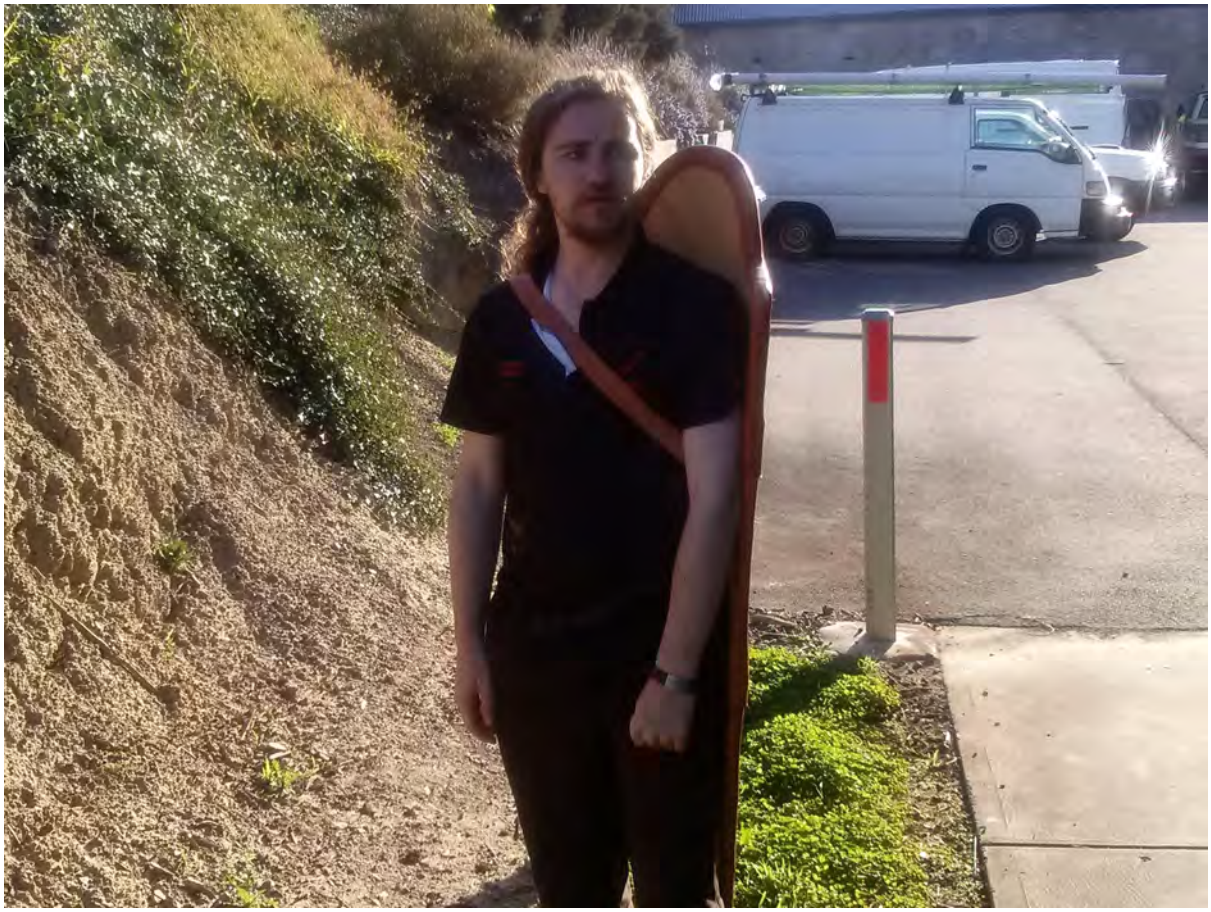
[18] The sword used was a Celtic sword modelled off the La Tene finds.

Appendix VI: Supporting Imagery for the 2012 and 2014 Experiments

Photo1
1/09/2014
Reconstructed Shields: These are the shields used during both 2012 and 2014 experiments. Note that there is some variation between individual designs such as the height the chest strap has been stapled at. Also note that these shields are made of single slats of timber and not wicker-weave which was impossible to achieve legally in Australia.

Photo 2
1/09/2014
Here you can see the front and profile shots of two shields allowing for an idea of the level of curvature and distance. Note that the shield width is 60cm before curvature and thus are smaller than the historical 80cm width predicted by the thesis.

Photo 3
27/08/2014
Here you can see the shield shown in profile in photo 2 being worn in action. This is the comfortable resting position that allows me to walk, move and fight with full mobility.



Photos 4-7
27/8/2014
The below photos were used in order to create the diagrams presented on shield grappling. Several other tests were done but were not as well photographed.

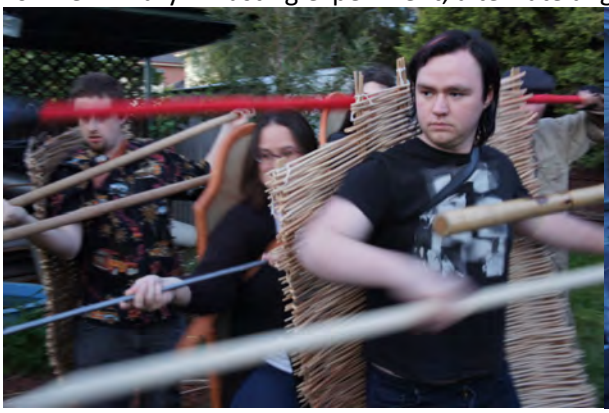
4. Attacker pushing back
5. Attacker pushing Forward
6. Attacker pulling left (Defender's right)
7. Attacker pulling right (Defender's left)

Photos 8-11
2012 Preliminary Experiment photos August.

8. August 2012 experimental crew

9. 2012 Preliminary Thrusting experiment

10. Preliminary Thrusting experiment, alternate angle

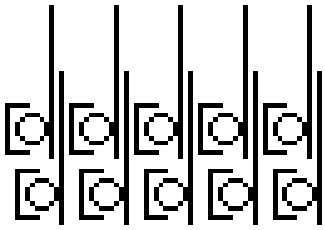


11. Rear view

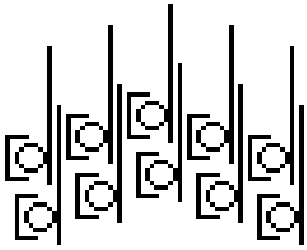
Representative Diagrams 1-3

Due to the haphazard nature of later photos, and the fact that not all participants in later tests wished for their photos to be made public, no further photos are included in this thesis. However, in order to better understand the 'formations' theorised in the 2012 tests, a series of simple diagrams have been created to convey what photos could not.

1. Wall formation



2. Wedge Formation



3. “Jacobite” or Scissor Formation