EXPIRIMENTING WITH PLUMBATAE AND OBSERVATIONS ON THEIR BEHAVIOR

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This study looked at the behavior of the plumbata, a unique Roman throwing weapon. This was done through the replication of weapon heads, shafts, and flights based off of previous research and through the incorporation of historical pictorial representations. The objective of this study was to include the important element of time and practices that had not previously been accounted for in earlier studies. This study also looked at near exact replication of the weapons based solely from the pictorial representations of historical manuscripts. This had been mentioned by previous researchers but had never been carried out. Basic results were that the weapon does indeed improve in range and consistency of behavior in flight providing increasing smooth flights and a max range of over 200 ft. The result of the picture based weapons was that they did not perform nearly to the ability of the non-pictorial based weapons.

I would like to acknowledge my Grandfather, without whom, I would not have been able to do most of this study. Thanks to him for his guidance and patience. Next to whom I owe gratitude is John Eagle and his colleagues who provided the groundwork with which I was able to base my studies and to use as a springboard for the next steps. Thanks to Dr. David Anderson and Dr. Joseph A. Tiffany for providing comments, guidance and ideas in my research. Finally thanks to Rev. Deris Rice, Rev. Laura Hoglund and all my friends and family who supported me with encouragements and interest in my work.

INTRODUCTION: A NEW WEAPON IN THE OLD WORLD

The Roman military has always been known for the power and ability of their infantry. As good as they were in close order combat, they always held an even more significant advantage over their foes. That advantage is the training that legionnaires and soldiers had in the effective use of hand launched missile weapons. Throughout most of its military history the army of Rome used specialized javelins to give their infantry an added punch. From the beginning of the republic to the end of the empire, the Romans, almost without exception, armed their main battle infantry with some kind of hand launched missile weapon.

While one could write volumes on all the forms of missile weapons with which Rome equipped her soldiers, there is one specific weapon that is of interest to scholars and archeologists. This weapon appears in the historical and archeological record around the fourth century A.D. This weapon has been called by historians and archeologists the "Plumbata" (Bishop and Coulston 2006:200). However, while the archeological remains have been examined and the historical accounts make mention of it, the plumbatae are relatively obscure.

Yet even as obscure as this weapon is, there are still many aspects of the weapon that can be studied through an active process of experimentation. By taking what is known, historical accounts, pictorial representations, and the archeological remains, then combining it with reasoned assumptions about Roman equipment, a picture of how the weapon may have looked and behaved in Roman hands can be compiled. This can be used to make a series of experiments that look at the missing elements of the weapon characteristics.

Therefore using direction from other studies and information from history and archeology, a series of experiments was designed to study the behavior and characteristics of the weapon. The reproductions based off of archeological remains and pictorial representations of particular head shapes gave a basis to discern how or if the particular weapons differed. The practice and throwing of the weapon consistently over a period of weeks allowed for the element of training and improvement as would have been seen with the Romans. Finally the observation of the weapons in flight gave the best evidence of how the weapons behaved from the point of release to the point of impact, allowing real time examination of this unique Roman weapon.

WEAPON AND EQUIPMENT CHANGES AT THE PERIOD OF PLUMBATA EMERGENCE, HISTORICAL SOURCES, AND ARCHEOLOGICAL MATERIAL

The approximate time that the plumbata begins to appear is the fourth and following centuries A.D. This period in Roman history saw a steady decline of the greatest power of the Roman military. Rome had been through over a century and a half of political turmoil, rapid imperial successions, military strong-arming, and frequent civil wars. As if this was not enough, Rome simultaneously suffered from barbarian raids and incursions on her boarders. Only the ascension of Diocletian brought a much needed respite; but once he retired, Rome slid back into periods, albeit less frequent and intense, of political and military strife (Southern 2006).

By the time of the plumbata's appearance, at least archeologically, the Roman military had seen a great decline. The historian Vegetius mentions the abandonment of armor because of "negligence and sloth" (Phillips 1944:25). While this is probably not a universal and should not be taken uncritically, it does signify the idea that change has occurred to the once greatest military force in the world (Elton 1996: 110-114).

The changes of the attitudes of the soldiers, at least mentioned by Vegetius, are not just inherent in the camp. There were changes on the field of battle that were to have far greater reaches in the military capability of Rome. In many ways, cavalry was superseding the infantry and the infantry were less and less the principle arm on the battlefield, being relegated to support roles (Phillips 1944:2). The Plumbata, because of its presumed range, (Eagle 1991) may reflect tactical desire or necessity for added range on the part of the battle line infantry.

While there were several other types of hand thrown ranged weapons (Elton 1996:108) the plumbata is unique. One peculiarity is that the weapon has a comparatively small head in relation to other contemporary weapons such as the spiculum, or the much more famous throwing weapon, the pilum (Elton 1996:109). Of the various ranged weapons of this time, it appears that the plumbata is used as a longer ranged weapon, thrown at a comparatively longer range, with several, Vegetius mentions, being thrown in succession (Phillips 1944:24). Upon Exhaustion of the light weapons, the "common missile weapons" (Phillips 1944:24) are then released. Therefore, from a principle historical source it appears that the plumbata is a kind of iron drizzle, before the steel rain.

Historically, there is comparatively little written about the plumbata. The few sources that are available mention only briefly the weapon. One important source is the Historian, Flavius Vegetius Renatus. He has already been spoken of several times, but he is an important figure in both the study of the plumbata as well as later Roman military history. His statement on the weapon is brief, but it provides insight as to the impetus of the so called "loaded Javelin" which he also calls "Martiobarbuli" (Phillips 1944:23). As an important aspect of his statements about the weapon, he notes their use by the famous Illyrian Legions that became distinguished mainly by their "extraordinary dexterity and skill in the use of these weapons" (Phillips 1944:23).

Not only does this provide a historical mentioning of the weapon, it also gives a possible historical indication as to the appearance of the weapon, prior to archeological findings. Vegetius mentions that the particular Illyrian legions "supported for a long time the weight of all the wars and distinguished themselves so remarkable that the Emperors Diocletian and Maximian on their ascension honored them with the titles of Jovian and Herculean and preferred them before all the other legions." (Phillips 1944:23).

If Vegetius's statement about the Illyrian legions is relevant to his discussion of the weapon, then it is possible that it could place it back into the late third century A.D. or even the mid third century A.D., significantly prior to the archeological finds. However, given its placement, it could only be an implanted anecdote about the prowess of these particular legions. Whether or not his statement about the legions is relevant to his discussion about the loaded javelin is more a matter of textual criticism. But, because he does place that statement within the contexts of his discussion of the weapon, the statement should at least be noted and given consideration.

Vegetius, for his discussion on the relative importance of the weapon, does not provide any dimensions as to the build and composition of the weapon. For that, there is the fourth century A.D. De Rebus Bellicis, written by an anonymous author (Elton 1996:118). De Rebus Bellicis is a manual on warfare and aspects of warfare ranging from military finance, field equipment, navy, and even strategy (Hassall and Ireland 1979).

Like Vegetius, De Rebus Bellicis's discussion on the plumbata is relatively short. Unlike Vegetius however, the anonymous author gives specific details as to how the weapon should be built. In the translation, it mentions two different types of Javelin. The first mentioned, and probably most damaging, is the "tribolatae" (Ireland 1979:10). Tribolatae is translated as the

"Caltrop" javelin (Ireland 1979:30). This, according to the specifications of De Rebus, is the most complex.

> Now it is made if a piece of wood fashioned like an arrow, to which, is carefully fixed an iron tip worked into the shape of a hunting spear, with the tubular end of the blade extended a little way: above this, with a short gap left in between, spikes like caltrops project, soldered on with lead. And at the lower end of the javelin are fixed flights to give speed, with enough space left above these flights, of course, for the fingers of the holder to be able to grasp. (Ireland 1979:30).

This is verbatim from the translation describing the weapon specifications. While there have been some plumbata found that have barbed heads (see Figure 3 and 6), such as those of Wroxeter (Musty and Baker 1974), it is so far unknown whether there are any that resemble exact forms to which De Rebus alludes. In any case, the relative Fourth Century AD date of De Rebus is approximately in line with the archeological findings of these particular weapons, which also begin showing up at around this era as well. (Bishop and Coulston 2006:200).

There is a second type of javelin that is mentioned in De Rebus. This weapon appears to be a simpler style called "Mamillatae" (Ireland 1979:10) or "Breasted":

> A shaft, nicely long and straight, will have fitted to one of its ends a piece of iron, round in section and tapering to a point, with a lead weight and flights attached at the same points as in the 'caltrop' type, so that the bulbous weapon, assisted by the weight of the lead and the swiftness of the flights, will be powerful enough to penetrate easily the enemy's shields and similar obstacles. (Ireland 1979:30-31)

This particular weapon, given the description, seems to be of a more straight forward nature. It apparently does not deal with the extra barbs or caltrops and has the specific purpose of defense penetration in mind (again see Figure 3 and 6). The lead weight and head are consistent with various archeological finds and certain weapons that have been found might have the penetrative qualities that this particular section of De Rebus mentions, even if they may not fit the ideal exactly (Bennett 1991).

Another very important aspect of De Rebus Bellicis is the fact that it has pictures in addition to descriptions of approachable detail. The plates that are provided in Hassall and Ireland (Hassal and Ireland 1979:Plate IX) are unfortunately only black and white, but nonetheless they still provide respectable visual clarity to discern some of the various forms of the plumbata weapons, either the Tribolatae or the Mamillatae and their attributes. Since the shafts of the plumbata remains are non-extant, the pictorial description of De Rebus becomes an integral part in the understanding of the unique weapons.

However, it is still a question as to whether the pictures of De Rebus are accurate in their practical representation. By this, one needs to ask if there are truly weapons that can be found that exactly match both the description and pictorial representation. Or whether the weapons are that of an idealized nature, only presenting a theoretical, if not romantic, representation that may not even be a practical weapon if constructed to exact specifications. Like Vegetius's statement, deciding that matter would be of a nature that is outside the parameters of this study. However, it is a note worth mentioning in that given the sometimes fluid nature of interpretation of representations, both pictorial and literary, that one should not commit to assumed particulars.

To supplement the historical material of the weapon, there are material remains of the weapon in good enough condition to describe it, according to historical descriptions, as plumbata(e). Over the years there have been several points that have been found in Britain (Musty and Baker 1974), several unique heads that have been discovered in what is now the Republic of Georgia (Bennett 1991), as well as others that have been found throughout Roman occupied territory (Bishop and Coulston 2006). Each of these remains have heads showing both differences, particularly the Georgian heads, but also similarities. Emphasizing prominently the similarities, *most* have a type of weight soldered to a shank. Except the Georgian heads, they

have barbs of some degree or another (Bishop and Coulston 2006). Finally, and most universally they are comparatively short to other weapons (Elton 1996).

The data that features prominently are the barbed remains from Wroxeter, Shropshire, conducted by Musty and Baker (Musty and Baker 1974). Here, they mention the barbed heads with a narrow shank with a lead mass enclosing a socket (Musty and Baker 1974). In their short article they give some dimensions of the head, twelve centimeters, and tried to figure for dissimilar material (Musty and Baker 1974) which would constitute a shafted throwing weapon.

As mentioned was slightly dissimilar, Plumbatae from Pitsunda by Julian Bennett show another group of these weapons. Where they were found is now in the area of the Republic of Georgia. Therefore, it shows a wide ranging use of the weapons and that they were not likely localized to one area. Unlike their Wroxeter counterparts, these particular weapons have a leaf shaped head. However, they are within ten to twelve and a half centimeters and contain the characteristic lead weight (Bennett 1991).

What is characteristic of both sites is that the weapons found here had what are called split sockets. (Bennett 1991) (Musty and Baker 1974). This is the method on which the weapon was fitted to the shaft. However there is another method that involves inserting the weapon into (see Figure 1), instead of around the wood of the shaft (Hassall and Ireland 1974:Fig 14a). This particular example is found at a place called Burge Castle in England (Bishop and Coulston 2006) and is suggested to have been an easier method of manufacture (Sherlock 1974).

There have been various example found throughout most of Western European Roman occupied lands. Some have been found along the Rhine and Danube frontiers (Bishop and Coulston 2006), but the prominent examples are those that have been excavated in England. Although, for their lack of fame, the Georgian heads do have a resemblance to the literary

descriptions of the “Mamillata” plumbata described by De Rebus (also see Figure 5). However, the most important aspect of the archeological remains is that the plumbatae were used, or at least can be assumed to have been used, in various circumstances and likely in several actions.

While the archeological remains do not by any means solidify the unknowns of interpretation of these weapons, they do provide invaluable knowledge as to how the plumbata were shaped, how heads may have been attached, and how prolific their use may have been. Knowing these aspects and using it to understand what is known already, hypothesis can at least be made that base themselves in both the historical and archeological. The knowledge that has been gained by the historians and archeologist mentioned within this work will has been used to formulate various assumptions that have been used to draw conclusions, or at least contribute to conclusions from future studies, that examine the unknowns based off of what is known.

EXPIRIMENTATION BASED ON PREVIOUS KNOWLEDGE AND STUDIES OF THE PLUMBATA

Because of the ambiguous nature of the plumbata it becomes necessary to make inferences from what is already known and create measures in which the unknown aspects of the weapon can be evaluated. There have already been a few studies within the previous thirty years which investigated aspects of the shaft and flight (Musty and Baker 1974, Eagle 1989). Musty and Baker made observations on the possible behavior of weapon based on the weapon heads found in Wroxeter, Shropshire (Musty and Baker 1974). Using these, they designed an experiment to evaluate the shaft length and how it was thrown. They referenced a turn of the century study using different techniques to throw a plain arrow on which they based their own experiments. Following the methods of that study, they were unable to obtain any significant range greater than thirty yards (Musty and Baker 1974:276). From their study, one can infer that they only

looked at a very few aspects of the throw of the weapon. They also appeared to ignore the pictorial representations of the anonymous *De Rebus Bellicis* (Hassal and Ireland 1979:Plate IX). This can be supposed in that their weapon that was over three feet in length (Musty and Baker 1974:276) and therefore highly disproportionate to the picture and resembling in no way the historical-pictorial description. For any methodological model to follow, Musty and Baker leave a lot to be studied and give only a very small picture of how this weapon may have worked.

By contrast, in 1989, John Eagle performed a study in which several heads were replicated and several aspects of weapon use and behavior were examined. Unlike the previous study, Eagle and his colleagues refer to the representations of *De Rebus*. In their conclusions they mentioned how the projectiles were approaching the dimensions in *De Rebus* (Eagle 1989:251). In addition they used a far more varied approach to their experimentations. They examined release as well as over versus under arm throw. They determined that a "pinch hold" was the best in terms of release and they were able to throw the weapon near 70 yards (Eagle 1989:250). Although, Eagle and his colleagues were more inclusive in their various variables, there are still areas of their study that they conceded could be pursued further. The most prominent concession they mention is that the participants of the experiments "had thrown the plumbatae less than a dozen times" (Eagle 1989:251) and they concede the lack of practice of the throwers in familiarity with the weapon may have affected the results.

For the purposes of this study, the number of throws over time is the greatest concern, but there are other small issues that could at least offer more details of information if not new information in itself. Overall the experiments carried out here are similar in their approach to John Eagle. However, a difference between the earlier study and present one is the time span over which the experiments were carried out. Another difference is that this study had more

flight observations and impact photography, thus providing a framework reference of flight path and behavior. Finally this study looked at the weapon performance of a replication of a plumbata, at least in proportion, to the picture of the *De Rebus* (Hassal and Ireland 1979:Plate IX). Using the solid foundation of Eagle's study, it is the purpose of this study to build upon earlier work, and expand our knowledge of the plumbatae using time and practice, more photographs, and close replications of the *De Rebus* representations.

Just as in the previous studies, replicas of the weapon heads were made. A total of three different heads were hand forged based on either archeological remains or depictions of the weapon in De Rebus. The heads were made of regular steel bar with heat applied to a malleable temperature. The heads, having been beaten to approximate shape were then ground down to the refined head shape using a standard metal grinder. While not an authentic manufacturing process, the grinder was used in order to speed the process of shaping and sharpening.

The heads were then tanged at the other end so to be able to set them into the shaft. This process was done based on archeological remains and suggestions of manufacture (Hassel and Ireland 1979:Fig 14) (see Figure 1). The ends of the shafts that were to receive the tangs of the plumbata were bored out using a standard drill bit. This then allowed the tang and shaft to receive each other easily and keep splitting to a minimum.

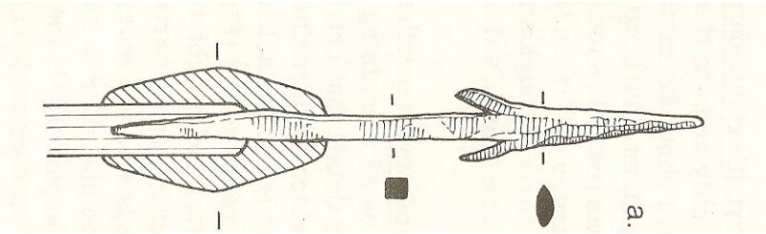

Figure 1. Archeological model for insertion of head into shaft.
(Hassel and Ireland 1979:Fig 14)

In accordance with the archeological remains the heads received lead casings at the head/shaft junction. However, before the weapons were cased, the molds had to be created. This mold creation process was conducted by boring out a two pieces of wood in approximate dimensions. Upon having removed the appropriate amount of wood, a malleable type of putty was filled into the space in the wood. This was then worked by hand to create the appropriate shape of the lead at the junction. This particular putty never hardens but it still retains its shape within the wood molds to create an appropriate shape of the molten lead. Once this was completed, the weapons were able to receive their lead castes. While not assembly line speed by any means, this method still allowed for reproduction of the same lead casing shape on a faster scale. Once the weapon received its casing, the weapon was fletched in accordance to pictorial representation such as that of *De Rebus* (see Figure 2).

After the weapons were created, there was a familiarization experiment that was conducted. This did not include any formal measurements, only pacing off how far the weapon flew beyond the previously measured distance of one-hundred feet. This particular aspect of the study was ONLY to familiarize the thrower with the weapon so that less time was spent learning to throw rather than measuring the throw. However, there were un-official measurements taken and observations of the weapons were noted.

While results will be discussed later, the preliminary familiarization period affected the parameters of the study significantly. This study had intended to look at overhand throws in the development of long range, such as those recorded by Eagle. However, after a few throws of both over and underhand, it was decided to eliminate the overhand throw in the study of distance. The thrower exerted significant force with the overhand throw, launching the weapon little more than one-hundred feet. With, comparatively little effort, an underhand throw launched the

projectile an estimated one hundred seventy feet. The over hand throw was repeated a few times but the decision was made to abandon the overhead throw in relation to distance measurement.

Problems Encountered within Methodology

Almost immediately there were significant problems that occurred throughout the initial familiarization throwing sessions and early recording throwing sessions. The primary issue that occurred was breaking of shafts. This problem is to be expected given the nature of the experiments. However this resulted in several occasions where the weapons had to be rebuilt from the beginning, existing heads notwithstanding. Another problem that occurred was the actual loss and inability to recover one of the heads. This resulted in another head (see Figures 5 and 6), of a different shape being used in the test. While these problems are not surprising, they are only disappointing from the perspectives that they destroy absolute consistency. Therefore, it is important to discuss the issued that have, at times, plagued the experiments.

One the issues of the shafts, which was the most pressing of the malignant occurrences, the inconsistencies that occurred were the amount and shape of the lead solder that attached the shank to shaft. While consistency was attempted as much as possible, every weight that was casted was unable to maintain a respectable resemblance to the other. While the nature of each of the weapon seemed un-affected by the relatively minute discrepancies in weight and shape, it is a note that should be mentioned particularly for the purpose for future experiments.

Far more significant than the reconstruction of shafts, was the loss of one of the experiment heads. Upon its loss, another head was used to continue the experiment. The greatest inconsistency was that the new head had a conical point as opposed to the flat heads that were intended to be experimented with. There is also a slight weight and length discrepancy in that this new head was slightly longer and heavier than the lost head. While these minute differences

seemed to have little effect on the weapon flight, especially when the weapon was released underhand, again it should be mentioned for the purposes for the interpretation of results and for future studies when considering head replication.

Methods on the Field

Once the replications of the heads had been completed, the experimentation was begun. There were several aspects that were initially addressed. The first was the type of throw, overhand or underhand, as to which was to yield the furthest distance. In relation to this, the grip was analyzed as to how it affected, or if it affected the flight and range of the weapon. The means of measurement recordation and weapon photography are also addressed.

The method of throwing was in a manner of arm extension to the fullest extent, holding the missile at the shaft lead junction, and releasing in the overhand position. The second style of throw was of an underhand manner in which the end part of the shaft was held either between the thumb and pointer finger, or later, held fully in the hand with the end of the shaft resting in the palm snuggly between the thumb, pointer, and digital fingers (see Figure 4). Using a full motion swing of the arm and a corresponding movement of the wrist was how the weapon was released to its flight. Further description and pictures of the best styles of grip will be discussed in the analysis section.

The grip, prior to the throw, was based off of the position of the flights on the weapon. The position of the flights was measured not by a standard measure, but by anatomical means. The flights mounted on one of the two projectiles were placed one half thumb length from the termination point of the shaft. The second weapon had flights mounted the length of the index finger from the termination of the shaft. Each weapon that was built, initially and subsequently,

were fletched using the pictorial representations in *De Rebus Bellicis* (see Figure 2 below). See the analysis section for pictures and further description.

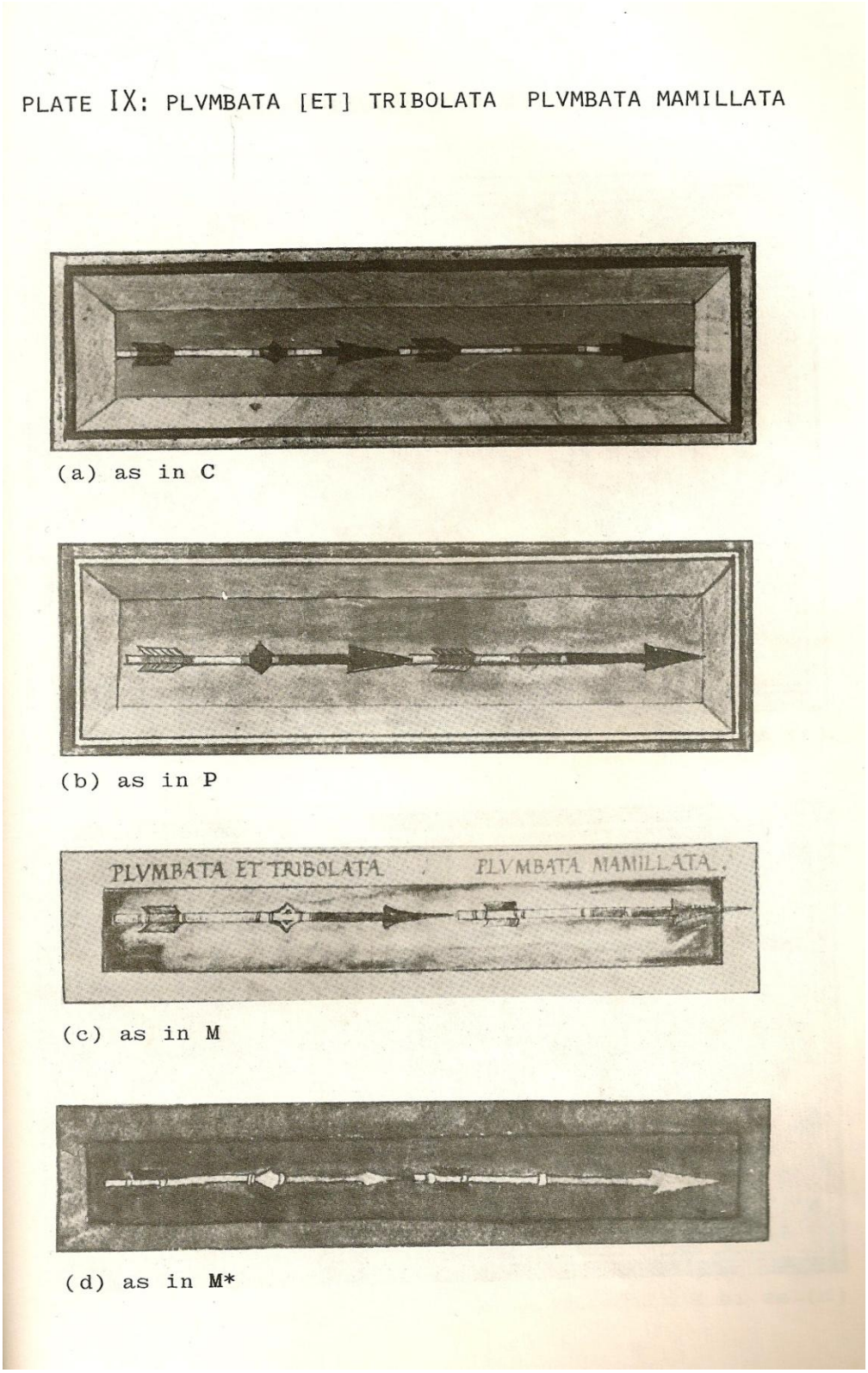

Figure 2. Taken from *De Rebus Bellicis* showing the late Roman depictions of the Caltrop and Breasted Javelin. The flight placement here provided the basis for the flight placement on the experimental weapons. (Hassal and Ireland 1979:Plate IX)

DATA ANALYSIS

Overall the results of the throwing sessions seemed to confirm the results previously seen in the study of Eagle and his colleagues (Eagle 1989). As was stated, the primary purpose of the present study was to take Eagle's research and expand the length of time that the behaviors of the missiles were studied. However, the primary element of the study, the measurement of distance and the underhand release, has been confirmed within the contexts of this study.

Upon completion of the first sets of weapons, there was a session of familiarization and measurements that were non-specific. Once familiarization was completed, then more detailed throwing sessions were performed in which more exact measurements were taken upon each throw as well as photographs taken when appropriate. Later sessions of experimentation included video of the throws and weapon behavior in flight, however these proved to be disappointing and therefore could not be used for analysis.

In the familiarization period, there were several different throws made between a measured, fixed range of 100ft marked by two posts placed firmly in the ground. Since this preliminary throwing session was considered only to be that of a familiarization process, there were no exact measurements taken. However, any significant throws beyond the fixed range of 100ft were measured off using a simple pacing method, with the paces averaging 3.5ft in length. The basic familiarization was that of both overhand and underhand throwing techniques and to observe weapon behavior in order to gain an idea of how the weapon would handle.

The most significant result from the familiarization process was the conclusion that the overhand throw in the traditional javelin style was a futile effort in the acquisition of maximum range data. During the conception phase of the experiment, it was intended to attempt to

maximize range of the weapon using a traditional javelin throw as a refutation of Eagle's previous studies.

There were several throws made in the traditional javelin style, gripping the weapon behind the lead weight. However, even with previous experience having thrown heavy javelin and practice with the plumbata, none of the throws ranged significantly more than 100 ft. Estimations were around 110 to 120 ft. When launched correctly, the javelins flew in a respectively even pattern with an identifiable arc in the flight from launch to impact.

Upon the completion of several throws in overhand manner, the underhand throw was attempted. Upon even the first attempt at an underhand throw, the weapon traveled a significantly farther distance than any of the overhand throws. With a comparatively small effort on the part of the underhand launch, the weapon traveled further than with the greatest effort for the overhand launch. The first weapon throw yielded a measure 10 paces beyond the previously recorded range. As mentioned, the measure of a pace is averaged to 3.5 ft. This then measured 135 ft as opposed to little more than 100 ft with the overhand launch. The longest throw during this unofficial session, several throws in but nonetheless only a small period of familiarization, yielded a distance of 24 paces beyond the fixed range calculated to 186 ft. Given the distance difference between the two throwing methods as well as the exertion of force in comparison to distance, it was decided to drop the overhand launch technique as a means of measuring range.

After this was decided, the experimentation continued this time only focusing on the underhand release as the means of achieving range. Later sessions were formalized by giving measurements of each throw, as well as photographing how the weapon is held in the hand, and the angle of the weapon when it impacted. In flight photography was attempted with no results, but a motion recording of one weapon from the point of release was more successful.

The second successful throwing session was started initially using two Plumbatae designated for this test P1 and P2 (see Table 1). P1 was a barbed head and P2 was an un-barbed head (see Figure 3 below). They also slightly differing locations of the flights**.** Each projectile was to be thrown in succession of the other and the throws measured. Unfortunately, the first projectile, P1, broke the shaft on the first throw. However, the distance of this projectile measured 168 ft. Therefore, some data was at least gained. Regardless of the first projectile malfunction, the experiment continued with good results from the second plumbata P2.

Table 1. Distance of the First Recorded Session

Throw Group	P1 Distance (Ft)	P2 Distance (Ft)
1	168	158
2	malfunction	165
3	-	155
4	-	195
5	-	187
6	-	148
7	-	182
8	-	189
9	-	159
Average Distance		170.8888889

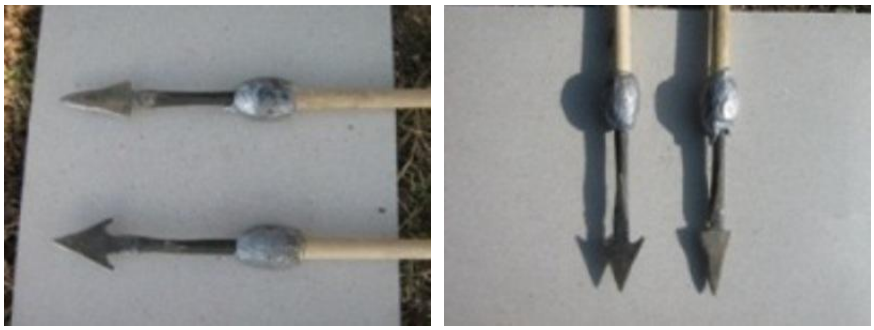

Figure 3. The first set of heads tested. The un-barbed head was eventually lost

This particular session was also helpful in determining a proper grip in holding the weapon. Using a hold between the thumb and forefinger did not seem to give as good control over the weapon release, in some instances causing a slight twinge of pain. The second palming grip, securing the weapon between the thumb and first two fingers was found to be the most comfortable as a controllable method of release (see Figure 4 below).

Figure 4. Grip that was most comfortable and useful

For the weapons themselves, this was significant for examining their behavior in flight. With each throw, the pattern of weapon performance was observed. This particular session was performed on March 18, 2010 and consisted of nine throw groups until both weapons suffered failure. Of all the throws, the shortest flight flew 148 ft. This was probably due to an overextension of the arm prior to the release causing a corruption of the throw. This particular throw also induced a flat spin and an ineffective impact. Aside from that particular throw, all the other throws ranged over 150 ft with the first throw ranging 168 ft (see Table 1). The farthest throw flew 195 ft. Three throws flew over 180 ft. Overall the flight of the weapons were fairly smooth. Because of the nature of the underhand throw, a vertical serpentine motion was noticed in most of the throws upon their release. These however were usually corrected around the apex of the flight parabola.

The next session was performed using a new type of weapon head. This weapon was built according to the designs on the Mamillata style of weapon head in *De Rebus Bellicis* (See Figure 5 and 6). This was based more off of the literary description of De Rebus rather than the pictorial representation.

Figure 5. The Mamillata, or Breasted Javelin type.

Figure 6. The Caltrop plumbata on top compared to the Breasted below

The flights of the weapon were also set to a seemingly ideal position. Instead of the extremes of finger and half thumb lengths from the end of the shafts to the position of the flights, a happy medium brought them one thumb length from the end of the shaft (see Figures 8 and 9) . This did not hinder grip, nor did it have a significant advantage of one position over the other. The flights caused the weapon a slight spin, either clockwise or counter clockwise depending on the orientation of the feather used for the flight. As for their use for weapon stabilization, the counterclockwise oriented flights caused the best stabilization.

Figure 7. Position of clockwise flights from half thumb length (top) to length of index finger (bottom)

Figure 8. Position of counterclockwise flights at half thumb length (top) and full Thumb length (bottom)

Figure 9. Impacted weapon with counterclockwise flights at full thumb length. This proved to have the best effect.

This particular section was performed on March 23, 2010. The reason for the delay was the malfunction of the shafts and difficulties in recasting the lead as well as continual shaft malfunction prior to completion. However, once these issues were resolved, the testing continued with insignificant modifications. It *must* be noted that the only weapon that was thrown was the Mamillata headed plumbata. The reason the other was not tested was because the head was not

as secure as was thought when brought to the field. The result was that the head and shaft separated with the head being unrecoverable for the duration of the test. Nevertheless, the Mamillata was successfully tested (see Table 2).

Table 2. Distance of the Mamillata weapon of the Second Recorded Session

Throw Group	Distance (Ft)
1	143
2	147
3	154
4	186
5	176
6	186
7	188
8	184
9	199
10	200 (?)
11	200 +
Average Distance	173.6666667

Here the weapons performed beyond expectation with throws approaching 200 ft of which the last two throws fell at or exceeded 200 ft. This is very close if not slightly exceeding the range that is recorded by Eagle and his Colleagues (Eagle 1989). The reason for the ambiguity was due to the weapons falling outside of the predefined measurement area.

There were 11 throws that were recorded; seven of which ranged over 180 ft with the last over 200 ft. In this session particular patterns were becoming noticeable. One in particular was that upon a correct release, the angle of impact was fairly predictable. A release meant for maximum range, which all were, usually resulted in a weapon that fell with a medium to middle high angle of impact (see Figure 9 above and Figures 10 below)

Figure 10. Shows the range of angles that the weapons usually impacted at.

In the flight itself, usually there was a slight wobble that occurred after the release. It is unclear as if it was an error in release or error in manufacture but the wobble seemed to have little impact on the general weapon performance. While the previous session had a vertical serpentine motion, the wobble of this session was slightly circular. The most logical explanation is that the flights were off just enough to result in slight variance. While the majority of throws had a slight wobble in their flight, there were a few that not any erroneous movement was perceived. As far as negative effects on flight pattern are concerned, let it be mentioned that this session saw flights exceeding 200 ft, of which there was very minor erroneous movement.

Figure 11. This shows the end of the measured range with the weapon impact marked by the brown clipboard

The next session was able to incorporate both the caltrop and breasted javelin heads. In an unsuccessful session the Mamillata broke and had to be reaffixed to the shaft. At this point the Tribolata head had been recovered so both weapons were reset. As if being struck by one of the

weapons themselves, the idea was presented to not drill the hole for the weapon insert, but to literally burn the insert into the shaft. By a small set of trial and errors and the weapons were constructed in this manner; burning the pyramidoidal shaped tangs into the shaft. Unlike the drilling method to bore out material in the wood shaft, this method suffered significantly less problems with shaft weakness and eliminated problematic cracking. This provides great insight into a method of manufacture for the mass production of the weapon.

In this session, consistency was finally achieved. It was also an opportunity to compare the Mamillata and Tribolata in their behavior and flight. There were 10 throws total, two throws per throw group, before one of the weapons malfunctioned. But of the 10, seven flew at or over 180 ft. An interesting note was that while the Mamillata was the most consistent in terms of its range, it was the Tribolata that gave a range of over 200 ft. It was also the Tribolata that had the best flight although the Mamillata was very close in its performance. Out of both weapons, all the throws had a middle to high angle of impact as in the above figures.

Table 3. Combination Throws. Third Recorded session

Throw Group	Mam Distance (Ft)	Trib Distance (Ft)
1	180	175
2	185	200 +
3	170	153
4	198	186
5	187	malfunction
Average Distance	184	171.3333333

The final session was an examination of the behavior of weapons when designed according to the pictures of *De Rebus* (see Figure 1). This was only a simple modification done by cutting the shafts of the existing weapons to match the proportions of the *De Rebus* representations (see Figure 11 below). Making sure to leave enough length to grip the weapon,

the flights were replaced to represent those of the *De Rebus* pictures. After this simple modification, the weapons were field tested.

Figure 12. The DRB pictorial based replicas.

In short, the modified weapons were a disappointment. It took a large amount of effort to launch the weapons which landed at a much shorter range than the long shafted weapons (see Table 4.) In addition to disappointing range, the overall behavior of the weapons proved to be far more erratic then did the long shafted weapons. Most noticeable was the propensity to wobble. While there may have been some wobbling in the long shafted weapons, it was far more prominent in the *De Rebus* shafts. Normally a small wobble would not have affected the landing of the long shafted weapon, but in the case of the *De Rebus* shafts, there were several throws where the wobble resulted in no effective landing. Often times, the fight was so chaotic that the functionality of the weapon was simply non-existent, landing awkwardly or flat.

Table 4. Distance results of *De Rebus* shafted weapons

Throw Group	Trib Distance (Ft)	Mam Distance (Ft)
1	153	156
2	152.5	161.5
3	164	169
4	172	178
5	164	163
6	153	153
Average Distance	159.75	163.4166667

CONCLUSIONS AND FINAL THOUGHTS

Time and practice were the primary concern of this study. This was to try to account for the time and training that would have likely been conducted by Roman soldiers. The time aspects of the study clearly showed that improvement can be made with even a little practice. This is exemplified in the increasing range and general consistency of the weapon throwing sessions. Through the inclusion of time and practice, one gets a closer picture of how the Plumbata would have functioned in the hands of a competent and disciplined Roman soldier.

Inclusion of the *De Rebus* pictures was also an intention of study. This was to see if the pictorial representations correspond with the functionality of the plumbatae. This study illustrated that an exact form of the *De Rebus* pictorial representations is less practical when compared to the other weapon forms. Given the significantly cut distance of the *De Rebus* weapons as opposed to the far greater range of the long shafted weapons, it is logical to conclude the *De Rebus* form would not likely have been used in a long range tactical application. Additionally, the chaotic nature of the flight also points to a less practical design. The proportions of the weapons on the *De Rebus* picture do not seem to comply with the physics needed in order to make as functional a weapon as the longer shafts. While disappointing, it is an important discovery in relation to performance and design.

Overall, there seems to be little doubt that the Plumbata has advantages over other hand thrown weapons. Given the style of the underhand throw, it is quite reasonable to think that the Roman battle line would have been able to deliver effective volleys with comparatively less effort and exposure. Because of the flight nature of the weapon, a well placed Plumbata volley should have been able to incapacitate at least a few of the enemy combatants. This possibility is

seen in the relatively high impact angle of the weapon when it descends, therefore coming down onto the head and upper parts of the enemy. Finally the most significant advantage is the fantastic range of the weapon. In many ways, what the Plumbata may lack in quality could certainly be made up for in quantity. Since it has easily twice the range of a heavy javelin, the number of volleys could be increased proportionately allowing more opportunity to take an enemy at a safe range. Having seen what the Plumbatae can do, it becomes clear that the Plumbata could be an effective weapon in the hands of a capable soldier.

This study looked only at a very narrow scope of the weapon and its characteristics. Given the still relatively unknown nature of the weapon there are many things that remain to be examined. If one takes Vegetius's ideals of drill and training, with continuous practice, one can assume an even greater range and consistency. Therefore for a further study, one could accommodate a thrower to throw a set of weapons in a continuous drill setting, instead of staggered sessions. In short, lengthen the amount of time to practice with the weapon and increase the frequency of tests.

Just as important as the behavior of the individual weapon is the volley. Let tactical groupings of the weapons be tested. Just as a Roman battle line would have volleyed the weapons, let a large group of similarly able bodied individuals throw the weapons in the tactical formations that would have presumably been used. Through this, one could study the weapon in a tactical application representative to what one might have seen on the battlefields of the Late Rome.

Penetration is a very important aspect that was not covered in this study. Penetration is as important as throw and handling. The perfect flight of a weapon is useless without the decent

capability to incapacitate or neutralize the intended target. Therefore a simple study of killing capability would add greatly to the knowledge of this mysterious weapon.

In many ways there is no limit as to what could be studied of this versatile weapon. Different battlefield applications, tactical variability, individual innovation, all these and probably far more are aspects that could be analyzed about the Plumbatae. A study of weapons is a study of the soldier. Study of the soldier, combat, and warfare are integral aspects of the study of culture and how that culture perceives itself and its relations to others. How a culture fights is how a culture lives. Therefore the simple study of a weapon like the Plumbata can be related to the greater study of the survival, expansion, and death of a great civilization.

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