defenders could often countermine the attackers' mines, and it was not always possible to dig mines—especially in rock.

The tactic of direct assault, using scaling ladders and battering rams, was also nearly always ineffective—the attack could be relatively easily countered by the defenders inside the fortress. Sometimes the terrain on which the fortification was built could not be easily surmounted, such as the Judean fortress at Masada, which, in the first century CE, held out for nearly three years before the Roman attackers constructed an earthen ramp, 114 meters high, to scale its walls.[2]

Very early, the need for heavy weapons, artillery pieces, with enough power to breach the gates and walls of fortresses was recognized. From these a missile—a stone or bolt—could be launched with enough force either to break down the wall or to weaken a part of it so that continual impact would eventually cause a collapse. In this way, the fortress would eventually yield to the attacker. Later it was found that these weapons, although their main targets were walls and fortifications, could also be used on the battlefield as long-range anti-personnel weapons.

The following three chapters will deal with the technology of medieval artillery. The first describes non-gunpowder artillery pieces: traction catapults, torsion trebuchets, counterweight trebuchets, and the incendiary compound known as Greek Fire. The second chapter discusses the invention and early use of gunpowder artillery, while the third chapter describes non-artillery siege machines, i.e., battering rams, siege towers, and so on.

Notes

1. There are many different editions and translations of Homer's *Iliad* and *Odyssey*, the earliest literary works on the Trojan War. For a modern interpretation of the war see Wood (1985) and Strauss (2006). On the fortifications see Fields (2004).
2. The account of Yigael Yadin's excavations of the site is found in a number of books, including Yadin (1969).

CHAPTER 4

NON-GUNPOWDER ARTILLERY

TORSION CATAPULTS

THE WORD CATAPULT IS A GENERIC TERM USED TO DESCRIBE ALL ANCIENT and medieval non-gunpowder propelled missile-throwing artillery. The first catapult may have been invented in the early fourth century BCE. In 399 in Syracuse, King Dionysius I, threatened by the Carthaginians and other enemies, assembled a large group of engineers to create an arsenal of weapons. Among these was the first non-torsion artillery piece, the *gastraphetes*. In essence the *gastraphetes* (which in Greek means "belly-bow") was little more than a large, powerful, and flexible bow. The flexibility of the weapon came from the material of the bow itself, which was a composite of wood, horn, and animal sinew: a wood core covered by a tension layer of sinew in front and a compression layer of horn in the back. This, using a sinew bowstring, supplied the propulsive force to the missile.

It was, in fact, not much different, although larger, from the handheld composite bow, which by the fourth century BCE had been known for several centuries. However, the difference between the handheld weapon and the *gastraphetes* was its power, supplied by the latter's elaborate stock apparatus. It consisted of a heavy stock, made in two sections. The lower section, the case, was fixed solidly to the bow. The upper section (or slider), of approximately the

same dimensions as the case, fitted into a dove-tailed groove in the case and was able to slide freely back and forth. On each side of the case was a straight ratchet with two curved bars, or pawls, fitted into the ratchets and attached to a claw-like trigger mechanism. At the end of the stock was a concave rest that the operator placed against his stomach and, with the front of the bow fixed on the ground, allowed him to withdraw the slider, attach the string to the trigger, load a missile, and discharge it. A man could thus draw the bowstring and discharge a missile with much greater power than was possible with the traditional hand-drawn bowstring. The *gastraphetes* had a range of between 50 and 100 meters greater than the hand-drawn composite bow, which has been estimated to have had a maximum range of 500 meters. More importantly, the missile was launched at greater velocity so that few pieces of armor could withstand it, although it was probably still too weak to breach the walls of even earth-and-wood fortifications.[1]

Non-torsion artillery technology spread quickly throughout the ancient world, and soon improvements were made to the design of the original *gastraphetes*. By about 360 BCE, winches had been added to the stock, allowing for easier and greater drawing power; this ultimately brought increased force, and therefore velocity, to the missile. A base was also added, increasing both the stability and size of the weapon.[2] Still, non-torsion artillery continued to be limited in force and power, both of which remained dependent on the strength and flexibility of the bow. If these were exceeded the bow simply broke. While some *gastraphetes* were equipped to fire stone balls, most fired only heavy, arrow-shaped bolts that also limited the force of impact.

To increase the velocity of the projectile, making the *gastraphetes* more powerful, it was necessary to change both the bow and the size and type of missile fired. Increasing the power of the bow was achieved by replacing the single, flexible bow of the earlier weapon with two non-flexible arms set in "springs" made from sinew. The users of the *gastraphetes* were probably aware that it was the sinew in the bow's composition that gave it its power, so by using the sinew to form tightly twisted "springs," the power of the artillery could be increased.[3] Apart from this development, the rest of the torsion catapult remained little altered from its non-torsion predecessor, with a heavy sinew string, slider, winch, ratchet apparatus, and trigger mechanism. The springs were the only significant change in technology, and this allowed for much more powerful devices firing missiles, now almost always stone, weighing from 13 to 26 kilograms, although stones as large as 162 kilograms are known to have been fired. When the bowstring was drawn back on a torsion catapult, the force was

transferred to the sinew springs which, when the trigger was pulled, made the bow arms spring forward, discharging the missile. The short, stout arms were able to withstand a much greater force than the flexible bow of earlier devices and together with the use of stone balls as ammunition meant that this weapon was capable of breaching the walls of fortifications and towns.[4]

It is believed that the first torsion-spring catapults were made by Macedonian engineers between 353 and 341 BCE and used afterwards by Philip II in his conquest of Greece.[5] The technology then passed to Philip's son, Alexander the Great, who used it in his conquest of Persia, the Middle East, Egypt, and India. Alexander seemed to have been particularly impressed by his catapults' power and used them successfully to take towns, such as Tyre in 332 BCE, which would have been nearly impossible to conquer by other siege methods.

After Alexander's death, torsion artillery technology, which had by then clearly supplanted non-torsion pieces, passed to his successors and from them to Carthage, Rome, and other lands. Over time, improvements to the mechanism were made to increase its flexibility, power, and range. Most important among these was the addition of washers to the springs, which meant that the distance that the arms of the catapult could be drawn back was easily adjusted. In this way the amount of force delivered to the missile at discharge could be varied: a close target could be struck by a looser tension on the springs, while a more distant target needed a tighter tension. The springs could also be loosed when not being used in military campaign, to keep from weakening the sinew from the constant stress of being tightly wound.[6] Other important innovations were the addition of bronze coverings over the springs, which kept them dry during rain or river crossings, and tripod swivel mounts, which allowed for a rapid change of direction in discharging missiles.[7] Improvements were also made in the operation of torsion catapults. Training and thorough practice in their use developed and actively encouraged by competitions between catapult operators. Training schools, especially those at Samnos, Ceos, and Cyanae, also resulted in increased skill in their use. Rhodian operators were particularly highly prized for their proficiency in catapult firing, and they were frequently employed by both Greece and Rome as mercenary artillery operators.[8]

In the ancient world the most sophisticated artillery was made at Alexandria under the Ptolemies, and their machines were much sought after. It is highly plausible that both Carthage and Rome, during the First and Second Punic Wars, faced each other using Alexandrian catapults. This gave Alexandria the impetus to construct some highly experimental catapult models. One of the most curious examples was a chain-driven repeating catapult described by Philon in the

last part of the third century BCE. In this machine, bolts were fed one at a time from a magazine into the slider trough by means of a revolving drum. The chain-link drive, operated by a winch, then fired the bolt and recocked the weapon by engaging the lugs on the chain links with a pentagonal gear. A trigger claw was locked and fired at the appropriate time by pegs mounted in the stock of the weapon, past which the slider moved. There were, however, many problems with this machine. First, because it was so elaborate, the need for it to be constantly repaired must have been great. Second, it fired only along fixed lines, and thus would have been useful only against fixed targets, like a fortification wall. There is, in fact, no indication that this weapon was ever constructed, and it may indeed have been only an engineer's dream design.[9]

The Romans made two important alterations to the traditional torsion catapult—which they called a *ballista*. First, they made it smaller and more portable. Known as the *cheiroballistra*, this variation of the older torsion model contained all of the former's parts and was probably not too much lighter. It was, however, more compact, easier to assemble, and easier to transport. In addition, the springs were set farther apart, giving a wider field of view, which made aiming easier. The bow arms seem to have been capable of greater range than larger torsion artillery. Clearly, this weapon was meant to be used on the battlefield, or at sea, rather than against fortifications.[10]

The second alteration to the traditional ancient torsion catapult was more extreme. Rather than simulating a bow using two vertical sinew springs with two arms swinging horizontally, the *onager* used only one horizontal spring and one arm swinging upwards. There was no bowstring; at the end of the single arm was a sling in which a missile, presumably a stone ball, could be placed for launching. The trigger was a piece of rope used to anchor the arm for loading. The arm was mounted on two large, heavy main horizontal beams held apart by a number of crossbeams. The *onager* was much more like our modern perception of a catapult than other ancient models. However, it should be noted that this weapon was infrequently used by the Romans, who continued to prefer traditional torsion artillery. Apparently, it appeared only at the end of the Empire and is mentioned only by one author, Ammianus Marcellinus (330–390 CE).[11]

That torsion catapults were effective in sieges and on the battlefield is without question. Although their range seems not to have differed much from non-torsion catapults or even from strong bowmen without a substantial decrease in accuracy—most stone-throwing artillery needed to be within 150 meters of a fortification to be effective[12]—the force of impact of a missile fired from one

of these weapons was astonishing. At the siege of Gaza, Alexander the Great was wounded in the neck by a catapult bolt that pierced both his shield and his breastplate. A skull unearthed at Maiden Castle in Dorset was pierced by a catapult bolt moving at such a high velocity that it did not smash it; had the missile been an arrow from a handheld bow, the skull would surely have shattered.[13] Perhaps the most vivid picture of the awe-inspiring power of these weapons comes from the pen of Josephus, the Jewish historian of the first-century Roman conquest of rebellious Judea, who details their use by the Romans at the siege of Jotapata in 67 CE:

> The force with which these weapons threw stones and darts was such that a single projectile ran through a row of men, and the momentum of the stones hurled by the engine carried away battlements and knocked off corners of towers. There is in fact no body of men so strong that it cannot be laid low to the last rank by the impact of these huge stones.... Getting in the line of fire, one of the men standing near Josephus [the commander of Jotapata, not the historian] on the rampart had his head knocked off by a stone, his skull being flung like a pebble from a sling more than 600 meters; and when a pregnant woman on leaving her house at daybreak was struck in the belly, the unborn child was carried away 100 meters.[14]

When the barbarian tribes invaded the Roman Empire in the fourth and fifth centuries, they were met by an enemy using artillery—*ballistae*, *cheiroballistae*, and *onagers*. Indeed, the Romans might have had catapults to defend nearly every fortification besieged by the invaders, and it is reported that several arms factories continued to supply artillery pieces for military use during the early invasions.[15] It is similarly recorded that in some engagements these catapults were successful in thwarting barbarian attacks. For example, Ammianus Marcellinus describes how one attack by the Goths was halted when a single large stone fired from an *onager*, despite hitting no one, caused such mass confusion that the attackers were routed.[16] And Procopius, writing about the defense of Rome in 537–38, provides a colorful witness to catapult destruction:

> ... at the Salerian Gate a Goth of goodly stature and a capable warrior, wearing a corselet and having a helmet on

his head, a man who was of no mean station in the Gothic nation . . . was hit by a missile from an engine which was on a tower at his left. And passing through the corselet and the body of the man, the missile sank more than half its length into the tree, and pinning him to the spot where it entered the tree, it suspended him there a corpse.[17]

Ultimately, however, even with the use of catapults, the Roman armies could not withstand the barbarian invaders. Indeed, it seems likely that there were many problems with their technology and use. First, many towns and fortifications probably did not have a large arsenal of catapults at the beginning of the barbarian invasions. After all, most western imperial towns had been very secure for a long time and had rarely, if ever, been threatened. Second, at this time many military detachments seem to have been unfamiliar with catapults and untrained in their use, a fact attested to by many contemporary authors. Finally, many of these machines were probably not in good working order. It has been estimated that the life of sinew springs was no more than eight to ten years, and many of the existing artillery pieces undoubtedly had strings that did not function properly.[18]

TRACTION TREBUCHETS

Following their victory over the Roman Empire, barbarian tribes do not seem to have acquired catapult technology from their conquered foes. Why this was the case has been the subject of debate among modern historians. Some, led by Kalvero Huuri, E.A. Thompson, and Lynn White, Jr., have contended that barbarians were simply unable either to use or to continue to construct Roman-style catapults.[19] They argue that, although there is some evidence of early barbarian use of artillery, at the siege of Thessaloniki by the Goths in 269 and at Tours by the Alemanni or Franks a century later, the use of artillery failed to prove significant, as the defenders were able to burn the catapults by hurling blazing missiles at them.[20] By the sixth century there is no further mention of them. Whether this was, as Thompson surmises, "owing to the low technical level of their [barbarian] society generally,"[21] or whether they simply did not feel the need for the use of artillery against fortifications that fell relatively easily to them by other means, cannot be known. For whatever reason, these historians contend, catapult technology seems to have passed into obscurity.

However, this thesis has also been questioned by a number of historians, namely David Hill, Carroll M. Gillmor, and Paul E. Chevedden, who argue that the reason for the barbarians' rejection of Roman catapult technology is that they had accepted an alternative: the trebuchet.[22] It is well established that trebuchets originated in China between the fifth and third centuries BCE, and from there diffused westward to Islamic lands by the end of the seventh century CE, where they continued to be used until the fifteenth century.[23] The earliest of these artillery pieces were large and had a long, tapering rotating beam supported on a wooden tower and base. The beam was positioned unevenly on the fulcrum—at a ratio of between 5:1 and 6:1 for a light trebuchet and between 2:1 and 3:1 for a heavy trebuchet. Attached to the longer, thinner end of the rotating beam was a sling in which projectiles, generally stone boulders, would be placed. On the opposite, thicker short section of the beam were secured 40 to 125 ropes that were pulled by a team of men—estimated to number between 40 and 250. By pulling in unison, the team generated enough force to discharge a projectile weighing between 1 and 59 kilograms in a relatively flat arc for a distance of up to about 150 meters.[24] It is this source of power that gives the artillery piece its modern name: the traction trebuchet.

None of these points is questioned by the historians mentioned above. However, the first group maintains that the traction trebuchet was not introduced to Western Europe until it was seen by the Crusaders when they attacked the Muslims on the First Crusade. The second group contends that trebuchets were known and used by Western Europeans as early as the sixth century. As evidence, they point to an eyewitness account of the siege of Thessaloniki by the Avaro-Slavs in 597 written by John, the Archbishop of Thessaloniki. In this account, John describes some siege machines of the Avaro-Slavs (known to him as *petroboles* or "rock throwers"), a description that seems to indicate that they were traction trebuchets:

These *petroboles* were tetragonal and rested on broader bases, tapering to narrow extremities. Attached to them were thick cylinders well clad in iron at the ends, and there were nailed to them timbers like beams from a large house. These timbers had the slings from the back and from the front strong ropes, by which, pulling down and releasing the sling, they propel the stones up high and with a loud noise. And on being fired they sent up many great stones so that neither earth nor human constructions could bear the

impacts. They also covered those tetragonal *petroboles* with boards on three sides only, so that those inside firing them might not be wounded with arrows by those on the walls. And since one of these, with its boards, had been burned to a char by a flaming arrow, they returned, carrying away the machines. On the following day they again brought these *petroboles* covered with freshly skinned hides and with the boards, and placing them closer to the walls, shooting, they hurled mountains and hills against us. For what else might one term these extremely large stones?[25]

These weapons had been transferred to the Avaro-Slavs by a captured Byzantine soldier named Bousas, a decade before the siege of Thessaloniki.[26]

Other references to siege machines appear frequently among the chronicles of the early Middle Ages, which perhaps indicates a continual use of the trebuchet,[27] including two riddles in the Old English *Exeter Riddle Book* that have been interpreted as describing catapults.[28] However, none of these references is descriptive enough to allow the validation of a more secure claim that traction trebuchets were being used, until perhaps the siege of Paris by the Vikings,

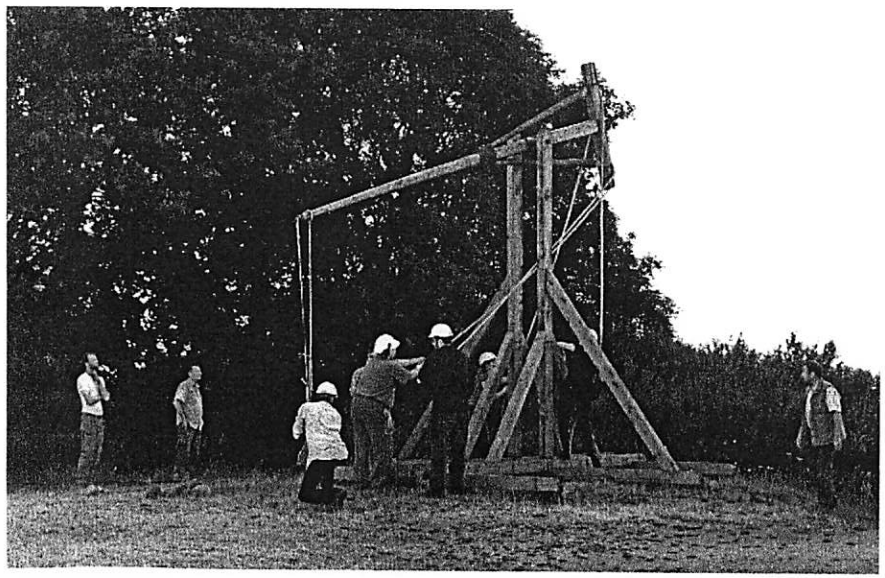

Fig. 4.1: Traction trebuchet at the Middelaltercentret, Nykøbing, Denmark. Photo by the author.

in 885–886. At this siege, according to the historical poem *De bello Parisiaco* (*The Attack on Paris*) by Abbo of Saint-Germain-des-Prés, the defending Franks deployed a type of defensive apparatus known as a *manganum* or *mangonel*, the mechanics of which were similar to the traction trebuchet—a rotating beam engine throwing huge stones against the opposing Vikings:

> The Franks prepared some heavy pieces of wood each with an iron tooth at the end, so as to damage the Danish machines more quickly. With coupled beams of the same length they built what are commonly called *mangonels*, machines for throwing vast stones, which could blast the lowly race of barbarians often blowing out their brains, crushing crowds of them and their shields. Not one shield that was hit did not break; not one unfortunate who was hit did not die.[29]

Yet the lack of corroborative evidence (despite the large number of sources on this siege, only Abbo's poem makes reference to the presence of *mangonels*), the lack of an elaborate description (there is no reference either to the shooter holding the sling or to a team pulling on ropes to discharge the stone), and the lack of a definitive conduit for the diffusion of this artillery technology from either the Avaro-Slavs or the Muslims (although some historians suggest that Charlemagne's forces may have learned it from their numerous attacks against the Spanish Muslims or from the Byzantines in Sicily) all undermine the credibility of this reference. More importantly, despite the possibility of similar weapons appearing again at the siege of Angers in 873, they seem to disappear from Western Europe until the twelfth century. Therefore, if these were indeed traction trebuchets, they may not have had an enduring influence on European military strategy.[30]

In 1147, two traction trebuchets were reportedly used by the Crusaders to capture Muslim Lisbon. They were operated by crews organized in shifts of 100 pullers who fired 5,000 stones in 10 hours—that is 250 shots per hour or one shot every 14½ seconds.[31] After this, traction trebuchets appear at sieges throughout Western Europe, being noted both in numerous narrative references as well as in a large number of diverse artistic sources. For example, traction trebuchets are depicted in a relief carving of the late twelfth to early thirteenth century in the church of St. Nazaire in Carcassonne (which seems to show a crew of women operating the traction trebuchet) and in illuminations

found in the *Maciejowski Bible* (Paris c.1250), the *Le chevalier du cygne* (French c.1200), a *Histoire du Outremer* (French c.1300), another *Histoire d'Outremer* (Jerusalem c.1280), the *Liber ad honorem* of Peter of Eboli (Sicily or southern Italy c.1200–20), and the *Skylitzes Chronicle* (Sicilian or Byzantine, twelfth to early fourteenth century).[32] There is also the famous story of the death of Simon de Montfort, the leader of the Crusaders waging war against the Albigensians in Southern France. In 1218, while besieging the well-fortified city of Toulouse, ironically using several of his own army's trebuchets to batter the walls, he was hit and killed by a stone cast by one of the traction trebuchets defending the city. According to *The Song of the Cathar Wars*, this machine was operated by "noblewomen, . . . little girls and men's wives."[33]

COUNTERWEIGHT TREBUCHETS

However, traction trebuchets had one fundamental flaw—they were inconsisten. Primarily, this was because the force exerted by the team of pullers was not consistent—depending, as it had to, on the strength and unity of a team of pullers. When a team was well trained it is likely that the force pulled was relatively constant from shot to shot. However, when a team of pullers was not well trained or had suffered losses in numbers, the force exerted would be very variable, resulting in a lack of consistency. Consequently, there was a need for an alternative power source, the counterweight trebuchet.

The counterweight trebuchet differed from its technological cousin in the substitution for the pulling ropes for a fixed counterweight, usually a box filled with stones, sand or some other heavy material, which provided the power to discharge the missile.[34] Not only did the counterweight allow for a more consistent discharge, i.e., each time it was discharged the force was the same, but it was also likely that it was more powerful than the traction trebuchet. The weight of the counterbalance depended, of course, on the size of the machine, but it is estimated that they varied from about 4,500 to about 13,600 kilograms and it is likely that they could propel projectiles, weighing between 45 and 90 kilograms, up to 300 meters. Larger projectiles might also have been used—what are thought to be fourteenth-century trebuchet balls made of marble and excavated at Tlemcen measured 2 meters in circumference (roughly 65 centimeters in diameter) and weighed 230 kilograms.[35]

The counterweight trebuchet first appeared around the middle of the twelfth century in the eastern and southern Mediterranean area, then spread

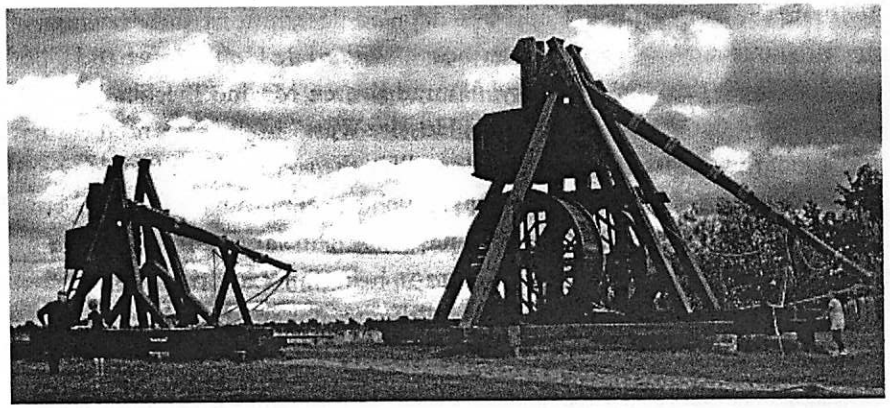

Fig. 4.2: Counterweight trebuchets from the Middelaltercentret, Nykøbing, Denmark. Photo by the author.

into northern Europe, the Middle East, and North Africa. It may have had a Byzantine provenance, as the earliest secure recorded use of the counterweight trebuchet was at the Byzantine siege of Zevgiminon in 1165, but the Byzantines may have learned the technology from elsewhere, as it is possible that both the Muslims and Crusaders were using the technology prior to this.[36] (It is also possible that a "hybrid trebuchet," which combined the elements of the traction and counterweight trebuchets, was also developed, although this theory is disputed.[37]) The Muslims seem to have especially favored this weapon, and they used it frequently against the Christians in the Holy Land, including against the strongholds of Hims in 1248–49 and Acre in 1291, where it is reported that they had 92 counterweight trebuchets.[38]

After this time the counterweight trebuchet appears throughout Western Europe and may have been used in conjunction with the traction trebuchet. The weapon appeared right across Europe—for example, in Flanders, where a counterweight trebuchet is depicted in an early fourteenth-century illumination of the *Roman de Saint Graal*; in England where it was known to have been used in Northumberland in 1244; and in Scotland, where it is found in a Carlisle charter illustration of 1316.[39] So prevalent did counterweight trebuchets become in Europe that they formed the basis, in thirteenth-century England, of a Royal Artillery arsenal, which served the military needs of kings John, Henry III, and Edward III (1199–1307).[40]

As Lynn White, Jr., contends, the counterweight trebuchet was "the first important mechanical utilization of the force of weight."[41] As such, it was of great interest to many technical writers and draftsmen of the late Middle

Ages and the Renaissance, leading to detailed descriptions and drawings of the mechanism by such eminent authors as Villard de Honnecourt and Giles of Rome in the thirteenth century; Conrad Kyeser, Marino Taccola, Roberto Valturio, and the "Anonymous of the Hussite Wars" in the fifteenth century; and Leonard da Vinci and Agostino Ramelli in the sixteenth century.[42]

Both traction and counterweight trebuchets seem to have been effective siege weapons. Although they were never used in large numbers—the 92 counterweight trebuchets at Acre in 1291 being an exception—they often brought a quicker resolution to a siege, although not always by breaching the walls. For example, at the siege of the abbey of Holyrood near Edinburgh in 1296, Edward I had three trebuchets that fired 158 stones in three days leading to its surrender, and in 1304, at the siege of Stirling, the same king used 13 trebuchets that fired 600 stones and within days breached the walls of the castle.[43] However, the best description of the destructive capabilities of these catapults can be found in the *Chanson de la croisade albigenoise*, which discusses the siege of Castelnaudry by the Occitans in September 1211:

> The besiegers set up their trebuchet on a road but all around they could only find stones which would have fragmented under the impact of firing. In the end they found three which they brought from a good league away. With their first shot they knocked down a tower. With their next, in everyone's sight, they destroyed a chamber. With the third shot they fired the stone disintegrated but not before causing great injury to those who were inside the town. Following this display of force, the town surrendered.[44]

Trebuchets were used not only to breach fortification walls, but also to intimidate and destroy the morale of the besieged. For example, stone missiles were sometimes replaced by incendiaries, the carcasses of putrefying and diseased animals, or even the bodies or body parts of captured enemies. At the siege of Schwanau in 1332, the besiegers from Strassbourg massacred 48 prisoners and placed their bodies in barrels that were then catapulted into the castle in an effort to frighten the besieged inhabitants.[45]

Although the trebuchet was the primary siege weapon for the next two-and-a-half centuries, by the mid-fourteenth century gunpowder weapons were beginning to make their presence felt on the battlefield and by the end of the century were making an impact in siege warfare. As gunpowder weapons became more effective and more powerful, the use of trebuchets declined, although they were present at almost all of the early sieges of the Hundred Years' War.[46] Indeed, it is clear that the two technologies, counterweight trebuchets and gunpowder weapons, were used side by side in both attacking and defending fortifications right down to the eventual demise of the trebuchet. They were present with gunpowder weapons in 1373 at the defense of Queenborough Castle.[47] And as late as Charles V's reign (1364–80), the French continued to build counterweight trebuchets and produce trebuchet balls while at the same time increasing their supply of gunpowder weapons.[48] A manuscript illumination from the Bodleian Library (ms 264), dated to the end of the fourteenth century, shows a counterweight trebuchet next to a cannon at the siege of a fortified city, although it is perhaps telling that the trebuchet stands loaded but unused while a gunner aims the cannon at the walls.[49]

Even with the advances in gunpowder artillery, trebuchets continued to be used into the fifteenth century: at the siege of Mortagne in 1405, at St. Omer in 1406, in Saint-Pol in 1419–20, in Touraine in 1421, at Paris in 1421–22 and in Picardy in 1422. Although trebuchets continued to appear in inventories until the 1460s and 1470s, it is clear that the use of this artillery technology was becoming more infrequent and sporadic—indeed it is likely that they were just in store at this time and not used.[50] Trebuchets were replaced by the new, and ultimately more powerful, gunpowder artillery.

GREEK FIRE

Of all the weapons and machines developed in the medieval period, perhaps the most mysterious is the substance called Greek Fire.[51] Although we know very little today about what Greek Fire was, it appears that we can divide it into three distinct weapons: an early liquid weapon pumped out of a nozzle; a liquid weapon that was put into small ceramic grenades; and a later solid incendiary probably based on gunpowder. The first two were used exclusively by the Byzantines and Muslims, while the third was used in Western Europe.

Although there is a great deal of uncertainty about precisely where Greek Fire originated, what it was or how it was discharged, all the evidence indicates that it was an incendiary weapon. The currently accepted account is that it was a weapon that spouted fire from ships and was invented by a man called Kallinikos of Heliopolis, who mounted them on ships of the Byzantine fleet to be used against Arab attacks on Constantinople from 671 to 678 CE.[52]