THE EVOLUTION OF ARMS AND ARMORS DURING THE CRUSADES

1095 – 1291 C.E.

An Interactive Qualifying Project Report

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Abstract

The Crusades were a major turning point in history which evoked a rapid evolution of arms and armors that persisted throughout the middle ages. The focus of this project is to outline the historical, technological, and geographical context that lead to such an evolution. The information we collect will be presented on a continually growing website developed by previous groups. A great helm will also be crafted, in a way that captures the style and spirit of the ancient craft of blacksmithing.

Acknowledgements

The group would like to thank Professor Diana A. Lados and Mr. Tom H. Thomsen for their advice and guidance in the research of the evolution of arms and armor during such a historically important period in history. We would also like to express our gratitude to Joshua Swalec for dedicating his time in helping us develop our project along with the use of his shop, without which we would have been unable to complete our project. His knowledge and expertise were essential in our effort to create a replica Great Helm of the late crusades using period appropriate smithing techniques. The group would also like to thank Professor Boquan Li and Yuwei Zhai, both of whom instructed us on how to properly mount, polish, and etch samples of metal, along with how to properly operate both the Vickers micro hardness and Rockwell hardness machines. Without the contributions of these individuals this project would not have been as detailed and successful. Thank you.

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Authorship

Adam Howard – Was responsible for the Evolution of Armor Through-out the Crusades and Body Armor of the Crusades. Also responsible for the Materials and Methods Section along with initial editing and formatting

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All other sections were a joint effort of the group.

Introduction

The Crusades marked a major turning point in the history of the Middle Ages and represented a colossal clash between both the Western and Eastern civilizations during the 11th through 13th century. With two of the greatest European powers butting heads in bloody armed conflict for over two centuries, the design and composition of armor became an increasingly important factor. Although few developments in arms and armor came about during the Crusades, the need for better and more protective gear increased greatly. The Crusades did however mark a high point in warfare, with some of the greatest tactical minds on either side relentlessly trading man for man through constant skirmishing. The incessant armed conflict of the Crusades put medieval armor and weaponry to the test. They present a culmination of medieval warfare, blacksmithing, history, and culture, making the Crusades a perfect snapshot of medieval history.

1 History of the Crusades

1.1 The Birth of the Crusades

While the true ending of the crusades is a heated topic of debate among medieval historians, the starting years are very well agreed upon. In the early 10th century, the House of Seljuq converted to Islam and migrated from their Turkish homeland to the plains of Persia. After emerging as the victor from a conflict with the Ghaznavid Empire, the Seljuq Dynasty went on to establish the Great Seljuq Empire, around the year 1050. The Seljuq Empire later dissolved as a result of internal conflict among the empires leaders, and this dissolution spawned many of the Turkish groups that Western (Christian) Crusaders would fight in the years to come (Smitha).

Forces from the Byzantine Empire struggled to fight back against the spread of this new Turkish Empire, but they were eventually defeated by the Seljuq armies in 1071. This battle struck the Byzantine Emperor, Alexius Comnenus, with a crippling blow on the power he exerted over his empire. For centuries, Christians had been allowed to make pilgrimages to the holy city of Jerusalem, which had a positive effect of boosting the city's economy (as the wealthier a city was, the more it could be taxed). However, the Seljuq and other Turkic forces did not care for this relationship, and travel was cut off between the Byzantium capital, Constantinople, and Jerusalem (“History of the Seljuq Turks”).

At this point of history it is important to note that Christianity was divided into two main schools of religious thought. A ‘Great Schism’ had severed the Eastern and Western branches of Christianity from one another, a sundering from which there would be no repair. The Greek faction was known as the Eastern Orthodox Church and was the religion of the Byzantine Empire. The Latin West was called the Catholic Church, the religion of the multiple medieval nations. This divide was prompted in 1054 by differing views over who would be head of the Church. The legates representing Rome excommunicated the Ecumenical Patriarch of Constantinople, Michael Cerulariussides, who in response excommunicated them as well (Jeremiads). After this fracture, the Eastern Orthodox made the Byzantine Empire its head.

Throughout the early 11th century, the Turks were strengthening their presence in Asia Minor by conquering neighboring lands and expanding their influence throughout the area. Byzantine was a close neighbor to this area and was the main opposing faction to the rising Turks. The Byzantine Empire, then being ruled by the Eastern Orthodox Christians, was the main power to oppose the spread of Islam in Asia Minor. Pope Gregory saw that the Byzantine Empire was under threat from this new, powerful Muslim nation and planned a military conquest that would help keep Byzantine lands out of the hands of the Turks, and mend the division between the East and West (Smitha). He never saw his plan enacted during his lifetime, but its spirit would soon be encapsulated by his predecessor, Pope Urban II.

In 1095, Alexius, knowing Byzantine's embrace of Christianity would lend him considerable influence with the Papacy of Europe, wrote a letter to Pope Urban II. In it, he requested that the Pope send forces to Eastern Rome to help his armies purge the growing Turkish presence and take back control of the Holy Land. He knew that the Seljuq Turks in Anatolia were a dangerous group that would soon threaten the walls of his own city, and with insufficient forces, outside help was the only option. Shortly after reading the letter, the Pope prepared a speech to give at the Council of Clermont. It was there, in November of 1095 that The Crusades truly began.

In his speech, the Pope spoke of the great atrocities that Christians were currently committing against one another. He was appalled that one Christian soldier would take another's life, and cried out at the degree of sin that his peoples were guilty of. Robert the Monk documented a particularly powerful excerpt from Urban's speech. "You should shudder, brethren, you should shudder at raising a violent hand against Christians; it is less wicked to brandish your sword against Saracens." Pope Urban II cleverly united warring kingdoms under the common ground of religious hatred, by turning his people's attention toward the horrific acts carried out by the Turks against the people of the Byzantine Empire. He promised reprise from sin, a process known as plenary indulgence, to any man who would wield his sword against the Muslim foes. '*Dieu le volt*' (God Wills it), echoed off the great halls of the council room. The Crusades were coming to a glorious start ("The Council of Clermont (1095)").

1.2 A Politically Motivated Movement:

Pope Urban II was certainly the primary agent in starting The Crusades. It was his drive that fueled the religious fervor of the people of Europe, and the original push to reclaim Jerusalem. The Pope justified the Crusades as being sacred in nature, and divine in importance: It was God's Will and that was all the justification he needed. But what most of his followers didn't realize at the time was that Urban II hoped to gain much more than the Holy Land in his conquest. He indeed had many secular motivations for declaring a crusade against the Muslims. Although his predecessor had imagined that the Crusades would help unite a divided Christian faith, Urban II saw them as an opportunity to strengthen the Roman Catholic Church through the acquisition of land in the Middle East in the name of the church.

As his successor, Urban had lived in the shadow of his mentor Pope Gregory VII. This could have motivated Urban to prove himself better than Gregory, and set up an even greater legacy in his own name. But in addition to his own interests, Urban also had the interest of the Roman Catholic Church in mind. While Emperor Alexius of the Byzantine Empire was himself a Christian, he was a member of the Eastern Orthodox Church, which had announced its separation from the Roman Catholic Church forty years prior, in 1054 (Konstantinides). Alexius's intent may have been to rebuild the bridge burned long ago between the two churches. By requesting a garrison of mercenaries to aid his cause, the Pope could easily recognize his good faith by sending such a force to help the beleaguered Byzantines. Urban had no wish to unite this divide between the two churches. Instead, he sent a massive Crusader army to help save Byzantium, in hope that once the battle was over, his Latin army would conquer the liberated lands in the name of the Roman Catholic Church, bringing him much glory and fame.

It makes sense to point out that the peoples of the 11th century had very little connection to the outside world, due in part to langue barriers and the slow rate at which news normally spread across Europe during the medieval period. Far off lands like Palestine and Jerusalem were almost mythical to them, lands they had most likely only heard about when attending church. In fact, most people had never even seen the Pope, for few of the people who lived during these times had the resources to travel to Rome. But even with all these limitations, news of the Crusades spread rapidly across the continent. Much like a presidential candidate would today, Urban made a great effort to campaign his cause and champion it as the will of God. "(Urban) visited various towns in southern France, preaching the Crusade" (Konstantinides), dedicating a host of various churches, and consecrating a great many altars. At various stops along his travels he would ceremoniously cut out a cross cloth to be placed on the shoulder of anyone wishing to join the pilgrimage to Jerusalem, which we now know as the Crusades.

Although Urban had marked August 15th, 1096 as the date on which to begin the march to Jerusalem, there was a group of peasants and commoners led by a zealous monk who couldn't wait to make a difference. The People's Crusade, as it is now known, was carried about by some forty thousand men, women, and children from across the continent. The crusade was fueled by the promises of wealth and a better life, an offer which the many peasants quickly took up. A monk known by the name of Peter the Hermit led "a company of 12,000 disqualified irregulars, moved by faith and famine […to] Constantinople like a cloud of locusts, hardly what Alexius had requested in his appeal." (Bantley) Sadly, starvation and exhaustion fed on their forces, and the People's Crusade ended in battle with Seljuq forces before it reached the walls of Jerusalem. This poor man's conflict enforces the apparent excitement that Urban had stirred up around the Crusades, and shows just how easily people were enticed into joining such a life changing conquest.

1.3 The First Crusade

The offensive pilgrimage towards Jerusalem that set out one year after Urban's speech at Claremont was divided into three fighting forces. The first was led by a number of Franks, most notably Peter Bartholomew, Duke Godfrey of Bouillon, and his brother Baldwin I of Jerusalem. This force followed along Charlemagne's Road, which led them through Hungary and eventually

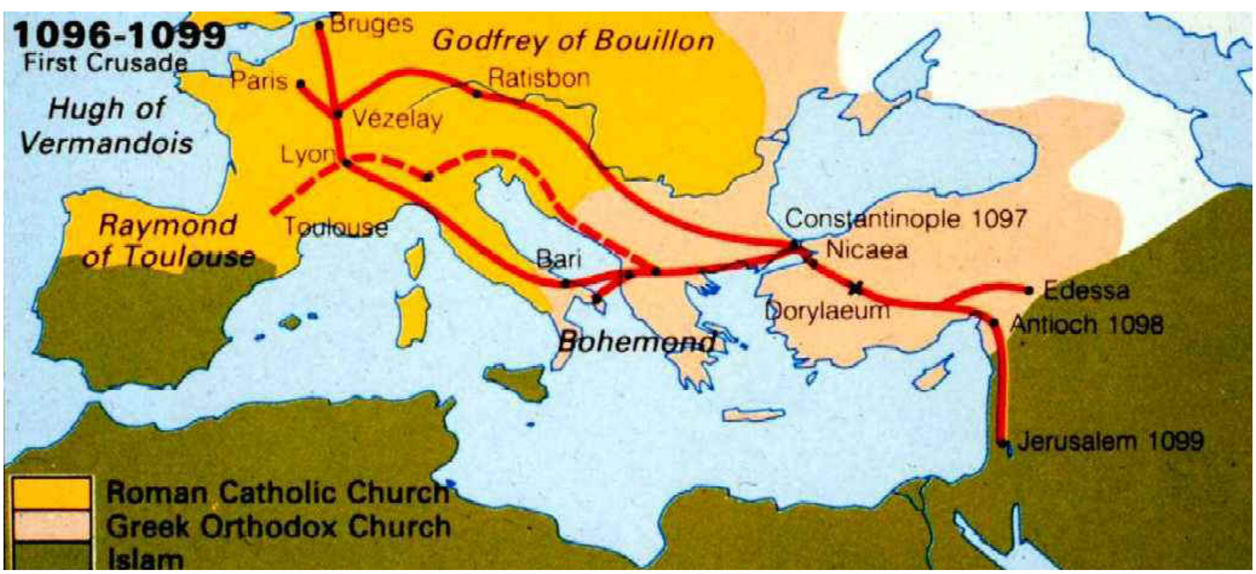


Figure 1: The path that the armies of the first crusade took to reach the Holy Land.(Web: "Second Crusade"

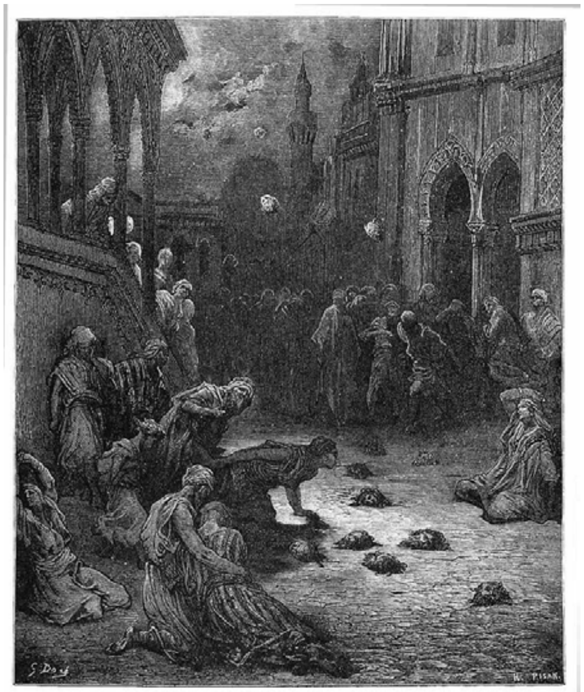
to Constantinople, where they took rest until the other armies arrived (Vicari). The Second contingency of knights and nobleman, under the command of Raymond IV and Adhemar of Puy, journeyed from Toulouse through the arduous mountain lands of Slavonia on their way to Constantinople (Vicari). "The third division, however, went by the ancient road to Rome. In this regiment were Bohemund, Richard of Principati, Robert (Count of Flanders), Robert the Norman, Hugh the Great, Everard of Puiset, Achard of Montmerle, Ysooard of Mousson, and many others."(Vicari) This third army traveled to the port of Bari, and crossed to Durazzo, where they were confronted in battle by Norman forces led by Tancred (Vicari). Bohemond and his men had ventured into a territory that had been taken from Emperor Alexois in 1085 (Britannica). After a small skirmish between Bohemond and the Normans, Tancred allowed the Crusaders to continue through to Constantinople, but required that they be escorted there by his men.

1.3.1 A Brief Stop In Constantinople

As the Crusader forces began to collect outside the gates of Constantinople, they discovered that Emperor Alexois did not quite see eye to eye with their cause. Alexois had no doubt planned out an intricate policy that he would enforce on the Crusader armies as they passed through the towering walls of his great city. If handled correctly, Alexois could harness the collective energy of tens of thousands of religiously charged zealots to combat the forces of the Turks. Months before, the Peoples crusade had stopped over in Constantinople and although Alexois admired their fervor, he was soon appalled by the news that these early crusaders had been causing trouble on the streets by looting and pillaging the many neighboring villas (Watson). Because of this, Alexois quickly ushered the peasant crusaders out of his city and began to devise his policy for dealing with future crusaders. Whenever a crusader army arrived, Alexois would contact its leader and offer provisions in exchange for their allegiance. If they chose to take an oath to the Emperor, they would promise to return control of any lands their army liberated to Byzantine rule (Vicari). This oath played an important role in the development of the many sovereign crusader states, which will be addressed later.

1.3.2 The Siege of Nicaea

After an intermission in Constantinople, the Crusader armies marched onward towards Nicaea, a Seljuq stronghold only fifteen miles distant from their current position. This towering fortress of the eastern lands sat between four miles of walls and a wide lake. The city's threat



13. Crusaders Throwing Heads into Nicaea
As a victorious gesture, severed heads from slaughtered Turks are thrown into the city by the Crusaders.

Figure 2: The Vicious immoral nature of the Crusaders is hard to ignore. Gustave Dore's illustration shows the severed heads of fallen Turks, thrown over the city walls by Christian Knights (*Gustave Dore*).

was too much to go overlooked, so Alexois sent the Crusader armies right up to its doorstep in an attempt to conquer the fortress (Richard). The Christian armies soon realized that although they greatly outnumbered the Muslim forces, they stood no chance of breaching its prodigious walls.

Furthermore, the conditions were unfavorable for a siege, as the Seljuq's could shuttle food and supplies into their city through the lake. But siege being the only option, the Crusader armies surrounded the walls and sent word to Byzantium of their situation (Krey, p.102). Alexios responded by bringing a fleet of ships to the shores of Nicaea's lake. These double masted warships, known as galleys, were utilized with great success throughout much of the Crusades. The ships were usually mounted with trebuchets used to harass land installations from the sea (DeVries, p.300). Under the cover of nightfall; the Byzantine forces approached the city's ports, prompting a quick surrender of the city to Alexois. Traditionally, the Crusade armies would sack any city it captured, stripping it clean of valuables and sometimes slaughtering its people while destroying anything that wasn't worth salvaging. Alexois forbade this practice, and made the armies march on through Asia Minor while he restored order to his reclaimed land. As the time went on relations between Alexois and the Crusaders would only continue to crumble throughout the First Crusade.

The crusaders' march through Anatolia was by no means a pleasant one. Famine and malnourishment brought on by a lack of supplies claimed the lives of many men and horses, as the desert sun took its toll on the Crusaders. Pillaging provisions from whomever they came across became a common practice among the crusading armies. The decision to split their forces and take different routes towards Antioch, their next objective, also proved to be a feverous mistake. Ambush by vengeful Muslim cavalry severely hindered, but failed to stop, the progress of one of the split forces. Hungry and battle worn, the fatigued crusader armies continued towards Antioch.

1.3.3 The Siege of Antioch

After its long travels, the Crusader armies, most notably those lead by Bohemond and by The Count of Toulouse, approached the Muslim city of Antioch. Like Nicaea, the city was a well-defended fortress that had been liberated from the control of Alexois fifteen years prior. The Crusader armies quickly defaulted to a siege formation and attempted to surround the walls of the Muslim stronghold. To their despair, the many Bulwarks of Antioch spanned a distance too great for the some 30,000 soldiers of God to fully encompass. The situation inside Antioch was made better by a steady supply of provisions that were snuck through the gaps in the Crusaders defenses. The turning point of the siege came when Bohemond befriended a tower guard named Pirus and convinced him to let his forces through, affording the Crusaders a chance to spill blood within the city's walls under the cover of darkness (Krey, p.151). An account by Raymond D'Aguiliers aptly describes the aftermath. "How great were the spoils captured in Antioch it is impossible for us to say, except that you may believe as much as you wish, and then add to it. Moreover, we cannot say how many Turks and Saracens then perished; it is, furthermore, cruel to explain by what diverse and various deaths they died."(Raymond D'Aguiliers)

The victory at Antioch became only a momentary respite in the greater conflict at hand for, in an ironic turn of events, Seljuq reinforcements led by a man named Kerbogha stormed the newly taken city and laid siege upon the Crusaders (Krey, p.168). Even though they were under provisioned and undermanned, the Crusaders held their ground against the Seljuq forces. The morale of the crusading forces was at an incredible low, and it wasn't until a spiritually driven monk uncovered a relic, the holy lance, that the Crusaders were able to raise their spirits to the point of standing a fighting chance against the Turks. With great cantor, the Crusaders cavalry burst through the city gates into the front lines of Kerbogha's forces. Surprised by the Christians numbers, the once adamant Muslim forces crumbled in fear and fled the scene. On June of 1099, the Battle of Antioch was finally won.

1.3.4 The Siege and Slaughter of Jerusalem

As June came to a dwindling end, the Crusaders finally found themselves nearing the city of Jerusalem. After a three year march, the 15,000 remaining Crusaders reached their final objective, the Holy City. They found the Fatmids who held the city to be well off with plenty of food and supplies to last them through a prolonged siege. In contrast, the Crusaders were starving and hadn't the provisions to last through the month. But good fortune brought them a group of Genoese mariners who came with the supplies needed to turn the tides in their favor. These sailors crafted siege ladders from wood salvaged from their ships, which would be used in the assault on the city (Krey, p.260). The height for these ladders was derived from the length of the shadow that the city walls cast at night. The Genoese sailors were able to craft enough siege ladders that nearly every other footman in the crusading army had one to himself (DeVries, p.168).

Before the Crusaders began their double fronted assault on Jerusalem, in which Raymond would storm the south gates, while the other armies battled in the north, they first fasted for three days and circled around the city. This was meant to mimic the siege of Jericho as told of in the Bible. The Crusaders followed religious omens very strictly, so when the priest Peter Desiderius received divine instructions to lead a procession around the city, they did not hesitate to do so. Once this procession was complete, the attack on Jerusalem began. Comradery and religious morale fused in the heart of each Crusader, giving each an unrelenting drive that collectively overwhelmed the Fatmid troops, who retreated into the Temple Mount (Fulk, p.110). When the

Crusaders had finally taken control of the city they ruthlessly massacred every non-Christian soul they could find, whether they be man, woman, or child. An account by Fulcher of Chartres provides some abhorrent imagery of the scene; “Indeed, if you had been there you would have seen our feet colored to our ankles with the blood of the slain.”(Fulk, p.110)

1.3.5 Aftermath

Most of the remaining Crusaders who had survived through the Siege of Jerusalem soon returned home to Europe to reap their well-deserved fame. Godfrey stayed behind to govern over Jerusalem with the title “Defender of the Holy Sepulcher” appended to his name. Upon his death, Godfrey’s brother Baldwin, who had recently took land in the county of Edessa, took over role as King (Britannica). Baldwin kept the throne in his family until Jerusalem was lost around 1187, during The Third Crusade. The other leaders of the First Crusade each set their sights on reclaimed Byzantine land that had not yet been repopulated by the Emperor. Bohemond quickly reclaimed Antioch, in which he formed a Crusader State to rule over. Raymond formed his own in Tripoli, which he left for his descendants after his death in 1105 (Britannica). Unwise leadership and pressure from both vengeful Turkish forces and an indignant Byzantine Emperor saw the eventual downfall of Antioch and other northern Crusader states in 1044, leaving Jerusalem to be the last Crusader stronghold found in the Holy Land.

1.4 The Later Crusades

The success of the First Crusade inspired future authorities to lead similar spiritually funded campaigns into the Middle East and the surrounding Asia Minor. The Second, Third, Fourth, and Fifth Crusades were more focused around keeping control of the territories liberated during the First Crusade though than conquering of new land. As the later Crusades had less of an impact on history, they will be summarized on a far briefer scale then the First Crusade.

1.4.1 The Second Crusade

After the first Crusader state, the County of Edessa, fell to Seljuq Turkish forces under the leadership of the Muslim general Zengi in 1044, Pope Eugine III called for a Crusade to recapture it (Britannica). This time, European kings; Louis VII from France and Conrad III of Germany, responded to the call of another Holy War. Conrad III led his men through Constantinople, where tension between Crusaders and the new Byzantine Emperor Manuel continued to climb. The new Byzantine Emperor was more concerned with expanding his empire then assisting the Crusaders in recapturing theirs. As Conrad's army was traveling to the Holy Land, they were caught off guard and utterly massacred while they marched across Anatolia (Britannica). Louis's army took a separate route, and after learning of Conrad's failures, abandoned the original plan of retaking Edessa. Louis VII and his men blamed the Byzantine's for Conrad's defeat, and instigated multiple unwarranted conflicts with Byzantine forces. Following these skirmishes between the Europeans and the Byzantines, Louis and Conrad's few remaining forces regrouped in Jerusalem. There, the two of them and Baldwin planned to use their armies to mount an attack on Damascus, one of the remaining Muslim cities in Asia Minor (Brundage, p.117). The Crusaders attempted a siege, but quickly retreated when they discovered that Muslim reinforcements planned to flank them. This was essentially the end of the Second Crusade, and was considered an utter failure. It diminished resolve amongst the soldiers and spread distrust and hatred for the Byzantine Empire all over Europe (Britannica).

1.4.2 The Third Crusade

A primary component in the success of the First Crusade had been the Schism existing in the Islamic climate of the 11th and 12th centuries. The Seljuq Turks, who had spread their influence all across Persia without hindrance, had converted to the Sunni sect of Islam. Their immediate enemies: the Christians and the Shiites, most notably the Fatmid Caliphate in Egypt. The Seljuqs spent most of 11th century fighting a two front battle with the Fatmids and the Crusaders. This crippled most of their empire and as a result, the true power of the Islamic forces was never realized during the early crusades. However, this would change shortly before the beginning of the Third Crusade (Knox), with the introduction of a new player: Ṣalāḥ al-Dīn Yūsuf ibn Ayyūb (in short: Saladin).

1.4.2.1 Muslim Unification Under Saladin

Saladin has been described as "a hero of Islam for his efforts to unite the Islamic states culminating in the capture of Jerusalem in 1187" (Krstovic). He started under the tutelage of Nur ad-Din, ruler of the Syrian territories under the Seljuq Dynasty, who quickly took a liking to the young warrior. Halfway through the 12th century, Nur ad-Din set his sights on Egypt, and sent young Saladin along with his uncle Shirkuh to Cairo. Egypt's sultan, Shawar, called upon Jerusalem (which was still under Christian rule) to help defeat his attackers. Nur ad-Din countered this by redirecting the Crusaders attentions with an attack on Antioch. This opening

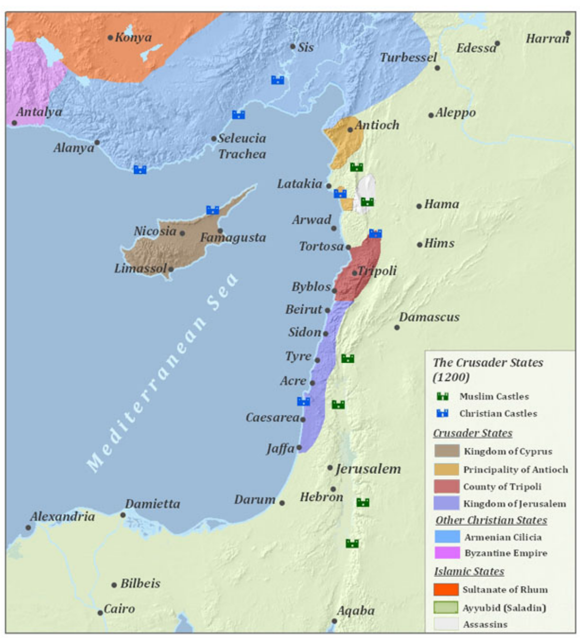


Figure 3: A snapshot of the Crusaders/Islamic territories around the time of the Third Crusade (Web: "The Crusades in the Holy Land").

allowed Nur ad-Din to conquer Egypt (Britannica). He quickly snuffed out the remaining Fatmid forces, and replaced the dead sultan Shawar with Shirkuh, who was eventually succeeded by Saladin. When Nur ad-Din died, Saladin inherited control of both Egypt and Syria. Through his diplomacy, level head, and tactical genius, Saladin soon united the disparate Muslim territories all across Asia Minor as part of a devout jihad against the Christian faith (Britannica).

1.4.2.2 Capture of Jerusalem

Saladin had accomplished what Pope Urban II had 100 years prior; he had used religion to unite an undisciplined aggregate of warriors under one roof, and inspire them to shed blood for his cause. With his forces now as numerous and committed as the Crusaders that originally captured Jerusalem in the First Crusade, Saladin campaigned southward. He made quick work of Acre, Nazareth, and Ascalon in just three short months' time (Britannica). With a majority of the Crusader forces defeated and the few remaining garrisons hunkered down in Tyre, Saladin earned the perfect opportunity to finally retake Jerusalem, which had been in Christian control for more than 80 years (Britannica).

1.4.2.3 European Response

The Third Crusade began as news of Jerusalem's fall propagated across Europe. This disrupted the spirit of Pope Gregory VIII (Urban's successor) who soon issued yet another call for Crusade to again liberate Jerusalem from Muslim influence (Britannica). Monarchs looking to expand their power immediately signed up their legions for this new Crusade. A sizeable force of Crusaders led by King Guy hastily set siege to Acre, one of Saladin's recently claimed strongholds. But with Saladin's ill-preparedness and Guy's forces submitting to famine, neither side could make sufficient headway. This stalemate drew on for months until the other Crusade respondents arrived from Europe. Among them was King Richard I, a frank leader with an intimate understanding of warfare and tactics. Joined by King Phillip II, Richard left for Acre in

1191. Upon their arrival in June, the siege was refueled and the Muslim garrisons inside the city eventually surrendered (Britannica). After taking the city, Phillip returned home and Richard was left in control.

1.4.2.4 The Battle of Asurf

When Richard and Phillip liberated Acre, they took for themselves many Muslim prisoners. Richard wished to move on with his crusader conquest, and made the decision to execute all his prisoners who would have otherwise hindered his progress. This began a vicious rivalry between Saladin and Richard (Oakeshott, p.29). With the prisoners out of the way, Richard led his forces towards Jaffa; a coastal city under Saladin's control, as a straight shot path from Acre to Jerusalem was non-existent.

Outraged at Richard's acts, Saladin grew more ruthless in his conquest, ravaging anything in Richard's path that could someway have been a benefit to his army. This forced Richard and his army to rely on supply ships that closely followed his path. Richard then arranged his army in a defensive, short-response time pattern. An unbroken wall of infantry hugged both mobile cavalry squadrons and caravans who walked along the sea side. (Oakeshott, p.30).

Saladin ordered his forces to ride along the flank of the Crusaders cavalry and pepper them with a foray of arrows. The Crusader forces were viciously battered with arrows and spears as they attempted to hold their formation. Eventually, their patience reached its end, and the forces sporadically charged the right and left Muslim flank. Caught off guard, Saladin's forces were slain and Robert and his men emerged victor (Fratini).

2 The Evolution of the Blacksmith During the Crusades

Throughout most of pre-industrial history smiths have played a vital role in the production and crafting of items ranging from simple bronze pots all the way up to complex suites of armor worn by knights. There are many different types of smiths who all played different roles in ancient society, but the one that has made the greatest impact on history was the blacksmith. The origin of the word blacksmith comes from the combination of the words smith, someone who works with hot metal, and black, referring to the iron that the smith worked with, as opposed to the white metals tin, silver, or gold (Alchin). It is quite clear that smiths of all types were greatly skilled and highly valued by the community of whichever town or village a smith decided to set up shop in. Much like a hardware store of today, smiths would provide basic necessities to maintain the machinery of everyday life.

It is important to discuss the level of knowledge medieval blacksmiths had, regarding the creation and use of different types of iron. The various types of iron used during the period of the crusades included wrought iron, cast iron, and steel, with each form of iron varying in carbon content. Iron, as an element, has a strong affinity for oxygen, hence why iron ores are oxides. Iron ores also contain varying amounts of impurities such as silicon, phosphorous, sulfur, and manganese (Fisher). Smelting, or reduction of, iron was a process by which ore, in this case iron ore, was heated using charcoal to free the iron from its chemically combined state as an ore and allow a blacksmith to obtain "pure iron" (iron with limited impurities). This process of reduction, using charcoal as a fuel source, and varying types of iron ores, led to a variety of iron types, all with differing qualities. Even with the creation of a multitude of basic iron types smiths could still work with the iron and through the infusion of yet more carbon into the heated iron, and create wrought iron, steel, and cast iron. The carbon content of wrought iron varied from 0.02-0.08% carbon, while cast iron had a carbon content of around 3-4.5% carbon (Fisher), and steel had a carbon content of approximately 1-2%. The quality of a smiths work was very dependent on the type of iron he used and this quality was reflected in his weapons and armor.

2.1 The Creation of Workable Iron

In order to first create weapons, tools, and armor, a blacksmiths required a continuous supply of metal with which to work with; it was for this reason that blacksmiths smelted their

Figure 4: Cut away of an iron bloom (Web: "Making Iron").

own ore to create a bloom, from the Old English word bloma meaning mass of metal (Cleere), or a spongy mass of iron and other impurities that a blacksmith would work with, shown here in Figure 4. To understand why the blacksmith did what he did to create the iron to be worked, we must first understand the nature of the iron ore. Iron ore essentially consists of two components – the iron compound, which could be a combination of iron, oxides, and carbonates, and a non-metallic part, called the gangue (Cleere), which consists of sands, silts, and clays. A smith needed to separate out these two components before he could properly work the iron into weapons or armor.

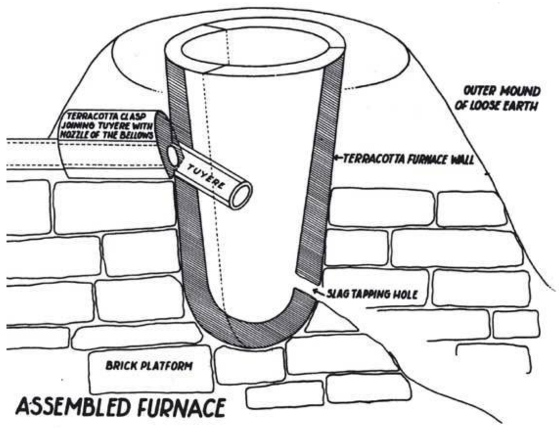


Figure 5: An early medieval bloomery furnace (Web: Wrought Iron Crafts RSS).

To do this blacksmiths would gather the iron ore to be worked and placed the ore, surrounded by charcoal, in a special furnace, called a bloomery, and create temperatures of up to 1200°C (Smith). These medieval bloomeries were usually long terra cotta pits that were surrounded by heat resistant walls made up of earth, clay or stone. These bloomeries needed to be air tight to ensure the proper flow of air during the reduction process and limit the access of undesirable air that might combine with the iron within (Smith). Near the bottom of these pits,

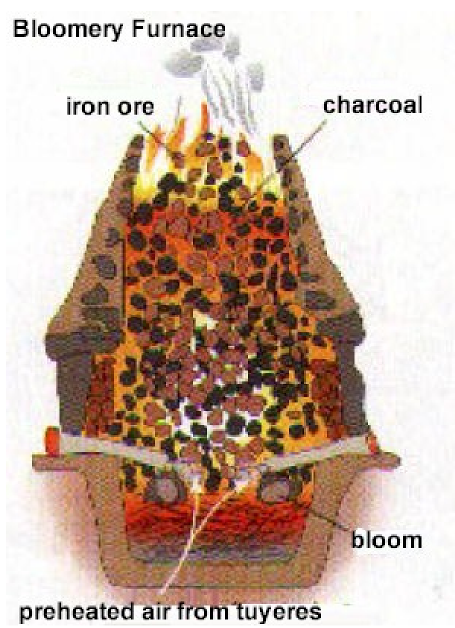


Figure 6: A bloomery furnace in use (Web: Themeister.co).

long pipes were allowed to enter through the walls and allowed air into the pit. These pipes, called tuyeres, allowed air into the pit either by a natural draft of air or by the use of bellows driven by man power. These tuyeres would ensure that the furnace had oxygen to feed the flames and keep the temperatures inside the furnace around 1200°C. Below even these pipes were holes, called a variety of names but usually called a slag tapping hole, which allowed the smiths to draw off the slag formed during the creation of an iron bloom. Slag will be discussed briefly further on in the bloomery discussion. A cut away of a simple bloomery forge can be seen in Figure 5.

Once the blacksmith had finished preparing the bloomery he would gather his supplies, which consisted of his iron oxide ores and charcoal, and would preheat his bloomery for smelting the iron. The preheating process might take up to half a day and would allow the bloomery to reach the desired 1200°C through the addition of charcoal at the top of the bloomery. Though the bloomery may be airtight to ensure that no unwanted air entered to interfere with the reduction process, the properties of the hot gasses rising would prevent the access of outside air (Smith). Once the bloomery had reached 1200°C lumps of charcoal and iron, known as a charge

Figure 5: Slag heap found near a medieval bloomery (Web: Flickr).

(Watson), would be added to the top of the furnace, as seen in Figure 6, at around two pounds at a time (Cleere). Charcoal was the fuel source of choice for smiths as it was fairly cheap, clean burning, and provided twice the heat given off during combustion as the wood it was made from (Watson). The ore would continuously move down the furnace, through increasing temperature levels, and interact with the charcoal and oxygen. These two elements would release carbon monoxide which acts as a reducing agent to the iron, reacting with the oxygen trapped in the iron and producing carbon dioxide, while leaving the iron particles, along with the rest of the gangue, to collect at the bottom of the bloomery (Smith). The main components of sand and clay, silica and alumina respectively, have very high melting temperatures, higher melting temperatures than were attainable with medieval bloomeries. To rectify this problem and remove the impurities from the metal, the silica and alumina were combined with other elements to allow for a much lower melting point.

To create these lower melting temperatures the silica and alumina were allowed to mix with some of the iron to create a compound known as fayalite (Cleere). Fayalite has a melting temperature of around 1150 – 1200°C and is termed fluid slag. Slag is the natural byproduct of the reduction process and consisted of the impurities found within the iron oxide, such as the silicones and metal oxides discussed above, along with some iron particles, and oxygen. This molten slag would flow down through the mass of iron and charcoal and could be tapped through the slag holes, allowing the smith to remove this slag from the smithing process. There are a few theories pertaining to the usefulness of slag in the reduction process, one of which being that "The formation of the slag protected the iron from reoxidizing as they passed in front of the tuyeres, where the atmosphere was extremely oxidizing. Below the tuyeres, some slag drained out of the pasty mass of slag and iron particles and fell to the furnace hearth. The final bloom was a porous lump of iron, somewhat refractory silicates and bits of unreduced ore that collected above the liquid slag.” (Cleere, p.526) This prevention of reoxidation was vital to the production of the iron bloom, as if reoxidation were to occur, the lump of porous metal would simply reform into iron oxide and the whole smithing process would be for naught!

Once the reduction process was complete the smith would be left with a small lump of porous iron that we know of as a bloom. The bloom would not only consist of pure iron particles but would also include various bits of slag that had not melted out during the bloomery process sandwiched between the layers of iron. Most of this slag would be beaten out of the iron when the blacksmith would begin his work with the bloom at a later date. Depending on the expertise of the blacksmiths in charge of running the bloomery furnace, a forge could produce around fifty pounds of iron at one time.

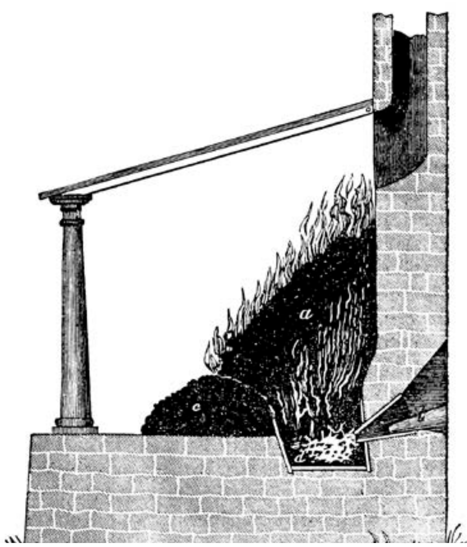


Figure 6: Side view of a Catalan furnace (Web: “Bloomery”).

Demands of iron for use in weapons and armor meant that new designs for forges were researched to increase the output of iron. One forge design that excelled at increased iron production was a forge known as the Catalan forge, shown in Figure 8. This type of forge was generally cup shaped, with stones place at the front and sides of the forge, up to a height of three feet (Fisher). The way this forge worked is that charcoal would be placed on the bottom of the forge, up to the level of the tuyeres, and on top of this would be placed two columns. One of the columns was charcoal, which was placed towards the front of the furnace, and the other was iron ore, which was placed towards the back of the furnace.

When the charcoal was lit and bellows were used to blast air onto the charcoal carbon monoxide would be blown onto the iron ore, thereby reducing the ore and at the same time keeping the ore from mixing with the charcoal. This produced relatively slag free blooms that blacksmiths could work with. Some early medieval forges could produce up to fifty pounds iron bloom for a blacksmith to work with. A more developed medieval forge, known as a Catalan forge, could yield up to three hundred and fifty pounds of iron bloom in a five hour heat (Fisher). Smiths would then hammer these blooms into manageably sized rectangles with which they could work with in their forge.

2.2 Working the Iron Bloom

Before a smith could work with his iron bloom he would first have to prepare it by beating out the remaining slag which was intersticed within the layers of iron and also form his spongy mass of iron into a more manageable form. Iron can be worked at the forge at a temperature of 1200°C and as stated above fayalite slag, along with other slags, are fluid at temperatures around 1150-1200°C. Thanks to these properties both of these processes could be performed at the same time (Cleere) allowing the blacksmith to efficiently use his time when working the bloom. For ease of transport, and in consideration of how the worked blooms would be shaped in the future, blacksmiths would form their worked blooms into rectangular ingots, seen here in Figure 9.

The iron ingot is a versatile shape as it allows a smith to hammer it into any blade or into flat sheets with which to make armor. The smith could also draw out his ingot and turn it into wire of various sizes. This wire could then be used to create chain mail. Needless of what the blacksmith intended to create, he first required the iron ingots to work his craft.

When smiths forged different weapons and armor with their iron ingots they were not aware of the carbon content of the iron and how that affected the iron's properties. Different

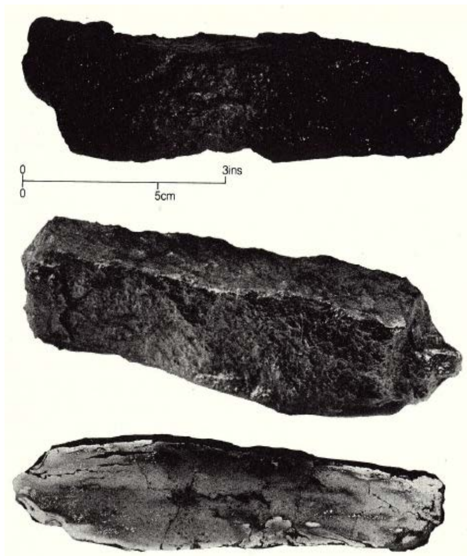


Figure 7: Iron blooms in ingot form (Cleere).

productions of iron during the bloomer process would occasionally produce either a form of mild steel, or cast iron, rather than the wrought iron the smiths had intended to create, each with different carbon contents described above. While the smiths did not know what was occurring during the forging process to create these different metals, they did know that these different material properties could be useful in creating superior arms and armor. The creation of steel could certainly be used to create blades that could hold a sharp edge far longer than iron could, or create pieces of armor that could withstand more blows than iron. Up until the time that carburization of iron was studied and well known medieval smiths continued to experiment with different methods to attain large quantities of steel.

2.2.1 Creation of Steel

The easiest way for a smith to obtain steel was to make a bloom and break it up into fragments, then search for the hardest fragments (Williams). The smith could then forge these lumps back together but at a loss of material in the forging process. A more efficient way to obtain steel would be to create an artifact of iron and then convert part of the iron into steel through the addition of carbon. To obtain these differing levels of carbon content the iron being worked by the blacksmith would have to keep the lump of iron touching the charcoal, away from contact with the air, and at a consistent temperature. Inside the forge, the surface of the iron would slowly absorb the carbon and it would spread throughout the iron. This process of hardening the metal, known as carburizing, or case hardening (Fisher), was in essence a way to create a hard, thin shell of the exterior iron while the interior iron remained soft and workable by the smith. The carburization of iron was a lengthy process and in the time it took to moderately carburize the center of a piece of iron, it would excessively carburize the edges. An alternative to case carburizing large pieces of iron, a smith could carburize small pieces of iron and the forge-weld them back together again in a process known as piling (Williams). Case carburizing was more suitable for cutting edges of swords than armor, and as such, the creation of steel for the production of armor will follow shortly.

2.2.2 Strengthening Steel Blades

When discussing the strength of both iron and steel an appropriate scale of hardness is required to differentiate between the various types of metals used by medieval blacksmiths. The scale to be used in the report will be the Vickers Pyramid of Hardness (VPH), where the units are in kg/mm^2. Pure iron crystals have a hardness of around 80 VPH, while more common medieval iron will have a hardness of between 100 and 180 VPH, due in part to the various amounts of slag and other impurities found within its lattice structure (Williams). Depending on the carbon content of steel, certain steels could have a hardness of 180 VPH for 0.2 % carbon content all the way to 260 VPH for a carbon content of 0.6 % (Williams).

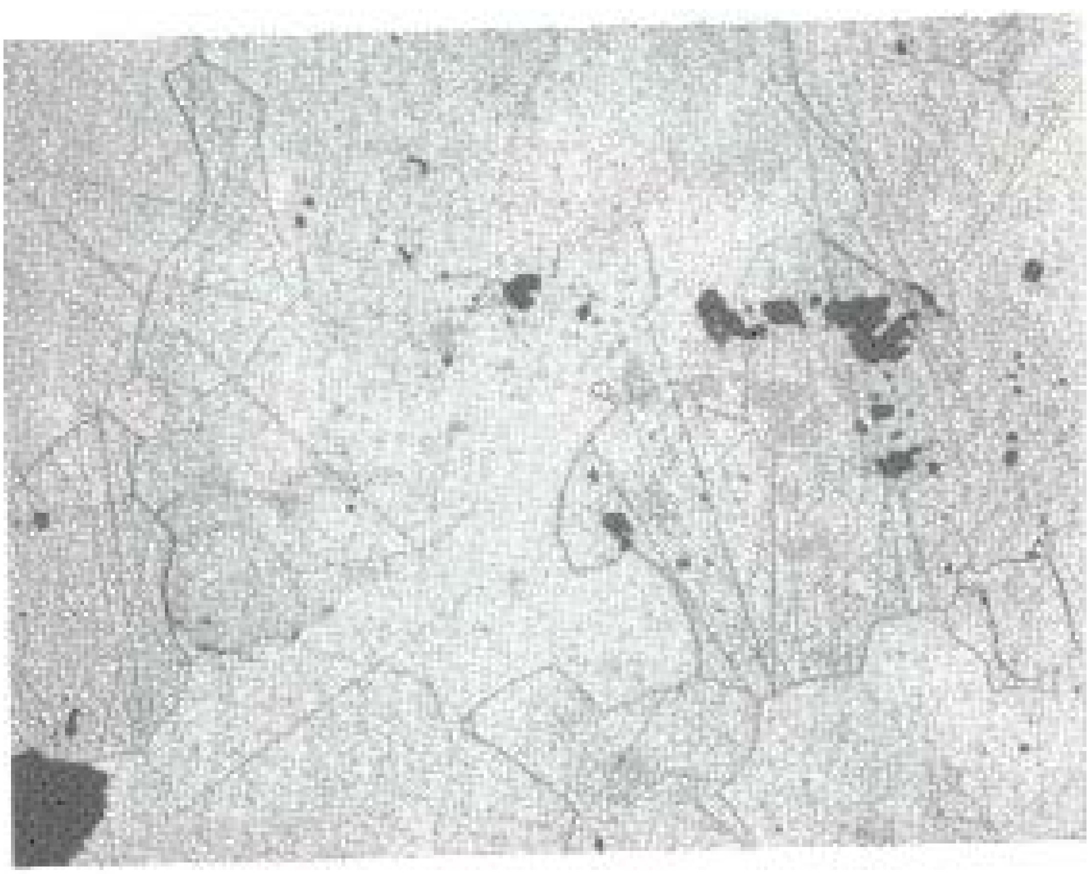


Figure 8: Photomicrograph of ferrite in iron (Williams, A).

When working with the metal, blacksmiths knew that the techniques for carburizing the iron along with slack-quenching, where slack-quenching is a process by which the metal is quenched in oil, molten lead, or some constituent liquid at a greater temperature than water, would increase the strength and durability of the iron, but they did not realize why this occurred. Slack-quenching will lead to an increased hardness of 300 to 400 VPH in the steel, but this

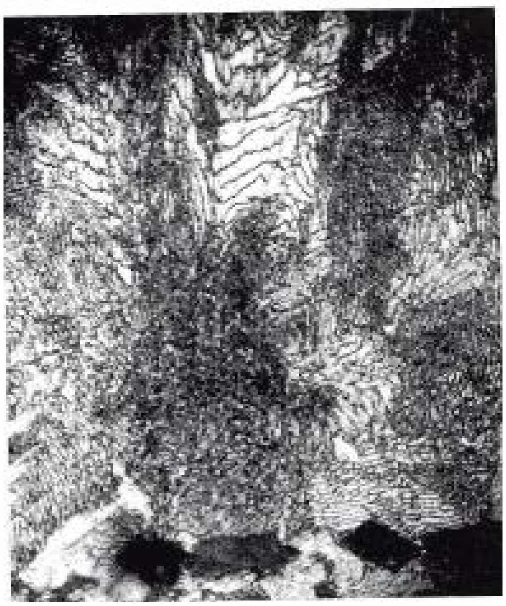


Figure 9: Photomicrograph of steel with pearlite (Williams, A).

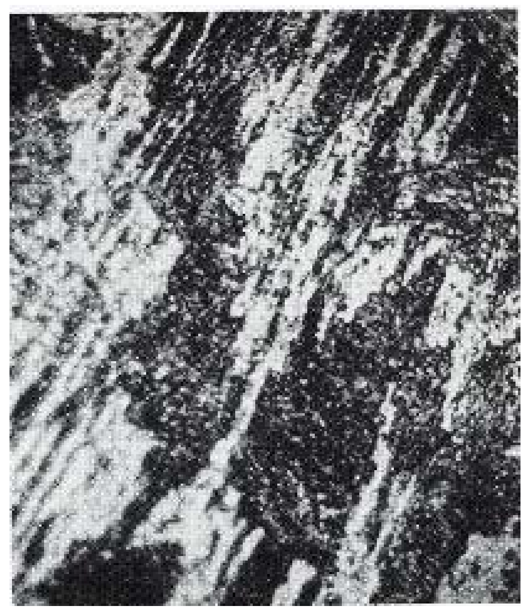


Figure 10: Photomicrograph of steel with bainite (Williams, A).

increase is dependent on the proportions of microconstituents formed during quenching. The microconstituents that could be formed when quenching the metal includes ferrite, pearlite, bainite, and martensite, all of which were formed by varying factors dependent on how the metal was quenched. Ferrite forms when iron cools from around 800-1000°C and the iron forms a random, interlocking array of crystals. The lower the carbon contents of the metal the large the proportion of ferrite that will be formed. Pearlite is formed when the metal, with a carbon content of approximately 0.8 %, is air cooled at temperatures of between 550-720°C and is a mixture of alternating layers of iron and iron carbide, known as cementite, which have an appearance to that of mother-of-pearl. A fast rate of cooling will lead to a finer spacing of the layers of iron and cementite, and therefore a harder pearlite (Williams). Alternatively, cooling steel at a rate faster than what allows pearlite to form, or holding it at a temperature ranging from 250-500°C, will lead to the formation of bainite, which is a combination of ferrite and cementite. Bainite is need-like in appearance and has an intermediate hardness between pearlite and martensite. Martensite is formed when the metal is cooled rapidly, such as through the process of quenching, and is an extremely hard combination of carbon in iron. Steels or other metals that have been cooled, but not completely quenched, have been shown to have microstructures that

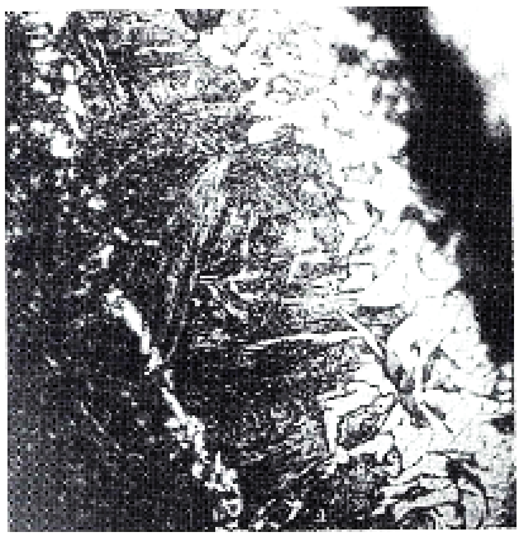


Figure 11: Photomicrograph of martensite in iron (Williams, A).

consist of a mixture of above constituents. It should be stated that the proportions of the above constituents in metals is dependent on the carbon content and the method of cooling.

To understand why these variances in strength happened we must look at the crystalline structure, like we did above, that made up the different kinds of iron being worked by medieval blacksmiths. The crystalline structure of iron includes not only the elemental iron itself but also harbors the different impurities and microconstituents that can be found within the iron. These elements would form different types of grains inside the structure of the iron, along with the grains formed by the iron. These different grains would lie in varying direction and angles to each other, and the different sizes and relative angles of these grains would help alleviate any stress that was placed upon the iron or steel. This meant that the force of a sword blow would dissipate across the grains rather than travel down a row of straight grains, which could lead to grain failure and cause the sword to shatter. Iron that was cooled quickly after being worked tended to form many small crystalline grains, and thus cause the metal to become hard and brittle, while iron that was left to slowly cool tended to form large, long crystalline grains that allowed for more flexibility (Watson).

It was up to the smith to know how to properly forge a blade and to prepare it for rigorous use by the soldiers of Europe and of the crusades. The quality of the sword depended on not only the smith's expertise in metal working but also on the way a blade was forged. Blades could be forged as follows, in decreasing order of quality: one homogeneous piece of steel, one heterogeneous piece of steel folded and forged, two or more heterogeneous pieces of steel forge-welded into a blade, a core of iron with welded-on steel edges, and finally a core of iron with carburized edges (Williams). As talked about above the blades were slack quenched in order to harden the blade and allowed it to hold an edge. If the carbon was high enough then the blade could be air cooled before an edge was ground onto the blade (Williams).

2.2.3 Creation of Mail

The formation of all chainmail started with some form of iron wire coming from the iron blooms most likely. The fastest way of making wire for mail was by drawing a rod of iron or metal through a succession of smaller and smaller holes in some form of plate. This method would produce a uniform wire that could be turned into mail (Williams). This wire would then be wrapped around some rod or mandrel to form coils, which would then be cut to form a series of rings (Burgess). The main way that a crusaders mail was most likely made was by linking each chain to at least two other chains and then riveting the chain together. A mail shirt common for the crusades time period could have consisted of 28,00 to 50,000 links, with this mail construction potentially taking up 1000 man hours to create (Williams).

3 Evolution of Armor throughout the Crusades

3.1 Body Armor of the Crusades

As long as there have been weapons, there has similarly been the need for armor. As weapons have evolved, armor has had to adapt to accommodate the ever-changing methods of inflicting harm. Some of the earliest examples of armor included iron helmets and cuirasses, worn by soldiers in Japan during the fourth century. These cuirasses consisted of iron plates strapped together with metal thongs. Lamellar armor, another early form of armor, started to be used in Japan by the fifth century. This type of armor consists of rectangular leather or metal pieces stitched together in rows. These early forms of armor were useful for absorbing sword blows or the impact of arrows in the area where the armor offered protection. However, soldiers during these early periods often were not outfitted with a complete set of armor that protected all parts of the body, and instead relied on a large shield for protection (Ffoulkes).

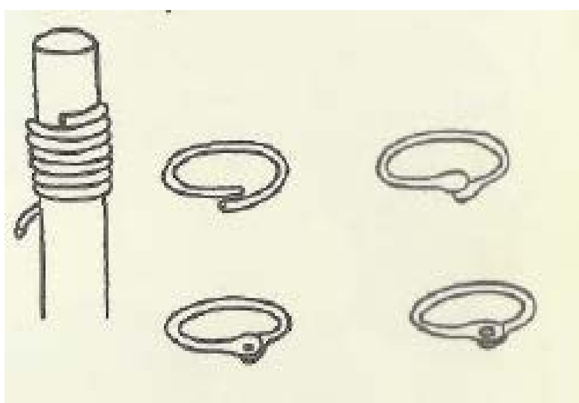


Figure 12: Rings used in chain mail were made from wrapping metal wire around a rod, and then flattening the ends (Ffoulkes, p.45).

During the time of the first crusades, armor had begun to take other forms besides these cuirasses and lamellar patterns. When the crusades first began around the turn of the 12^{th} century, armor was very similar throughout all of Western Europe. The main component of armor at this time was a shirt of connected iron rings, known as chainmail, which usually extended all the way down to the knees. Chainmail, simply referred to as mail, is a piece of armor constructed from thousands of metal rings woven together into different kinds of mesh. Armorers had to learn the unique craft of making mail, of which there are no counterparts in other smithing disciplines. The process started with a solid bar of iron. The iron then had to be drawn out into wire before it could be woven. Before the process of wire drawing became widely known around the middle of the 1300s, the making of the wire was a very unrefined, laborious process. This is because the iron had to be manually beaten out from the solid bar and hammered into wire.

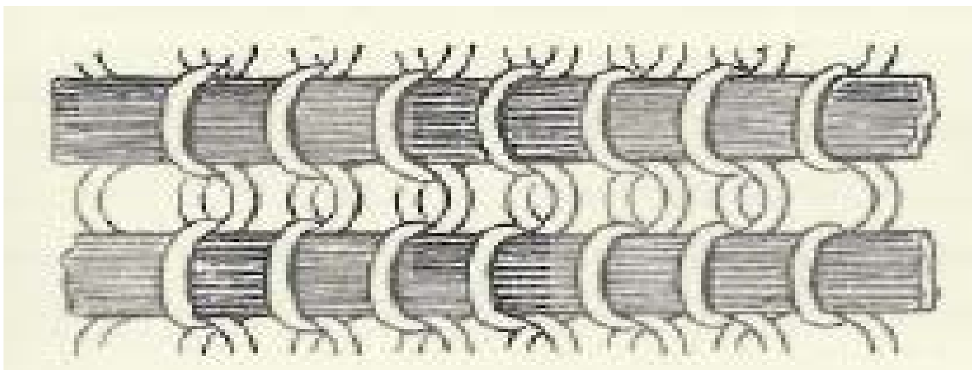


Figure 13: Depiction of banded mail made with leather straps on every other row of rings (Ffoulkes, p.47).

Early specimens of mail have very thick, rough, and uneven wires for this reason. After making the wire, it was twisted around a rod in a spiral pattern, shown here in Figure 14. The wire was then cut into rings long enough to have the ends overlapping. Then the ends of the rings were flattened and bored through with holes, so that they could be fastened with a small rivet. Before the armorer joined the ends of the rings, they were interlaced with each other to form the armor. Each ring passed through four other nearby rings. When all of the rings were interlaced with each other, a rivet was used to join each ring to complete the armor. Occasionally, for reinforced strength, this process was done with two rings used for every one that would be used in normal mail. Sometimes even, flat rings were used, however, it is not known if these rings were obtained from cutting flat sheets of metal, or from flattened wire. Clearly any of the above processes required a lot of labor, and many hours invested in the craftsmanship. There also existed a variety of mail known as banded mail. This type was the same in all regards, except for a strip of leather threaded through every other row of rings. This helped to reinforce the armor and keep the mail in place.

As time progressed the mail worn by soldiers and knights continued to elongate and by the 11th century mail was down to the wrist and had multiple individual separate parts, such as leggings and hoods (Blair, p.44). When mail was meant to open, so that it could be put on and taken off more easily, it was fastened by tying laces. Leggings of mail were laced together at the back of the leg. The coif of mail, which was worn under a conical helmet, was sometimes kept secure by a lace fastener around the temples as well (DeVries).

Figure 14: A full piece of banded mail leggings would be worn as such (Ffoulkes, p.47).

It is uncertain what was worn under mail during the twelfth century. Depictions of the time show people either wearing nothing under their mail, or wearing a simple tunic. Since it seems that this would be unbearably uncomfortable to the wearer, it is unclear if this was actually the case.

During the second half of the 1100s, wearers of mail adopted a loose surcoat that was worn over the armor. It is thought that these surcoats were originally used for practical purposes. For example, they were likely useful in combating the high heat on long marches, because the surcoat served as a barrier between the sun and the very heat conductive iron mail, thus preventing the metal from reaching extreme temperatures. This was certainly important for the soldiers of the crusades, as they had to march through deserts while fighting in the Middle East. Another practical use was to protect the armor from the rain and other elements it would invariably be exposed to. However, despite the seemingly practical uses, surcoats primarily served as aesthetic pieces by the year 1200. By this time, surcoats were widely used, prevalently with mail armor. Most of the time, surcoats were worn to midcalf or shorter, but could be made to touch the ground. There also existed a very stiff kind of surcoat with a raised collar, which was meant to add to the defense capabilities of mail. For reasons unknown, it never became widely popular among the armies of Europe.

Figure 15: Modern photo of Brigandine armor (Web: Armor of the Ages).

The fourteenth century saw a major change in the kind of armor popularly produced and worn. During this time, plate armor, rather than mail armor, began to rise to prominence. This was probably due in part to combat the rising effectiveness of bowmen at the time, as mail armor couldn’t hold up against a well-placed arrow to the chest. This weakness could be seen when arrows could punch through the rings of mail instead of being deflected. Additionally, the flexibility of mail meant that it could not provide enough resistance to a crushing blow. It should be noted though that chainmail was usually worn with a quilted undergarment, or gambeson (Williams). For this reason, cuirasses started to replace mail shirts.

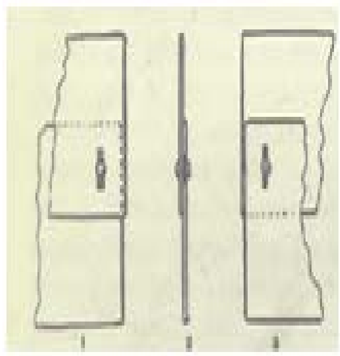


Figure 16: Top, side, and bottom view of a sliding rivet (Ffoulkes, p.52).

A cuirass is a rigid piece of armor meant to protect the torso from harm. Cuirasses at this time were generally made as one or two large rigid pieces of iron that would connect at the shoulders and down the sides of the torso, leaving openings for the head, arms, and waist. Despite their resistance to arrows and an increased resistance to blows from weapons, there was also a drawback to cuirasses when compared to mail. A soldier in a cuirass was far less maneuverable than a soldier in mail. This was because the armor was made as either one or two solid, rigid pieces that were not at all flexible. To address the problem of maneuverability, the concept of plate armor began to emerge. The two main types of plate armor at this time were Brigandine and splinted armor, with both types being small metal plates attached onto a fabric foundation. The difference between the two was that Brigandine armor had plates riveted on the inside of the fabric, while splinted armor consisted of metal plates on the outside.

In the case of the Brigandine armor, the small plates were wider at the top, and overlapped in an upwards direction. This is due to the human torso being wider at the chest than at the waist, and because of that, the armor conformed to the figure while having the plates overlap. Brigandine armor and plate armor in general, offered the best of both worlds of mail and cuirasses. Because of the form-fitting and overlapping design, plate armor offered the maneuverability of mail, and the metal plates offered the protection of the cuirass.

A coat of linen and metal plates fashioned as displayed in the diagram, is known as a jack. A jack was typically made up of six separate panels, where each panel was constructed with lots of overlapping metal plates. A jack had two of these panels for the chest, two for the back, and two smaller ones for the shoulders. The materials necessary to make a jack were about 9 yards of linen, two dozen laces for fastening, and 1650 steel plates. The jack was also sometimes further reinforced by including two large plates of steel on each breast on top of the garment. This allowed for additional strength at the chest while still allowing the torso freedom of movement.

Another feature of plate armor that allowed for increased maneuverability was the sliding rivet. This piece of technology was constructed by fixing the rivet in the upper plate of a piece of armor, and making a slot of about three-quarters of an inch in the lower plate. This then allows the plates to move apart and come together without exposing the body of the wearer. Plate armor granted the torso freedom of movement backwards and forwards, without sacrificing any defensive capabilities (DeVries).

3.2 Helmets of the Crusades

3.2.1 Early to Mid Crusades: 1095-1170

One of the earlier forms of helmet that was worn by the knights of the crusades was what is known as a conical helm. This specific style of helmet was very popular during the early medieval ages and was known by its German name, the Spangenhelm. In German Spangen refers to the strips of metal that would form the structure of the helmet while helm simply means helmet. A conical helm could be constructed using two different methods, with one type being referred to as a "segmented" helmet and a second type referred to as a "banded" helmet (Vesey). When constructing a segmented helmet an iron band was formed that then supported vertical bands of metal that would converge at the apex of the skull and would be hammered together and overlaid with more metal, as seen in Figure 19. In the banded helmet a blacksmith would form an iron head band along with attaching two more semicircular iron bands to the head band that would cross at right angles to each other at the apex of the skull. Metal would then be hammered together over the equal segments to form a solid helmet. Whether segmented or banded the main pattern that was used to create these helmets was to rivet iron plates together, which would then be strengthened with the attachment of an iron rim (DeVries).

Figure 17: Sectional view of Spangenhelm pieces (Web: The Ancient Goths).

In addition to providing protection to the skull, the conical helm also provided limited protection to the face through the incorporation of a nasal bar that would extend down the length of the face and was riveted to the base of the helmet. Along with providing protection in the form of a nasal guard, ear or cheek guards could be added for extra facial protection against attacks aimed at the face. These helmets could also be worn over a chainmail coif, or have one attached to the head band for additional protection against facial attacks. Several helmets that have been preserved in Poland and England show that some were made without nasal guards and two showed signs of having mail directly attached to the rim (DeVries). This shows that while creation of this type of helmet was common across Europe, addition of various defensive elements was left to the local smith to add.

Figure 18: Medieval kettle helmet worn over a chainmail coif (Web: Chivalry – Medieval Warfare).

A second type of helmet used by the early crusaders was a type of helmet called a kettle hat. These helmets were simple conical or spherical helmets, usually made of two or more sheets of metal, which had a broad brim running around the circumference of the helmet, as seen in Figure 20. These sheets of metal would be heated and hammered by the medieval armorsmith and would be riveted together by thin, long rectangular sheets of metal. The brim of the kettle helmet would either be made to be horizontal or would be given a downward slope, which would provide the wearer protection from blows delivered to the head. These blows could involve a multitude of sources including, but not limited to, sword blows, maces, hammers, arrows and also from projectiles aimed from above, such as rocks and boulders dropped on foot soldiers during a siege (Vesey).

Figure 19: Kettle helmet worn over an arming cap (Web: Arming wear).

In some cases the brim of the helmet was so long, and had such a vertical tilt, that vision slits were punched through the solid metal to provide vision to the wearer. Kettle helmets could easily be worn over a chainmail coif with the aid of linen padding and what is known as an arming cap, as seen in Figure 21. An arming cap is a close-fitting skullcap worn either under or over a chainmail coif and was used as a buffer system between the skull of the wearer and the helmet. This padding system helped prevent chaffing of the skull during prolonged periods of being worn and, in combination with the slope of the brim, would help dissipate the energy of blows directed at the wearer's skull. To keep the helmet from falling off during battle soldiers used a simple strap system to keep the helmet in place. It is this combination of armor that has led to the stereotypical picture of the medieval foot soldier.

Kettle hats were common throughout Europe, though they are believed to have first been produced in England around 1011, and were known by many names such as Eisenhut in German and chapel de fer in French, both meaning iron hat in English. In fact the kettle helmet received its name in part to its resemblance to the cooking pot with which is shares its name. Kettle hats were generally considered infantry hats, not suitable for the pomp and extravagance of the knightly class, but they were extremely versatile and provided excellent protection. Along with providing a good measure of protection for the common soldier kettle helmets were also very easy to produce and it was not uncommon for entire companies of men to wear these helmets.

These two helmets were certainly not the only types of helmets to be found in early medieval Europe but these styles were the most prevalent in the armies of this time period for a few reasons. For the Spangenhelm this style was commonly used by the Norse and Viking armies, and when both of these groups spread throughout Europe they brought along with them knowledge of how to forge such helmets. As such, the people who lived in areas that had been visited by both these groups began to forge arms and armor in a much similar manner and so began the increased use of the conical helm. The continued use and development of the kettle helm is due to both its ease of construction and its cheapness. Compared to the more advanced pieces of armor that the knightly crusaders were wearing, a kettle helmet was a cheap yet effective piece of armor for the foot soldiers.

3.2.2 Mid- to Late Crusades: 1170-1295

As the crusades wore on it became apparent to the crusaders that more protection was needed to prevent life threatening injuries while wearing mail armor (Lacombe). To achieve this goal of increased protection, around the turn of the 13th century the armorsmiths began to experiment with new helmet designs, designs which would incorporate an increase in face and neck defense (DeVries). The first of these new helmets that was deemed a success by knights and smiths of the time was simply a skull-cap with the attachment of a face mask. The shape of the skull-cap did not matter, for what was most important was the addition of the face mask, and as such the shape and sizes of the skull caps varied widely. These face masks had rudimentary air holes for ventilation and slits for vision. This impairment of vision was acceptable to the knight for the added protection the mask provided, and with training could be accounted for (DeVries).

Figure 20: A typical great helm with chin strap (Web: Crusader Helmet).

This form of helmet slowly evolved, as this early version lacked adequate ear and neck protection, and soon enough the entire helmet extended to cover the entire head. The final evolution of this type of helmet, seen around the year 1220, was completed by the increase in size of the helmet, as it encased the wearers head and provided protection to all the vital points of the head. These Great Helms, as they came to be known, were cylindrical in form, normally long enough to reach the shoulders, usually flat at the top, and typically placed over a chainmail coif (Lacombe). Vision bars or slits, called vues or sights, were more professionally pierced to allow for a limited line of sight and small holes were drilled below the sights to allow the knight ventilation, much like the earlier version. Depending on where the helmet was made a great helm would either be held in place by both the mail coif and arming cap worn by the knight, or have some type of leather strap attachment that would allow the knight fasten his helmet in preparation for the coming battle. A typical great helm can be seen in Figure 22.

With the increased protection provided by the new type of helmet there were also a number of drawbacks with this design. The first problem that the crusaders had to deal with when wearing this helmet was the increase in weight brought about by the increase of coverage. While the knight might have his entire head protected from lethal blows, iron is not a light metal and as such knights would suspend the helmet from their saddle and only don their helmet when they were about to enter battle. A second problem the knights faced with this helmet was a lack of fresh air when the helm was worn. Even with an adequate number of ventilation holes drilled into the front of the helm, it was still very constricting, especially when worn in conjunction with a coif or arming pad. Adding that to the fact that the crusaders were fighting under the hot sun of the Middle East, and it is easy to see why knights would only wear their helmets when it was utterly necessary.

3.3 Shields of the Crusades

Shields were often the trusted defense of infantrymen and knights alike throughout history and this certainly did not change during the Middle Ages. Before plate armor became a commonplace form of protection, strong shields were used to block both attacks and projectiles from causing bodily harm to the soldier. Long since different metals were the crafting material of choice for different forms of protection, or if a soldier couldn't afford the price, thick sheets of wood were combined with paste to make a durable aegis. This wood was normally layered with the paste and tanned leather to create a durable shield. Unlike iron, which simply dents under blows from swords and other weapons, these designs were prone to cracking or falling apart if they suffered too heavy an impact. Similarly, as different variations of shields were produced (from circular to triangular), so too was the defense strategy of an army. Tactical geniuses concocted a uniform defense for a large group of soldiers, which utilized the individual shields each person held. This technique, known as the Shieldwall, had each member of a battalion overlap their shields with one another, to form a movable, effective bulwark. From behind the rows of shields, one could similarly lash out with their weaponry, or bash down their enemies using physical force.

With the evolution of the shield came seemingly simple changes that made enormous differences. For one, the straps located behind the blocking part of the shield were modified for better control over blocking. A handle or strap would be grasped by the hand, and a secondary strap would fit over the arm. This made it possible so that a soldier could put the power of their weight behind both attacks and blocks. Another change was that shields depicted who the user fought for, so that allies could be discerned in the midst of battle. Sometimes the image was as simple as a cross, to show the soldier's faith in Christianity, while other times, embroidery in the shield's center or corners gave more details as to whom they owed allegiance.

4 Weapons of the Crusades

During the Medieval Ages a knight was only as useful as the weapon he wielded. If a knight could not arm himself properly, he could not defend his lands, or fight in any of the various conflicts that raged during the time. Kings and lords needed good men to fight and kill for them when they desired to conquer new lands. This reality was ever apparent during the time of the crusades, when most of the feudal nations of Europe were hell-bent on retaking the Holy Land in the name of God. Thousands of men, knights, and common foot soldiers all, flocked to their lord's banners and prepared for their long crusade. All these men needed to be outfitted with weapons for the coming fights and there certainly was a multitude of weapons to choose from, ranging from swords and axes, to spears and lances.

4.1 Swords

The swords used throughout most of the early medieval period and well into the 15th century varied widely in terms of size and weight, but the pattern of the classical medieval sword remained relatively unchanged. For swords forged during the crusades, the average weight was around three pounds, with there being two general classes of swords: the “War Sword”, and an early form of the “Two-hand Sword”. The War Sword had an average length of forty-five inches, with a thirty-eight inch blade and a seven inch grip. The Two-handed Sword had an average length of sixty-two inches, with a fifty inch blade and a twelve inch grip (Oakeshott). It almost seems impossible that a knight or common soldier could wield a three pound weapon for hours on end without collapsing in exhaustion after a few minutes of use. What must be understood is that these warriors had been trained from a young age to wield such heavy weapons. Starting with lighter, smaller weapons a young boy may practice daily to build up his strength and by the time he was fifteen, he would be able to wield a full-sized weapon.

There are three main elements of a typical medieval sword: the blade, the cross-guard, and the pommel (Oakeshott). The blade was simply the essence of the sword, and was usually double edged with a fuller running down the center of the blade. The cross-guard consisted of two pieces of iron or metal that would join together where the blade met the hilt. Cross-guards usually were forged straight but some swords did have guards that would curve upward toward the blade (Norman & Pottinger). The purpose of the cross-guard was to protect the wielders hand from being slashed by his opponents' blade, and to prevent his own hand from sliding on the hilt and getting cut by the sword. The pommel of the sword was the main counter balance to the weight of the blade. Without the addition of a pommel, a blade would be too heavy and unwieldy for even the most skilled knight. On most swords forged during the Middle Ages, the pommel was simply a knob of metal at the end of the hilt, but there was some shaping to these knobs as well. "Tea-cosy" and Brazil-nut-shaped pommels were popular up until 1180, and then disc-shaped pommels (usually with a beveled edge or raised center) came into use (Norman & Pottinger). It is important to recognize that the swords knights wielded were specifically designed for continual use. Because of that fact, these weapons were crafted to be less than three pounds on average, so that the knight would not tire from extended fighting (Oakeshott, p.58).

One type of sword that became popular during the 13th century was a single-edged blade known as a Falchion (Norman & Pottinger). The falchion was mainly used by the common foot soldier but was on occasion used by the knightly class. Descending from the Viking weapon known as the Sax, the Falchion was generally shorter than the common War Sword and had a curved cutting edge near the tip of the blade and a straight "back". That is, one side of the blade was flat and held no edge. This weapon's weight distribution held most of the weight near the tip of the blade, meaning that these weapons had a great amount of shearing force and could be used to devastating effect against armored foes.

Figure 21: Crusader Hand-and-a-half sword (Web: "Crusader Hand-and-a-Half Sword").

On the Medieval battlefield or during skirmishes, these different swords would frequently clash with the heavily armored knights. Protection of the cranial area, afforded by Great Helmets, would often make a lethal cut or decapitating blow impossible. It was because of this fact that knights who had the money would invest in this safeguard to their livelihood. One of the downsides to this Helmet, however, was that the eye slits were an unfortunate opening for the crafty opponent. Given some precision, an arrow or carefully placed sword could slip through the defenses of the Great Helm, and pierce into the crusader inside. Pitted against a War Sword in honorable combat, the Great Helm took its advantages in not having a large amount of neck area exposed for a killing blow, while also shielding the face. At the same time, the Great Helm could only withstand so much force when struck, so a brutal cleaving strike from the War Sword could stun or impact the defensive crusader. With its large size, the Great Helm was a bigger target than an unprotected head, yet the protection it gave couldn't be matched. Where the Great Helm really stood out was against deflecting attacks, such as stabs from the War Sword, slashes from the Falchion, or stray arrows. The thick metal composition of the helmet could brush off such offenses with ease.

4.2 Daggers

The daggers used during the Middle Ages were not simply scaled down versions of swords, but weapons that came in two distinct fashions. There was the classic dagger, with a tapered double-edged blade, and the knife-blade, with one curved edge and a straight back (Oakeshott). The earlier form of medieval dagger, found around 1000-1150, was called a “cultellus” and mostly resembled a modern day kitchen knife. Up until 1230 daggers were viewed as mainly a peasant's weapon or tool for an assassin. As time passed though, knights realized that daggers were an effective short-range offense. Even then, daggers were used as a last resort, for when a knight's other arms were broken, or the knight was fighting in close quarters (Norman & Pottinger).

Figure 22: A common dagger used by Crusaders (Web: "Hand Forged Crusader Dagger, XII and XIII Century").

Oddly enough, for approximately forty years after knights began using daggers, they are never seen wearing these weapons in tapestries, paintings or illuminations. From about 1290 CE onward, knights are shown equipped with daggers on their belts, over the right hip. Perhaps this can be explained in that the overall opinion concerning daggers took a while to change from what it once was. No longer was it ignoble for a knight to wield this smaller blade, but until the idea caught on, they were left out of the artistic chronicles that depicted them. As befitting of a knight's high status, daggers worn by them were crafted in more shapely forms with matching cross-guards and pommels. The designs of daggers after 1300 seem to have been near endless and dependent on either the blade smiths or buyers personal taste. Much like the crusader shield, the designs that were employed in making the daggers seemed to reflect who the knight fought for, or what held sentimental value to him.

4.3 Axes

For most knights, the sword was the main weapon of choice during the Crusades, with the axe being a secondary weapon (Oakeshott, p.41). Axes were utilized if knights fought on foot, or their sword had been lost. This does not mean that the axe didn't have its place among the weaponry used during the crusades, for it was a formidable armament and tool. At first commonly used by the infantry, with the spear and lance most utilized by mounted soldiers, this handheld weapon could be also be transformed into a ranged projectile with a throw from the wrist. These axes tended to be small and one handed as to allow them to fly properly after being thrown by the soldier. The other type of axe used by knights and soldiers was the broad battle-axe which was a large axe with a broad cutting edge (Edge, p.49). During the twelfth century lighter axe-blades came into fashion to supplement the use of other, more Viking like great axes. These lighter axes tended to be the same length but with the head of the axe weighing less

(Oakeshott, p.256). Notably, from the fourteenth to sixteenth century, axes saw a rapid evolution from narrow one-handed tools, to "poll-axes" or large hafted axes, used for smashing heads from afar (Oakeshott, p.48). These axes were surprisingly as popular in battle, as they were in solving disputes in "trials by combat". Duels of this type were conducted in arenas reminiscent of boxing rings, with combatants given the choice of wearing full armor against their opponent (Oakeshott, p.49).

Figure 23: Modern Crusader Axe (Web: "Axes, Maces and Polearms").

4.4 Crossbows

One of the major developments towards the end of the crusades was the ranged weapon, the crossbow. This advanced device, though some of the earliest crossbows were little more than wood stocks with trigger releases and a groove for the arrow, which combined a reloadable bow with a firing mechanism, saw its arrival near the year 1066 (“The Armoury”). Though it took quite some time to perfect, the crossbow held its advantages in being able to load before the fighting actually started, and being easy to aim. Unfortunately when the weapon first emerged, it also held many flaws (“The Armoury”). These included having a slow load time to re-fire, misfiring when not intended to, and the amount of skill and labor it took to make one. Since this weapon was so unreliable at first, the crossbow didn't see much exposure to battles until after the crusades (“The Armoury”). In fact, Anna Comnena, daughter of the Byzantine Emperor Alexois I Komnenos, described it as a novelty weapon during the Crusades (Williams, p.48). The firing

Figure 24: A common cross bow of the Middle Ages (Web: "Medieval Crossbow").

mechanism was made to be less finicky to avoid unintended shooting, and the techniques to craft them were made easier as this weapon went through its evolution. But from the point of view of the crusades, this was a rare weapon indeed to see on the battlefield (“The Armoury”).

4.5 Lances

One weapon that is emblematic of the knights who went on the Crusades is the knightly lance that each mounted knight carried into battle. Since its inception in the fourth century the lance has changed almost little; it is a long stout spear ranging from nine to 11 feet long, with uniform thickness throughout the length of the shaft (Oakeshott, p.258), though there are some indications that the lance gradually became smaller as it tapered to a point (Edge, p.46). This would have allowed the lance to have greater penetrating power. The head of the lance was usually small and leaf shaped, most likely to allow the spear to penetrate the armor of the target.

As time went on long shafted weapons gained a variety of names from the people who chronicled the usage of said weapons and some names included Gaesa, Godendac, croc, Faus, faussal, Pikte, Guisarme, and Vouge(Oakeshott, p.259).

Figure 25: A typical lance for a crusading knight (Web: "Medieval Lances of Kinghts").

4.6 Islamic Swords

Facing the Christian Crusaders were of course the Muslim warriors with their own arsenal of weaponry. Though at the initial dawn of the crusades the Muslims fought with blades much akin to the European straight swords, time saw the evolution and distinction between the two warring faction's armaments (*MyArmoury.com*). The first truly separate sword that the Muslims wielded was the sabre. This one-handed sword had a slight curve to the blade which allowed it to be swung more fluidly and faster than a simple straight sword (*MyArmoury.com*). The idea of the curvature to the blade originally came from the heart of Egypt, and following the successes of its construction, the sabre found its way all throughout the Middle East (*MyArmoury.com*). Particularly, this blade was known for having a slight thickening of the metal towards the tip of the weapon, having a hilt that followed the same curvature as the blade, and little to no pommel. The lighter and more sophisticated cousin to the sabre was the scimitar

Figure 26: A typical Saracen scimitar used against the crusaders (Web: *Sword Forum International*).

(*MyArmoury.com*). This newly employed design allowed the more versatile blade to be used even from horseback. Often time the blades were even given a bit of flexibility so that could "bend" while fighting ("Islamic Swords"). It was due to the quickness and bending ability of the scimitar that it could be considered more effective than the Crusader's counterpart.

4.7 Tiger Claws

The Muslim secondary weapon of choice was much more subtle than the axes and daggers that the Crusaders chose. This discrete handheld weapon was crafted in imitation to the claws of the ferocious beast in which it draws its name: Tiger Claws. Four wicked claws stuck

Figure 27: Medieval tiger claws (Web: "Maharaja: The Exhibition").

out of a piece of metal, and could be fitted into the fist with two holes for fingers (*MyArmoury.com*). This was as much a weapon of surprise as it was a tool of last resort, for it couldn’t likely parry a sword with much success. Instead, the Tiger Claw relied upon being unexpected by an opponent, and raking havoc with its sharp points (*MyArmoury.com*). Originating from India, this specialized weapon gained popularity within the Muslim Crusader's movement, for its stealth and simplicity. A set of tiger claws could even be fashioned with relatively little knowledge of blacksmithing techniques, and because of this, they saw widespread use (*MyArmoury.com*).

5 Materials and Methods

5.1 Great Helm Construction Procedure

The helmet shown in Figures 30 and 31 was chosen to be created for the fulfillment of the project requirements. It is an open-source Solid Works model in the style of a typical great helm of the period.

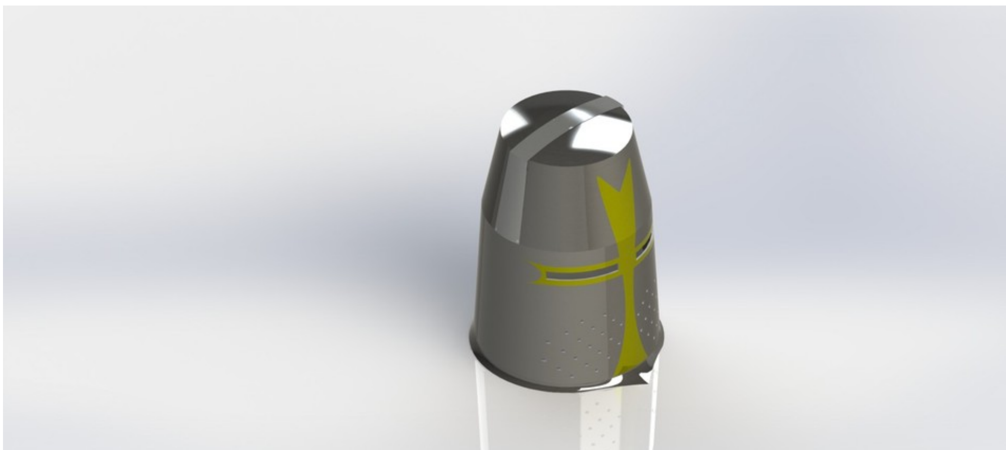


Figure 28: Solid Works model of the great helm.

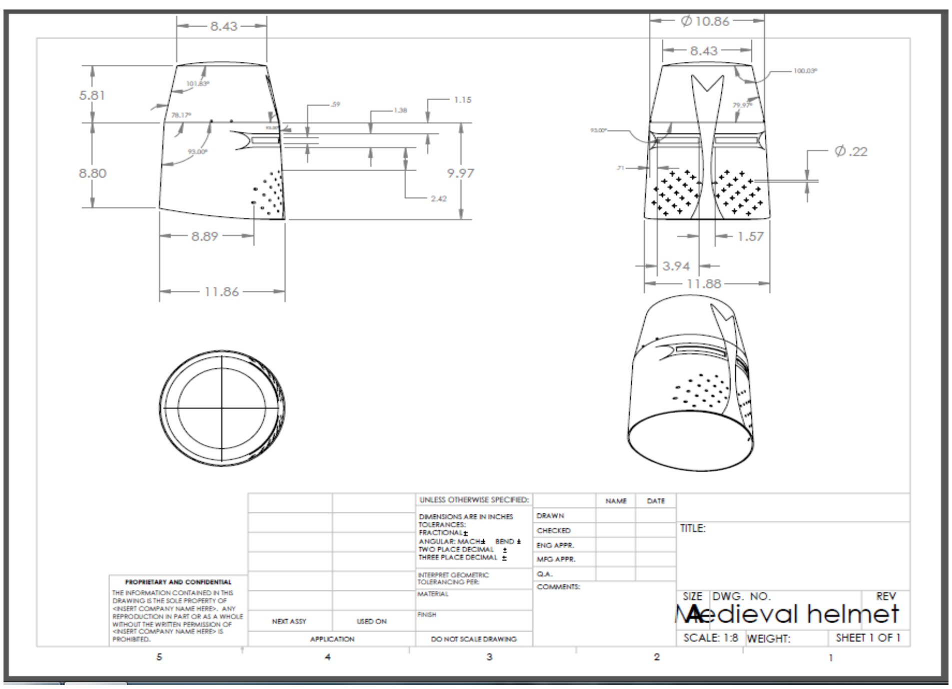


Figure 29: Engineering drawing of the great helm.

After the CAD model was obtained, the software was used to create engineering drawings of the helmet (shown below). The piece was constructed in three separate parts that were then connected to form the helmet: a cylindrical part that forms the bottom of the helmet that extends to just above the eye slits, another cylindrical part that forms the upper space (where the forehead would be), and a flat circular piece for the top. For construction, three 4 x 4 ft. sheets of 18 gauge steel were used.

Figure 30: Using a plasma cutter to cut the sheet steel.

First, the bottom cylindrical piece was constructed. A ruler and chalk were used to mark the metal. To cut the steel sheet to the right height, a plasma cutter was used.

The metal sheet was placed on a table with the end to be cut hanging off. Weights were used to keep the sheet in place, and a metal guide bar was clamped down so that straight lines could be achieved with the tool. After the part was cut out, the eye slits were made. Chalk was used to mark the outlines of the eye slits, and the plasma cutter was again used. Because the cuts made by the plasma cutter were rough, multiple tools then had to be used to round and shape the edges of the eye slits.

Figure 31: Using a dremel to shape the edges of the eye slits.

The second step was to create breathing holes for this bottom piece. A straight edge was used to create a 45 degree angle under both of the eye slits. The placement of the holes was determined by creating sets of parallel lines that were perpendicular to this, yielding a matching geometric pattern of breathing holes.

Figure 32: Drawing the breathing hole pattern onto the steel.

After all of the points were marked for the breathing holes, a hammer and handheld metal tip was used to score the metal. Scoring is a technique where physical indentations are made in metal so that holes can be made accurately. In this case, scoring was used so that a drill bit would easily catch the indentation to make a hole exactly where the points were marked.

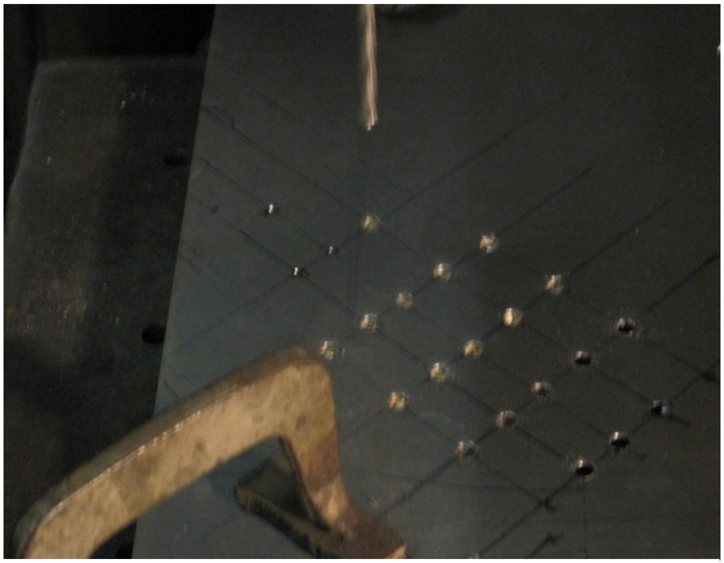


Figure 33: Using a drill press to make the breathing holes.

A period blacksmith, lacking a powered drill, would instead repeatedly score the metal on both sides until penetration was achieved.

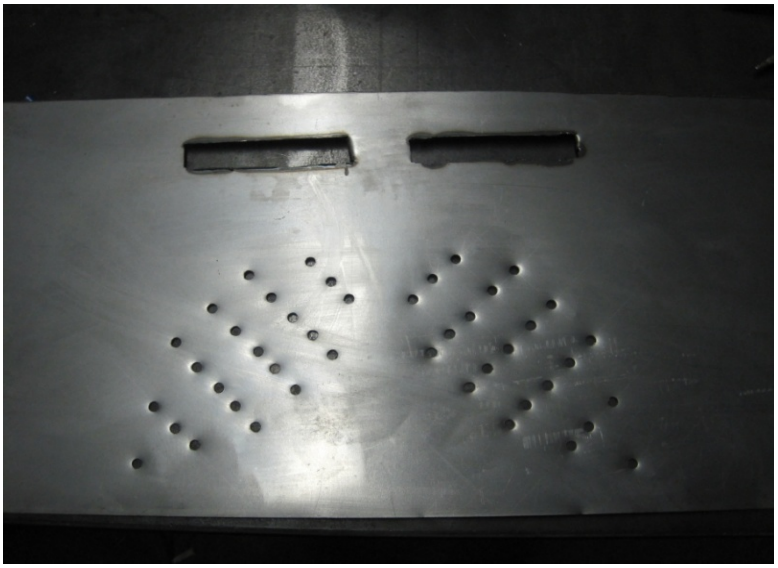
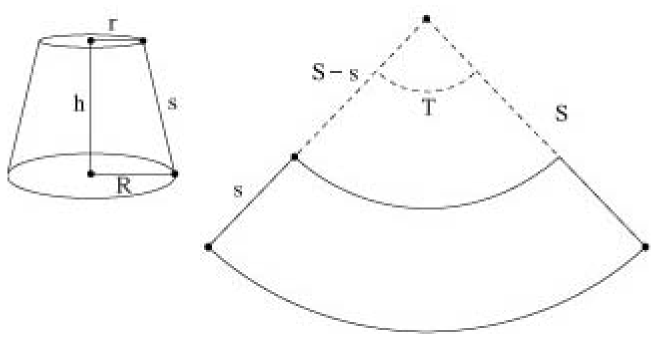


Figure 34: Faceplate with completed eye slits and breathing holes.

Next, the top circular piece was constructed. This was the simplest piece to create. A compass and chalk were used to draw a circle of the correct diameter onto a piece of the sheet steel. The plasma cutter was used again to make a rough cut. Then, the piece was clamped down and a metal grinder was used to smooth and round the edges.

The final piece to be created was the upper cylindrical part of the great helm. It can be seen by looking at the drawing that the of this part are tapered, not straight like the bottom piece. In other words, this part is a frustrum of a cone, whereas the bottom part is a simple cylinder. Because of this, the following diagrams and equations were used to draw a correctly sized piece:



$$(R-r)/s = r/(S-s) = R/S = T/(2*Pi) = \sin(t),$$
$$s^2 = h^2 + (R-r)^2,$$

$$R - r = h*\tan(t),$$

$$s = h*\sec(t).$$

Figure 35: Geometry and equations used to construct middle piece of the great helm ("Building a frustum").

Once the piece was drawn on paper, it was cut out to serve as a template. This template was then used to trace the piece onto the sheet steel. The plasma cutter was used to cut the piece out. Like the top piece, this part had to be clamped down and grinded to smooth around the edges.

Figure 36: The cut out frustum, before being bent into shape.

It was decided that copper rivets were to be used to attach the three pieces of the helmet together. These copper rivets were created from copper wire with a diameter of 3/32 of an inch. To make the rivets, first a piece of copper wire was held in place with a vice clamp. Then, an oxycetalyn blowtorch was used on the end of the wire to quickly melt a small portion of the copper. As the copper melted, gravity would cause the liquid metal to flow down and then adhere to the colder copper below.

Figure 37: Using the oxycetalyn blowtorch to melt the end of the copper wire.

This would form a small rounded head on the copper wire. Once these rivet heads were formed they would be cut off with a wire cutter at a distance approximately equal to one and a half the length of the diameter. This process was repeated until enough rivets were made for the project.

Figure 38: Copper rivets created from melting copper wire.

Figure 39: The four parts of the helm, before riveting or bending.

After all the needed pieces were created, the helmet was made by using the copper rivets to attach the individual parts. First, the two bottom pieces were connected. A drill press was used to create a row of holes on the edges of each piece. Then, the holes on each piece were aligned and the rivets were placed head down through the holes.

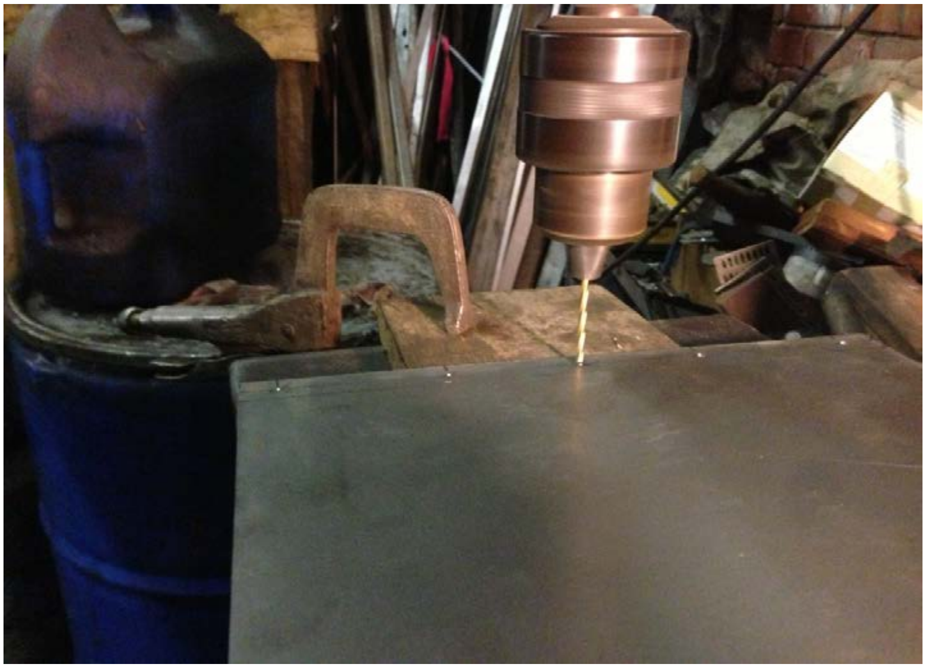


Figure 40: Using a drill press to make holes in the metal.

Figure 41: Copper rivet threaded through the holes in the metal pieces.

The rivets were flattened with a hammer to secure them in place and connect the two pieces.

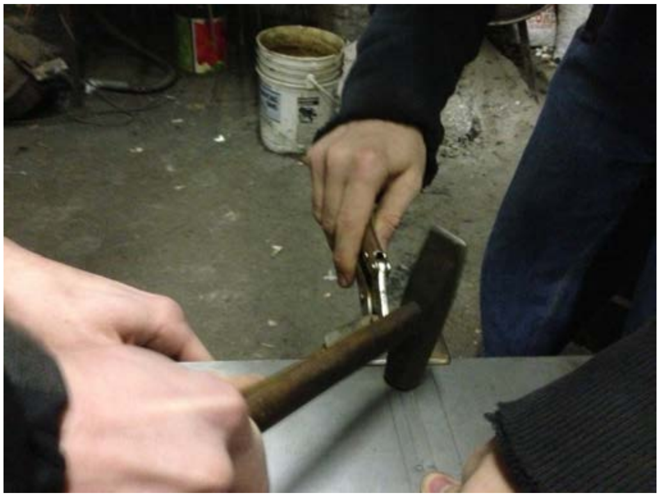


Figure 42: hammering a rivet to fasten the metal pieces together.

The third step was to make the bottom piece a cylinder. To do this, the rounded surface of an air tank was used to help bend the metal by hand.

Figure 43: Bending the bottom piece around a curved surface to form a cylinder.

After the metal was bent into a cylinder, clamps were used to keep it in place as the two ends were riveted together.

Figure 44: Riveting the bottom part.

Figure 45: Completed section of the helmet.

Next, the frustum was created using the same procedure as the cylinder.

Figure 46: Riveting the frustum together, using a clamp to apply pressure.

Figure 47: Top frustum after riveting.

The frustum was then attached to the top of the cylinder. To do this, copper rivets with small rectangular steel tabs were used. A power drill was used to drill six holes spaced symmetrically near the top edge of the cylinder.

Figure 48: Drilling holes for the rivets and tabs on the bottom piece.

For each hole, a steel tab was riveted at the bottom to the cylinder on the inside. Then, the tops of the tabs were drilled with a second hole, so that they could be riveted to the frustum. In this manner, the cylinder and frustum were fastened together.

Figure 49: Steel tabs after being riveted to cylinder, but before being riveted to the frustum.

The fourth step was to rivet the top piece to the frustum. This was done in the same fashion as the previous step, using rivets and tabs. In this case, the tabs were bent at a 90 degree angle so that they could be riveted to the flat top piece.

Figure 50: Frustum attached at the top of the bottom piece by copper rivets.

To rivet the tabs to the top piece, the entire helm was placed around a piece of wood of the same height. Using the wood as a brace, the top piece was then placed and drilled through, along with the tabs. All the rivets were placed, and the helmet was turned upside down, while holding the top piece in place. The flat top of a blacksmith's hammer was used to pound the rivets, attaching the frustum to the top piece.

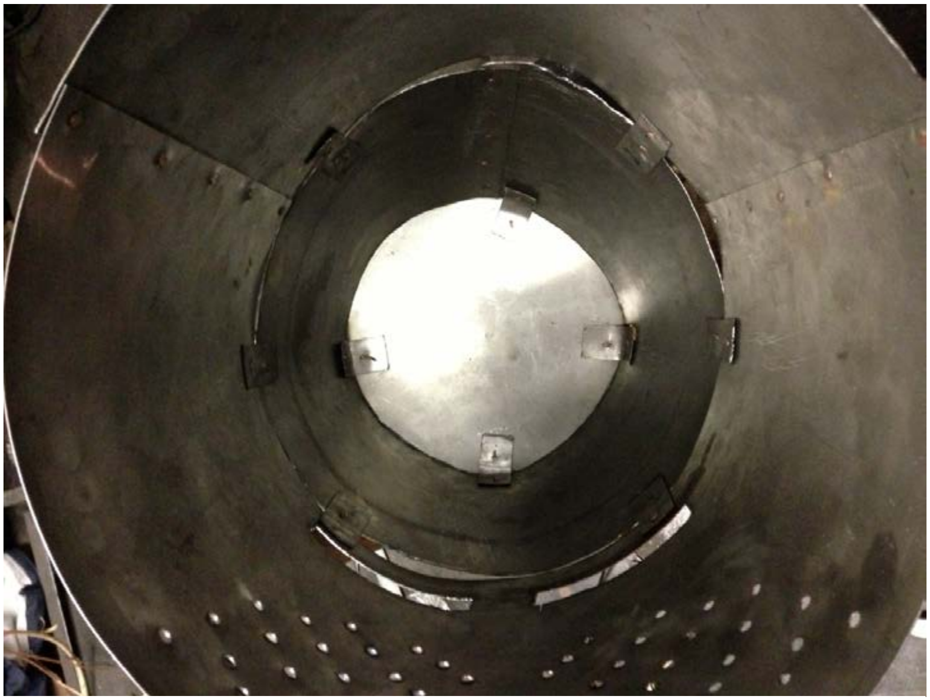


Figure 53: Top-down view of the upside-down helmet. Note the steel tabs attaching the cylinder to the frustum, and the frustum to the flat top piece.

After the top piece was fastened to the frustum, the helm was structurally completed.

Figure 54: Great helm with all parts fastened together.

The fifth step was to polish and refine the piece. First, a metal grinder was used to smooth and take off any protruding edges on the helmet.

Figure 55: Using a metal grinder to smooth out edges on the helm.

Figure 56: The helm after being coated with Rust-Oleum.

Next, the helm was cleaned and polished using mineral oil and sand paper. The purpose of this sixth step was to clear the helm of any dirt or debris so that it could be coated with rust resistant enamel. One coat of Rust-oleum brand primer was applied and allowed to dry for 24 hours. Then, 2 coats of Rust-oleum spray paint enamel were applied to seal the primer, and the helmet was allowed to dry for another 24 hours.

The seventh step was to add to the aesthetics of the helmet. To do this, the group decided to add a copper leaf decal to the front of the helmet. After the copper leaf was obtained, a jeweler's press was used to create even flatter sheets of copper. Then, tin snips were used to cut the leaf into the appropriate shapes. The copper leaf was then glued into placed and pressure was applied for an extended period of time to ensure that the metal was properly held in place. To increase comfortability when wearing the helmet the group also created some insertable padding. This padding will go inside the helmet and will pad the top of the wearers head and the sides of his face.

Figure 57: The copper leaf cut into the desired shapes and placed on the helmet.

5.2 Materials Analysis

Two different material samples were analyzed for the project requirement. The examined materials were the smooth side of the 1018 sheet steel, and the plasma-cut edge of a piece of 1018 sheet steel. Both samples were prepared for analyzing by the following methods.

First each sample was placed in the bottom of a small container and slowly pushed into the plastic until it is properly gripped by the plastic. The samples were then surrounded by the plastic mold material, which was a type of compressed plastic powder, and placed within a special mold making machine, in this case the SimpliMet 3000, an automatic mounting press. This machine would use high temperatures to melt the plastic and then used pressure to compact the plastic around the metal samples. Both of the groups mounted samples can be seen below.

As the surface of the samples were scratched and laden with blemishes, both samples were first cleaned off and smoothed out by etching and polishing. The group used the polishers, which were essentially rotating wheels of abrasive material, in the materials processing lab on the top floor of Washburn Shops. These polishers were used to remove the initial scratches and blemishes on the top of the samples and the group started out with the most abrasive polisher and

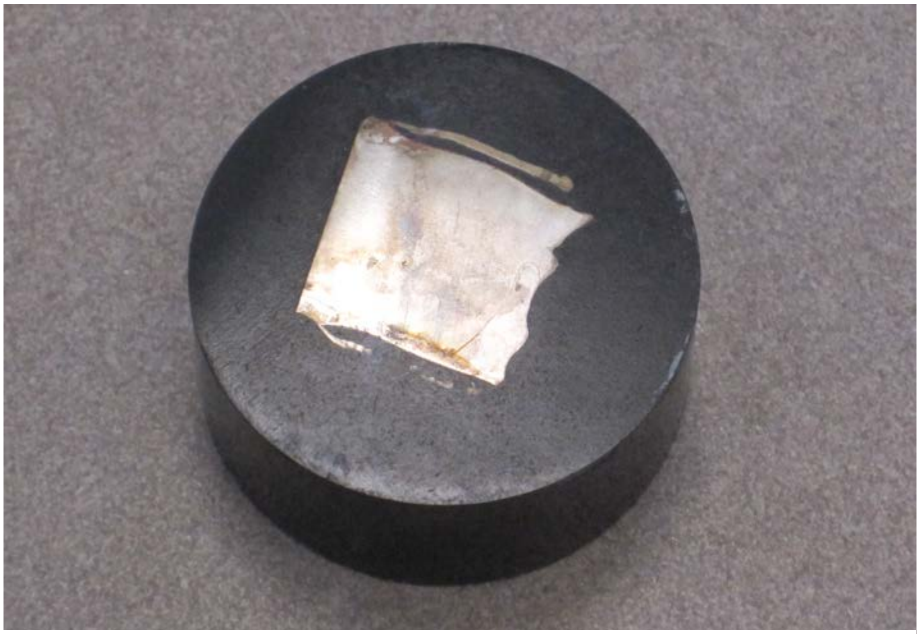


Figure 58: The sample mounted in epoxy.

finished with the polisher with the finest abrasive. These polishers were kept continuously wet to avoid developing friction between the abrasive and the sample and to also wash away the layers of the metal and plastic that were removed. Next, a nitric acid solution, known as Nital, was applied to the surfaces of the polished samples with a Q-tip. This process is called etching and is used to dissolve away some of the impurities on the surface of the sample. This acid was then washed off with ethyl alcohol to stop the etching process. This process accentuates the grain boundaries found within the samples. Once these two steps had been completed, the group was ready to photograph our steel with a high powered optical microscope.

The pictures seen below is a magnified view of the microstructure of our untreated 1018 low carbon cold rolled sheet steel. From the below surface microstructure the group was able to determine that the steel was in perlite-ferrite region on an iron-carbon phase diagram. Since the

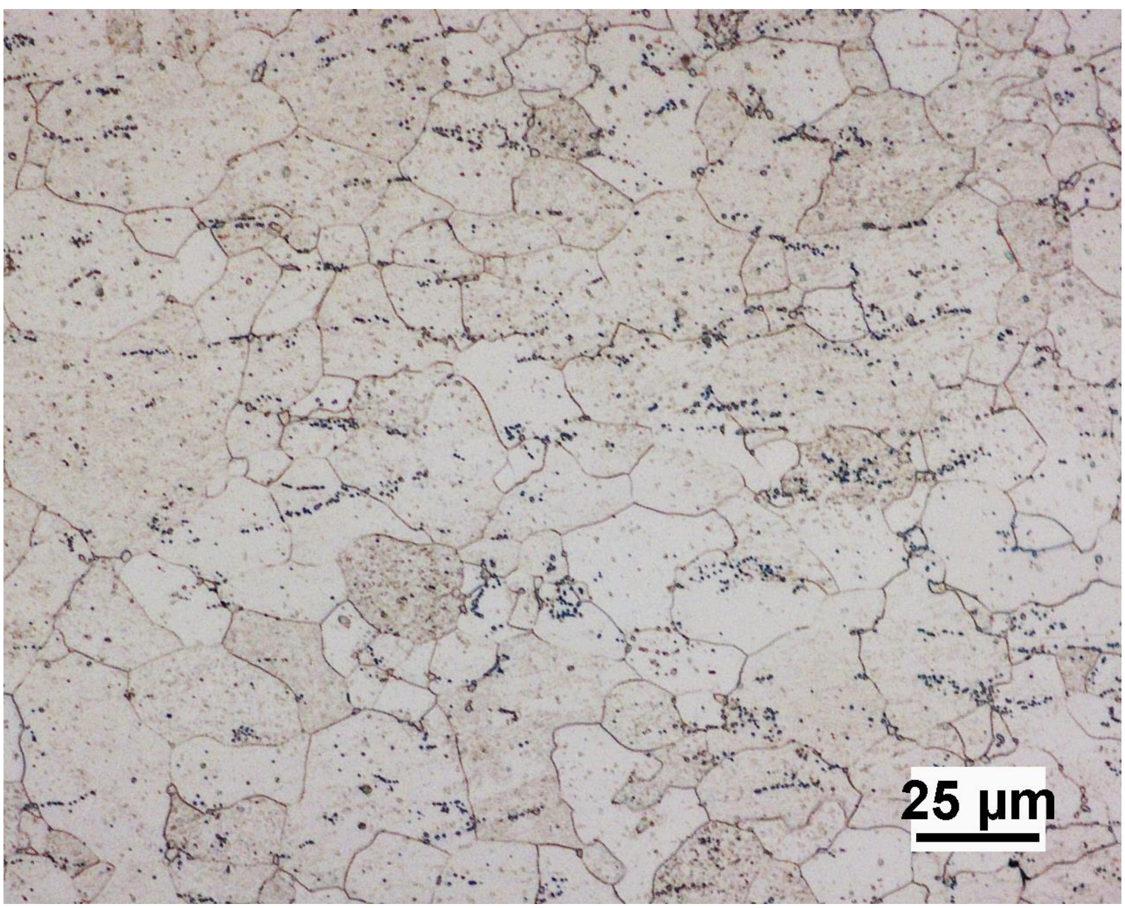


Figure 59: Magnified optical view of the microstructure.

groups steel had been untreated during the duration of the project the group was asked to determine if the steel had undergone any phase changes during the initial production of the cold rolled sheet steel used during the project.

Before the group discusses the phase changes during the initial production of the steel we must first discuss what cold rolled steel means. Cold rolling is a process by which the metal to be worked is set between a set of rollers set at a certain pressure and then compressed and squeezed to a specified thickness. The amount of strain induced by the rollers determines the hardness and material of the metal being worked (Cold Rolling). This process usually occurs below the metals recrystallization temperature (Cold Rolling Steel and Metal) and can increase the strength of the metal by up to twenty percent. Recrystallization of metal is when deformed grains in the metal are replaced by new un-deformed grains that nucleate until the entirety of the old grains has been replaced. Recrystallization is accompanied by a loss in ductility and a reduction of strength and hardness. This combination of processes creates a versatile product that is suitable for a variety of tasks.

Before steel can be cold rolled it must first be hot rolled after it has been formed in the forging process. When steel is hot rolled it is put through a set of rollers that apply pressure and, much like the process for cold rolling, its dimensions are expanded and its material properties are altered. The hot rolling process usually occurs at temperatures between 900 and 1100°C. The steel is then initially cooled with water at temperatures ranging from 500 to 750°C (Fisher G. H.). When looking at a phase diagram for steel we can see that hot rolled steel with low carbon content, in this case .18%, we can see that the steel initially formed an austenite crystalline grain structure. Austenite forms when alpha iron undergoes phase transitions at high temperatures to what is known as gamma iron. The phase diagram for steel can be seen below and the phase for steel at 900 through 1100°C with a carbon content of .18% can clearly be seen in the austenite phase. How quickly the steel is cooled determines the rate are which carbon is disbursed through the metal and what type of grains are formed, with a rapid cooling forming fine grained pearlite and a slow rate of cooling forming a more coarser grainer pearlite. Once the steel had been cooled until it was at room temperature it was then put through cold rolling process and was rolled into its final shape and ready for sale.

With this knowledge the group was able to analyze the microstructure of our metal sample, as seen in Figure 59. Knowing the carbon content of the steel used in this project and how the metal was produced the group used the Fe-C phase diagram to determine its microstructural phases. The group was able to determine that the steel had ferrite and pearlite

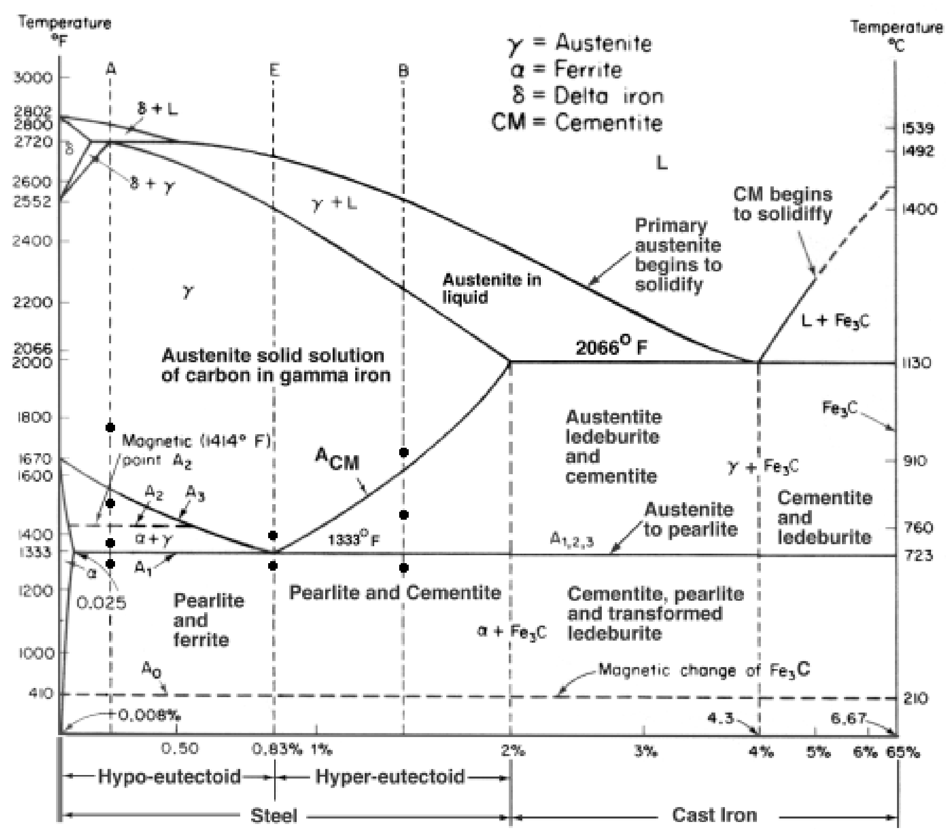


Figure 60: Phase diagram of steel at different temperatures and carbon contents (Web: Library for Scientific Analysis).

phases at room temperature, with a carbon content of .18%

Pearlite is an eutectoid phase constituted of alternating layers of ferrite and cementite. Ferrite is a ductile body centric cubic structure that can hold small amounts of carbon, while cementite is a brittle phase that consists of 6.7% carbon, the balance being iron (Metallurgy). Cementite is a hard and brittle phase that is embedded in a ductile ferrite matrix. The combination of these two phases defines the type of steel, and the strength of the resulting material is dependent on the cooling rate seen during processing. This type of steel, which was used by the group, has overall desirable properties for all around work, and is generally considered a good quality steel.

6 Conclusion

The Crusades left a perennial ripple in humanity's timeline that drastically changed the course of history. This was a time period that had its mix of appalling atrocities and appealing heroics. Indeed, it has been the subject of much academic and historical debate, as well as amateur fascination. What started off with a messianic cry for glory and reprise slowly dwindled into a mechanism for settling political gripes and expanding personal territory. The subject of the Crusades has enough substance to satisfy the intellectual palette of any academic or historian. While the Crusades are fascinating from a historical and anthropological standpoint, at the heart of all the conflict are the materials that made these battles possible. The Crusades encompassed a prolific period of metallographic evolution. It offers a perfect snapshot for the study of medieval arms and armors.

Works Cited

1. Alchin, L. (December 20, 2011). Medieval Life and Time - Medieval Blacksmith. Retrieved November 19th, 2012, from http://www.medieval-life-and-times.info/medieval-life/medieval-blacksmith.htm
2. "The Armoury." Markville.edu. N.p., n.d. Web. 20 Feb. 2013. <http://www.markville.ss.yrdsb.edu.on.ca/history/west/websites/HIST25/The War Room.htm>.
3. Atiya, A. S. (1962). *Crusade, Commerce, and Culture*. Bloomington, IN: Indiana University Press.
4. Bantley, C. (2004). The People's Crusade (1096 AD)A DBA Variant Army List. Retrieved Oct. 8th, 2012 http://www.fanaticus.org/DBA/armies/Variants/PeoplesCrusade.html
5. Blair, C., & Leonid, T. (1986). The Complete Encyclopedia of Arms & Weapons. Italy: Simon and Schuster.
6. Burgess, E. M. (1953). The mail-makers technique. *Antiquaries Journal*(33), 48-55.
7. Cleere, H., Crossely, D. W., & Worssam, B. C. (1985). *The Iron Industry of the Weald*: Leicester University Press.
8. Cold Rolling. Retrieved April 27, 2013, from <http://www.efunda.com/processes/metal_processing/cold_rolling.cfm>
9. Cold rolling steel and metal. (2008). Retrieved April 27, 2013, from http://www.paramount-roll.com/services/cold-rolling.asp
10. "The Council of Clermont (1095)." *Thelatinlibrary.com*. N.p., n.d. Web. 12 Oct. 2012. < http://www.thelatinlibrary.com/imperialism/notes/clermont.html>
11. Dale, A. (2010). What weapons did the Muslims use in the crusades? Retrieved February 27, 2013, from http://www.myarmoury.com/talk/viewtopic.php?t=18570
12. DeVries, K. R. (1992). *Medieval Military Technology*. Peterborough, Ont. Canada: Broodview Press Ltd.
13. Edge, D., & Paddock, J. M. (1988). *Arms and Armor of the Medieval Knight*. Hong Kong: Crescent Books.
14. Ffoulkes, C. J. (1967). *The Armourer and His Craft*. New York: Benjamin Blom.
15. Fisher, D. (1963). *The Epic of Steel* (First Edition ed.). 49 East 33rd Street, New York 16, N.Y.: Harpers & Row.
16. Fisher, G. H. Difference between Hot & Colled Rolled Steel. Retrieved April 27, 2013, from <http://www.ehow.com/about_6508403_difference-hot_-_amp_-cold_rolled-steel.html>
17. Fortescue, A. (1911). Michael Cærularius *The Catholic Encyclopedia* (Vol. 10). New York: Robert Appleton Company.
18. Fratini, D. (October 2013). "Military History Online." *Military History Online*. Retrieved Web. 04 Oct. 2013, from <http://www.militaryhistoryonline.com/crusades/articles/arsuf.aspx>
19. Hall, B. Medieval Iron and Steel: Simplified. The ORB: On-line Reference Book for Medieval Studies. Retrieved 11/26/2012 <http://www.the-orb.net/encyclop/culture/scitech/iron_steel.html>

20. Hinckley, M. About Medieval Blacksmithing. Retrieved from www.eHow.com website: <http://www.ehow.com/about_4671801_medieval-blacksmithing.html>
21. "History of the Seljuq Turks." *Turkeyforyou.com*. N.p., n.d. Web. 11 Oct. 2012 <http://www.turkeyforyou.com/travel_turkey_seljuks>
22. "Islamic Swords" Umich.edu. N.p., n.d. Web. 22 Feb. 2013. <http://www.umich.edu/~eng415/topics/war/Islamic_Swords.html>.
23. Knox, E. L. (1999). Islam During the Crusades.
24. Konstantinides , T. A. M. s. s. The Schism of the Roman Catholic Church from the Eastern Orthodox. from http://www.orthodoxresearchinstitute.org/articles/church_history/michael_theschism.htm
25. Krey, A. C. (1921). *The First Crusade: The Accounts of Eyewitnesses and Participants*: Princeton.
26. Lacombe, M. P. (1996). *Arms and Armour in Antiquity and the Middle Ages* (C. Boutell, Trans.). Conshohocken, PA: Combined Books, Inc.
27. The Metallurgy of Carbon Steel. (2002). Retrieved April 27, 2013, from <http://www.gowelding.com/met/carbon.htm>
28. *MyArmoury.com*. N.p., n.d. Web. 20 Feb. 2013.
29. Norman, A. V., & Pottinger, D. (1985). *English weapons and warfare, 449 - 1660*: Dorset Press.
30. Oakeshott, R. E. (1964). *A Knight and His Weapons*. London: Letterworth Press.
31. Pernoud, R. (2003). *The Crusaders*. San Francisco: Ignatius.
32. Rickard, J. (2001). Siege of Nicaea, 14 May-19 June 1097. <http://www.historyofwar.org/articles/battles>
33. Seljuk Dynasty of Turkey. (2010, March 29th, 2012).
34. Smith, R. (June 14, 2007). Bloomeries. Retrieved January 20, 2013, from <http://web.archive.org/web/20070614173348/http://www.unc.edu/courses/rometech/public/content/mines_and_iron/Roger_Smith/roger/BLOOM4.htm>
35. Smitha, Frank E. "The Seljuk Turks against the First Crusade." *Macrohistory.com*. N.p., n.d. Web. 05 Oct. 2012. <http://www.macrohistory.com/h3/casia01b.htm>
36. Tyre, W. o. Historia Rerum in partibus transmarinis gestarum, XVII (pp. 675-679).
37. Vesey, N. (1964). *Arms and Armor*. New York: G.P. Putnam's Sons.
38. Vicari, J., George. (2002). The Secular Motivations of the First Crusade (pp. 39): Air University Maxwell Airforce Base.
39. Watson, A. A. (1968). *The Village Blacksmith*. Toronto, Canada: Fitzhenry & Whiteside.
40. Williams, A. (2003). *The Knight and the Blast Furnace A History of the Metallurgy of Armour in the Middle Ages & the Early Modern Period* (K. Devries Ed. Vol. 12). Boston: Brill Academic Publishers.

Figure References

1. "The Ancient Goths." Heavengames. 17 Dec. 2012 <http://www.heavengames.com/cgi-bin/forums/display.cgi?action=ct>.
2. “Arming wear.” *By the Sword Inc.* Web. 13 Feb. 2013. http://www.bytheswordinc.com/c-717-arming-wear.aspx
3. "Armor of the Ages." *Lagunablanca*. N.p., n.d. Web. 1 Dec. 2012.
4. "Axes, Maces, and Polearms." *Preferred Arms*. Web. 8 Feb. 2013. <http://preferredarms.com/images/weapons/large/axes_and_maces/Crusader-Axe.jpg>.
5. "Bloomery." *Shelf3d.com*. N.p., n.d. Web. 23 Jan. 2012. <http://shelf3d.com/i/bloomery>
6. "Building a Frustum." *Building a Frustum*. Web. 2 Feb. 2013. <http://mathforum.org/dr.math/faq/formulas/BuildFrustum.html>.
7. “Chivalry: Medieval Warfare.” *chivalrythegame.com*. Web. 13 Feb. 2013. http://www.chivalrythegame.com/forums/viewtopic.php?f=8&t=1500
8. Cleere, H., Crossely, D. W., & Worssam, B. C. (1985). *The Iron Industry of the Weald*: Leicester University Press.
9. "Crusader Hand-and-a-Half Sword." *Christies.com*. Web. 8 Feb. 2013. <http://www.christies.com.cn/LotFinder/LotDetailsPrintable.aspx?intObjectID=5302965>.
10. “Crusader Helmet.” *Medieval Weaponry.co.uk* Web. 13 Feb. 2013. http://www.medieval-weaponry.co.uk/acatalog/crusader-helmet.html
11. "The Crusades in the Holy Land." Web. 13 Feb. 2013. <http://www.explorethemed.com/Crusades.asp?c=1>.
12. Ffoulkes, Charles J. *The Armourer and His Craft*. New York: Benjamin Blom, 1967. Print.
13. *Flickr.com*. Web. 5 Feb. 2013. <http://farm3.static.flickr.com/2102/1515819375_45c583392c.jpg>.
14. "Grenada, the Stahlhelm, and the Symbolism of Empire." Jeremiads. 17 Dec. 2012 <http://www.jeremiads.net/2012/07/02/grenada-the-stahlhelm-and-the-symbolism-of-empire/>.
15. *Gustave Dore.* Web. 6 Feb. 2013. <http://commons.wikimedia.org/wiki/File:Gustave_dore_crusades_bohemond_alone_mounts_the_rampart_of_antioch.jpg>
16. "Hand Forged Crusader Dagger, XII and XIII Century." *Wulflund.com*. N.p., n.d. Web. 04 Nov. 2012. <http://www.wulflund.com/waffen/dolche/scharfe-dolche/hand-forged-crusader-dagger-xii-and-xiii-centurz.html>.
17. “Iron-Steel Phase Diagram”. *Library of Scientific Visual Analysis*. Web. April 27. 2013
18. "Kingdoms, Christianity, and the Middle Ages in Europe, Page 26." World History. 11 Dec. 2012 <http://curriculum.kcdistancelearning.com/courses/WHISTx-HS-A08/a/unit4/html/section_5_page_26.html>.
19. “Knight Lance.”*getasword.com* 22 April, 2013 http://getasword.com/spears-and-lances/814-knight-lance.html
20. "Maharaja: The Exhibition." *Vam.ac.uk*. N.p., n.d. Web. 4 Oct. 2012. <http://www.vam.ac.uk/content/articles/m/maharaja-the-exhibition/>.

21. "Making Iron." *Knife Gallery*. Web. 5 Feb. 2013. <http://www.knifeblades.dk/knives_gallery.htm>.
22. "Medieval Crossbow." *Uncrate.com*. N.p., n.d. Web. 8 Nov. 2012. <http://uncrate.com/stuff/medieval-crossbow/>.
23. "Medieval Lances of Knights." *Stromthecastle.com*. N.p., n.d. Web. 04 Oct. 2012. <http://medieval.stormthecastle.com/armorypages/lances.htm>.
24. MyArmoury.com. N.p., n.d. Web. 20 Feb. 2013. <http://www.myarmoury.com/talk/viewtopic.php?t=18570>.
25. "Second Crusade." *Second Crusade*. N.p., n.d. Web. 04 Oct. 2013. < http://www.medievaltymes.com/courtyard/images/crusades/second/second_crusade_route_map.jpg>
26. Sword Forum International. N.p., n.d. Web. 223 Feb. 2013. <http://swordforum.com>.
27. *Themeister.co*. N.p., n.d. Web. 5 Feb. 2013. <http://www.themeister.co.uk/hindley_images/forge_bloomery.jpg>.
28. *Wrought Iron Crafts RSS*. Web. 5 Feb. 2013. <http://wroughtironhub.com/wp-content/uploads/2010/07/bloomery-300x244.jpg>.
29. Williams, A. (2003). *The Knight and the Blast Furnace A History of the Metallurgy of Armour in the Middle Ages & the Early Modern Period* (K. Devries Ed. Vol. 12). Boston: Brill Academic Publishers.