

**HISTORICAL EVOLUTION OF SAMURAI ARMS AND ARMORS  
JAPAN, 700 AD – 1880 AD**

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## **Abstract**

The samurai warrior class of Japan has always fascinated the western world due to the intriguing contrast between their strict military training and frightening efficiency, and their deeply spiritual customs and surprisingly refined artistic talents. The purpose of this project was to explore the evolution of this contrasting nature from the inception of the samurai class around the 8<sup>th</sup> century to its abolishment in the 19<sup>th</sup> century, and to see how this cultural evolution and the evolution of available materials and processing methods affected the construction and characteristics of the samurai's weapons. Out of these weapons, the katana, the signature long blade of the samurai class was the primary focus. As part of this project, a sample katana was constructed using near-traditional methods and its material properties were explored using modern mounting and inspection techniques. In addition, the previous year's project website was updated to include the efforts made during this project.

# Acknowledgements

We'd like to thank Professor Diana A. Lados and Mr. Tom H. Thomsen for guiding us through the amazing venture into the world of historical evolution of materials and cultures that this IQP has been for us. We would also like to extend our appreciation to Joshua Swalec, who dedicated both his time and his forge to this project. His instructional advice and great expertise were instrumental to our effort to create a replica of a samurai katana using traditional forging. Lastly, we would like to thank Professor Boquan Li who patiently instructed us on how to mount, polish and etch samples and how to properly operate the Vickers microhardness and the Rockwell hardness machines. Without all of these individuals, this project would not have been as comprehensive and successful as it was. Thank you.

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# Authorship

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- The Heian Period: Rise of the Samurai
- The Katana, History
- Other Weapons of the Samurai, The Wakizashi
- Other Weapons of the Samurai, The Tanto
- Glossary

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- The Tokugawa Period – Peace & Prosperity
- The Katana, Materials & Manufacturing Process
- Construction of a Sample Katana, Plan
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- The Azuchi-Momoyama Period – Unification & Order
- Other Weapons of the Samurai, The Bow
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- Armors of the Samurai
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# 1. Introduction

This project is a part of the Historical Evolutions of Materials in Arms and Armors Interactive Qualifying Project series. The primary purpose of this project is to examine the evolution of the weapons and armors of the samurai warrior class of Japan, in terms of design, materials and manufacturing process, within the context of the samurai's tumultuous history and intricate culture. Another main goal of this project is to record the construction of a replica of one of the weapons used by the samurai and analyze the material properties of the result. The last purpose of this project is to update the online database website that was developed for the previous iteration of this project series with the information gathered during this project.

The samurai, one of the most famous military forces in the world, emerged during the 7<sup>th</sup> century in pre-medieval Japan and remained active until their abolishment in the late 19<sup>th</sup> century. Originally used as mercenary forces, the samurai quickly became the primary military force in service of the Japanese Empire and, soon after, the effective ruling class of all Japan. Although the samurai transitioned relatively rapidly from simple military lives to high court functions and inter-clan intrigues, their military-inspired core values and moral codes were religiously maintained. In fact, their refined sense of honor and devoted spirituality were so prominent that they inspired great tales of valor that resound with readers to this very day. This strange balance between deadly efficient military might and gentlemanlike noble nature is exemplified by the graceful weapons and armors that the samurai carried and wore.

In order to illustrate the cultural evolution of the samurai and the evolution of their arms and armor in the proper historical context, this report begins with a brief historical review of the

six main time periods that the samurai were active in between the 7<sup>th</sup> century and the 19<sup>th</sup> century, followed after by a review of the samurai's evolving culture throughout these periods. This report then details the evolution of the samurai's weapons and armors, based on the historical and cultural information that was provided in the beginning sections. The main questions that this report attempts to answer for these arms and armors are:

- What designs were originally used?
- What materials were originally used?
- What manufacturing processes were originally used?
- How did these designs, materials and manufacturing evolve over time?
- What was the historical and cultural context of each stage of this evolution?

Finally, a record of how our team constructed a replica of a katana, the signature samurai long blade, is given along with an analysis of the material properties resulting from the forging process of such a weapon.

For the convenience of the reader, a glossary of the main Japanese terms used in the course of this report is provided in the appendix section.

## **2. Review of Japanese History 710 AD – 1870 AD**

In order to understand the cultural evolution of the samurai, as well as the evolution of the shapes and materials of their weapons and armors, one must understand the historical events that led to the samurai's rise, prominence, and eventual decline. These events can be divided into six distinct periods:

- The Nara Period, 700 AD – 794 AD
- The Heian Period, 794 AD - 1185 AD
- The Kamakura Period, 1185 AD - 1467
- The Sengoku Period, 1467 AD - 1573 AD
- The Azuchi-Momoyama Period, 1573 AD - 1603 AD
- The Tokugawa Period, 1603 AD - 1876 AD

This chapter therefore provides a description of each period and the main events that occurred within each period. It should be noted that this is not a comprehensive review of each time period, but only a summary of the main events of each period that pertain to the samurai.

### **2.1 The Nara Period: Humble Beginnings**

The roots of the samurai lie in the Nara Period, a period between 710 A.D. and 794 A.D. marked by continues heavy Chinese influence on Japanese culture, technology, and military doctrine (Van Goethem, 2008). Japan's government at the time mirrored that of China, consisting of political, rather than military, leaders. Unlike previous eras, the Emperor and Imperial court were content to watch conflicts unfold from afar, unwilling to ride into battle as their predecessors often did (Brynat & McBride, 1989). The military was modeled after its

Chinese counterpart, requiring every capable man in Japan to enlist under the direct command of the emperor (Turnbull, Samurai Warfare, 1996).

While these ill-trained draftees, known as heishi, made up the vast majority of the Imperial Army, it also contained a small professional, mounted fighting force that grew as the period progressed (Turnbull, Samurai Warfare, 1996). Slowly, the peasant and military classes separated, a process greatly accelerated by Fujiwara clan-leader and Imperial court member Fujiwara Nakamaro, who relied on professional military men over conscripted heishi soldiers (Bryant, Early Samurai AD 200-1500, 1991). The idea of a professional army grew more and more popular, culminating in the abolition of the draft in 792 (Turnbull, Samurai Warfare, 1996). In place of heishi, warriors from regional, mercenary clans filled the ranks of the imperial military. Thus, by the close of the Nara Period, Japan had a more professional army, comprised of the very first of the samurai. These samurai began forming into clans during the Heian period (Turnbull, Samurai Warfare, 1996).

## **2.2 The Heian Period: Rise of the Samurai**

The Heian Period, lasting from 794 AD to 1192 AD (Turnbull, Samurai Warfare, 1996) marked the samurai's true rise to power. Considered by many to be the peak of Japanese cultural development, the period represented a shift from the adoption of foreign practices to the development of internal ones (Kitagawa, 1990). As Japan's culture bloomed, the power of the samurai clans did as well. During this period, houses and clans of samurai began to form (Bryant, Early Samurai AD 200-1500, 1991). The feudal lords of these clans were able to obtain land and control it with the samurai armies under their command. Able to provide lower taxes and better protection for the common people in their land than the increasingly disconnected

central government, the samurai slowly won the loyalty of the people (Sansom G. B., 1978). As the central Emperor's power slowly declined, the regional samurai clans became the de-facto rulers of the provinces and the dominant forces in both the economic and political arenas.

However, as the clans' power grew, so did their conflicts. With the central government too weak to intervene, samurai clans were free to act in their own interest against other clans and the government. The late Heian Period saw a large increase in rebellions, such as the Masakodo Rebellion in 935, the Early Nine Years War in 1055, and the Later Three Years War several years later (Brynat & McBride, 1989). In addition, war between the clans was rampant as well. The big samurai families of the time were the politically influential clan Fujiwara, and the samurai military clans Taira and Minamoto (Turnbull, Samurai Commanders 940-1576, 2005). Their battles shaped the era, culminating in the Gempei War of 1180, in which the Minamoto clan rebelled against the current Taira clan rule and seized the capital of Kyoto, forcing the Emperor to proclaim the Minamoto leader Shogun; grand military general and effective ruler of Japan. The Emperor was then effectively banned from participating in the government and was relegated to a purely ceremonial role (Turnbull, The Samurai Sourcebook, 1998). The results of Gempei War fully cemented the Shogunate as the new form of government and officially declaring the samurai as the ruling class of Japan. The birth of the Shogunate was the beginning of the Kamakura period (Turnbull, The Samurai: A Military History, 1996).

## **2.2 The Kamakura Period: The Shogunate, Rule of the Samurai**

The establishment of the Minamoto Shogunate ushered in the Kamakura Period, a golden age for the samurai spanning the years between 1192 AD and 1467 AD (Turnbull, Samurai Warfare, 1996). During this time, the Minamoto clan built a strong feudal government based on military might and the rule of the Shogunate – the government of the Shogun over all samurai houses and over all Japan by extension. This period marked the height of the military strength of the samurai class under the stable rule of the Shogunate. The Minamoto Shogunate ruled Japan for almost 150 years and was able to successfully repel two Mongol invasions in 1274 and 1281 (Turnbull, Samurai Warfare, 1996).

In 1331, a failed attempt by Emperor Go-Daigo to restore imperial rule toppled the Minamoto Shogunate, allowing his Ashigaka clan allies to assume control of the Shogunate in 1338 (Turnbull, The Samurai: A Military History, 1996). These allies later turned on him, sparking a war that ended with the Ashigaka solidifying their Shogunate rule in 1392 and forcing the line of emperors out of the government again. An uneasy peace reigned throughout Japan from this point until 1467, when the outbreak of the Onin War ended the Shogunate's golden age (Turnbull, The Samurai: A Military History, 1996). The Onin war marks the beginning of the Sengoku period of Japanese history.

## **2.3 The Sengoku Period – War Among the Daimyos**

The events of the Sengoku Period, which lasted from 1467 AD until 1573 AD, dealt a great blow to the Shogunate institution. Beginning with the ten year Onin War of 1467, the Sengoku Jidai (“Warring States Period”) was a period of all-engulfing war and chaos for Japan. A dispute between two influential family heads over the future heir of the Shogun ignited long-



standing tensions between Samurai noble families (Brynat & McBride, 1989). As violence erupted in the capital of Kyoto and across Japan, the Shogun stood by and did nothing to quell the fighting. In the power vacuum generated by the conflicts and the apathetic Shogunate, many resourceful individuals seized the opportunity to gain or strengthen their own positions (Turnbull, Samurai Warfare, 1996). These individuals rallied anyone who wanted to fight to their side and made themselves lords over local domains. Thus, the daimyos , “[big] names” (Turnbull, Samurai Warfare, 1996), were born out of both the few who managed to keep their power during the conflagration and those who were wise enough to seize power during the chaos. Without the Shogunate’s involvement these local domains had full autonomy and could operate based on local laws without paying taxes or owing anything to the decaying central government. Accountable only to themselves, the daimyos were free to pursue their own agendas, resulting in intense infighting that only the strong were able to survive (Brynat & McBride, 1989).

As a result the Sengoku Period saw a large rise in ashigaru forces; foot soldiers recruited from the commoners with little equipment or training (Turnbull, Samurai Warfare, 1996). With food and coin difficult to come by due to the constant fighting, many of the less affluent daimyos chose to rely on the ashigaru in their employ over the much more expensive samurai. The importance of the easily re-trained ashigaru only increased with the Portuguese introduction of guns to Japan in 1542 (Brynat & McBride, 1989). Learning to use a gun was relatively easy and with enough guns and expendable men an army could fill the air with shots that were sure to be devastating, regardless of where they hit. This made the ashigaru forces nearly as important to the militaries of the time as the elite samurai archers and spearmen (Turnbull, The Samurai Sourcebook, 1998). The lessened reliance on samurai forces in favor of ashigaru, coupled with the impotence of the Shogunate severely weakened the samurai’s standing. While samurai still

held their status as a prestigious, honorable, elite force, much of their old prestige and power were lost (Louis & Ito, 2008). The samurai would never truly recover from these cultural losses.

After the chaotic times of the Sengoku period, Japan was in need of a strong leader that could reunite the clans and restore peace. This leader was Oda Nobunaga, whose efforts mark the beginning of the Azuchi-Momoyama period.

## **2.4 The Azuchi-Momoyama Period - Unification & Order**

The Azuchi-Momoyama period, lasting from 1568 AD to 1603 AD (Louis & Ito, 2008), can be described as the legacy of a single man; a legendary samurai named Oda Nobunaga. Through strength of arms and shrewd political negotiation, he fought to reunify the war-torn provinces of Japan and restore the Shogunate to power (Turnbull, Samurai Warfare, 1996). His innovative tactics during this campaign, such as his use of Portuguese arquebus guns to defeat samurai cavalry archers (Louis & Ito, 2008), prompted a shift further away from highly specialized samurai troops. While Nobunaga was killed in an ambush in 1582 (Brynat & McBride, 1989), his dream of a unified Japan was carried forward by his generals, resulting in the complete reunification of Japan in 1590 by his general Hideyoshi (Turnbull, The Samurai Sourcebook, 1998).

With the reunification of Japan complete, Hideyoshi set about restructuring Japanese society. He sought to heighten the division between the peasantry and the nobility by only allowing the samurai nobility to carry swords (Louis & Ito, 2008). This separation of duties not helped Japan's weakened economy by allowing the peasants to focus on farming and mining rather than warfare, but made rebellion by the lower classes more difficult as well. Furthermore, it served to make the katana the symbol of the samurai, as they were the only ones allowed to

carry these weapons. At the end of Japan's unification period, the samurai became more of a standing national army, alongside ashigaru forces, that was only used when needed, rather than the ever-fighting clan specific warriors they once were (Jansen, 2000).

After the restructuring of the Japanese worker and warrior classes, Japan settled into a long period of peace known as the Tokugawa period.

## **2.5 The Tokugawa Period – Peace & Prosperity**

The establishment of the Tokugawa Shogunate in 1603 AD (Louis & Ito, 2008) ushered in the Tokugawa period and the final stages of decline for the samurai class. With peace reigning throughout Japan for the first time in hundreds of years, the need for the samurai's martial prowess was greatly reduced (Turnbull, Samurai Warfare, 1996). At the same time, economic growth and a shift to coinage as the primary means of commerce elevated the merchant class, the Chonin, above their traditional station, putting them on par with the idle samurai (Honjo, 1932). The samurai's land based economy of earlier periods fell apart, forcing many samurai to turn to Chonin loans in order to support themselves.

As the period progressed and coin became ever more dominant, the samurai began to falter. With no need for their combat skills, many turned into Chonin themselves, becoming merchants instead of warriors. Others sold their feudal lands to pay off debts to Chonin, transferring even more power into the hands of the merchant class (Honjo, 1932). The Shogunate made several attempts to alleviate the samurai's plight, including the cancellation of all loans made to samurai at some point, but could not keep the samurai in good financial standing (Jansen, 2000). Eventually, the situation became dire enough that the samurai revolted, overthrowing the Shogunate and restoring an Imperial system (Jansen, 2000). Following the

revolution however, the new Emperor forcefully disbanded the samurai in 1876 as part of the Meiji Restoration that began in 1864 (Louis & Ito, 2008). Thus, ended the samurai era in Japan.

The following chapter introduces who the samurai were, how their unique philosophy developed over the course of their history and how this philosophy affected every aspect of their lives, including their perception of warfare and styles of combat.

## **3. The Samurai – the Ultimate Warrior Class**

The word samurai means “one who serves” (Turnbull, *The Samurai: A Military History*, 1996). The samurai, therefore, are servants of their lord, of the emperor and of all of Japan. This ultimate sense of duty, which is embedded in the samurai’s name, can be traced back to their religious beliefs and cultural customs. This chapter contains information about the evolution these beliefs and customs as well as the samurai’s view of combat and their role as warriors in Japanese society. This information is given here to give better context for the development of the samurai’s arms and armors, which is described in the following chapters.

### **3.1 Social Structure**

As was mentioned in the historical review section, samurai and their families were generally a part of a clan. One must wonder, however, how these clans formed, why they formed and whether the clans operated as business units or expanded families. This section seeks to answer these questions and shed more light on the social world of the samurai.

#### **3.1.1 Clan Formation**

Initially, around the Nara and early Heian periods, samurai had no distinctive clans. Each samurai had his own web of connections to other samurai and lords, but was altogether his own independent unit. It was therefore common for the samurai of that period to share their loyalty among different “clients” that they provided mercenary services for. These bonds were business-like, without the emotional connections that came in later periods (Ikegami, 1999).

In the late Heian period, however, clans of samurai began to form. These clans were known as “houses” (“ie”) in Japanese. Originally, these houses were just a formalization of one-

to-one business relationships (Turnbull, Samurai Warfare, 1996). A lord with an estate would offer his hired samurai housing in exchange for exclusive services from them. This housing offer also extended to the samurai's families. Over time, a strong sense of loyalty developed between the lord and his hired samurai. Eventually, the samurai were incorporated into the lord's household and their lineages became a part of his clan, effectively joining the lord's "family" (Ikegami, 1999). The business relationship between the samurai and the lord was then transformed into clan and family loyalty.

### **3.1.2 Clan Loyalty**

In Japanese society, the core social unit has always been the family, rather than the individual. The formation of the samurai clans therefore created a strong, self-contained military unit whose loyalty to each other was equivalent to one's loyalty to one's own blood relatives (Turnbull, Samurai Warfare, 1996). These new samurai clans played a pivotal role during the Sengoku period, when Japan fragmented into fiefdoms. The strength of the fiefdoms was directly related to the strength and size of the samurai clans that controlled them (Ikegami, 1999). Inter-clan warfare was therefore an important matter of protecting and strengthening the honor and influence of each clan, and of each samurai lineage as a result.

However, this sense of familial loyalty and filial loyalty toward the clan and the clan's lord was a two-edged sword. Whereas the successes of the clan translated into the successes of its lord and vice versa, the same could be said for the failures of both. A lord's political blunders reflected just as badly on the clan's honor as losing a battle and the ultimate losses of honor for a clan were either to suffer total loss in combat or to lose its lord and all his heirs. Samurai whose heirless lord had been killed became known as "ronin", leaderless and without honor. Ronin

were generally expected to follow their lord into death, sometimes while avenging their lord's honor as the "Tale of the Forty-Seven Ronin" depicts (Ikegami, 1999).

In some cases ronin or samurai were able to switch clans and still maintain honor. This was much more popular before the peaceful Tokugawa period, since Japan's political state was in constant flux. In addition, a samurai clan could adopt individuals into the clan, such as warrior monks or distinguished ashigaru. During the Tokugawa period, however, clans were much more static and it was considered extremely dishonorable to change one's allegiance to a different clan, even for a Ronin. The samurai clans of the Tokugawa period were more obsessed with the concepts honor and loyalty than their predecessors since their primary role during the Tokugawa peace had switched from active military to political nobility (Ikegami, 1999). By the end of the Tokugawa period, many samurai had lost their lives to the concept of clan honor, whether via voluntary suicide or via sanctioned inter-clan warfare.

## **3.2 Religious Beliefs & Culture**

The religion of the samurai is a complex entity born out of the polytheistic melting pot of religions that Japan had cultivated throughout its history. Thus, Japan's native spiritual religion, Shintoism, was supplemented by healthy portions of Buddhism and Taoism, which were imported from China and other nations over time. This resulted in a strange mix of all three that varied between each individual person, family or clan, based on personal preferences and traditions (Kitagawa J. M., 1990). Compounded on top of this was the samurai's own warrior code, Bushido, which added its own flavor to the warrior class' views of the common religions of the time (Nitobe, 1905). There is therefore no wonder that sayings such as "born Shinto, die Buddhist" developed in Japan, as the Japanese picked and chose which domains of life and death

each religion governed (Kitagawa J. M., 1990). This concept is essential to understanding how the samurai's specific mix of religious beliefs that is described below affected their culture, values and choices in everyday life.

### **3.2.1 Shinto**

Shinto, the native religion of Japan, is based on the worship of spirits and nature. Over the course of Japan's history, Shinto underwent several transformations due to the ever-changing religious and political climates, but several of its core principles endured until the 19<sup>th</sup> century and beyond. These core principles include the belief in Kami – protector spirits or gods, filial loyalty to one's head of family or clan, loyalty to one's ancestors, the need to keep one pure from contaminations of the body and soul, and the belief that everything and everyone is interconnected through a shared, intrinsic divine nature (Kitagawa J. M., 1990). These relatively simple precepts made Shinto extremely popular in Japan over its entire history.

Even as Buddhism replaced Shinto as the primary religion in Japan after the Nara period, Shinto still remained a substantial part of everyday life. The Emperors of the Nara and Heian period sought to institutionalize Shinto alongside Buddhism because of its popularity so that, while adopting many Buddhist customs, the Japanese people continued to pay their respects to local Kami spirits during the Shinto religious holidays and prayed at Kami shrines before making big decisions (Kitagawa J. M., 1990).

For the samurai, Shinto took on additional meanings in order to fit their unique social nature as a warrior social class. For instance, filial loyalty was expanded to include loyalty to the lord and head of the clan. Similarly, although each samurai had their own personal commitment to their own honor and their ancestors' honor, this too was expanded to include the honor of their



lord and his ancestors. In all other aspects, however, the Shinto customs of the samurai were the same as those of everyone else (Kitagawa J. M., 1990).

### **3.2.2 Confucianism, Buddhism & Zen**

As mentioned before, Buddhism slowly permeated Japan from the Nara period and on until it became extremely prominent in Japanese culture, especially in the royal courts. However, the pervasiveness of Shinto among the Japanese people forced Buddhism to change into localized versions that included several concepts from Shinto and were unique to Japan.

For instance, several of the theoretical views of the original Buddhism religion were too obscure and difficult to grasp for the common Japanese people. Many therefore chose to follow a different path of Buddhism, called Zen. Zen had originally developed in China, under the name Chan, which means meditation. At its core, Zen focuses on the concept that the ideas of Buddhism and the true nature of things cannot be fully understood unless they are experienced (Kitagawa J. M., 1990). Therefore, practitioners of Zen experience the here and now and find within these experiences the hidden, true spiritual meanings and a kind of spiritual perfection that would otherwise elude them if they simply tried to memorize them.

Zen also included beliefs of ridding one's mind of contaminations via meditation, which resonated with the Shinto beliefs of purity that the samurai held. This also included ridding oneself of imperfections as well, which explains the great care for detail and accuracy that we associate with the samurai to this day. Therefore, starting with the Nara period, the samurai began to incorporate Zen meditation into their daily training and their art and writing often referenced Zen concepts, beliefs and customs (Kitagawa J. M., 1990).

These concepts of Zen were also in line with Confucianism, which also crossed over to Japan from China. Confucianism is a humanist ethical system, in which man is believed to be capable of controlling himself and his fate through learning and striving for self-perfection. Confucianism also includes concepts of filial loyalty to one's family and one's ancestors. Therefore, this way of thought came naturally to the Japanese people. The samurai were great proponents of both Zen and Confucianism (Kitagawa J. M., 1990). Zen gave new religious meaning to everything they did, transforming their lives into deeply spiritual experiences, and Confucianism transformed their training and way of life into a sacred journey toward perceived self-perfection.

As Shinto grew and changed as a result of Buddhism taking hold in Japan, the concept of a Buddhist afterlife was incorporated into the Shinto belief. Originally, death in Shinto was merely a matter of an impurity that had to be dealt with and an opportunity to add another ancestor Kami to the pantheon of the family or the region. However, the Buddhist afterlife, which is simply a continuation of life before death in a different world, was very appealing to the Japanese people and to the samurai specifically. Under this new belief, death for the samurai represented a great opportunity for glory and honor that would continue with them into the afterlife. In addition, death did not release them from their loyalty bonds to their clan and to their lord (Kitagawa J. M., 1990). This allowed the samurai to gladly take their own lives in the event of their lord's death, as the highest expression of loyalty and as a culmination of their journey toward being the perfect loyal servant.

Many of the above ideas and precepts found their way into the samurai code of honor that came to be known as Bushido, which is described below.

### 3.2.3 Bushido

Bushido literally translates to “military-knight-ways”, or “the precepts of knighthood”. It is the code of moral behavior that every samurai must uphold in order to be considered a true samurai. The term Bushido came to be known during the early Tokugawa period, in the 17<sup>th</sup> century. Up until then it had remained an unwritten, unofficial set of rules and ideas that was passed from one generation of samurai to the next. Although the official Bushido code came into being relatively late in samurai history, it drew many of its precepts from the early Shinto, Zen and Confucianism concepts that the samurai had incorporated into their lives over time (Nitobe, 1905). Thus, stories of the reckless bravery of the samurai and extreme devotion to their lord existed since the early Heian and Nara periods, such as *The Tale of Heike*, which became popular during the 12<sup>th</sup> and 13<sup>th</sup> centuries and describes the great daimyos’ honorable behaviors during the Gempei wars of the 12<sup>th</sup> century - well before the Tokugawa period (Ikegami, 1999).

The basic precepts of the Bushido code are justice, loyalty, honor, courage, love and courtesy. The perfect samurai, therefore, is a man who upholds justice and honor as the highest values, who is not afraid to go into battle or die for his lord, who loves all things in the world and is capable of great compassion and who is a perfect gentleman in matters of etiquette.

Underlying these was the idea that the heart, and not the dry, intellectual mind, should guide a samurai’s actions. These ideas unite the concepts of loyalty and connection with all things from Shinto and the concepts of experiencing the moment and gaining glory and honor in death from Zen into the Confucianism view of the “perfect gentleman” – a cultured, learned man, skilled in the art of war (Nitobe, 1905). In many respects, Bushido is the Japanese equivalent to the European code of Chivalry that was upheld by the knights of the medieval ages.

## **3.3 Tactics**

Now that the social and religious contexts of the samurai have been reviewed, attention can be given to the evolution of the samurai's unique combat techniques. This section contains information about the samurai's changing roles in combat throughout their history, as well as a brief review of the primary weapons of the samurai.

### **3.3.1 Development of Armies**

During the Nara and Heian periods, samurai warriors were largely independent fighters. Although they served together in their lord's military, each samurai focused primarily on solitary tactics that would stand out from the crowd, attract the attention of the lord and bring about a promotion. Since each samurai warrior strived for perfection in his personalized tactic, when grouped together they were an unstoppable force versus the untrained and easily intimidated drafted forces that served as the main body of militaries at the time. Versus each other, however, the fight was more evenly matched and many tales romanticize the battlefield duels between opposing samurai and the clashing of their individual fighting styles (Ikegami, 1999).

During the Sengoku period, however, clans began to train their samurai as units that were meant to fight collaboratively. During this tumultuous period, samurai-commanded armies became larger and more skilled through experience, including the drafted ashigaru forces. This meant that individual samurai could be overrun by semi-skilled ashigaru forces if they failed to work together. Each samurai still worked toward achieving individual fame, but through strategic genius and command skills rather than through mere fighting prowess. This trend continued into the Azuchi-Momoyama period until the Tokugawa peace broke out (Turnbull, Samurai Warfare, 1996).

### 3.3.2 Primary Weapons

The samurai have always been known as deadly, elite military units. However, their greatest worth was not in front-line fighting with swords, but with providing support from horseback. Before the 14<sup>th</sup> century, the most deadly and useful weapon a samurai wielded was the bow (Turnbull, *The Samurai Sourcebook*, 1998). From horseback, the samurai were able to rain arrows onto enemy troops either from a distance or from close combat while maintaining the mobility and protection afforded to them by their mounts. Samurai frequently trained in how to shoot a bow with both hands while galloping and competed in archery competitions in order to increase their accuracy to a deadly precision (Turnbull, *Samurai Warfare*, 1996).

However, this changed during the Sengoku period. While in previous time periods only samurai were allowed to use bows, ashigaru were now given this privilege as well. This meant that instead of firing off a few, highly accurate shots, an army could simply fill the air with arrows, since the ashigaru greatly outnumbered the small, specialized samurai forces. This allowed the samurai to learn how to excel with a new weapon – the spear. Spears could be used both as thrown weapons and as stabbing weapons, while giving a samurai the advantage of a greater reach than that of a sword and a greater distance between him and his target (Turnbull, *Samurai Warfare*, 1996).

Throughout the samurai's active military career the katana sword was rarely used. In battle, it was reserved for close combat either from horseback or from the ground. However, such situations were relatively infrequent and undesirable for the samurai. That said, the samurai were still masters of the sword and trained with it incessantly. The greatest test of their skills, however, was against each other, either during battlefield duels or during interpersonal and inter-clan feuds. During the Tokugawa period, when the military skills of the great majority of the

samurai were no longer needed, such clan feuds and personal duels became the primary combat focus for this military elite (Ikegami, 1999). The primary weapon of the samurai of this period was therefore the katana, for those who kept it rather than selling it for extra funds, or the wakizashi, the smaller sister sword to the katana (Turnbull, Samurai Warfare, 1996).

Now that the samurai's social, religious, and tactical roles throughout history have been examined, the specific evolution of their arms and armors can be reviewed. The next few chapters provide such a review of the evolution of the major weapons and armors of the samurai, their composition and their construction methods.

## **4. The Katana – a Samurai’s Spirit**

The katana is the long sword that has always been associated with the Japanese samurai warriors. The katana is primarily a slashing sword, but its unique structure allows it to also be used as a stabbing weapon and a parrying weapon for defense (Turnbull, *Katana: The Samurai Sword*, 2010), due to its high resilience. It can be used either one-handed or two-handed, depending on the type of stroke to be delivered and the amount of force the samurai wished to impart to the blow. The katana was worn with the cutting edge facing up, thrust into a samurai’s wide belt (Joly & Hogitaro, 1913).

The katana underwent several changes since the introduction of swords to Japan from China (Morimoto, 2004). This chapter will describe the primary features of the katana, its historical evolution and the manufacturing process that was developed for it over time.

### **4.1 Description & Anatomy**

The katana is comprised of a blade between two and three feet long. In general, the tang is about a fifth of the length of the blade, with a hole near its end. The lengths of both tang and blade have changed with time, however, as will be reviewed in the history section below. The wooden handle, or “tsuka”, of the katana covers the tang fully. The handle is drilled through, such that a peg could be inserted into it, through the hole in the tang, in order to secure the handle onto the blade. The wood of the handle is usually covered with leather or stingray skin and then wrapped with rough silk cord, to provide a better grip (Joly & Hogitaro, 1913).

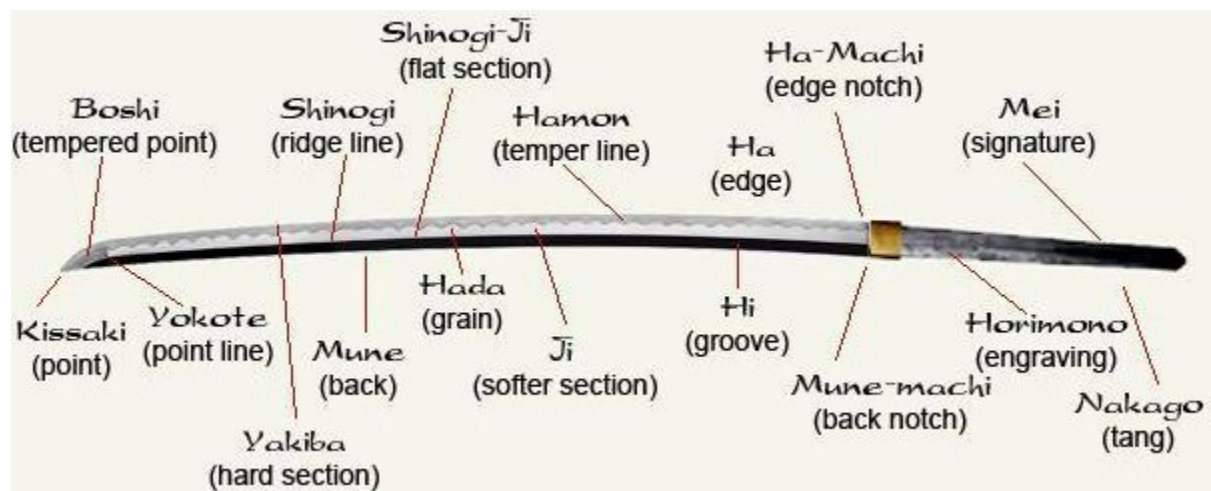
The blade itself is slightly curved, with a single sharp edge on the convex side of the curve. The blade has a ridge running along it and ends at a sharp point. Along the blade’s edge, a

distortion pattern called the “hamon” can be seen. This pattern is used as a measure of the quality of the blade and its composition (Turnbull, *Katana: The Samurai Sword*, 2010).

At the point where the katana’s handle and its blade meet, a hand cross guard called a “tsuba” is often present. The tsuba is both practical and decorative and can be made of more precious metals than steel. The wrapped can also be fitted with ornamental fittings that match the tsuba, for a more decorative look. Sometimes, spacers are used on one or both sides of the tsuba, to provide a tighter fit for it and a collar is fitted onto the base of the blade to provide extra strength to the point where the blade and cross guard meet (Turnbull, *Katana: The Samurai Sword*, 2010).

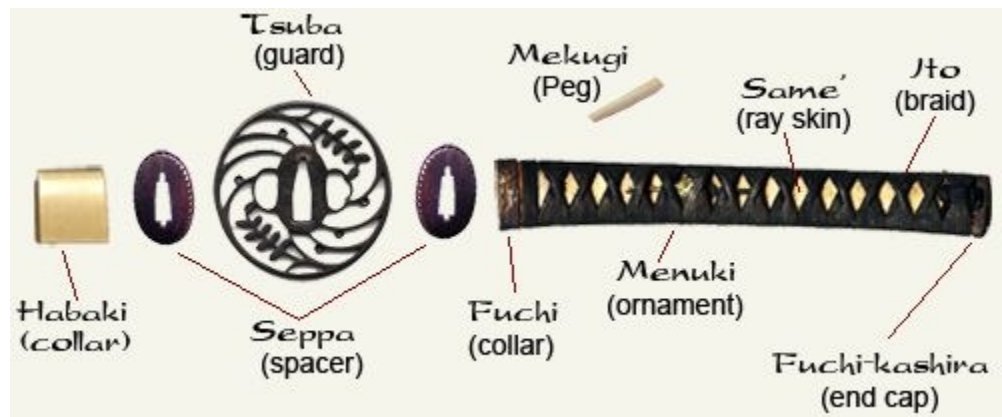
A decorative, small crest piece, called a “menuki” is often embedded into the handle, peeking out from between the wrappings. This crest piece usually belonged to the person or clan for whom the sword was made (Joly & Hogitaro, 1913).

The images on the next page show a full guide to the names and locations of the different parts of a katana and its handle.



**Figure 1: Katana Anatomy – Different Parts of the Blade.**





**Figure 2: Katana Anatomy – Different Parts of the Handle.**

## 4.2 History

The katana is the result of nearly a thousand years of sword refinement, the final stage in a process of continuous evolution dating back to the creation of the first Japanese swords in the 5<sup>th</sup> century. This section describes the evolution of the katana from its humble beginnings to its place of honor in Japanese society.

### 4.2.1 Introduction of the Curved Blade

The first swords were known as Chokuto, “Straight Swords”, and were little more than steel long swords derived from Chinese and Korean designs. Long, straight, and single-edged, they lacked the distinct curvature that defines the katana as it is known today (Morimoto, 2004). The curve emerged during the Nara Period, as a result of sword smiths attempting to create a better cutting blade. By repeatedly hammering a single side of the sword, smiths found they could create a finer edge, and thus, a sharper blade. Because one side of the sword was made longer than the other, the blade curved slightly. While at the time this was little more than a side

effect of the sharpening process, it would eventually become an integral part of the katana's design (Turnbull, *Katana: The Samurai Sword*, 2010).

These initial curved swords, known as Jotoko Tachi, or “Ancient Long Sword”, were constantly improved throughout the late Nara and Heian Periods (Nagayama, 1998). The rise of the samurai class as elite mounted units necessitated a longer sword that would reach foes from horseback and an even sharper, more curved blade. Such a curvature provided a mechanical advantage over straight blades for cutting power and reduced the sword's resistance when slicing through a foe. This was particularly useful when fighting from horseback, as the forces generated by a high resistance from the blade can knock the sword from a mounted combatant's hand, or even dismount the combatant altogether. Japanese sword smiths responded to this demand with the Tachi, an intentionally curved blade roughly 85cm in length that proved dominant in mounted combat (Morimoto, 2004). By the dawn of the Kamakura period, the success of the Tachi made it a staple of samurai across Japan.

#### **4.2.2 Emergence of the Stronger, Shorter Katana**

The Mongolian invasions during the mid-Kamakura period prompted additional changes to the Tachi as Japanese sword-makers confronted problems with their prior designs. Mongolian swords were thick and sturdy, and many Tachi proved too fragile to withstand them. To fix this flaw, Japanese sword smiths combined a thicker blade with improved metallurgical techniques to create a stronger sword. In addition, the typically deep temper lines of the Tachi blade were narrowed, as deep lines made the blade too brittle. The result was Tachis that were strong, flexible, and razor sharp (Nagayama, 1998).

During the late Kamakura Period, as towns and cities grew and close-quarters combat became more common, the Tachi was changed once again, reshaped into the legendary katana. Designed for hand-to-hand combat, the Katana combined drawing the blade and slicing with it into a single action, making it far faster than the bulkier Tachi. The katana was shorter than the Tachi, measuring roughly 73cm long, which allowed for greater speed and maneuverability in the often cramped spaces of urban combat. With these improvements the katana quickly became the most iconic of the samurai's weapons and a paragon of their fighting style (Turnbull, *Katana: The Samurai Sword*, 2010).

The pinnacle of Japanese sword making, the Katana changed little after its inception during the late Kamakura period. While the quality of the blade waxed and waned with Japan's inner turmoil, few distinct changes were made to the blade's design. Names changed, with swords from the Sengoku period being called Shinto, and those from the Tokugawa Period Shinshinto, but at its core the Katana remained largely the same (Joly & Hogitaro, 1913).

## **4.3 Cultural & Religious Meaning**

As was mentioned in the previous chapter, the katana held a special place in the hearts and minds of the samurai. This section will examine this meaning within the context of the samurai's unique culture and religion. In addition, this section will examine the meaning the katana held for the sword smiths who made them.

### **4.3.1 The Meaning of the Katana to the Samurai**

From their Zen teachings, samurai learned to strive for perfection in their combat skills in order to be as sharp and deadly as their blades. In a certain sense, therefore, the Japanese katana was not merely a sword, but an extension of the soul of the warrior who yielded it and a

reflection of his skills on the battlefield (Nitobe, 1905). Traditionally, when a katana was made by a master blacksmith, it was made with a specific “personality” that was meant to match that of the samurai who had commissioned it. This “personality” could manifest itself in the length of the blade, its width, its composition, in the fittings that decorate it and in other parameters (Joly & Hogitaro, 1913). After a samurai received such a sword he was supposed to keep it by his side for the rest of his life. The only exceptions to this were katanas that were not made for a specific person for combat purposes, but which were made as gifts or as ceremonial items (Joly & Hogitaro, 1913).

This sentiment is the reason for still allowing the samurai to carry katanas after the rest of the population was prohibited from doing so during the early Tokugawa period (Jansen, 2000). In addition, samurai who sold their swords were considered to be extremely dishonorable. Some samurai who had no choice but to sell their swords often sold only the blade and fitted the handle with a wooden blade in order to make it seem as if they still had the full katana (Nitobe, 1905). It is no wonder then that the end of the samurai era began in 1876 with Emperor Meiji’s proclamation that samurai too could no longer carry katanas in public (Jansen, 2000).

### **4.3.2 The Meaning of the Katana for the Sword Smiths**

In addition to having such deep meaning to the samurai themselves, the katanas also held a strong meaning for the sword smiths who made them. Beginning with a period of prayer to Buddha or the Shinto kami spirits, a blacksmith would embark on a deeply spiritual journey on his own, personal path toward perfection when making a katana (Turnbull, *Katana: The Samurai Sword*, 2010). The image on the next page shows how the sword smith’s workshop’s was sanctified using holy paper streamers as well as the presence of a “botsudan”, a small shrine for Buddha and the kami. The smith and his apprentice are both wearing ceremonial white clothes,

which shows how strong the connection between the spiritual meaning of sword making and the physical act of forging a blade was for these individuals.



**Figure 3: Ceremonial Nature of Blade Forging.**

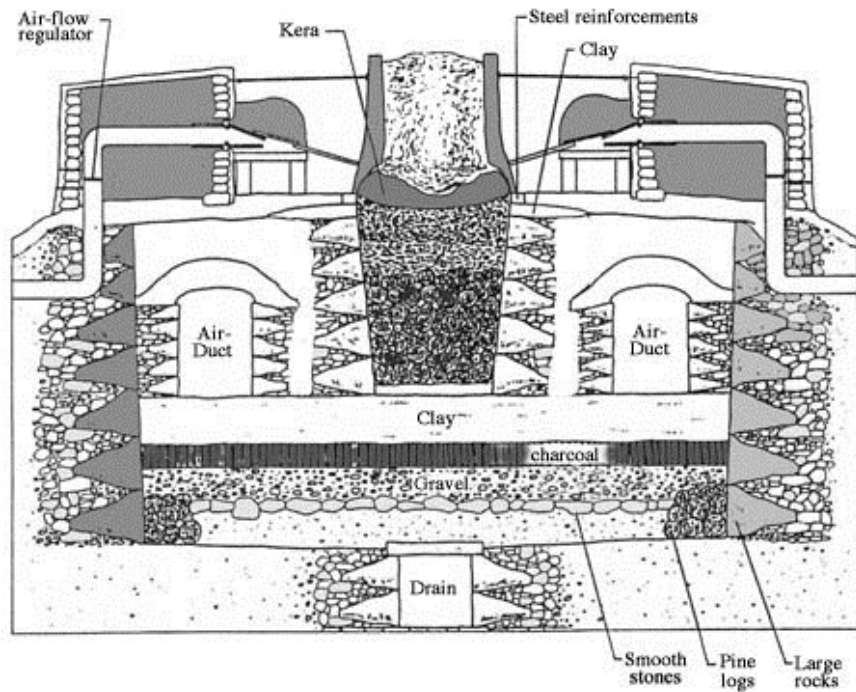
## **4.4 Materials & Manufacturing Process**

The katana has an anatomy that has varied from its earliest forms to its more recent designs. The most common design observes a structure of hard, high-carbon steel jacketed around an inner bar of softer, low-carbon steel (Kapp, Kapp, & Yoshihara, 1987). This gives the katana the ability to hold its famous edge while being able to sustain usefulness throughout combat. The tang, unworked throughout the process, is used as the focus around which the handle and later the sheath are made.

### **4.4.1 Smelting the Steel**

The first step in making a katana is making the steel, and for that, one needs a tataru. A tataru is a handmade clay furnace situated over a large, pre-made structure of ash, clay, stones

and logs (Kapp, Kapp, & Yoshihara, 1987). It starts with a large pit being dug into the ground that is upwards of 9 feet deep, 10 feet across, and 20 feet long (Kapp, Kapp, & Yoshihara, 1987). In the middle of this pit, a small 2ft by 2ft drain running the length of the pit is dug and lined with stones, dirt, and clay and covered with boards or stones (Martin, 2009). Next, the sides of the pit itself are lined with large rocks and layers are put down starting with dirt and pine logs followed by a layer of rocks, then layers of gravel, charcoal and clay. At this point, while the layers are about halfway to ground level, three structures are built into the pit. The first two, as seen in the picture below are air-ducts made with clay and rocks.



**Figure 4: Tataru Furnace Schematics.**

The last one will eventually become the base for the furnace itself, and that is a large stone and clay pit filled with ash and charcoal. The white areas around these structures are filled in with soil and the entire pit is topped with clay. This involved structure is important to the

production of the steel because it is imperative to keep as much moisture away from the furnace as possible. The ash/charcoal pit directly underneath the tatara draws moisture directly away from the tatara itself, and the air-ducts give the moisture someplace to go before heading down to the drain (Martin, 2009).

Once the pit is finished, though, the tatara can be built in earnest. As stated earlier the tatara is made by hand, so naturally its construction begins with 10 inch thick clay bricks set up in rectangular shape of 15ft by 5-6ft. Its walls are built up to about 5-6ft high and coated with more clay as mortar. The walls of the tatara are built around two lines of bellows pipes with holes above each pipe to allow for direct observation of the smelting steel. Further, two holes for slag run-off are built into the wall at the bottom of both walls of the tatara. A layer of charcoal is added to the bottom of the newly made trough, lit, and allowed to burn down to ash to dry the walls of the tatara (Kapp, Kapp, & Yoshihara, 1987).

Finally, the tatara is ready for production of steel. A new layer of charcoal is put down and lit. Once it reaches the correct temperature, a layer of iron sand known as satetsu is added, followed immediately by another layer of charcoal. This process of adding layers is repeated every 30 minutes for 3 days straight. The furnace, burning at around 1500°C, will burn off the impurities in the 10 tons of iron fed to it while adding carbon from the burning of 13 tons of charcoal, leaving steel behind. At the end of the third day, the walls of the tatara are torn down and a 2.5 ton block of steel known as a kera is left behind. The kera is broken into chunks and inspected by hand for quality. About half of this block is considered tamahagane, or steel that has a carbon content ranging from 0.6% to 1.5%. Of that, about two-thirds will be ideal with 1.0% to 1.2% tamahagane. The rest can be used by combining pieces of low and high carbon steel to get the carbon content closer to the ideal. The half of the kera that is not tamahagane can also still

be used, but it must be run through a different forging process to add or remove carbon from it before it can be used in the construction of a sword (Morimoto, 2004). The image below shows a tatara in action, making tamahagane by firing iron ore and charcoal.

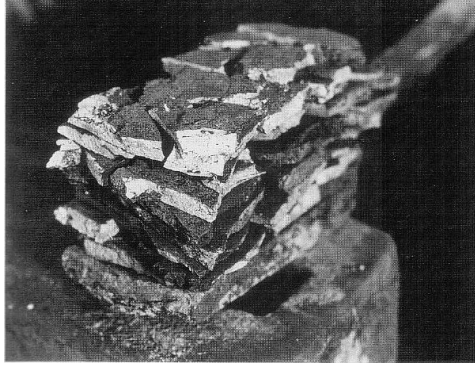


**Figure 5: Tatara Furnace Burning Iron into Tamahagane Steel.**

#### **4.4.2 Forging the Katana**

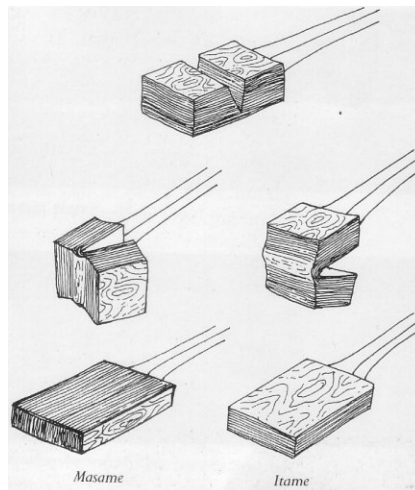
Once quality is determined the tamahagane to the swordsmiths who inspect the pieces for themselves and pick which pieces to use to forge the high-carbon outer jacket, and which pieces to use for the low-carbon core. A typical swordsmith hammers down and breaks up the tamahagane into flat squares of about 1 inch square and about  $\frac{1}{4}$  inch thick (Kapp, Kapp, & Yoshihara, 1987).





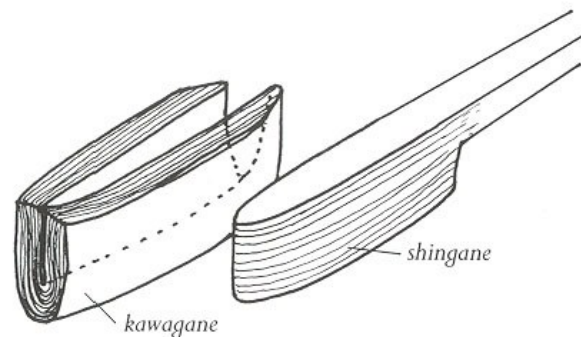
**Figure 6: High Carbon Tamahagane Steel Squares.**

These the smith puts onto a steel plate he made attached to a handle, covers it in paper and clay to keep them together, and heats the entire bundle to around 1300°C to weld the pieces together. After the pieces are welded, the smith will begin to hammer the metal into a longer bar, occasionally covering the metal with clay and straw-ash to keep from losing too much carbon to oxidation. Eventually he will fold the result in half and begin again, forging the two layers together and stretching the metal out. After about six or seven folds, the smith will cut the metal into 3 sections and set them aside (Kapp, Kapp, & Yoshihara, 1987).



**Figure 7: Hard Steel Shell Initial Block Formation.**

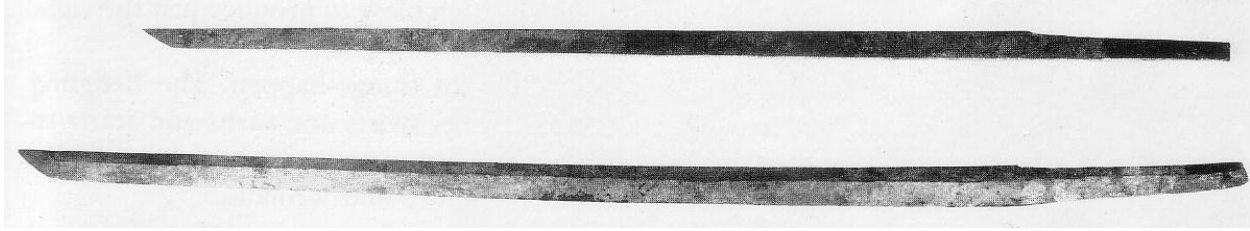
The smith will then take four of these sections and repeat the original process. Once he has folded this new set of steel together about 6 or 7 times, the smith will set it aside, and begin work on the core steel. The swordsmith selects a 2-lb chunk of tamahagane that has a carbon content around 0.5%. Instead of using the same technique as the jacket steel, though, he will simply hammer this steel into a flat bar that he folds as many as ten times. What is left is a narrow bar of steel weighing about a quarter of what it started at. He next takes the high carbon steel from earlier and forms it into a 15-in long U shape (Kapp, Kapp, & Yoshihara, 1987).



**Figure 8: Formed Soft Steel Core to be Inserted into the Hard Steel Jacket.**

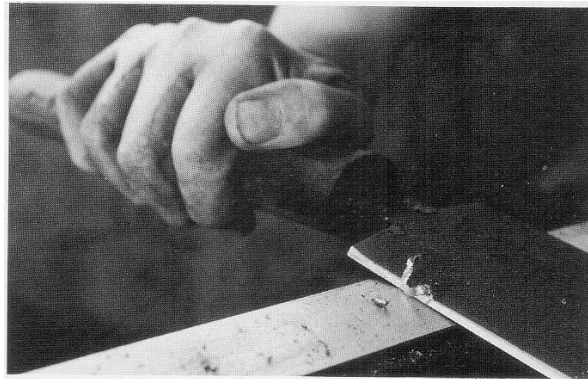
The low carbon bar is then placed inside the U and the whole bundle is heated to 1300°C or higher. The swordsmith hammers the steel so that the hard-steel jacket completely envelops the softer core. A mistake at this stage could potentially destroy the sword at the later stages, so the swordsmith must be careful in his work (Morimoto, 2004).

Now the swordsmith works on shaping the sword's blank. The smith will lengthen the newly wrapped steel until it is at about 90% of its desired length (Kapp, Kapp, & Yoshihara, 1987), as can be seen below in the comparison between a blank and a final katana.



**Figure 9: Blank, 90% of Desired Length, vs. Fully Shaped Blade.**

Heating in patches of 6 inches, he will work on forming the edge and ridgeline of the sword, being careful to keep the sword almost completely straight while he does so. Once the blank is finished, the smith uses a draw knife called a sen to shave off any irregularities and unevenness on the surface of the metal (Kapp, Kapp, & Yoshihara, 1987).



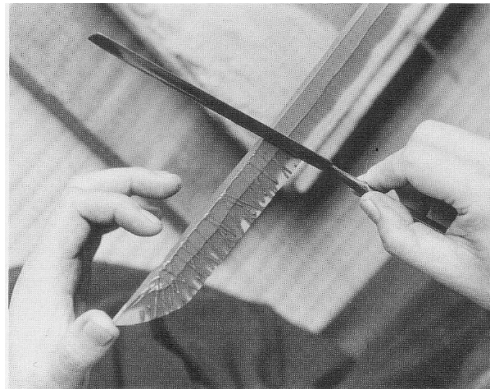
**Figure 10: Shaving Off Irregularities in the Blade.**

The back and edge of the sword are filed down and evened out before the entire sword is ground with a rough carborundum stone (Morimoto, 2004).

#### **4.4.3 Final Quench**

When it comes time to perform the final quenching of the sword, the smith coats the sword in clay; thinly along the edge but thickly along the back of the sword. Because of steel's structural qualities, its primary form of hardening is by cooling down from a high heat. The

speed at which this cooling takes place affects the form the steel takes. The thinly coated area of the cutting edge will cool quickly from the roughly 900°C to form martensite, which is a harder form of steel than its natural austenite. If cooled slowly, as the portion of the blade with a thicker layer of clay will, it will form into ferrite and pearlite. This quality of steel allows swordsmiths to make the defining mark of a good katana; the hamon. The hamon is created by taking advantage of the effects layered clay has on the cooling speeds of steel. Designs written into the clay will often form a distinct difference in the form of the steel that, with polishing, will become visible as the hamon line (Kapp, Kapp, & Yoshihara, 1987).



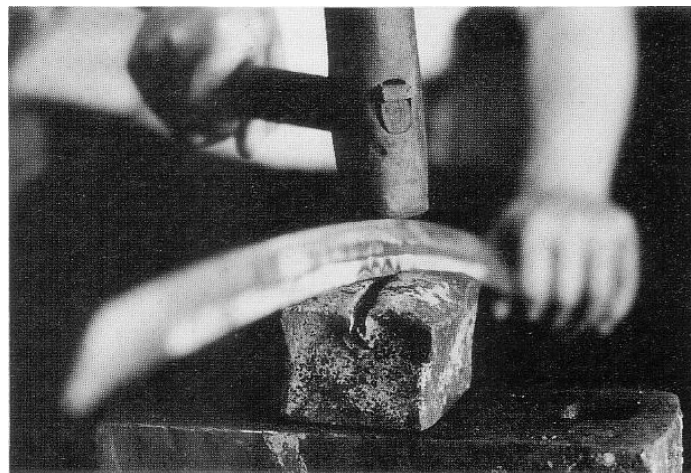
**Figure 11: Covering the Blade with Clay for the Final Quench.**

Once coated, the sword is heated evenly to over 700°C. It is very important that the sword be evenly and uniformly heated, because differences in temperature can be fatal to the sword when it is quenched. Once heated, the sword is plunged into a trough of water where the cooling curves the sword and makes the distinctive changes in the steel (Morimoto, 2004).



**Figure 12: Quenching of the Blade in a Trough of Water.**

The blade is then cleaned of the clay and the edge and curvature are given slight fixes if they need it by heating small portions of it at a time and using gentle hammer strokes (Morimoto, 2004).



**Figure 13: Adjustments to the Final Blade via Gentle Hammering.**

The sword is now technically finished, though it looks nothing like the stereotypical samurai blade, glistening with its hamon and reflective sides. The smith will now take the sword and begin to polish it. Using a grinding wheel and polishing stones, he will clean the lines of the

sword, grind down and sharpen the edge, and generally prepare the sword for the next stage of polishing. This is also the stage of the sword where any decorative grooves are added. The process of making grooves can take as many as two days and requires the application of specialty tools such as U-shaped drawknives, round files, and small polishing stones. Once this is finished, the sword is sent for final polishing and handle fitting (Kapp, Kapp, & Yoshihara, 1987).

#### **4.4.4 Constructing the Handle & Sheath**

The handle and sheath of the katana are traditionally made from the same piece of magnolia wood, or other expensive woods. Both are cut, finished and lacquered as part of the same process (McDonald, 2002). Beginning with a single piece of wood, the general shape of the combined handle and sheath is carved out. The sheath is curved, to match the curve of the blade, but the handle can be straight or curved depending on taste. Most katanas were made with curved handles that matched the curve of the blade, since the continuous final shape of the sheath and handle was considered to be very beautiful (Joly & Hogitaro, 1913). This single sheath and handle piece is then bisected along its length and the handle is then separated from the sheath.

Once the blade is finished, the shape of its tang is carved out of the two handle pieces and the shape of the blade is carved out of the two sheath pieces. The fit is of supreme importance at this stage. The tang must not be able to move inside the handle, since the resulting vibrations of the metal on the wood due to continuous use of the sword could shatter the handle in the wielder's hands. However, it should be possible to easily remove the tang from the handle for maintenance without damaging the interior of the handle. Similarly, the blade must slide easily into the sheath but must not fall out of the sheath unless it is drawn. There should also be enough space for a thin film of oil covering the interior of the sheath, either from oiling the sword during maintenance or from a built-in oil distribution in the sheath (Kapp, Kapp, & Yoshihara, 1987).

After the shapes of the tang and blade are cut into the handle and sheath pieces, the pieces can be glued together and their final, smooth shape can be carved and grinded out of the wood. A hole is then drilled at a slight angle through the handle, to match the hole in the tang. A peg is then inserted into the handle, through the tang, to secure the handle around the blade. The angle makes the peg's fit very snug, such that it does not slip free unless pounded on (Kapp, Kapp, & Yoshihara, 1987).

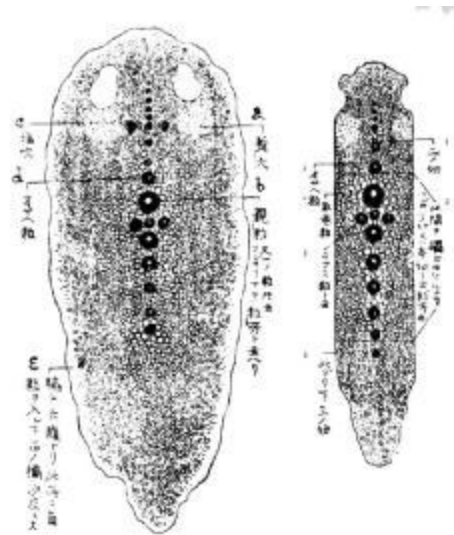
The next stage in the construction process is decorating the handle and sheath. Usually, the sheath is lacquered and painted while the handle is wrapped with stingray skin and silk cord. However, styles and fashions introduced a great variety into this final stage of the katana's construction. Sheaths were therefore sometimes wrapped with stingray skin and silk cord as well and handles were sometimes just lacquered and painted to match the sheath, without being wrapped. For lesser swords, it was not uncommon to leave the handle and sheath as bare wood, ground smooth and oiled but otherwise untouched. After this step, all that remains is to fit the blade with a cross guard and decorative, metal finishing (Joly & Hogitaro, 1913).

The next section describes the process of wrapping the handle and the advantages of this process over other styles of handle finishing.

#### **4.4.5 Wrapping the Handle**

As mentioned above, styles and fashion governed many of the customs that were developed regarding the finishing of the katana's handle. In addition, since the wrapping affected the quality of the final sword, cheaper swords used different materials than more expensive swords for this part of the sword's construction.

Although any leather can be used to wrap the wooden core and any thread can be used to wrap the final handle, the best known materials used for handle wraps are stingray skin and thick silk cord (Turnbull, Katana: The Samurai Sword, 2010). Stingray skin, much like shark skin or alligator skin, has nodules that give the surface of the skin a rough, scale-like texture (Joly & Hogitaro, 1913), as can be seen on the next page.



**Figure 14: Samegawa, Stingray Skin with Nodules.**

From an aerodynamic perspective, these nodules allow the flow of the water to separate around the stingray as it swims, allowing it to move quickly through the water, with little resistance from the separated flow. For katana handle purposes, however, the nodules simply provide a surface with high friction to the handle, allowing the wielder of the sword to maintain grip even with sweaty hands or while wearing gloves (Turnbull, Katana: The Samurai Sword, 2010). The thick silk cord creates grooves in the handle that allow the fingers of the wielder to settle into them and therefore enhances the grip as well.



The quality of stingray skin is measured by the unique pattern of the nodules of the skin, their color and their hardness. Stingrays have a hard, white, ridged section on their back. The more complex the pattern this hard section has and the larger and more uniform the rest of the nodules are, the higher the quality of the skin. Stingray skins are naturally a grayish white, but they can be dyed like any other leather. Traditionally, the skin used for the handle was bleached white and the silk cord was blue, black or brown. However, other colors of skin and cord could be used for different occasion or for different decorative purposes (Joly & Hogitaro, 1913).

The skin must first be soaked in water in order to make it pliable. An adhesive is then applied to the handle and the skin is wrapped snugly around the handle. The adhesive does not have to be strong and traditionally was simply a sticky rice paste. Once dry, after about 24 hours, the skin contracts and grips the handle very firmly. High quality swords have a full wrap, with the stingray skin covering the entire handle and no gaps. In lesser quality swords, however, only panels of stingray skin are applied to the handle along its wide sides. The silk cord hides the uncovered parts of the handle, such that the difference between the high quality and low quality swords is difficult to spot (Nelson, 2008).

After the stingray skin is dry, the silk cord is wrapped around the handle. There are many possible patterns for the wrap, depending on the purpose of the sword and how decorative or combat ready the blade needs to be (Joly & Hogitaro, 1913). Most commonly, the plain, triangle pattern of the combat wrap is used, with small or no variations. This pattern can be seen in the image on the next page.



**Figure 15: Tsukamaki Wrapping Triangle Pattern.**

In order to make exact triangles, the cord must be wrapped very tightly in a precise pattern. To help with this, rice paper panels and triangles can be applied to the handle in order to help the cord settle into the correct pattern. This step is purely optional, however, since a talented handle wrapper can form the triangle pattern accurately without it. During the wrapping process, the menuki crest piece is inserted between the ties (Nelson, 2008), as can be seen below.



**Figure 16: Menuki Insertion into the Handle.**

After this, the decorative fuchi and kashira are fitted onto the handle. The fuchi merely slips onto the handle and is held in place by the cross guard. The kashira, however, has a hole through which the silk cord is tied as the last step of the wrapping process. Once this is done, the

sword is finished and can optionally be fitted with a decorative saego or mounted on a stand (Nelson, 2008) as can be seen below.



**Figure 17: Full, Mounted Katana with Wrapped Handle & Sheath.**

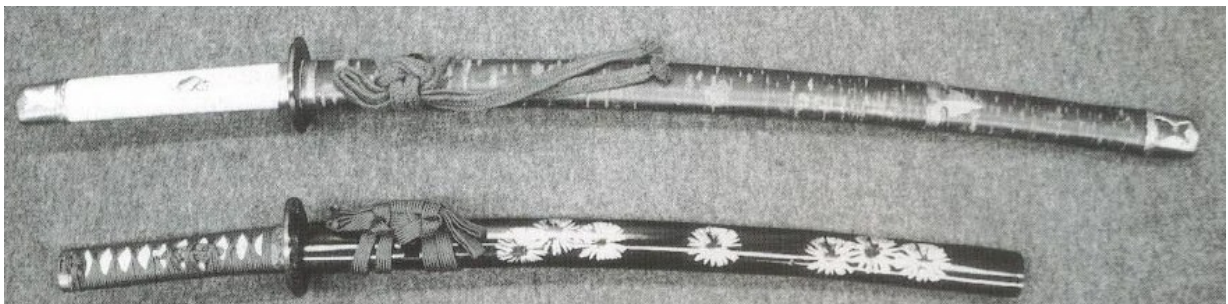
## 5. Other Weapons of the Samurai

As a long blade, the katana could not be used in every single situation the samurai faced in combat. As was explained in previous chapters, the samurai actually had several main weapons they utilized other than the katana. This section describes the evolution of these weapons and the materials that were used in their construction.

### 5.1 The Wakizashi

#### 5.1.1 History of the Wakizashi

The wakizashi emerged between the 15<sup>th</sup> and 16<sup>th</sup> centuries, created as a short sword companion to longer blades such as the tachi and katana (Joly & Hogitaro, 1913). Just as the katana's shorter length made it better than the tachi for urban combat, so did the wakizashi's shorter length make it better for even smaller spaces such as indoors (Turnbull, Samurai Warfare, 1996). The image below shows a comparison between a katana and the shorter wakizashi below it.



**Figure 18: Comparison Between Long Katana & Shorter Wakizashi.**

This sword's lighter weight and smaller size made it ideal for stabbing and thrusting, making it popular as an off-hand and backup weapon alongside the katana, often used to deliver

the finishing blow to foes (Turnbull, *Katana: The Samurai Sword*, 2010). Samurai would typically wear both, a combination known as daisho or “big-little”, both on and off the battlefield. In fact, it was often customary that a samurai leave his katana at the door when entering a restricted area, but maintain possession of their wakizashi (Joly & Hogitaro, 1913). Furthermore, the blade was the most common instrument used to commit Seppuku, the samurai suicide ritual (Nitobe, 1905). However, unlike the Katana, the wakizashi were never exclusive to the samurai; merchants were free to carry them as well (Nagayama, 1998).

### **5.1.2 Characteristics of the Wakizashi**

Physically, the wakizashi has many more variations than the katana. With a blade between 30 and 60 centimeters long, the sword can be divided into two classes: the shorter o-wakizashi and the longer ko-wakizashi (Joly & Hogitaro, 1913). In general, the shorter the blade the greater, the sharpness as there is less need to thicken the blade for strength. Thus, in many ways the wakizashi can be considered a smaller, yet equally sharp version of the Katana.

### **5.1.3 Materials Used in the Wakizashi**

In terms of materials, the wakizashi was usually forged of just the hard type of steel used for the outer shell of the katana. However, some wakizashi blades were made out of a soft steel core and a hard steel sheath, much like many katanas. This made the blade much more expensive and was generally considered to be a step up in quality, although it did not do much to change the blade’s base sharpness or flexibility since its length was so small (Nagayama, 1998).

## 5.2 The Tanto

### 5.2.1 History of the Tanto

The tanto is the oldest of the three common blades used by samurai, a traditional Japanese dagger dating back to the Heian period. The Tanto has had many names over the course of history and has changed lengths rather dramatically. However, it was always considered to be a short, stabbing weapon used for close combat and self-defense (Joly & Hogitaro, 1913). Initially, the tanto was used as a companion to the tachi, the long sword intended for mounted combat. This pairing mirrored the later katana/wakizashi set, with the tanto being used for close quarters combat and for finishing a kill. There are even records of the tanto being gifted alongside a tachi or a katana to a prominent lord during the Heian period, showcasing its importance to the samurai at the time (Joly & Hogitaro, 1913). As the tachi lost prominence to the katana, the tanto still remained a staple of samurai armament, though its role in combat was greatly reduced. Though for a time it was common to see a samurai with all three blades (Turnbull, *Katana: The Samurai Sword*, 2010), the tanto was eventually relegated to use by the lower classes, particularly as a method of self-defense for women (Joly & Hogitaro, 1913). A typical tanto can be seen below.



**Figure 19: Example of a Tanto from the Kamakura Period.**

## **5.2.2 Characteristics & Materials of the Tanto**

Unlike the curved katana and wakizashi, the tanto retained the straight blade of pre-Heian swords, and was either single or double edged. Furthermore, the 15 to 30 cm blade was designed for stabbing instead of cutting, possessing a thick blade for maximum penetration (Joly & Hogitaro, 1913). Constructed from a single type of steel, the tempering process used ensured the tanto was just as sharp as its katana and wakizashi companions, such that it could even be used for beheading to confirm a kill (Turnbull, Samurai Warfare, 1996). However, its small size made the blade exceptionally tough and far better for penetration than either the katana or the wakizashi.

## **5.3 The Bow**

### **5.3.1 History of the Bow**

As previously mentioned, the early samurai depended heavily on the bow as their primary combat weapon, which was fired from horseback. Due to the height of the horse, the katana was not as effective a weapon for the mounted samurai, since the mobility of the horse means that they could move across the battlefield while remaining at a distance and continuously firing accurate shots into enemy troops (Turnbull, The Samurai Sourcebook, 1998). Early samurai battles often involved an archery duel between the samurai on either side, before the armies closed to close combat (Turnbull, Samurai Warfare, 1996).

However, since the armors of the Nara and Heian period were bulky and reduced the samurai's mobility, they limited the range of possible firing angles, and often interfered with drawing and releasing the bow effectively. In addition, the bow had only offensive capabilities and had to be discarded in favor of other weapons once a charge into enemy lines was needed

(Turnbull, Samurai Warfare, 1996). Nevertheless, due to the samurai's unmatched skill with the bow and advances in armor development that allowed greater mobility, the bow remained the main weapon of the mounted samurai for almost four centuries before eventually being replaced by the spear (Turnbull, Samurai Warfare, 1996).

### **5.3.2 Characteristics of the Bow**

The Japanese bow has a distinctive shape that is almost unique in the world. While most bows are symmetrical around the firing point, so that there is an equal amount of wood above and below the area where the arrow is placed, the Japanese bow takes a different approach. Because the bow was designed to be used from horseback, there was a limit to how large the bow could be to still be used effectively, but a lack of heavy woods such as were used for European bows meant that the bow had to be large to distribute the forces involved in accurately firing an arrow to long distances. Therefore, instead of creating symmetrical bows the samurai used bows that were fired from only a third of the way up the bow, while the remaining two thirds were above the firing hand. This made the bows very long, around 6 feet in size, but still able to be fired from horseback. This structure gave it the strength and resilience that was required for combat (Turnbull, The Samurai Sourcebook, 1998).

Like its unique shape, the Japanese bow also had a unique method of drawing. While most European archers would hold the bow at chest level and then draw the string and arrow back, the Japanese held the bow above their heads, perpendicular to the ground. They then drew the bow string out as they pulled their arms down, so that when the bow was fully drawn it was at shoulder level. This was done to avoid hitting the horse while drawing the long bowstring. The image below shows an example of a person beginning to draw a Japanese bow by holding it above his head, as can be seen on the next page (Turnbull, The Samurai Sourcebook, 1998).





**Figure 20: Drawing a Japanese Bow From Above the Head.**

### **5.3.3 Training with a Bow**

In order to train the samurai in the art of being able to hit a target from atop a moving horse, competitions based around horseback archery were created. This type of training regimen is still practiced to this day and is known as “yabusame”, a type of competition that often takes place at festivals. An example of a challenge at these competitions is illustrated in the image on the next page, which shows a samurai firing at a small, stationary target from horseback (Turnbull, Samurai Warfare, 1996).



**Figure 21: Archery Training via Competition Challenges.**

## **5.4 The Spear**

### **5.4.1 History of the Spear**

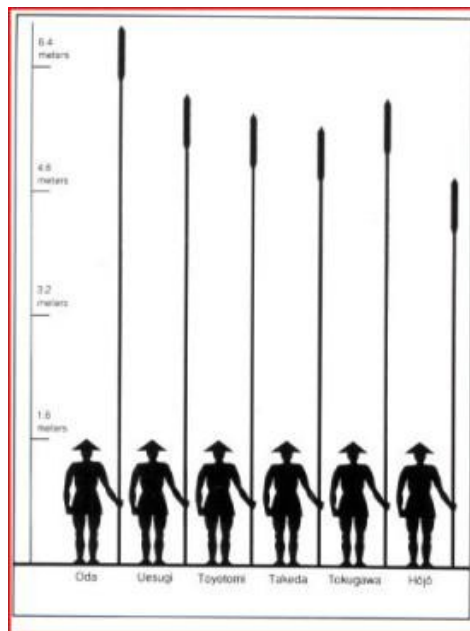
In the early days of samurai warfare, before the 14<sup>th</sup> century, the ashigaru were the main spear-wielders (Turnbull, Samurai Warfare, 1996). The spears, known as naginata, were considered to be graceless, inaccurate weapons and the ashigaru, who used them primarily to stop samurai cavalry charges from the front lines, were considered to be disposable (Turnbull, The Samurai Sourcebook, 1998). The more noble side of the naginata was its expert use by samurai women, who were as well trained with the naginata as samurai were with the katana, which was forbidden for women to use (Nitobe, 1905). However, around the Sengoku period a shift took place in the role of mounted samurai. Instead of being archers, the samurai transitioned to using a lance like European knights, sacrificing range for the ability to make a devastatingly accurate charge. This lance was known as the yari and was based on its predecessor, the naginata, but was much longer (Turnbull, Samurai Warfare, 1996). The shift to cavalry charges also forced the spears of the ashigaru to adapt as well. The naginata of the past was relatively short and therefore extremely ineffective against the longer lances used by the mounted samurai. Therefore, from the Sengoku period the ashigaru started to use the same spear as the mounted warriors, to give them a fighting chance against the lance's range (Bryant & McBride, The Samurai 1550-1600, 1994).

### **5.4.2 Characteristics of the Spear**

The naginata was composed of a shortened sword blade attached to a lacquered shaft. This allowed for a cutting edge, at the sacrifice of stabbing strength. Often thought of as the Japanese equivalent of the glaive, it was a versatile weapon. The yari, the Japanese lance that

replaced the naginata, was much longer, often at least 8 feet long. While there were several different lance tips, the most common was a steel point with a triangular cross-section (Turnbull, The Samurai Sourcebook, 1998).

As time went on, the yari was lengthened even further, eventually reaching a length of 5.6 meters used by the troops of Oda Nobunaga, as shown in the figure on the next page. The extra reach granted by the spear was offset by the difficulty in wielding it, but keeping your enemy as far away as possible and discouraging the dangerous mounted charges was a priority (Bryant & McBride, The Samurai 1550-1600, 1994).



**Figure 22: Comparison of Spear Lengths based on the Army (Latest to Earliest).**

## **6. Armors of the Samurai**

While the katana of the samurai was believed to be their soul, it was not their only distinctive mark. The armors of the samurai were equally unique to each samurai, allowing him to stand out from the crowd and be recognizable even from a distance. This was important for any samurai who wished to be promoted for their performance (Turnbull, *The Samurai Sourcebook*, 1998). Like the katana, the structure of the samurai's armor evolved as time went on. As warfare intensified in Japan, the samurai's armors progressed from a lamellar scales pattern to metal bands and eventually full plates.

### **6.1 The Helmet**

The kabuto, or helmet, was easily one of the most striking parts of the traditional image of the samurai. As mentioned before, the samurai wanted to be seen and distinguished from one another and their helmets reflected this (Bryant & McBride, *The Samurai 1550-1600*, 1994). They often had embellished crests on prominent display, or additional rivets and differently colored lacquer designs. Some embellishments involved things such as buffalo horns made of wood, or red suns painted onto the sides. In addition, while European helmets, such as those used by knights, covered a good portion of the face in order to protect the head as much as possible, the kabuto did not cover the samurai's face. Face-covering armor existed, and was known as men yoroi, but was rarely used. This face armor was more mask-like and was meant more for intimidation than protection. Fierce visages were painted on the men yoroi, and sometimes moustaches made out of horsehair were glued onto it as can be seen in the image on the next page (Bryant & McBride, *The Samurai 1550-1600*, 1994).



**Figure 23: Example of a Decorated Kabuto with False Hair.**

It is interesting to note that the helmet itself went through little in the way of evolution. The main part of the helmet remained a ridged bowl throughout the different time periods. Some changes to the original shape were made over time mainly for greater comfort for the head, but otherwise the helmet remained static (Bryant & McBride, *The Samurai 1550-1600*, 1994).

## **6.2 The Chest Piece**

The earliest sets of samurai chest armor were based on a lamellar construction, as can be seen in the figure in the next page, and were called keiko. Lamellar armor is constructed from rectangular scales that are pierced through so that they can be tied together into a single suit of armor. This type of armor had the benefit of being relatively light, since the structure alternated between iron scales that covered vital regions and leather scale-like pieces. Each scale was also lacquered to give the armor a polished look and provide additional hardening for the leather (Turnbull, *The Samurai Sourcebook*, 1998).

Due to its simplicity, this type of armor is easy to create and maintain. Like most examples of samurai armor until the 15<sup>th</sup> century, the keiko set all of its weight upon the samurai's shoulders. While this did allow for slightly greater mobility, it also made the armor somewhat uncomfortable to wear for extended durations. Samurai always wore their armor while travelling to and fighting on the battlefield, in order to cut down on the amount of baggage that they had to carry separately. Therefore, comfort became a priority. Eventually, samurai began tying the armor around their waist to shift some of the weight down, like backpacks with built-in waist belts do today (Bryant & McBride, *The Samurai 1550-1600*, 1994).



**Figure 24: Sample of Scaled, Lamellar Armor.**

Before the 13<sup>th</sup> century, the main two types of armor that were used by samurai in Japan were the yoroi armor and the do-maru armor (Turnbull, *Samurai Armies 1550 - 1615*, 1992). The *yoroi* armor was heavier and boxy, designed to provide a mounted samurai with great protection. However, it was also stiff and limited the samurai's mobility while on foot. The samurai therefore eventually transitioned to the more flexible do-maru armor style, which eventually

became the modern style known as tosei gusoku. The first step toward this change was shifting more of the weight of the armor onto the hips, to make wearing it for longer periods even easier (Turnbull, *The Samurai Sourcebook*, 1998).

The chest, known as the do, was the piece that changed the most over the course of the samurai's history. While beginning as simple lamellar armor, around the beginning of the warring states period the idea of creating the armor out of bands of lamellar scales, or even a simple rectangular piece, became more common. Using a unified set of bands allowed the armor to have a varying width along the body, so that more weight could be transferred to the hips (Turnbull, *The Samurai Sourcebook*, 1998). It also produced the look that is most closely associated with the traditional samurai, with overlapping layers, as can be seen below.



**Figure 25: Traditional Samurai Do-Maru Armor.**

When the Europeans arrived their sets of plate armor influenced the Japanese armorers to change the armor styles. In addition, the arrival of guns to Japan meant that samurai needed a much stronger armor (Bryant & McBride, *The Samurai 1550-1600*, 1994). The most famous of the styles created in order to counter gunshots was the Yukinoshota-do. The surface of this armor was completely smooth to better deflect projectiles, with all of the lacing hidden under the surface. The creators of this armor were so sure of its abilities that they provided samples that had been tested quite literally in the line of fire. In terms of appearance, the Japanese became greatly enthused by the look of the European breast plate. After the Europeans arrived in 1542, more solid styles of do appeared within a few years which were obvious copies of the European's style of armor. In some cases, actual pieces of European armor were incorporated into the Japanese armor sets and were simply lacquer over. An example of the more plate-oriented armor style can be seen below (Turnbull, *Samurai Armies 1550 - 1615*, 1992).



**Figure 26: Example of Europe-Influenced Japanese Plate Armor.**



## 6.3 Additional Armor

In addition to the kabuto and do, the two other main pieces of armor were the kusazuri, the thigh guards, and the sode, which protected the shoulders (Bryant & McBride, *The Samurai 1550-1600*, 1994). Like the helmet, these also evolved very little. Remaining composed of bands, likely for mobility, these pieces were often physically separate from the do. The sode eventually became smaller to avoid hampering movement as hand-to-hand combat became more prevalent.

The last piece of armor that was considered to be optional was the kote, or armored sleeves. Since this was the last piece of the body left uncovered, but would interfere with the samurai's abilities to use his bow and sword, it was used less frequently than the other parts of the armor (Turnbull, *The Samurai Sourcebook*, 1998). An example of this piece and the sode can be seen on the next page.



**Figure 27: Example of Sode from the Edo Period.**

The final evolution of samurai armor came during the peaceful Tokugawa period. As suits of armor were no longer worn into battle, they became decorative pieces with many old styles revived as artistic tributes. In addition, impractical designs of armors were adopted due to

their look. An example of this type of decorative armor can be seen below (Bryant & McBride, The Samurai 1550-1600, 1994).



**Figure 28: Example of a Full Piece of Edo Period Decorative Armor.**

## 7. Constructions of a Sample Katana

Considering that making a true masterpiece of a katana can take several months, it was decided that it would be more beneficial to manufacture a sword of a lesser quality that can be finished within the time constraint of the project. The above research had showed that it was a viable option to use the traditional method of inserting a rod of soft steel into a shell of hard steel and form the result into the shape of the blade within a reasonable time frame. The plan, therefore, contained the following steps:

- Purchase the metal required for the hard steel shell and soft steel rod
- Assemble a block out of each of the steels, one of high-carbon (hard) steel and the other of low carbon (soft) steel
- Work the hard steel block into the shape of a folded “v”
- Insert the soft steel block into the “v” shaped hard steel block
- Work both into a single welded block by closing the shell around the soft steel
- Stretch the resulting block into the shape of a sword blank
- Defining the shape of the blade from the blank and cleaning it
- Covering the blade in clay and quenching it to obtain the required curve

After the following steps, the plan was to fit the resulting blade with a wooden handle, wrap it in the traditional manner using stingray skin and silk cord and then fit it with traditional fittings. These fittings could either be purchased, along with the other materials required to make the handle, or they could be forged from any excess steel that was purchased for the blade.

Like most battle plans, however, this plan had to undergo many changes since the actual process of making the sample katana replica was more difficult and involving than predicted.

Most prominently, a brittle failure in the hard-steel/soft-steel block during the blank making process forced the team to switch to an emergency plan that could be completed within our time constraints. Under the new plan, the blade was to be constructed entirely of hard steel, without folds, in order to show what the remaining steps of the original plan would have looked like had the blank not failed.

The full description of all the changes that were made to the original plan can be found in the Process section of this chapter, following a description of the materials that were purchased for the constructed replica. The final section of this chapter details the results of the process that was used, as well as the material properties of a sample of the welded hard-steel/soft-steel block.

## 7.1 Materials Used

Originally, 5160 Tool Steel was selected as the hard steel for the sword’s shell, but it turned out to be highly problematic. After a failed attempt to fold this steel once as a proof of concept, it was discovered that the 5160 steel has a larger percentage of chromium than other types of high-carbon steel, which makes it extremely difficult to weld it to itself unless one is working with temperatures higher than 2000°F. The following shows the properties of this steel.

**Table 1: 1018 Steel Properties from the Manufacturer**

<b>5160 Steel Properties from Admiral Steels</b>	
<b>Standard Specifications:</b>	ASTM A689 & A304
<b>Typical Composition:</b>	C 0.56-0.64%, Mn 0.75-1.00%, P 0.035% max, S 0.040% max, Si 0.15-0.30%, Cr 0.70-0.90%
<b>Typical Hardness:</b>	Rockwell C 25-35
A fine grain chromium alloy. It is produced with a hot rolled round edge ideal for flat spring applications. Chromium aids wear and shock resistance and promotes better heat treat penetration.	

Since the facility used for the forging of the sword could not achieve these high temperatures, 1095 Spring Steel was purchased as a replacement. 1095 steel has a similar carbon content to 5160, but does not have any chromium content. The table below shows the properties of 1095 Spring Steel, as stated by the manufacturer:

**Table 2: 1095 Steel Properties from the Manufacturer**

<b>1095 Steel Properties from Admiral Steels</b>	
<b>Standard Specifications:</b>	ASTM A568 (sheets) A830 (plates)
<b>Typical Composition:</b>	C 0.90-1.04%, Mn 0.30-0.50%, P 0.20% max, S 0.025% max, Si 0.15-0.30%
<b>Typical Hardness:</b>	As rolled: Rockwell C 15-45
The highest of the carbon grades, this is a continuous cast, fine grain, fully killed steel (#5 or better). Material is low phosphorus, low sulfur, calcium treated to enhance internal cleanliness. In the as-rolled condition, material is well suited for abrasion resistant applications. In the annealed condition, the material may be cold formed (hot forming suggested for critical bends) with excellent heat treat results.	

For the soft steel, 1018 mild steel was used. Luckily, the facility was able to supply this metal for the group with no additional cost. The following image shows the properties of this steel, as rated by an online comparison site.

**Table 3: 1018 Steel Properties from Online Source**

<b>1018 Steel Properties from www.onlinemetals.com</b>	
<b>Standard Specifications:</b>	ASTM A568 (sheets) A830 (plates)
<b>Typical Composition:</b>	C 0.18%, Mn 0.60-0.90%, P 0.40% max, S 0.05% max
<b>Typical Hardness:</b>	Rockwell B71

As can be seen by the above information, the hard steel has almost eight times the carbon content of the soft steel that was used.

For the katana's handle, a finished wooden core was ordered, since sculpting the core out of wood would have been a very time consuming process. However, stingray skin and silk ito cord were obtained separately in order to wrap the wooden core manually. The images on the next page show the stingray skin and silk cord ordered for this purpose, in WPI colors:



**Figure 29: Silk Cord for Katana Handle Wrap.**



**Figure 30: Stingray Skin for Katana Handle Wrap.**

A cross guard and decorative fitting were also ordered, since machining them would have been complicated and would have also added too much time to the construction process. These fittings can be seen in the image on the next page.



**Figure 31: Finishing for the Sample Katana.**

The final budget can be seen in the table below:

**Table 4: Final Replica Budget Breakdown**

<b>Item</b>	<b>Use</b>	<b>Price</b>
5160 Tool Steel	Final blade	\$86.88
1095 Spring Steel	Hard steel shell of blade attempt	\$36.73
1018 Mild Steel	Soft steel core of blade attempt	\$0
Wooden handle	Handle core	\$19.99
Stingray skin	Handle wrap	\$53.78
Silk cord	Handle wrap	\$6.00
Fittings	Decoration & tight fit	\$49.49
<b>TOTAL:</b>		<b>\$252.87</b>

## 7.2 Process

Starting with the 1095 spring steel, three one-foot sections were cut and spot welded onto each other to make a block that was 1 foot long,  $\frac{3}{4}$  of an inch tall, and 1 inch wide. This block was heated to orange/yellow in color then hammered down to produce a weld, as can be seen in the image below.



**Figure 32: 1095 Steel Forging.**

It was then ground down to remove the minor imperfections like where the metal did not overlap properly and then it was reintroduced into the forge a small section at a time. As small pieces of the metal were heated it was hammered with the thin edge of the hammers to spread the metal into a larger plate. This was widened to accommodate a block of 1018 mild steel that was prepared in a similar fashion. Once the 1095 was widened enough that it could easily be wrapped around the 1018, a tang was formed out of the end of the 1018 and the process of wrapping the steels began. To ensure a steady fit, the 1018 was spot welded to the plate of 1095



before the metal bundle was placed into the fire. The image below shows the 1018 steel, held by its tang, and the plate of 1095 steel that was to be wrapped around it.



**Figure 33: Joined 1018 Steel and 1095 Steel.**

Once the bundle was hot enough (orange to yellow in color) to allow for proper welding, it was removed, hammered into a special device that assists in curving metal, and placed back within the forge. This process was repeated several times along the length of the metal to ensure proper welding. This method worked marginally well until one portion of the metal bundle became too hot and cracked outward, effectively ruining the bundle. The image on the next page shows the results of this brittle failure.



**Figure 34: Brittle Failure of the Hard Steel/Soft Steel Blade.**

In an effort to save time, resources, and to produce a viable example, it was decided to reattempt the making of the sword with only a single type of metal, rather than two. Using the 5160 tool steel that was first purchased for the sword, a piece of material 3.5 feet in length was cut and lengthened through hammering.



**Figure 35: 5160 Blade Second Attempt.**

The lengthening process was more aimed at defining an edge and a tang than adding any more length to the blade. With the edge defined, the tip was given its distinctive taper, and the tang was produced. Once finished with the initial shaping the entire blade was sanded down. The images below show the grinding process as well as the finished, silvery blade.



**Figure 36: Grinding the Sword.**



**Figure 37: Final Blade with Silvery Finish.**

The blade's edge needed to be thinned to between a  $1/16^{\text{th}}$  and a  $1/10^{\text{th}}$  of an inch, the back of the blade needed to be uniform, and the blade needed to be free of major dents, divots, and imperfections.

Once the blade was free of these things it was covered with refractory mortar. Refractory mortar is a type of clay mortar that is used in high temperature applications and we felt that it would do the best job of acting as clay for quenching. The image on the next page shows the clay application process.



**Figure 38: Applying Refraction Clay to the Blade Before Quenching.**

Once the mortar was dry the sword was placed into the forge and it was heated evenly throughout its length by being pulled in and out of the forge slowly, allowing the flames to reach all parts of the sword. Once the metal reached the point of being non-magnetic (again, orange-yellow in color), it was plunged into a trough of water, as can be seen below, to try to induce the rapid cooling intrinsic with the formation of the katana's well-known shape.



**Figure 39: Quenching the Blade.**

Sadly, the clay did not perform as intended. Although the blade was successfully quenched and a slightly wavy hamon pattern can be discerned along its edge, the blade itself did not curve. During the heating process it seems that the clay became detached from the blade, such that almost all of it came off almost immediately when the blade was quenched. Despite this, the blade itself was still usable for the next step – fitting and wrapping the handle for it.

As was described in the traditional process for making a katana's handle, a wooden core was used for our handle. Since this core was purchased separately from its fittings, it had to be carved to fit them before the stingray skin could be applied. The image below shows the carved handle with the fuchi fitted onto it.



**Figure 40: Carved Tsuka Handle.**

The next step was to size the same, the stingray skin piece to be fitted onto the blade. The piece of stingray skin that is depicted above shows very bright, white Emperor Nodules, which are considered a very classy feature of a wrapped katana handle. Therefore, the same piece had to fit such that these nodules would show up between the triangles of the wrappings. The cut same piece and the tools that were used to fit it onto the handle can be seen on the next page.



**Figure 41: Cut Same Piece & Handle Wrapping Tools.**

The next step was to wet the stingray skin and use watered down glue to adhere it to the handle. To make sure the same stayed close to the surface of the tsuka handle, silk ito cord was used to bind the entire handle tightly. This assembly was then left overnight to dry, so that the stingray skin would have the time to shrink and, together with the glue, strongly adhere to the handle. The following image shows the wrapped handle assembly.



**Figure 42: Wrapped Handle Assembly, Left to Dry Overnight.**

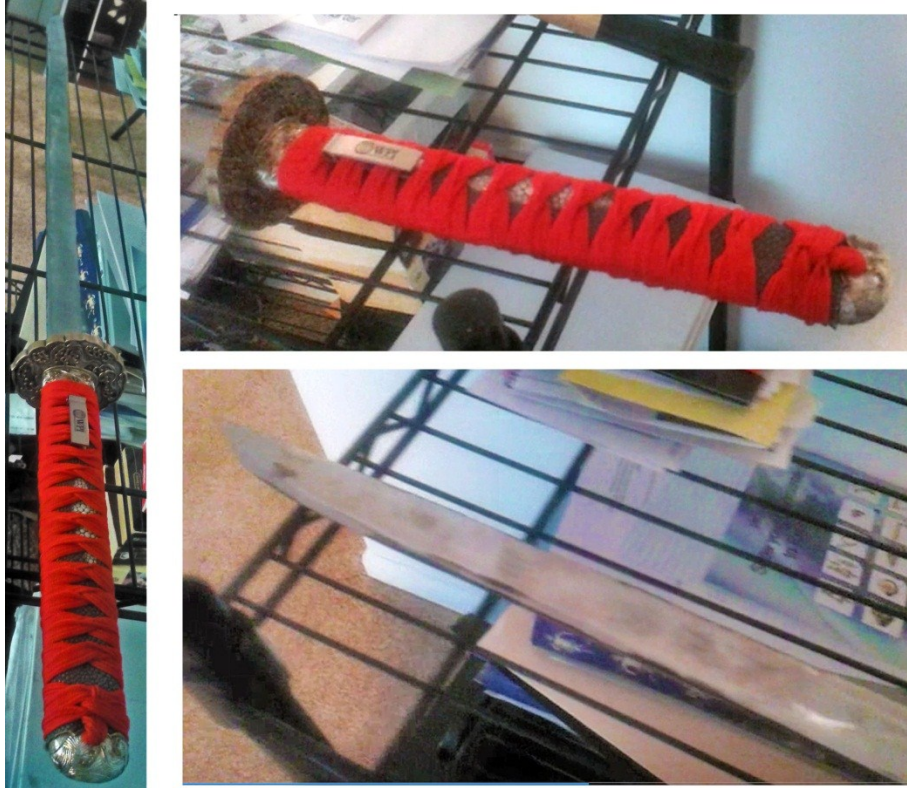
The next day, any excess same skin was trimmed from the sword and the ito wrapping process began in earnest, as the following image shows. The final sword can be seen in the Results section below.



**Figure 43: Silk Ito Wrapping.**

## **7.3 Results**

In the end, the experience of making a katana blade using traditional or near traditional methods turned out to be very difficult and time consuming. However, despite multiple failures and a lack of experience with forging techniques, we were able to successfully make a blade and fit it with a handle to form a final product. The final katana blade and handle thus created can be seen on the next page from various angles.



**Figure 44: Final Replica of a Katana.**

Although it is not made of two different types of steel and is not curved, its forging process was still representative of the methods that the old sword smiths had used.

In addition, a smaller version of the hard steel/soft steel blank was successfully forged for the purpose of examining the effects of the forging process we had used. To check if this process produced any serious benefits over standard forging practices, we carried out two different hardness tests, in addition to taking pictures through an optical microscope.

Before we could do this, we needed to cut and mount samples of interest out of the small auxiliary blank that was made. Mounting involves creating a plastic “shell” around the sample of interest. In simple terms, the sample is placed on the bottom of a container, and the plastic mold material, either in powder or solid form, is placed over the sample. At this point, the container is



exposed to high pressure and heat within a specialized machine, forming it into a solid piece, as pictured below.



**Figure 45: Etched & Mounted Blade Sample.**

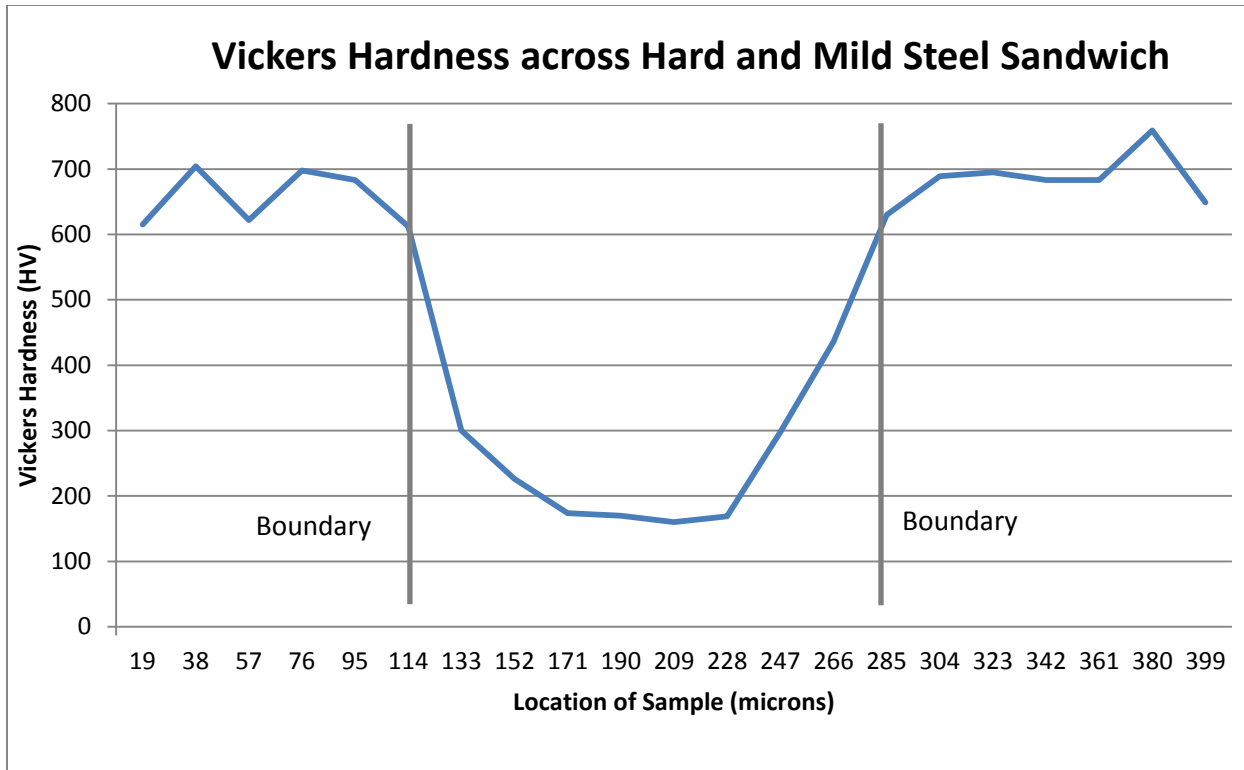
Once this is complete the sample surface must be flattened and any contaminations have to be removed. Therefore, the mounts are polished using a polishing wheel and sandpaper. The wheel is continuously kept wet to clear away the particle debris created through the polishing. After polishing the mount with a rough sheet, successively finer papers are used in order to smooth the surface, removing any scratches that may have been made by the previous level of roughness. Finally, an extremely fine diamond surface is used to polish the mount's surface to a mirror finish.

However, a highly reflective surface is difficult to photograph. Therefore, a process called etching is used to exaggerate the outlines of the sample's microstructures. There are many different "etchants", acids used to etch the surface, as some are better at accentuating specific traits in specific materials than others. We used Nital, a 2% concentration of nitric acid in water.

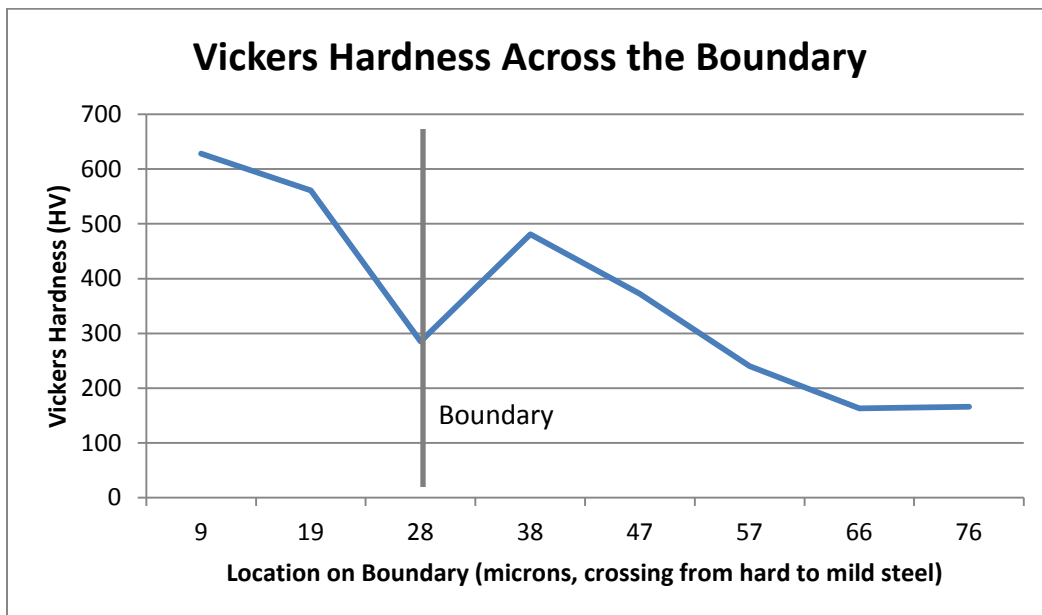
This etchant is the most commonly used solution for steel, and is most effective at revealing alpha grain boundaries (Buehler SUM-MET, 2004). This solution was applied to the surface of the mounts for 30-50 seconds, and then washed off with ethyl alcohol. This produced surface traits that were easily observable under the microscope, as shown in the pictures below.

The two hardness tests that we used were the Rockwell scale and the Vickers scale. The Rockwell scale is a measure of the indentation hardness, and produces a dimensionless number based upon the head used to create the imprint. For example, to test the hardness of a steel sample such as ours, a 120° diamond cone, known as a “C” head, is used to create the indent. (Rockwell Scale) Multiple readings were taken from different points on the sample and averaged to create a more accurate reading. The Vickers microhardness scale is based on a much smaller area than the Rockwell test’s scale and involved using a microscope to place indentation and then measure the size of the indentation to determine how deeply the machine’s diamond tip was compressed given the level of force used. Based upon the indentation size, the hardness of the material can be determined (Buehler SUM-MET, 2004). This, like the Rockwell scale, produces a dimensionless number used to determine the relative hardness of the surface.

We performed the Rockwell test on our sample that represented the flat of the katana’s blade, as the surface is homogenous, and would not differ between different areas. However, we performed the Vickers test on the sample that created a cross-section of the blade to measure the hardness across the boundary between the 1095 steel and the 1018 steel. The results of the Vicker hardness tests can be seen in the following graphs.



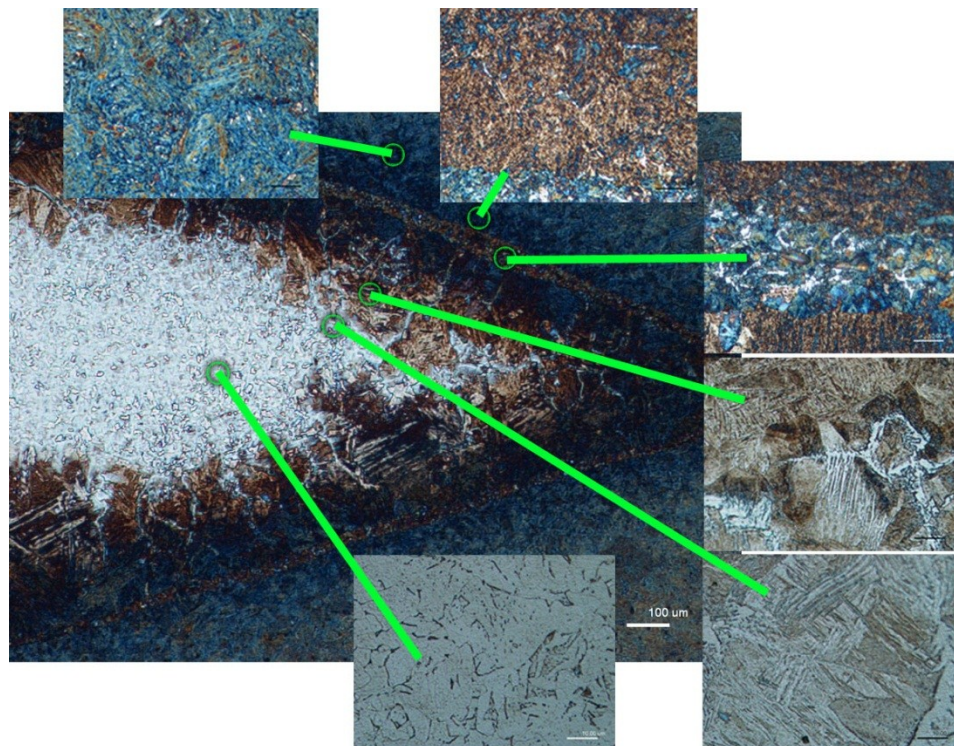
**Figure 46: Vickers Hardness Results across Both Steel Sections.**



**Figure 47: Vickers Hardness Results across the Boundary between Steels.**

The first graph is based upon measurements across the sample, starting from the hard steel, crossing the mild steel, and then crossing back into the hard steel. The second set of values and graph was generated from small steps across the boundary between the hard and mild steel, starting on the hard steel side and crossing into the mild steel. From the above graphs it is clear that the hardness of the outer hard steel is far greater than the hardness of the inner soft steel core. It is interesting, however, to see that the boundary itself is a particularly weak spot in what is otherwise a gradual decrease in strength from the hard steel portion to the soft steel portion.

Optical microscope pictures were then taken to get an idea of how the grains within the steel had been affected by the forging. These images can be seen on the next page, showing the different grain formations across both boundaries.



**Figure 48: Grain Images Above & Below the Soft/Hard Steel Boundary.**

The main image of the soft steel wedge within the hard steel shell was taken at x5 magnification, while the smaller grain images were all taken at x100. The scale on the main image is for 100  $\mu\text{m}$ , whereas the scale on the smaller ones is for 10  $\mu\text{m}$ . These images clearly show the difference between the mild and hard steels and the boundary between them. The differences in grain size between the 1095 and the mild steel are also visible, as smaller grains mean that the material is tougher. The grains of the 1095 are much smaller than the mild steel, meaning that the hard steel will hold a cutting edge for the katana, while the mild steel gives the blade some give to keep the sword from being too brittle. These images also clearly display the different phases within the steel. Phases represent the way that the steel hardens as it is heated and have different properties. The phase diagram below shows the different phases and at what temperature they form based on the carbon content.

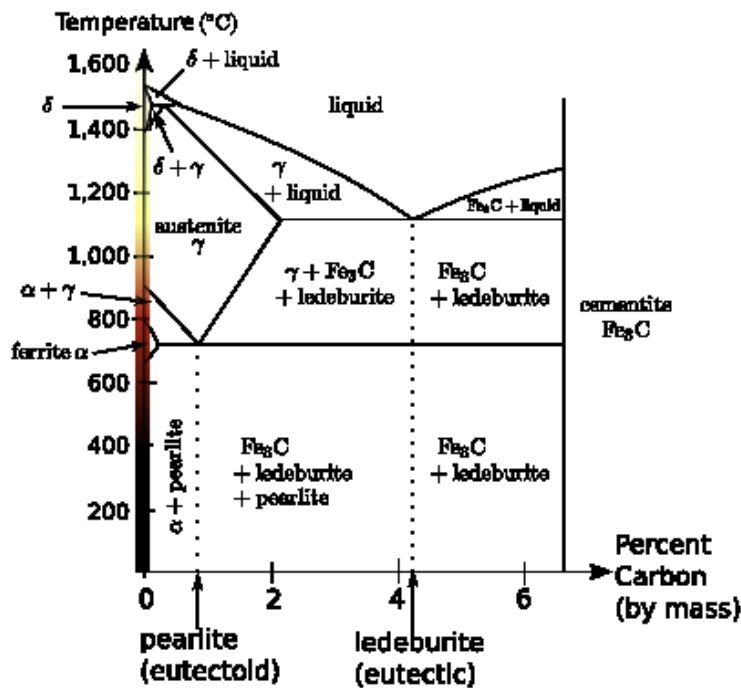


Figure 49: Fe-C Phase Diagram.

The phases that show up in our steel are austenite, martensite, carbides, and ferrite. It should be noted that martensite does not appear on the phase diagram, as it is technically not an equilibrium phase, because it is formed from rapid cooling of the structure, as opposed to the slow cooling that is expressed in the diagram. The 1095 steel has a carbon content of approximately 0.9% to 1.02%, while the mild steel has a carbon content of between 0.16% and 0.29%. The outer shell is therefore composed mainly of austenite and martensite. Austenite is the more common form of carbon steel, and the state in which most of the 1095 was in before forging. Martensite forms when austenite is rapidly quenched, and is tougher than austenite. However, it is also more brittle, and so a certain balance must be reached to avoid making the blade too soft (too much austenite) or too brittle (too much martensite). (Wikipedia, Martensite)

The close up image of the boundary between the 1095 and mild steel reveals some interesting phases that have formed. Close to the boundary, carbides, also known as cementite in steel, have formed. These large structures come from a combination of carbon and a non-magnetic material. Because steel becomes non-magnetic when heated to a certain level, (approximately 950°C) this cementite forms from the austenite and martensite close to the edge of the 1095 steel as it was welded to the mild steel. This is in keeping with the phase diagram above, and this cementite is formed as a part of our forging process. Interspersed between the carbide structures is the martensite that the cementite was formed out of, with temperature differences and carbon distribution dictating where the carbides were formed.

Finally, the mild steel is composed mainly of the ferrite phase of steel. This is a  $s^{\circ}$  low-carbon state of steel, but it is generally far softer, as obvious from our Vickers hardness test. The outer steel's austenite and martensite phases are very strong, but the strength drops off at the boundary due to carbides, and reaches its low point within the ferrite. The closer examination of

the boundary in the Vickers result graphs finds that the loss of strength is almost linear, as the sample transitions across the phase diagram, with the exclusion of the weak boundary point.

To provide context for these results unforged stainless steel usually has a HV of 140-180. Our sample is much harder. This remains consistent with approximate conversion of the Rockwell values (Struers). The average Rockwell hardness rating for the flat outer hard steel wall that was tested was 50C. This is notable because the standard Rockwell hardness of a piece of unhardened 1095 is approximately 31C (Properties Carbon Steels). So in the process of forging the sword, we managed to increase its hardness value to a level close to modern knives.

## 8. Conclusion

Throughout this report, we have studied the samurai's culture and how it was tied to the tools of their trade – their arms and armors. We considered how the samurai's role was shaped by the times that they lived in, and how they chose to evolve themselves as time went on. The image that rose up from this study was that of a peculiar contrast between deadly warriors and men of art and poetry, between generals of war and spiritual, family oriented men. The samurai remain a cultural icon of the Japanese, and are known the world over as the perfect union between their contrasting natures. All of the weapons of the samurai also skirted this balance between form and function, elegance and deadliness. Even the katana, their signature weapon, was both a weapon of war and a spiritual icon. In our attempts to forge a sword in the same method as the smiths of their period, we came to realize how difficult and demanding the construction of a katana really was. The dedication and skill that went into the weapons that the samurai smiths had created was the discipline that shaped the samurai's spirit throughout the medieval history of Japan, a master's craft that was perfected across generations to create a powerful and versatile weapon. It is therefore amazing to experience the ancient transformation of a block of steel into an implement of war under the force of our hammers and grinding stones, following in the old smiths' footsteps. Using modern material science methods of inspection we also saw first-hand how the forging process these smiths had used centuries ago was innovative and surprisingly refined. The famed katana strength is a direct result of their forging process, which was able to generate an alloy stronger and more flexible than anything at the time. The katana, therefore, much like the samurai who used it, is a true marvel of history.



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# 11. Appendices

## Appendix A: Glossary

<b>Name</b>	<b>Type</b>	<b>Description</b>
<b>Kanai</b>	<i>Geographical Locations</i>	The provinces around Kyoto, especially Yamashiro, Yamato, Kwatchi, Izumi, Settsu, Iga, Tamba, and Ômi.
<b>Ashigaru</b>	<i>Personal Titles</i>	‘Light feet’: infantry. Largely developed in response to the Onin War, the Ashigaru became the backbone of all daimyo armies in the 16th Century, especially after the widespread adoption of the matchlock. Until the 1590’s, an ashigaru was normally a peasant who worked in his home village when not on his lord’s campaigns.
<b>Azuchi-Momoyama period</b>	<i>Historical Events</i>	1568 – 1603
<b>Bushi</b>	<i>Personal Titles</i>	Warrior.
<b>Bushido</b>	<i>Cultural Terms</i>	‘Way of the Warrior’. First recorded in the 16th Century (in the Koyo Gunkan and other such works), the term Bushido has come to act as a blanket expression for the philosophy and mindset of the samurai, in particular the ideals of honor and bravery.
<b>Chokuto</b>	<i>Weapons</i>	"Straight Sword", straight single edge Japanese sword
<b>Chonin</b>	<i>Personal Titles</i>	A class term for merchants and artisans, who figured in



		below the peasants and above outcasts on the social scale.
<b>Daimyo</b>	<i>Personal Titles</i>	'Great Name'; term used to describe the autonomous lords of the late 15th and 16th Centuries who exercised personal authority on a multi-province, multi-district, or, in some cases, multi-village level.
<b>Daisho</b>	<i>Weapons</i>	When A Katana and a Wakizashi are worn together in a pair this is called a Daiso.
<b>Do</b>	<i>Armor</i>	Chest armor
<b>Do-maru</b>	<i>Armor</i>	Early foot-soldier armor
<b>Emperor Go-Daigo</b>	<i>Important Individuals &amp; Families</i>	Emperor of Japan during 1318-1339
<b>Fujiwara</b>	<i>Important Individuals &amp; Families</i>	One of the three powerful clans during the Heian period who are descendants of the imperial family.
<b>Gendaito</b>	<i>Weapons</i>	"Modern Sword"
<b>Genpai war</b>	<i>Historical Events</i>	A conflict between the Taira and Minamoto clans during the late-Heian period of Japan.
<b>Hakama</b>	<i>Armor</i>	Type of riding pants
<b>Heian Period</b>	<i>Historical Events</i>	794 – 1185
<b>Jokoto</b>	<i>Weapons</i>	"Ancient Swords"; refers to blades before 965 A.D.

<b>Kabuto</b>	<i>Armor</i>	Samurai helmet
<b>Kana</b>	<i>Cultural Terms</i>	Phonetic syllabary popular in and after the Heian Period, though generally reserved for the common people and women. Edicts and codes commoners were expected to understand were often written in kana, as were popular books and the like.
<b>Kanji</b>	<i>Cultural Terms</i>	The adopted Chinese characters that are used in the modern Japanese writing system along with Kana.
<b>Katana</b>	<i>Weapons</i>	Traditional long sword of the samurai. Renowned for its toughness and cutting ability. The katana, or tachi, became prominent during the later Kamakura period, although it was considered secondary in battle to the bow and later the yari spear.
<b>Keiko</b>	<i>Armor</i>	Early Japanese lamellar armor.
<b>Kera</b>	<i>Weapons making</i>	Block of Steel and Iron obtained after the traditional smelting processes
<b>Kimono</b>	<i>Armor</i>	Long-sleeved robe. Traditional Japanese dress
<b>Koto</b>	<i>Weapons</i>	"Old Sword"
<b>Kusazuri</b>	<i>Armor</i>	Thigh-guards
<b>Lamellar Armor</b>	<i>Armor</i>	Armor consisting of hundreds of connected scales.
<b>Meiji Restoration</b>	<i>Historical Events</i>	A chain of events that restored imperial rule to Japan in 1868. The Restoration led to enormous changes in Japan's political and social structure.

<b>Men Toroi</b>	<i>Armor</i>	Face armor
<b>Minamoto</b>	<i>Important Individuals &amp; Families</i>	One of the three powerful clans during the Heian period who are descendants of the imperial family. The Minamoto defeated the Taira and started the first Shogunate.
<b>Ming China/Dynasty</b>	<i>Important Individuals &amp; Families</i>	The Ming Dynasty, also Empire of the Great Ming, was the ruling dynasty of China from 1368 to 1644.
<b>Naginata</b>	<i>Weapons</i>	Japanese pole weapon similar to the European Glaive.
<b>Nara period</b>	<i>Historical Events</i>	710 – 794
<b>Nihon-to</b>	<i>Weapons</i>	"Japanese Sword"; refers to blades after 964 A.D.
<b>Oda</b>	<i>Important Individuals &amp; Families</i>	A family of Japanese daimyo who were to become an important political force in the unification of Japan during the Sengoku period.
<b>Onin war</b>	<i>Historical Events</i>	A civil war that lasted 10 years (1467 - 1477).
<b>Ronin</b>	<i>Personal Titles</i>	‘Wave Man’; a samurai without a master. Many samurai were made ronin by the vicissitudes of the Sengoku Period, and so formed the basis for many bandit groups and outlaw bands that plagued the countryside into the Edo Period. Though not employed by a daimyo, a ronin was still entitled to wear his swords.

<b>Sakimori</b>	<i>Personal Titles</i>	"Defenders"; the main military force in Japan during the Nara period.
<b>Samurai</b>	<i>Personal Titles</i>	"One who serves"; the traditional warrior class of Japan until 1876. While of obscure origins, the samurai emerged as a powerful force by the 10th Century and after 1192 acted as the de facto rulers of Japan.
<b>Sekigahara, Battle of</b>	<i>Historical Events</i>	A decisive battle on October 21, 1600 which cleared the path to the Shogunate for Tokugawa Ieyasu. This is considered the unofficial beginning of the Tokugawa Shogunate.
<b>Sengoku Period</b>	<i>Historical Events</i>	Sengoku Jidai, 'The Country at War'. 1477-1600. The term Sengoku jidai is taken from a roughly comparable episode in Chinese history.
<b>Shinsakuto</b>	<i>Weapons</i>	"Newly made Sword"
<b>Shinshinto</b>	<i>Weapons</i>	"New New Sword"
<b>Shinto</b>	<i>Cultural Terms</i>	Japan's indigenous religion, based on the worship of spirits.
<b>Shinto</b>	<i>Weapons</i>	"New Sword"
<b>Shogun</b>	<i>Personal Titles</i>	Military ruler of Japan; a shortening of sei taishogun, or 'barbarian/rebel-quelling lord general'.
<b>Shogunate</b>	<i>Cultural Terms</i>	Term used to describe the government of a shogun.
<b>Sode</b>	<i>Armor</i>	Shoulder-guards

<b>Tachi</b>	<i>Weapons</i>	Traditional Japanese long Sword used before the Katana.
<b>Taira</b>	<i>Important Individuals &amp; Families</i>	One of the three powerful clans during the Heian period who are descendants of the imperial family. The Taira were defeated by the Minamoto.
<b>Takeda</b>	<i>Important Individuals &amp; Families</i>	A famous clan of daimyō (feudal lords) in Japan's late Heian Period to Sengoku period.
<b>Tamahagane</b>	<i>Weapons making</i>	"Jewel Steel"; used as the primary material in a Japanese sword.
<b>Tang China/Dynasty</b>	<i>Important Individuals &amp; Families</i>	The imperial dynasty of China during 618 to 904.
<b>Tanto</b>	<i>Weapons</i>	Traditional Japanese "Dagger"
<b>Tatara</b>	<i>Weapons making</i>	Traditional clay furnace that is used to make kera (steel)
<b>Tokugawa</b>	<i>Important Individuals &amp; Families</i>	Family which ruled over Japan from 1600 to 1867.
<b>Tokugawa Period</b>	<i>Historical Events</i>	1600 – 1867
<b>Tosei gosoku</b>	<i>Armor</i>	"modern armor". Samurai armor styles that were banded as opposed to scaled.
<b>Wakizashi</b>	<i>Weapons</i>	Traditional Japanese "Short Sword" or more precisely,

		"Companion Sword".
<b>Yabusame</b>	<i>Weapons</i>	Japanese mounted Archery.
<b>Yari</b>	<i>Weapons</i>	Straight headed spear.
<b>Yoroi</b>	<i>Armor</i>	Style of samurai armor, mainly used by riding samurai
<b>Yukinoshota-do</b>	<i>Armor</i>	Type of samurai armor. Specifically developed to withstand arquebus bullets
<b>Masakodo Rebellion</b>	<i>Historical Events</i>	Rebellion led by Taira no Masakado against the central government in 939.
<b>Oda Nobunaga</b>	<i>Important Individuals &amp; Families</i>	Initiator of the unification of Japan under the shogunate in the late 16th century.
<b>Hideyoshi, Toyotomi</b>	<i>Important Individuals &amp; Families</i>	A daimyo warrior, general and politician of the Sengoku period who unified political factions of Japan.

## Appendix B: Collected Material Hardness Data

### Rockwell Hardness Test values:

Test 1: HRC 41.1

Test 2: HRC 52.2

Test 3: HRC 56.1

Test 4: HRC 50.6

**Average: HRC 50.0**

To provide context, 55-65 HRC is a good range for high-quality steel blades such as knives made of Hardened High Carbon Steel (Wikipedia, Rockwell).

### Vickers Hardness Test Results:

Position on Sample (crossing)	HV
19	615
38	704
57	622
76	698
95	683
114	612
133	300
152	226
171	174
190	170

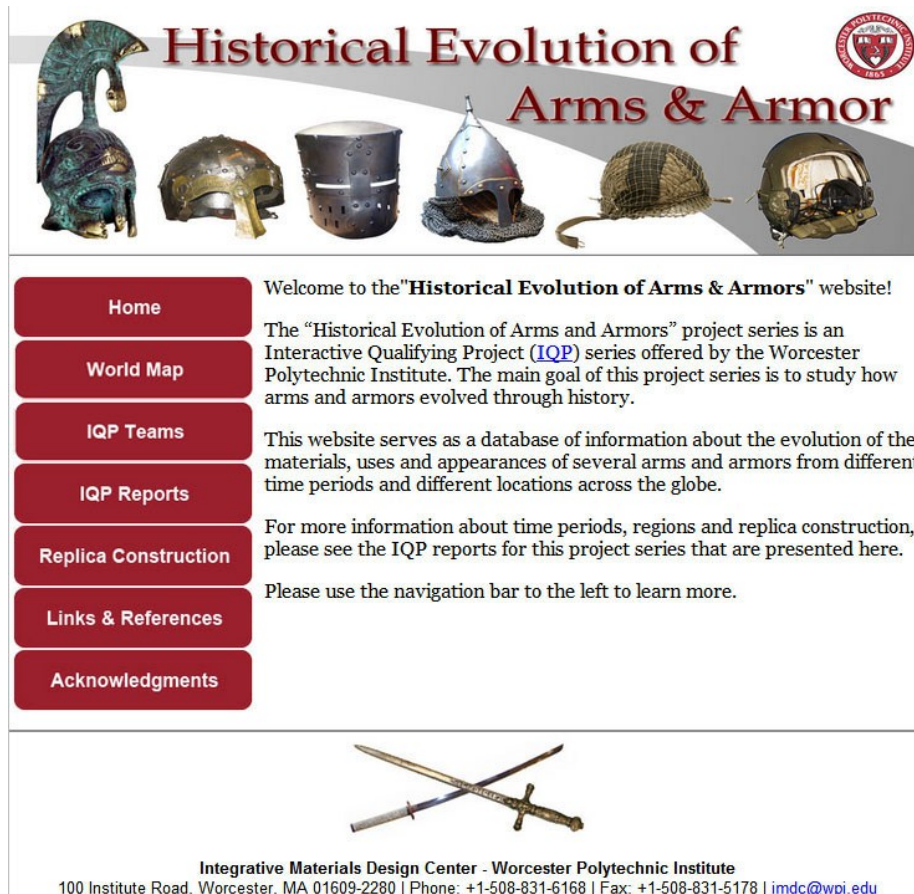
209	160
228	169
247	298
266	436
285	630
304	689
323	695
342	683
361	683
380	759
399	649

Location on Sample Boundary	HV
9	628
19	561
28	285
38	481
47	372
57	240
66	163
76	166

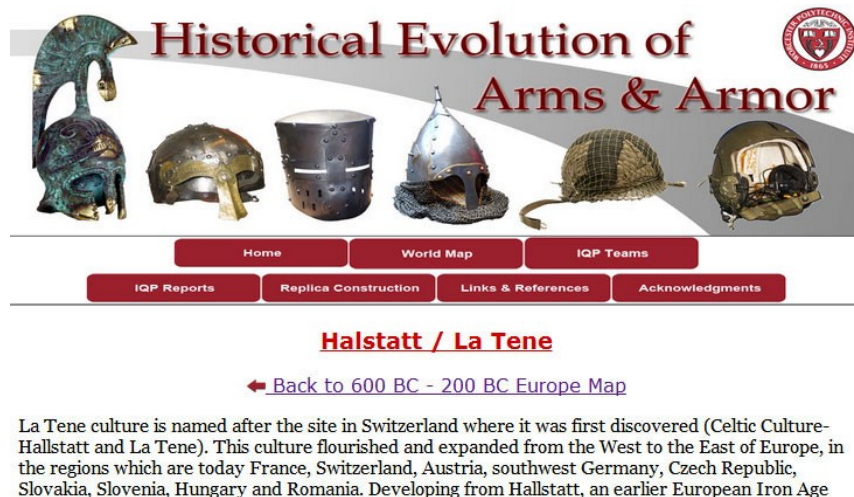


## Appendix C: Updating the Online Database Site

Since the previous iteration of this project used the Dreamweaver software to generate the original website, we chose to do so as well. The first order of business was to design a unified look for all the pages of the site in order to give it a slightly more professional and streamlined look. For this purpose, we used Dreamweaver's "Template" feature to create a template containing the site's banner and navigation buttons, which could be applied to each of the content pages. The following images show the two templates main that were used on the new version of the site:

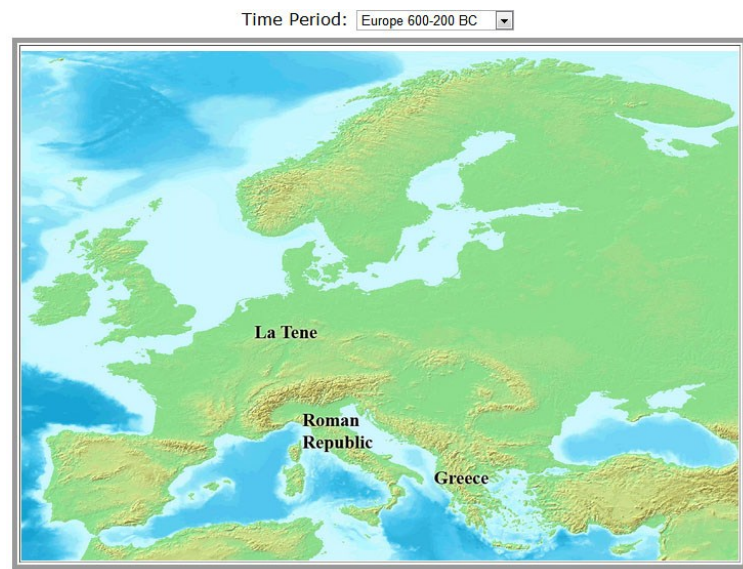


**Figure 50: New Website Main Template with Sidebar Navigation.**



**Figure 51: More Spacious Template with Top Navigation.**

The first template was used for general pages, such as the main page, the reports page and other pages that had only a small amount of content. The second template was used on all the pages that require more space to fit their large amounts of content. These include the map pages for each region and the specific arms and armors pages. An example of a map with period navigation at its top can be seen below.



**Figure 52: Clickable Map and Navigable Time Periods Example.**

Each of the black labels in the above map is clickable and leads to the arms and armors page for the specific area the label is associated with. This functionality is a carry-over from the previous iteration of the site, but the size and quality of the maps have been standardized to maintain the same look throughout the entire page.

As a final note the site as a whole is relatively “low tech”, using only Dreamweaver features and HTML. However, some scripts and more advanced features were used in order to enhance the site. For instance, in order to keep all the files associated with the templates in one folder and to make the code slightly more general, a Javascript script file was placed in each sub-folder that contains content pages. This script file tells the page where its root directory lies, such that the site can always find its main directory and the templates folder therein. In addition, special code was added in order to implement the opening lists, which unfold the lists of team members in the Teams page and the listed reports per year in the IQP Reports page.

# Appendix D: Katana Making Process Documentation

Please see attached video file.

