

# Damascus Steel and Crucible Steel in Central Asia

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"Everything is mine," said gold;  
"Everything is mine," said Damascus steel;  
"I can buy anything," said gold;  
"I can acquire anything," said Damascus steel.

Pushkin, 1827 (translated by Bogachev, 1952)

For hundreds of years, swords made of Damascus steel have been famous for their flexibility, retention of a sharp edge and beautiful surface pattern. There are two broad categories of swords that are made of what is called Damascus, Damascene or Damask steel. One category was made by forging different strips of iron and steel together and is known as pattern welded Damascus steel. This method was used throughout Europe and Asia. The second category of Damascus steel was made from an ingot of crucible steel and is known as crucible Damascus steel. This method has historically been associated with the Wootz steel made in the Indian subcontinent. A reexamination of the sources of information traditionally used to maintain the myths and legends about Damascus steel indicates that many beliefs are based on little or no hard evidence. It is becoming apparent that Central Asia was a major producer of crucible steel.

This article is divided into two parts. This first part discusses the textual and archaeological evidence for crucible steel production in Central Asia. The second part is a short profile of the famous Russian metallurgist, Pavel Petrovich Anosov, who successfully replicated Damascus steel during the 19th century.

## PART I

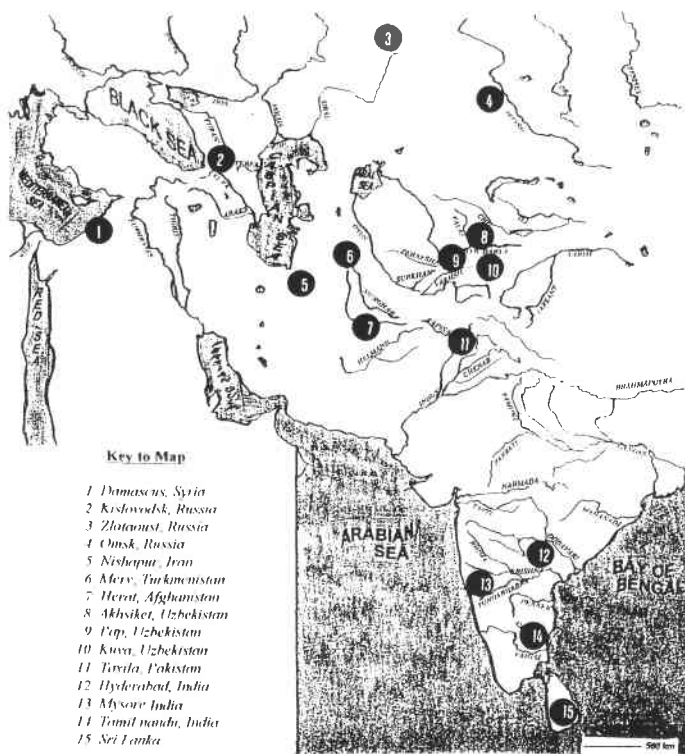
Central Asia (Figure 1) has played a key role in many aspects of history. For millennia, many different cultures were found within Central Asia and the surrounding area. Contacts between the cultures were promoted primarily via the so-called Silk Road. The Silk Road was a series of trade routes running east-west, linking China and the cultures around the Mediterranean, and north-south, linking India to southern Russia. Silk was not the only item traded along the route; spices and other exotic goods, in addition to ideas and knowledge, were also passed along in each direction. Although certain routes of the Silk Road were in use for thousands of years, trade was often interrupted, often for centuries, due to invasions. Arabs, Turkic tribes and Mongols are just



some of the invaders who attacked the prosperous cities along the route and caused the downfall of many of them.

The recent dissolution of the Soviet Union has greatly facilitated the exchange of scholarly information between the former Soviet states and the rest of the world. This has allowed the author the opportunity for collaborative research with scholars in three different areas of Central Asia, the results of which greatly increased understanding of the production and use of crucible steel in Central Asia. The first collaboration, which initiated this research, resulted in the discovery of a crucible steel workshop at the ancient city of Merv in Turkmenistan (Feuerbach et al., 1997 and forthcoming; Griffiths et al., 1997). It was also reported that crucibles used in steel production were found at various sites in Uzbekistan (Papachristou and Swertschkow, 1993); the author was able to collect samples of the crucibles. In order to investigate the prospect of crucible steel being present in western Central Asia, a collaborative project was undertaken by Irina Arzhanstava from Moscow State University, Sergei Savenko, director of the Kislovodsk Local Museum, and the author. The project involved sampling bladed objects from the Kislovodsk museum. The results of these three investigations make up the body of this article.

Weapons made of iron only truly surpassed those made of bronze after craftsmen were able to produce and work steel. Steel is an iron-carbon alloy with a carbon content of around 0.8%, which is between that of wrought iron and cast iron. Steel is hard but not brittle and can be sharpened; therefore it is desirable for knives, swords and certain tools such as files and chisels.



**Figure 1. Map of Central Asia and surrounding area. Places mentioned in the text are labeled.**

In antiquity there were a variety of methods used for making steel. The first was by directly smelting the ore into steel. This method was comparatively rare, but evidence for direct smelting has been found in Japan, Sri Lanka and the Altai Mountain region.

A more common method of making steel was by carburizing (adding carbon to) wrought iron. Iron with virtually no carbon is known as wrought iron, which is relatively soft and can be shaped by hammering. If a sword is made of only wrought iron, it can bend in battle. The use of wrought iron and steel made of carburized wrought iron was comparatively widespread and can be found in objects from Europe, Asia and Africa.

In China, the first type of iron used was cast iron (Wagner, 1993). Cast iron has a relatively high carbon content, generally over 2%, and is hard but brittle. A sword made of only cast iron can shatter in battle. Steel was made by decarburization (removing carbon).

Crucible steel is made in a ceramic container, i.e., a crucible. In the past it was made by two methods that tended to have geographic preferences: the Indian Wootz process and the Central Asian Fulad process. Many articles have been written about the Indian Wootz process, but virtually nothing has been written about the Central Asian Fulad process. There is archaeological evidence for the Wootz process as well as numerous ethnographic studies, but studies of the Central Asian process are rare.

In general, Indian Wootz crucible steel is produced by placing plant matter and low-carbon iron (wrought iron or bloomery iron) into a closed crucible and heating it to a high

temperature for hours. The carbon from the plant material diffuses into the wrought iron, a carburization process, and the result is steel. The crucible is removed from the furnace while it is hot and is quickly cooled. The crucible is broken and the Wootz crucible steel ingot is removed.

What is known about the Central Asian Fulad process is that it was fundamentally different from the Indian Wootz method. There are still many questions regarding the Fulad process and research is continuing, but there are suggestions that the method included mixing low-carbon iron (such as wrought iron or even partially roasted ore) and high-carbon iron (such as cast iron or charcoal) and placing them together in a crucible, which was then heated to a high temperature. The mixture of the high- and low-carbon iron formed steel. After firing, the crucible was left in the furnace to cool slowly, after which it was taken out of the furnace and broken to remove the crucible steel bulat (ingot).

Modern metallurgists may say that the two processes were similar because both used a crucible to produce steel. However, if viewed from the point of view of the history of technology, the archaeological remains and the cultural setting within which the steel was made, the materials and techniques used were really quite different.

#### TEXTUAL EVIDENCE FOR CRUCIBLE STEEL PRODUCTION

Along with written ethnographic accounts of crucible steel production, there are historical texts which may be referring to crucible steel. A reference that is often cited as evidence for early crucible steel is by Pliny (d. 79 A.D.).

But of all the varieties of iron the palm goes to the Seres with their fabrics and skins. The second prize goes to Parthian iron; and indeed no other kinds of iron are forged from pure metal, as all the rest have a softer alloy welded with them

(Rachkam, 1995, p. 233)

There are still arguments regarding who the Seres were, but it is generally believed that they were from India. Most arguments stop at the first sentence and overlook the part of the statement that discusses Parthian iron. The translation suggests that Seres and Parthian iron are similar and that they are "pure" metals, possibly referring to the fact that crucible steel is a single comparatively homogenous metal that is "purified" from slag in a crucible.

The earliest reference to crucible steel is from the 3rd century A.D. by the Alexandrian alchemist Zosimos, who wrote that the process was "invented by the Indians but exploited by the Persians" (Craddock, 1998). There is also a reference in the Talmud to steel used for weapons being transported from India to Persia (Craddock, 1998). In addition, there are Chinese refer-

ences to steel with a pattern being made in India, Sasanian Persia and Kashmir (Smith, 1988; Schafer, 1963; Needham, 1958).

Islamic texts describe a process which has been interpreted by translators to be crucible steel production. The interpretations are based on textual descriptions alone and the exact meaning of some of the technical terms is still under debate. The following is a translation from al-Tarsusi (fl. late 12th century A.D.).

Take one rotl of female iron (narmahan), and half a rotl of male iron (shabaquan). Collect the mixture in a pot and put on it 5 dirhems of magnesia and a handful of acid pomegranate bark. Let the fire blow on it until the alloy melts. Take it out and make a sword

(Bronson, 1986, p. 43; translated from Cahan 1947).

Another Islamic writer, Al-Beruni (973-1048 A.D.), who lived in Central Asia, described a similar crucible steel process and wrote that Indian and non-Indian swords are made from the steel. He also wrote that crucible steel

was the method used in Herat and gave two different qualities of steel. One was the result of melting components 'equally so that they become united in the mixing operation and no component can be differentiated or seen independently'. Such steel is suitable for files or similar tools. The second quality was obtained if the degree of melting of the wrought and cast iron was different for each substance' and thus the intermixing between both components is not complete, and their parts are shifted so that each of their two colors can be seen by the naked eye and it is called firind.

(Al-Hassan and Hill, 1986, p. 77).

Firind (also transliterated as Farand) is translated either as Damascus (Allan, 1979, p. 77) or pattern (Al-Hassan and Hill, 1986, p. 254).

If the textual evidence is accurate, it implies that crucible steel was produced in Central Asia and India from at least the 3rd century A.D. and possibly even as early as the 1st century A.D. It also suggests that crucible steel with a pattern was produced in Herat during the late 10th or early 11th century A.D. Herat in modern-day Afghanistan is in the Khorasan region of Central Asia, along with the cities of Merv in modern-day Turkmenistan and Nishapur in Iran.

#### DAMASCUS STEEL

The most famous objects made from crucible steel are Damascus steel blades. The blades' appearance is caused by the carbon content, the cooling rate, the elemental composition of the original bulat (crucible steel ingot) and the method used to forge the object. Crucible steel is not just any steel, it is high-quality homogenous steel with little slag. Roughly speaking,

there are four factors that have the possibility of producing different patterns. The carbon composition of the steel, either high-carbon (hypereutectic) or low-carbon (hypo-eutectic), affects the microstructure and therefore the pattern. The cooling rate also affects the pattern. Differences in carbon content and cooling rate affect the microstructure and in turn the behavior of the steel and the type of pattern that can form.

Recent experiments by Prof. Verhoeven and others (Verhoeven et al., 1998; Verhoeven and Pendray, 1992; Verhoeven and Peterson, 1992) suggest that a slow cooling rate is important because it allows impurities to separate out so that, after forging at a low temperature for a long period of time, the necessary Damascus steel pattern is produced. The slow cooling rate allows elements such as manganese and vanadium to concentrate in certain areas of the microstructure, which affects the formation of the pattern when it is forged. These elements appear in very small amounts, around 100 parts per million. Cooling the ingot quickly produces a finer microstructure and limited separation of elemental impurities. A slow-cooled ingot has a coarser structure and a more extensive separation of elemental impurities. Of course, the method of forging also produces additional variations in the pattern.

#### THE INDIAN WOOTZ PROCESS

There are four locations in India and one in Sri Lanka where remains of Wootz crucible steel production have been studied. All of the Wootz crucible steel remains from India are from historical contexts and have ethnographic descriptions of the process as well. A discussion of these and other ethnographic descriptions can be found in Bronson's admirable paper (1986).

The only firm archaeological evidence for Wootz steel production comes from Sri Lanka and is attributed to the 6th-10th centuries A.D. (Wayman and Juleff, 1999). There are two sites from Tamil Nadu in South India where crucible steel is reported to have been made. A site at Kodumanal, dated to the 3rd century B.C.-3rd century A.D., contained crucibles and iron processing remains. However, the reports lack sufficient descriptions of the crucible remains for the Kodumanal site to be confidently relied on as an early crucible steel site. The second site is Mel-siruvalur, South Arcot district, (Srinivasan, 1994) where crucibles used for Wootz steel production were confidently identified. These are only surface finds, however, and the date when the crucibles were used is uncertain. From central India, Wootz steel was produced during the 19th century A.D. at Gatihosahall, formally called Mysore (Anantharamu et al., 1999; Freestone and Tite, 1986).

Where evidence is available either from archaeological sites or ethnographic reports, all of these Wootz remains have certain features in common: the crucibles are composed of ordinary ferruginous clay with rice husks used as temper

and are conical (south India) or elongated (Sri Lanka) with pointed or rounded bases, the crucible charge is composed of one type of iron and wood and/or leaves and the steel was removed from the furnace while hot and was cooled quickly.

Nineteenth century crucible steel remains from Konasamudram, Nizamabad district, formally called Golconda, Andhra Pradesh (Lowe et al., 1991; Lowe, 1989), need to be mentioned. These are reported as being the remains of a Wootz process. However, when compared against the remains from India and Central Asia, the materials and techniques used for this process, apart from the use of rice husks as temper, more closely resemble those of Central Asia.

#### THE CENTRAL ASIA FULAD PROCESS

Only recently were archaeological remains of crucible steel production found in Central Asia. Remains were also found at Pap (unpublished data) and at Akhsiket in Uzbekistan. Akhsiket is a particularly interesting site because thousands of crucibles used in steel production were found there. The extent of the remains suggests that the site remained in use for a long period of time. The Uzbekistan crucibles share some common features with the Turkmenistan crucibles, but all Central Asian crucibles are very different from the Indian Wootz crucibles. The Central Asian crucibles are cylindrical, approximately 8 cm in diameter, flat-bottomed and made of a high-refractory white firing clay.

A crucible steel workshop was discovered at the ancient city of Merv in Turkmenistan by members of the International Merv Project. This workshop is the first single-period crucible steel workshop to be excavated and to have its remains studied in detail by various methods of laboratory analysis. The workshop is dated to the early Islamic period, 9th–10th century A.D.

Merv was an important administrative and military center of the Persian, Parthian and Sasanian empires, often being the easternmost military outpost from which invasions were made or against which it was defended. During the Parthian and Sasanian periods, Merv was a very important trading city on the Silk Road, being at the east–west and north–south crossroads.

The earliest reference to steel production at Merv was by Plutarch (46?–120? A.D.), who stated

While the Romans were in consternation at this din, suddenly their enemies dropped the coverings of their armour, and were seen to be themselves blazing in helmets and breastplates, their Margianian steel glittering keen and bright, and their horses clad in plates of bronze and steel

(Perrin, 1915, p. 387).

Merv was in the region called Khurasan, which is mentioned as a steel manufacturing center by the 9th-century Islamic scholar Al-Kindi. During this period, Khurasan was

known for manufacturing swords made of local iron and, apparently, iron all the way from Sri Lanka. It is also claimed that during the 10th century the region produced weapons and breastplates (Allan, 1979).

The development of the cities of Merv was different from that of many other cities. The cities lie next to rather than on top of each other. The first city was Erk Kala, which is believed to have been founded in the 6th century B.C. During this time, the city was called Margiana. The second city to be built was Gyaur Kala and was located south of Erk Kala. It was founded in the 3rd century B.C.

During the 8th century A.D., a new city, Sultan Kala, was being built to the east of Gyaur Kala. With the population moving into this new area, Gyaur Kala became the industrial area. It was in Gyaur Kala that the metallurgical workshop was found next to the main east–west road. Surrounding the crucible steel workshop were other workshops which worked materials such as copper alloys and ceramics.

Among other finds, the excavation (Figure 2) uncovered four furnaces, the remains of mud brick walls from buildings and a pit (Herrmann et al., 1993–1995). Inside the pit were many pieces of green glassy slag and hundreds of broken crucible pieces. The original shape of the crucible was reconstructed by studying many crucible fragments and their various characteristic features (Figure 3). All crucibles were 8 cm in diameter and are estimated at having been 18–20 cm high. The crucibles were made of a high-refractory white firing clay with few impurities. Quartz fragments and grog (small pieces of used crucibles) were used as temper. The crucibles are cylindrical in shape with a flat bottom and were made on a pottery wheel. A separate pad was attached to the bottom of the crucible.

This separate pad raised the crucibles off the floor of the furnace into the hotter region just above the floor and facilitated the removal of the crucibles after firing. Larger pieces of grog were put on the floor of the furnace between the crucibles. Their function was to aid hot air distribution in the furnace by adding turbulence and also to prevent the crucibles from firing to the floor of the furnace. They provided an easily removed furnace floor that facilitated the removal of the crucibles and ash after firing.

Three of the four furnaces were used to make steel. The fourth was probably a blacksmith's hearth. The furnaces had a unique design (Figure 4): they were about 80 cm in diameter, approximately 60 cm in height, and had a central tuyer rising from the floor of the furnace for the inlet of air. On the side of the furnace was a single exit flue for gases, which meant that the top of the furnace needed to be closed and, probably, dome shaped. The interior wall of the furnace was lined with a clay-like material similar to the crucible pads. After use, the furnaces were broken into to remove the crucibles. At least one furnace was relined and reused three or more times.



Figure 2. Excavation at Merv. Note how close the 9th–10th century A.D. remains are to the surface. The mounds in the background are part of the ancient wall which surrounded Gyaur Kala.

It is estimated that the furnace reached temperatures between 1250 and 1550°C, which was unusually high for an ancient furnace. Charcoal was used to fire the furnace but, because of its design, the furnace acted much like a deep fuel bed or gas producing furnace. Gas given off by the charcoal mixing with water vapor given off by the crucible produced hydrocarbons. These hydrocarbons burned, increasing the temperature and reducing the need for more charcoal.

The design and choice of materials used in steel production at Merv indicate a well-established and highly efficient process. This is particularly significant because Merv is situated in the middle of the Kara Kum desert and there are no known iron ore or refractory clay sources nearby; all materials had to be imported. The clay used for the crucibles could withstand the high temperatures and stresses during firing without failure. Many of the broken crucibles were not discarded but were broken up further. The broken pieces were sorted according to size and each size was used for a different purpose. The smallest pieces (~0.2–0.5 cm) were used in the crucible as grog, the next-largest pieces (~0.5 cm) were used as grog in the pads and to line the furnace walls, medium-sized pieces (~1 cm) were used to line the floor of the furnace and large pieces (5–10 cm) were used as filler in the mud brick furnace walls.

It is estimated that about 2000 crucibles were made during the life of the workshop and that each crucible could contain a steel bulat weighing about 2 pounds. Therefore, the site could have produced up to 4000 pounds of steel.

Exactly which ingredients were put into the crucible is still under investigation. Unfortunately, only low-quality raw materials are usually found in the archaeological record because good-quality materials were used in the process. Therefore, only unwanted waste material is found, not raw materials or finished products. However, lumps of corroded iron were found in the crucible pit. They are still under investigation because many of them are too corroded to assess if they were iron, cast iron, steel or crucible steel. Many pieces have to be sampled in the hope that a few will contain vestiges of uncorroded metal or remnant

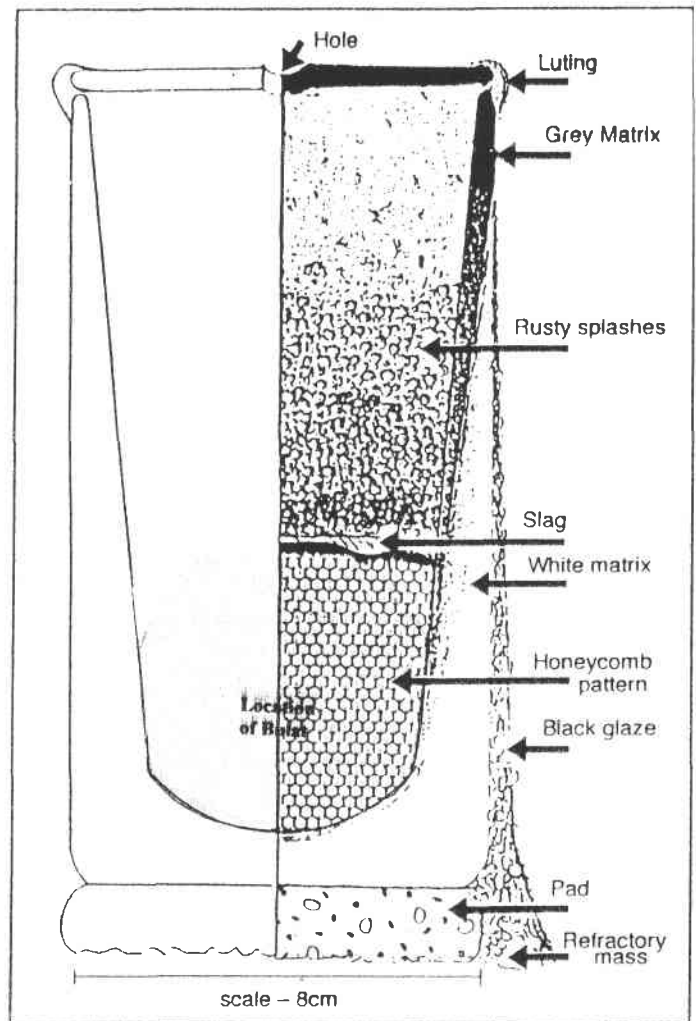


Figure 3. Reconstruction of the crucible and the location of the bulat inside the crucible.

structures in the corrosion that can be identified as being characteristic of one of the iron-carbon alloys. What the evidence from the crucibles does suggest is that cast iron may have been one of the raw materials because there is evidence of a carbon

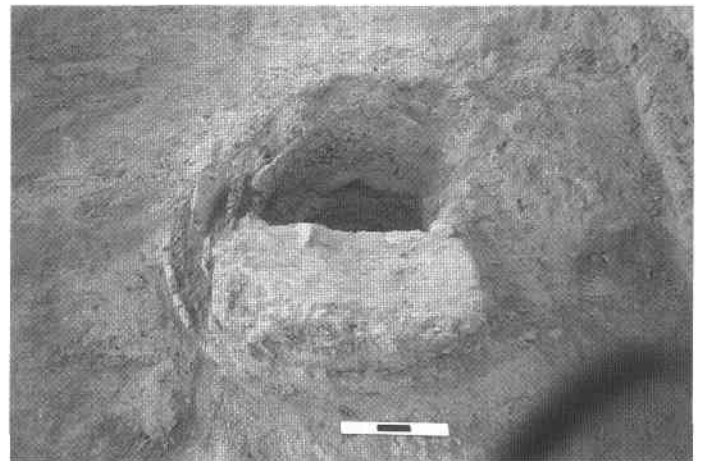


Figure 4. A partially excavated furnace. Part of the furnace on the right side is missing. This is where craftsmen would have broken through the furnace wall to remove the crucibles.

boil (the exsolution of carbon in the presence of oxygen; this is akin to opening a bottle of carbonated water) that caused steel to splash onto the sides of the crucible. There is also some evidence for bloomery iron in the form of what may be bloomery slag, but this is still under investigation.

When corroded lumps were sampled, a bulat was discovered. The microstructure indicated that this was a high-carbon steel which was slowly cooled. Electron probe microanalysis indicated that it contained small amounts of other elements, including manganese. This is significant because one of the most famous Damascus patterns is called Kara Khorasan (black Khorasan). In order to form this pattern, the original bulat needed to be high-carbon steel with specific impurities that was slowly cooled. The Kara Khorasan pattern was presumably named after the place where it was made. As stated above, Merv is located in the Khorasan region, and Islamic writer Al-Beruni in the 11th century A.D. discussed swords with *firind* (pattern) being present in Khorasan. It cannot be stated with certainty if craftsmen were producing swords with a Kara Khorasan pattern at Merv. However, it is quite possible that they did because the bulat has the correct structure from which the pattern could have been produced if it was forged correctly. Unfortunately, unless a forged object is excavated it is not possible to know the details of forging methods.

#### CRUCIBLE STEEL SWORDS AND OBJECTS

There are a number of published reports of crucible steel objects in Central Asia. The earliest known objects made of crucible steel are from Taxila in north India. Two swords and an ax were excavated from a presumed 1st–3rd century A.D. context. Although Taxila is located on the Indian subcontinent in present-day Pakistan, the culture of 1st–3rd century Taxila is more closely related to Central Asia than to central and south India.

The two next earliest swords, found as part of the author's research, are from the 3rd–4th century A.D. and were excavated near Kislovodsk in the Russian Northern Caucasus. They were excavated from a cemetery and are attributed to the Alan culture. One sword is complete (Figure 5) and the tang is a separate piece of iron attached with a rivet (Figure 6). Only a fragment remains of the other sword (Figure 7).

The discovery of crucible steel at Merv led the British Museum Research Laboratory to investigate the type of steel used in the manufacture of the Sasanian swords in their collection. The swords are attributed to the 5th–6th centuries A.D. and are thought to be from northern Iran. One sword was found to be made of crucible steel (Lang et al., 1998).

The third crucible steel sword the author examined was from the Kislovodsk Museum, was excavated from a Machte cemetery horse burial and is attributed to the 7th century A.D. Unfortunately, only a fragment of the sword

remained. The fragment is slightly over 21 cm long and 4 cm wide. It appears to have been a double-edged straight sword.

A sword excavated at Nishapur in the Khorasan region of eastern Iran and now in the Metropolitan Museum of Art, New York, was examined by Dr. Gilmore and found to be made of crucible steel (Dr. Brian Gilmore, personal communication). It is attributed to the 9th–10th century A.D. (Allan, 1982). This is a very significant find because it is contemporary with the metallurgical workshop at Merv and because Nishapur is in the Khorasan region. The sword, however, would not have had a Damascus steel pattern.

The final crucible steel sword from Kislovodsk is attributed to the late 11th century A.D. (Figures 8 and 9) and was excavated from a cemetery at Koltso Gora. The style is similar to the so-called "Sabre of Charlemagne" which is believed to be of Russian or Hungarian origin and is attributed to 950–1025 A.D. (Nicolle, 1999, p. 36). There are some distinguishing features on the Koltso Gora sword, including a geometric motif in the decoration, the use of wire and a ring on the hilt, a suspension point adjacent to the hilt on the blade and a smaller guard.

The production and use of crucible steel in Central Asia is apparent. All of the earliest examples of crucible steel objects are from Central Asia and there is also evidence for large-scale production of crucible steel in Central Asia that potentially could have made swords with a Damascus steel pattern. None of the swords examined would have had a typical Damascus steel pattern although some may have exhibited a fine mottled surface pattern when etched.

Contrary to popular belief, it appears that Indian Wootz was *not* the steel used to make Damascus steel swords because all ethnographic references to Indian Wootz state that the crucibles were taken out of the furnace when hot and cooled quickly. This is inconsistent with the formation of a characteristic Damascus pattern. However, it must be said that Wootz crucible steel could still have made a good-quality sword which might have had, under certain circumstances, a faint surface texture. Therefore, the myth that Damascus steel was primarily made of imported Indian Wootz is unsubstantiated as all evidence suggests otherwise. Also, there is no evidence, archaeological or textual, for Damascus steel ever being made in Damascus, although evidence may lie under the present-day city. The myth that Damascus steel arrived Central Asia via Tamerlane after he sacked Damascus and brought all the craftsmen to Samarkand is totally

Sample #2  
Object: Straight sword  
Location: Kiln Yar  
Cemetery 3  
Date: 3<sup>rd</sup> - 4<sup>th</sup> c. AD  
Length: 82 cm  
Width: 4 cm.  
Comments:  
Tang is separate piece of iron



Figure 5.

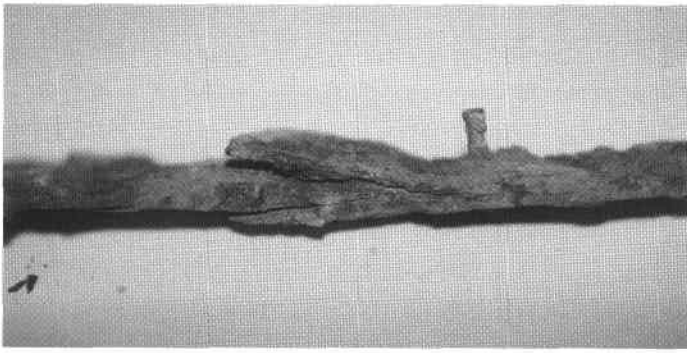


Figure 6. Detail of the 3rd-4th century A.D. sword from Kiln Yar showing how the tang was attached to the blade.

incorrect because crucible steel was in Central Asia centuries before Tamerlane was born. The myth stating that the art of making Damascus steel was lost and needed to be rediscovered is also untrue. It is true that certain factors influencing the underlying cause of the pattern were not understood until only a few years ago, such as the role of trace elements. However, Damascus steel was replicated at will by different methods to form different patterns during the 1800s. This will be discussed in Part II.

Undoubtedly India did produce swords made of crucible steel and, if we are to believe Zosimos' statement, crucible steel originated in India, but this does not necessarily mean southern India but perhaps northern India, which geographically can be considered part of Central Asia. Until further archaeological work is undertaken in India to establish reliable dates for the crucible steel sites, the evidence as it stands indicates that crucible steel, and probably swords with the traditional Damascus steel pattern, was produced in various locations in Central Asia.

## PART II

### GENERAL PAVEL PETROVICH ANOSOV

To anyone who has studied crucible Damascus steel, the name Pavel Petrovich Anosov (also transliterated as Anosoff) is well known, but to others, especially to those outside of Russia, his name is less familiar. From 8 to 10 September, 1999, the town of Zlataoust celebrated the anniversary of the birth of Anosov. Zlataoust is in the southern Ural mountains of Russia. The area has a wealth of mineral deposits and complex geological structures. There is evidence that the area has been mined for stone and ore since prehistoric times.

Anosov was born in 1799 in St. Petersburg. In 1817 he graduated from the St. Petersburg Mining Cadet Corps and

Sample #15  
Object: blade  
Location: Klin yar  
Date: 3<sup>rd</sup>-4<sup>th</sup> c. AD  
Length: > 76 cm.  
Width: 5 cm.



Figure 7.

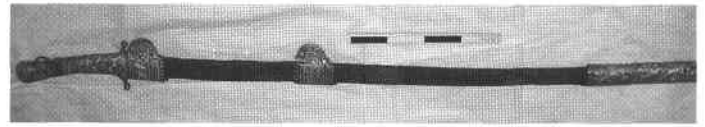


Figure 8. The saber from Koltso Gora.

was sent to the mining and processing plant at Zlataoust. In 1819 he was made supervisor of the damascened weapons department of the small Zlataoust arms factory. It was Anosov who made Zlataoust the premier arms factory of Russia during the mid-19th century. From the beginning of his work at the Zlataoust factory, Anosov received commendation from some mining officials and from others received reproach.

Anosov is best known outside of Russia for his crucible Damascus steel research, but his discoveries did not begin there. He was the first to produce a geological map of the Zlataoust region and discovered deposits of malachite, gold, corundum and graphite. The discovery of these and other minerals near Zlataoust had important economic consequences for Russia and as well as for Britain. Until the time when Anosov discovered these deposits near Zlataoust, these materials were imported from Britain and were therefore very costly for the Russian economy but benefited that of the British. Anosov received commendation for these discoveries and for saving the factory, and therefore Russia, money. He also devised methods of making refractory crucibles from local materials rather than importing crucibles from Germany. Among numerous other discoveries, Anosov's independent metallurgical innovations included etching and using a microscope to study steel, tempering in compressed air and reusing iron and steel scrap by remelting them in clay crucibles. He also understood and utilized gas carburization of iron for steel production as early as 1836.

Anosov's work toward discoveries and innovations was not for self gratification but rather he sought to make Russia less reliant on other nations. He was also concerned with the deforestation which was occurring around Zlataoust due to the high demand for wood. He introduced a system of reforestation by sowing seeds for pine trees.

In addition, he strived to ease the tasks of Russian serf workers. One of his first innovations was to improve the locally made scythes. Expensive scythes from Austria were imported into Russia. Anosov's method of cast steel created scythes

Sample #1  
Object: Saber  
Location: Koltso gora  
Cemetery 1  
Grave 41

Date: Late 11<sup>th</sup> c. AD  
Length: 98 cm  
Width: 3 cm  
Thickness: 5 cm

Comments:  
Well preserved Slightly curved

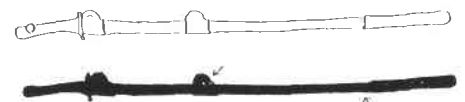


Figure 9.

which remained sharper longer than the Austrian scythes, thus easing the tasks of agricultural workers. For this he received a gold medal from the Moscow Society of Agriculture. He also improved the working facilities in the factory for the workers.

During the 1800s, Russia was undergoing many socio-economic changes. The Urals were seen as a dangerous place, especially the mining and arms factories. The serf workers were generally treated badly by the administration and the factory was under cruel and often violent military control. Apparently, Anosov was very different from the other administrators. The workers thought of him as a very kind and sympathetic man, which was illustrated by the fact that when he was transferred from the Zlataoust factory to the Altai, the workers gave him a fond farewell; even Anosov was said to have shed tears.

During the 19th century, many scholars throughout Europe were seeking methods for improving steel. Damascus steel, with its legendary properties and attractive surface pattern, attracted much attention in the metallurgical community. Some Western scholars question whether or not Anosov actually produced high-quality crucible Damascus steel. Some Russian scholars state that Anosov travelled to the East and forced an oriental blacksmith at knife-point to tell him the secret. The evidence provided by his notes and comments from contemporary sources, however, suggest that he obtained his knowledge by more scientific methods. Anosov concentrated his research on establishing the relationship between the pattern and properties of the blade because some patterns were known to appear on better-quality swords. He conducted experiments on the factors which could influence the pattern, including the crystal structure and composition. After many experiments with different plants and other carbon-containing substances, he concluded that the form of the carbon was unimportant but the amount of carbon in the steel was crucial.

Anosov, inspired by the research of Stodart and Faraday (Hadfield, 1931, p. 250), also experimented with different alloys. He concluded that steel should be pure in order to produce a pattern. This we now know to be true up to a certain point, but we also know that trace elements are necessary (Verhoeven et al., 1998, pp. 58–64), but these need to be present in an amount which Anosov was not able to detect. He studied the effect of titanium, manganese, silicon, chromium, silver, gold, aluminum and platinum. While performing these studies of alloys, he independently concluded that silicon effects the formation of graphite, that chromium increases the hardness and improves the finish and discovered the effects of other alloying elements.

Anosov documented four general methods which he used to produce crucible Damascus steel: 1) direct reduction from the ore, 2) fusion of cast iron with iron oxide, 3) casting steel into a mold and 4) reacting iron and carbon. Anosov also discussed the characteristics of the shrinking phenomenon and the necessity of slow cooling for crystal growth as well as

the necessity of repeated forging at low temperatures and the different methods of producing different patterns. Textual, archaeological, ethnographic and modern replication evidence shows that these methods can produce steel with a Damascus pattern. Anosov succeeded in producing Damascus steel swords with the characteristic pattern and properties, including swords that could cut silk in the air and bend to a 90° angle and spring back with no apparent structural damage.

It has been suggested that the “legend” of Anosov and his crucible Damascus steel was an inflated product of Soviet propaganda or Russian nationalism, but this is definitely not so. There are accounts of British explorers who met Anosov in Russia. Their praise of him as a good-hearted man and a brilliant metallurgist exceeds even the Russian descriptions. In 1847, while Anosov was stationed in Zlataoust, he was visited by Thomas Witlam Atkinson, a British artist and explorer who was spending seven years travelling around Siberia, Mongolia and Central Asia. He describes Zlataoust as the “Birmingham and Sheffield of the Ourals [sic]” (Atkinson, 1858, p. 117), and indeed it was (Figure 10).

Atkinson was very impressed with the organization of the buildings, the variety and quality of the weapons and the beautiful decoration on the swords. He says that he had never seen, in either Birmingham or Sheffield, “any establishment which could compare. . . . Indeed this is the most extensive and best-arranged fabrics of arms in Europe” (Atkinson, 1858, p. 118). He then describes General Anosov as “one of the most skillful and ingenious metallurgists of the age” (Atkinson, 1858, pp. 117–118). Atkinson saw many of Anosov’s Damascus steel blades and urged him to publish his experiments and findings sooner rather than later, but unfortunately Anosov only lived long enough to publish an abridged version of his research. This paper, “On the Bulat,” was published in the Russian *Gorny Journal* in 1841 and was translated into French and German in 1843.

Another British Explorer who befriended Anosov was Major James Abbott of the Honourable East India Company’s Artillery. Major Abbott was very interested in the manufacture of Damascus steel, stating that from a very early age he had a passion for everything which had to do with arms. He came across many blades in Central Asia and India. Although Abbott did not fully agree with Anosov’s classification of Damascus steel or his estimation of the quality of different types, he did think that Anosov produced high-quality Damascus steel swords. Abbott stated (1884, p. 347), “So far Colonel Anossoff [sic]; a man whose researches in this department of science have enabled him to revive the natural damask, in a degree of perfection which I have never observed in the workmanship even of the ancients, and which certainly cannot be approached by fabrics of any European nation at present existing.” Anosov inspired Major Abbott so much that in his book he included a section on



Damascus steel written by General Anosov before his own discussion of his observations of Damascus steel.

In both of their written accounts, Atkinson and Abbott are distressed that Anosov was far from his family and that his life's work appeared to not be appreciated in Russia. Anosov's research abruptly ended on 13 May 1851 when he died while posted in Omsk. Atkinson stated, "my friend died at Omsk—not one member of his family was near to soothe his last moments or receive his parting blessing; they being in St. Petersburg, near two thousand miles distant" (1858, p. 120).

Although his obituary praised him, the animosity felt by some of the mining officers became apparent. The mining officers of the Zlataoust arms factory wanted a portrait of Anosov to be hung in the factory but this was refused by the administration. This animosity was also noted by Major James Abbott, "Alas, his country has not added one stone to his simple monument, or a line to his epitaph. He lies forgotten by all except his family, and a few friends who knew his worth" (Atkinson, 1858, p. 121). In 1852, the workers at the Zlataoust plant made voluntary contributions to have a memorial stone placed on Anosov's grave in Omsk. After his death, the official mining community reversed many of the advances which Anosov made: they returned to importing Austrian scythes and began importing British steel again. Anosov's Damascus steel research was virtually forgotten, as noted by Atkinson (1858, p. 121): "[in] 1853, on my visit to Zlataoust, I found that a damask blade could not be manufactured."

General Anosov's Damascus steel research again became known to British scientists in 1922. During February and March of that year, the metallurgist Colonel N. T. Belaiew was invited to give a series of lectures at the Royal School of Mines-Imperial College, University of London. Colonel Belaiew was introduced to Anosov's research on Damascus steel blades by his professor, D. K. Chernov. In the 1860s, Chernov was sent to Zlataoust and there learned about General Anosov's work. When he returned to the Academy in St. Petersburg, he lectured to his students

about crucible Damascus steel. One student who became particularly interested was N. T. Belaiew. Colonel Belaiew based his Damascus steel research on that of General Anosov.

These metallurgists and others solved many questions about the production of Damascus steel. This information is now being used in a new way to help understand how Damascus steel was produced in antiquity by comparing the evidence from replication experiments to that found on archaeometallurgical remains. In particular, Anosov's research continues to be used as a foundation upon which new research can build. History shows that Anosov's research is not forgotten. In addition to the conference in Zlataoust, on 27 October 1999, the Polytechnic Museum in Moscow organized a conference for the opening of a new exhibition honoring Anosov and Chernov. Chernov also researched Damascus steel and reproduced it using Anosov's notes.

On a final note, the author recently discovered, in a letter written to Faraday by Roderick Impey Murchison (James, 1996 letter 1432), that Anosov sent a sword to Faraday in appreciation of Faraday's research. After the author's inquiries, the sword was found in the Faraday Museum, Royal Institution, London. The tip of the blade does indeed show a fine Damascus pattern. The rest of the blade appears to have been cleaned but not re-etched; the pattern, therefore, is not visible. On the back edge of the sword is engraved, in Russian, "From Anosoff to Faraday 1842 Zlataoust."

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Figure 10. Zlataoust during the 19th century, before the church was demolished by the Soviets.

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