An investigation of the varied technology found in swords, sabres and blades from the Russian Northern Caucasus

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Introduction

In 1999, IAMS generously provided the author with a grant for travel to Russia to study the microstructure of blades from the Russian Northern Caucasus. Thirty-seven blades were studied including knives, daggers, spearheads, sabres, single-edged and double-edged swords, ranging in date from the 3rd to the 12th century AD (Figures 1-35). Vickers hardness tests were only performed on a few samples because the original purpose of the study was solely to determine if any of the blades were made of crucible steel. However, it was later decided that it was important to publish the results of the metallographic investigations of all the samples due to the fact that there are few published reports on blades from this region.

The first group of eighteen blades were excavated in the Kislovodsk depression, and are now housed in the Kislovodsk Museum, Russia. These were dated by associated finds or by stylistic attributes. The second group is comprised of nineteen blades from the Upper Kuban River region, and are now in the Jewish University Museum in Moscow, Russia. These blades were not uncovered during controlled excavations and therefore have no associated archaeological contexts or firm date; however their style indicates that they are late Medieval.

Metallographic Examination of the Blades

A section of each blade was removed using a Plas-plug tile cutting saw with a wafer thin diamond impregnated blade. The Kislovodsk samples (KIS) were often taken from less corroded areas or where the blades would not be disfigured. All the samples of the Jewish University Museum blades (JUM) were taken from the area near the handle so as not to disfigure the blade. The reader should be aware that in using this method of sampling, the sample taken may not always be representative of the entire blade. For example, if the edge near the tip was carburised, or if a piece of steel was forge welded to the tip, the sample will not necessarily exhibit these features, and therefore will not be characteristic of the blade as a whole. However, any disfiguration to the blade is minimal and easily disguised by filling the hole with resin, if desired, or by placing the mount fixtures over the hole.

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The samples were mounted in resin with the transverse side positioned for examination. The mounted samples were ground and polished using standard metallographic procedures (e.g. Scott 1991, 63-66). All the samples, except those that were completely corroded, were examined before and after etching in 3% Nital. The examination of the samples indicated the use of iron, carburised iron, crucible steel, forge welded or piled iron and steel (Table 1). The samples are now housed at the Ashmolean Museum, Oxford, UK.

Iron Blades

Nine blades seem to be composed solely of iron: three from Kislovodsk (KIS #4, #5, #14) and six from the Upper Kuban River region (JUM #5, #10, #11, #12, #13, and #16). The microstructures were composed of ferrite grains with varying amounts of slag inclusions. It seems possible that at least some of the blades had either a carburised steel edge or an edge of steel forge welded onto an iron core. A purely iron blade would not have held its shape or an edge during use, unless the purpose of the blade was for display or ceremony; however, blades composed solely of iron are known from numerous time periods, such as those from Celtic contexts. It is more likely that the evidence for steel may have corroded away or is not observed because the sample is not representative of the entire blade. In the iron sword KIS #4, the occurrence of intergranular corrosion is clear. The possible exception to this is blade KIS #14, which was ritually bent. Some of the ferrite grains are 0.5 mm in length, indicating a very soft blade that would be beneficial in bending the sword to such a twisted shape. It may have been deliberately made for a ritual and/or burial and therefore there was not necessarily a need to give the blade a sharp edge and the presence of carbon would have impeded bending.

The microstructure of the sabres reveals iron and not steel. It may be that the area near the handle was made from a softer metal to provide some flexibility to the blade, but the edge of the blade may have been made of steel. Although the samples are composed of iron rather than steel, three blades show evidence of quenching (JUM #11, #13 and #16). JUM #13 appears to have carbide or nitride etch pits which, according to Samuels (1980, 69), often appear in quenched ferrous objects. JUM #11 and JUM #16 have laths inside the ferrite grains. These may also be a form of carbides or nitrides that sometimes appear as laths in ferrite (see Tylecote and Gilmour 1986, 5). Quenching is usually associated with steel and not iron, as quenching has a dramatic hardening effect on steel, but virtually no effect on iron. The process involves heating steel to between 700 - 850 °C and then suddenly cooling it in water or another substance such as oil. The evidence of quenching suggests that either part of the blade was composed of steel, and the smith may have quenched the blade as a matter of course, or the sample did not reflect the composition of the entire blade.

Carburized Iron Blades

The metallographic examination of the samples revealed that eleven of the blades (KIS #3, #8, #12, #13, #17, and JUM #1, #3, #4, #6, #18, and #19) are composed of steel or have a steel edge made by carburising iron. This was determined by the observation that the samples had a relatively continuous increase in the amount of carbon from the core outwards, hence more iron-carbon phases towards the exterior edge of the object. The most common microstructure was intergranular pearlite/bainite/martensite between grains of ferrite (KIS #3, #12, #13, #17, JUM #4, #6, #19). The depth of carburization, the grain shape and size differ between samples, indicating variations in forging techniques and the rate of cooling. One sabre (JUM #1) and the dagger (JUM #3) appear to be evenly carburized throughout the sample. This may be due to the use of a steely bloom or a longer carburizing period that increased the depth of penetration of the carburized area.

KIS #8 possesses a very different microstructure. The blade is composed of tempered martensite and the tang contains areas of plate martensite. The tempered martensite would have produced a hard and sharp blade. Another blade composed of martensite is JUM #18. Small lines within the grains may be nucleation points of lath martensite (see Samuels 1980, 329).

Layered Blades

Eleven blades were made by forge welding layers of iron and steel: KIS #6, #7, #9, #18, and JUM #2, #7, #8, #9, #14, #15, and #17. The process of forge welding involves heating the iron or steel to at least 1300 °C and then hammering (forging) separate pieces together to form a single piece. A steel layer can be welded to the cutting edge, or many layers can be "piled" on each other and welded together, thus producing what is known as piled steel. The difference between forge welding and piling is the number of layers of iron and/or steel, but there is no standard number which distinguishes between them. Blades KIS #18 and JUM #9 were clearly made of piled iron/steel and the many layers are observed as alternating light and dark bands in the etched sample. JUM #8 appears to have a piled edge forge-welded onto an iron layer.

Forge welding is fairly easy to detect when a sample is etched. The samples of all the forge-welded blades have zones with different carbon contents. These zones appear as lighter or darker bands and represent the original individual iron or steel pieces. Elongated areas of slag inclusions at the joints between what were separate pieces can be observed in virtually all of the samples (e.g. KIS #7). Particularly noticeable in sample KIS #6 was an area that etched lighter than the other areas. This is a common feature often observed in forge-welded pieces and is often attributed to the presence of arsenic (Tylecote and Gilmour 1986, 15), but could also be due to other elements.

Crucible steel

There is not a singular characteristic that can be used to conclusively distinguish crucible steel from other types of steels. However, the appearance of characteristics including a lack of slag inclusions, a homogenous carbon content across the sample, a mottled appearance across the sample, and spheroidal/globular cementite in a pearlitic/ferritic matrix, all point towards the use of crucible steel because these features are not commonly observed together in other types of steel.

According to these criteria, four blades from Kislovodsk, #1, #2, #10 and #15 are made of crucible steel. The latest blade examined was Kis #1, a late 11th century AD sabre from Koltso Gora. The handle, guard, two-point suspension points and the tip guard are gold plated over a copper alloy. The gold plate is decorated using *repoussè* or a similar method into intricate geometric patterns. The sabre is attributed to the Saultovo Mauaskaya culture, a culture related to the Khazar Turks, before the invasion of the Tatar-Mongols (Arzhantseva, pers. com.).

KIS #2 was one of the earliest blades examined. It is associated with an early Alani burial at Klin Yar, dated to the 3rd – 4th century AD. The sword has a handle made of piled steel which was riveted to the blade.

KIS #10 and #15 are only pieces of blades. Both blades are attributed to the Alani culture. KIS #10 is a fragment of a presumably double-edged sword from the 7th century AD. The blade was found in a horse burial. Horse burials were a common practice among pagans for centuries across Central Asia and in Europe and are usually associated with nomadic groups.

Examining the four crucible steel blades under low magnification after etching revealed that each exhibited a mottled pattern consisting of elongated light and dark areas, in a preferred orientation parallel to the blade. This feature was also noted on crucible steel blades reported by Lang *et al.* (1998), Allan and Gilmour (2000), and France-Lanord (1969). The clarity, size and concentration of the mottled areas differ between samples. KIS #1 has a clear pattern over the entire sample with mottled areas around 0.5 mm long and 0.05 mm wide. The mottled pattern of KIS # 2 is not as clear. The mottled areas are difficult to measure as they are so faint, but appear longer and much thinner than in the previous sample. In KIS #10 and KIS #15 the mottling appears to be more random than in the previous samples. The mottling tends to be more spherical and unevenly distributed throughout the sample. This mottling was also apparent after etching with Oberhoffers' etch, therefore signifying that the effect is due to segregation of minor and trace elements that occurred during solidification. The mottled pattern may reflect the original dendritic structure that has become flattened and elongated during forging.

Under higher magnification, the differences in microstructures become more visible. The microstructure is very fine and difficult to observe as it consists of cementite needles that are beginning to break up and form elongated globular cementite. There is no preferred orientation of the cementite. Some of the cementite seems to be located at prior austenite grain boundaries. The matrix is composed of irresolvable pearlite. The hardness was determined to be 345 VH. The hardness and structure is comparable to a 1.5% C experimental sample made by Furrer (Harsh 2001). KIS #1 contains elongated inclusions and these were identified as manganese sulphide inclusions by EPMA spot analyses as Mn 20%, S 19%, and Fe 40%. The high iron content may be from the surrounding matrix due to their small size. Manganese could have been part of the initial bloomery smelting ore as it is often found in association with iron ores (Rostoker and Bronson 1990, 99). It is possible that different parts of the ore body contained areas particularly rich in manganese and the different percentages in the slag reflect the use of ores from different areas, or perhaps different ore or iron sources. However, due to the comparatively low temperatures used in the production of bloomery iron, their presence is comparatively rare and the manganese ends up in the slag (Rostoker and Bronson 1990, 19). Alternatively, the

manganese may have been deliberately added to the crucible charge. The archaeometallurgical study of crucible steel production remains from Merv, Turkmenistan, revealed two groups of crucible steel slag, one with a high percentage of MnO (12%), and one with a low percentage (2%). Manganese sulphide inclusions have been found in other crucible steel objects (Allan and Gilmour 2000, 478). Furthermore, there is historical textual evidence for the deliberate addition of manganese to the crucible charge.

The fragments of KIS blades #10 and #15 have a similar microstructure. In both blades, elongated cementite needles and prior austenite grain boundary cementite are beginning to break up and display a more globular appearance. The matrix is composed of very fine pearlite.

The microstructure of KIS #2 is comparable to that seen in some blades with a Damascus pattern. The microstructure is composed of globular cementite in a DET matrix (Divorced Eutectoid Transformed matrix of cementite particles in ferrite, see Verhoeven *et al.* 1998). The DET microstructure indicates that the blade was air-cooled (Verhoeven *et al.* 1998). The cementite has a diameter from about 1 to 5 µm. This is consistent with Verhoeven *et al.*'s (1998) finding that Damascus steel has an average cementite diameter of about 6 µm. The cementite alignment is best seen in the preferential corroded area and the backscattered image. However, the alignment of the cementite is not very strong indicating that the blade would not have had a crisp "Damascus" pattern.

The globular cementite alignment in KIS #2 is similar to Zschokke sword #7 which had diffuse bands of elongated cementite particles. This suggests that, if etched, the sword would have had a faint Damascus pattern. This would make the sword the earliest known sword with a Damascus pattern. It is unclear if the sword was originally made with a separate handle or if the handle was a later addition, perhaps to mend a broken sword retrieved in battle. The presence of aligned cementite and the apparent Damascus pattern may explain why the tang/handle was riveted on rather than forge welded on. Forge welding is the process of heating two pieces of iron/steel together to form one piece. Typically the pieces are heated to white heat, around 1300-1400 °C and then forged together (Wagner 1993, 274). This high temperature would adversely affect the spheroidal cementite thus eliminating any Damascus pattern observed on the surface of the blade. The smith might have been aware of the effect the heat would have had on the blade and might not have had the knowledge or resources available to reproduce the pattern. It may have been easier to rivet a handle on rather than to eliminate the pattern and possibly produce a blade with inferior properties.

Perhaps one of the most important outcomes of the research is the observation of preferential corrosion in crucible steel blades, particularly KIS #2. The iron/steel matrix corrodes first, leaving uncorroded cementite. This has also been observed on the blade from Nishapur (Allan and Gilmore 2000, 55). This is significant as often blades found in archaeological contexts are heavily corroded. But this indicates that if the blade was made of crucible steel, evidence might still be present in the corroded product.

Discussion

The examination of the blades indicated that different materials and techniques were used to make blades in the Russian Northern Caucasus. The identification of four crucible steel blades is particularly important because the only other comparatively early crucible steel objects known from an archaeological context are those from Taxila country: one from the 1st century AD and two from the 5th (Marshall 1951, 536). The next published object made from crucible steel is a Sasanian sword attributed to 6th or 7th century Iran, now housed in the British Museum (Lang *et al.* 1998; Craddock 1998, 48). A sword excavated at Nishapur in Iran and now in the Metropolitan Museum of Art, New York, is presently attributed to the late 8th – 9th century AD (Allan and Gilmour 2000, 54). This makes KIS #2 and KIS #15 the second and third earliest known crucible steel objects, and KIS #2 the earliest known blade that could have exhibited a crucible Damascus steel pattern, if it were etched. In the 3rd century AD Zosimos, the Alexandrian alchemist, wrote about crucible steel production (Craddock 1998). Therefore, this suggests that knowledge and use of crucible steel reached the western frontiers of Central Asia by at least the 3rd century AD.

According to Kaminsky (1996) a preliminary study of early medieval weapons excavated from cemeteries in the Northern Caucasus showed changes over time in the mode of warfare, associated with different local tribes and nomadic populations. Given the nomadic and warlike nature of the tribes, it is not surprising that so many different techniques were employed to manufacture the blades. Many, if not all of the blades, were aquired via tribute, trade, or booty. Only the analysis of more blades will give a more complete picture of materials and manufacturing techniques of the blades used by different tribes.

Acknowledgements

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Location	Sample #	Microstructure	Blade Type
Kislovodsk (KIS)	1	Crucible steel	Sabre
	2	Crucible steel	Double edged sword
	3	Carburized iron	Double edged sword
	4	Iron	Double edged sword
	5	Iron	Sabre
	6	Forge welded	Sabre
	7	Forge welded	Dagger
	8	Carburized iron	Sabre
	9	Carburized iron	Sabre
	10	Crucible steel	Double edged fragment
	11	Too corroded	-----------
	12	Carburized iron	Double edged sword
	13	Carburized iron	Spearhead
	14	Iron	Double edged sword
	15	Crucible steel	Double edged sword
	16	Too corroded	----------
	17	Carburized iron	Sword fragment
	18	Iron	Knife
Jewish University Museum in Moscow (JUM)	1	Carburized iron	Sabre
	2	Forge welded	Double edged sword
	3	Carburized iron	Dagger
	4	Carburized iron	Double edged sword
	5	Iron	Sabre
	6	Carburized iron	Sabre
	7	Forge welded	Sabre
	8	Forge welded	Sabre
	9	Layered	Knife
	10	Iron	Knife
	11	Iron	Knife
	12	Iron	Knife
	13	Iron	Knife
	14	Layered	Knife
	15	Layered	Knife
	16	Iron	Knife
	17	Layered	Knife
	18	Carburized iron	Sabre
	19	Carburized iron	Knife

Table 1: Summary of the blades' microstructures

Figure KIS #1
This sabre was found at the Koltso Gora, Cemetery 1, Grave 41, and is attributed to the late 11ᵗʰ century AD. It is made of crucible steel. VPH 345.
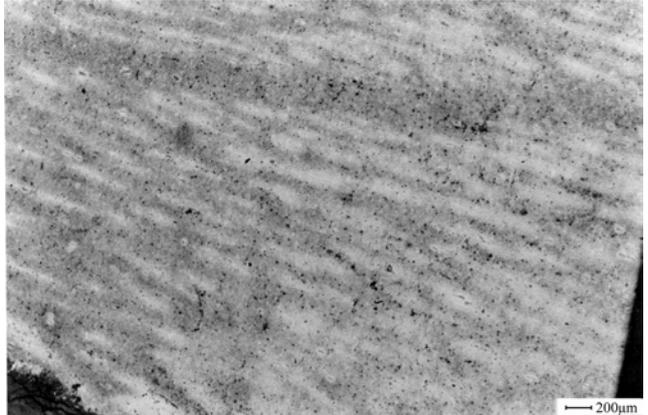
Figure KIS #2
The double edged sword is attributed to the 3ʳᵈ – 4ᵗʰ century AD and is from Klin Yar, Cemetery 3. The blade is made of crucible steel. VPH 220. Cementite, beginning to align, can best be observed in the preferential corrosion and the SEM backscattered image. The handle, showing a banded structure (top), is not made of crucible steel and is riveted on to the blade.
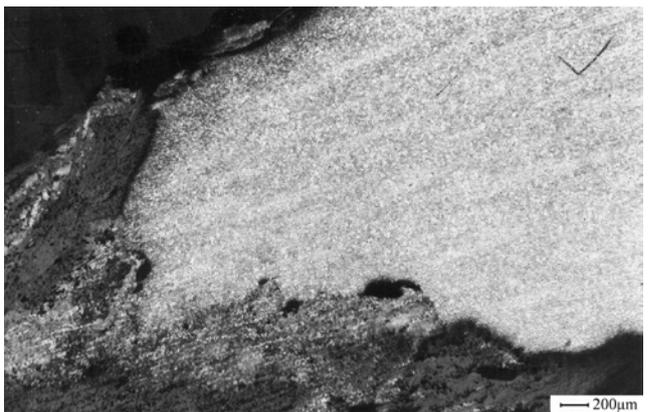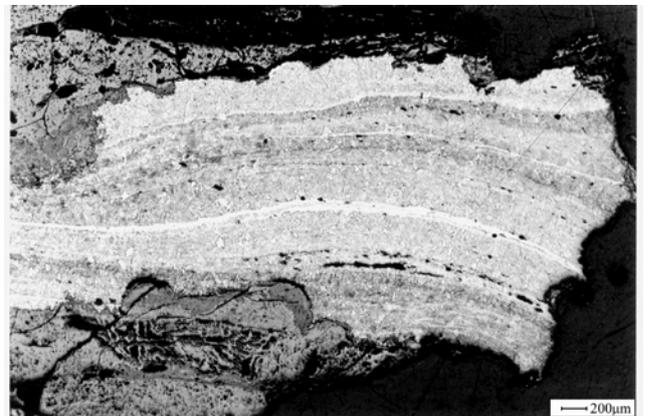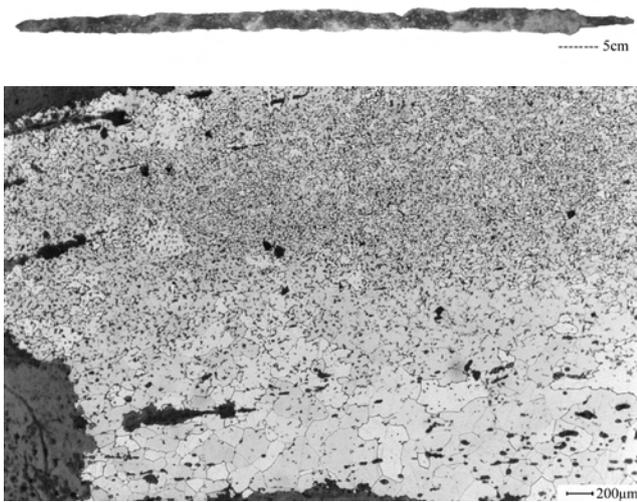
Figure KIS #3
This double edged sword is attributed to the 4th – 5th century AD and is from Visokogorny.
The sword may be of European origin; however, this type of sword was also used in Central Asia. It probably had a guard which has not survived. The microstructure indicates that the sword is composed of carburised iron. Comparatively large grains of ferrite can be observed in the centre of the blade. The presence of intergranular pearlite indicates higher carbon areas. The gradual increase of carbon, from the ferritic centre of the blade to the higher carbon edge, indicates a carburisation process.
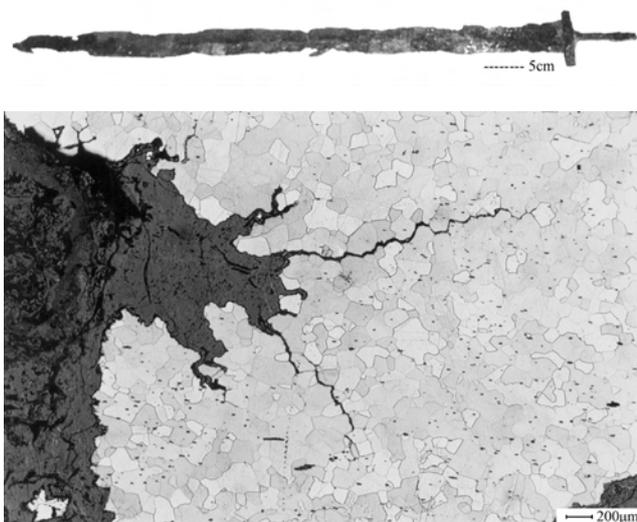
Figure KIS #4
This 5th – 6th century AD double edged sword from Kislovodsk, with the prominent straight guard, is reminiscent of European swords. The metallographic sample is composed of corrosion and ferrite. The microstructure shows a relatively even distribution of non-metallic inclusions appearing as black oval shaped dots. These are believed to be slag. Intergranular corrosion can be clearly observed where the corrosion meets the preserved metal. VPH 128.
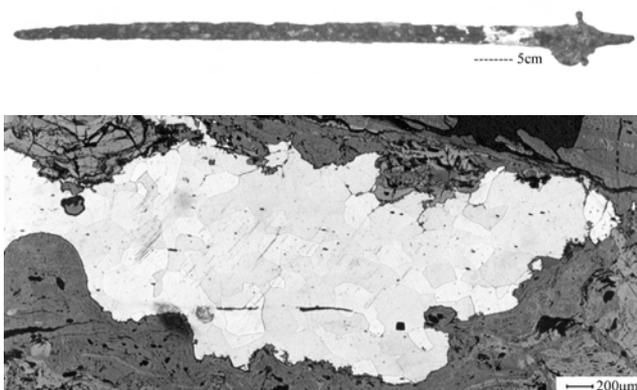
Figure KIS #5
This 10th – 12th century AD sabre, with a small guard and curved suspension point, from Ooloo Dorbumly, is similar to another North Caucasus sabre, number 712 h discussed by Nicolle (1999, 278). The style is found on Turkish sabres and is a common Central Asian style. The sample taken from this sabre is mostly corroded with only this island of ferrite grains visible. The sabre probably had a carburized edge which has corroded away. VPH 138.

Figure KIS #6
This sabre is attributed to the 10th – 12th century AD from Ooloo Dorbumly.
The sabre had a higher carbon steel forge welded onto a lower carbon steel
centre. The hardness of the interior is 167 whereas the carburised edge is
215 VPH. The steel has few non-metallic inclusions but elongated areas of
corrosion.
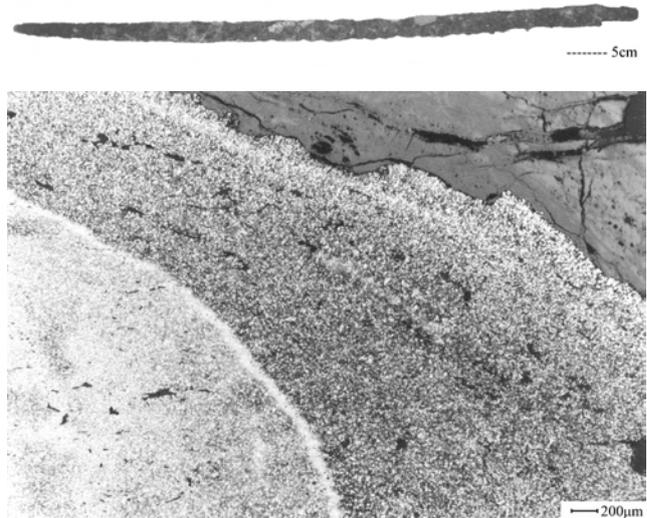
Figure KIS #7
This 11th century AD dagger from Rim Gora was probably made from a piece
of a broken sabre. This is suggested by its odd "sabre like" shape. This sample
is composed of at least two layers of forge-welded steel. A band of elongated
slag inclusions is observed between the two layers. The area below the slag
inclusion shows a rapidly cooled hypo-eutectoid (c. 0.5% C) steel with inter-
granular ferrite and Widmanstätten ferrite in a matrix of irresolvable pearlite.
The finer phase has a hardness of 250 VPH while the coarser phase has a hard-
ness of 167 VPH. The darker area of the hilt has a hardness of 226 VPH and
the lighter area has a hardess of 167 VPH.
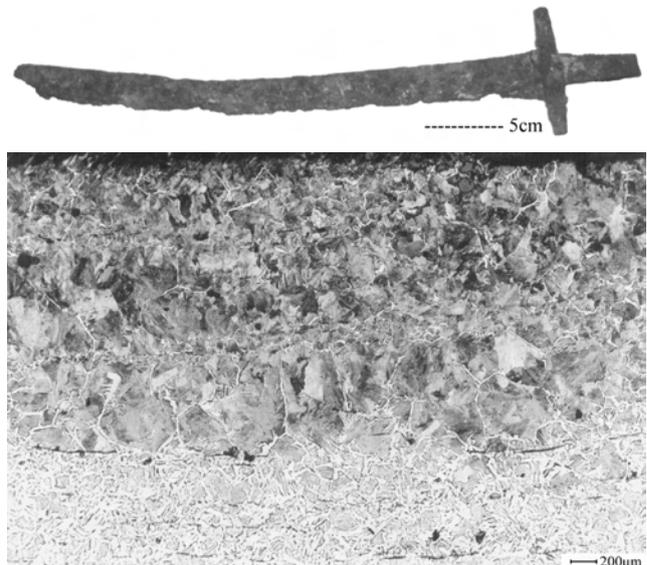
Figure KIS #8
This 11th century AD sabre from Rim Gora is attributed to the late Alan-Turkic
culture. The sabre is made of carburised iron, which was quench hardened
and tempered, producing lath martensite in the blade and plate martensite on
the tang. Elongated slag inclusions and other non-metallic inclusions were
observed in the microstructure. The blade would have been very hard but
brittle. During the microhardness testing the martensite cracked. 463VPH.
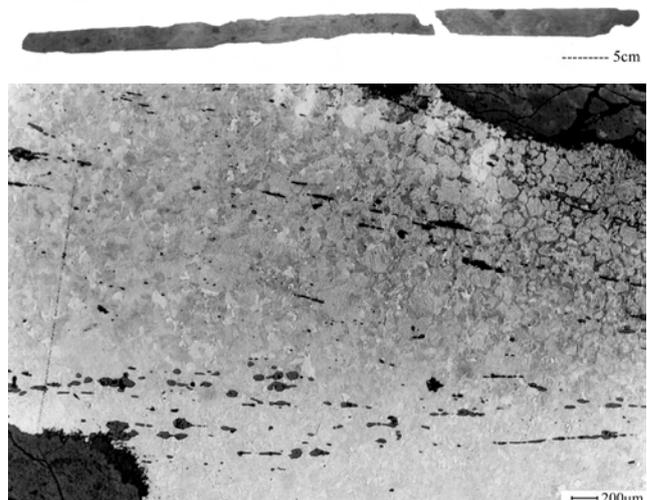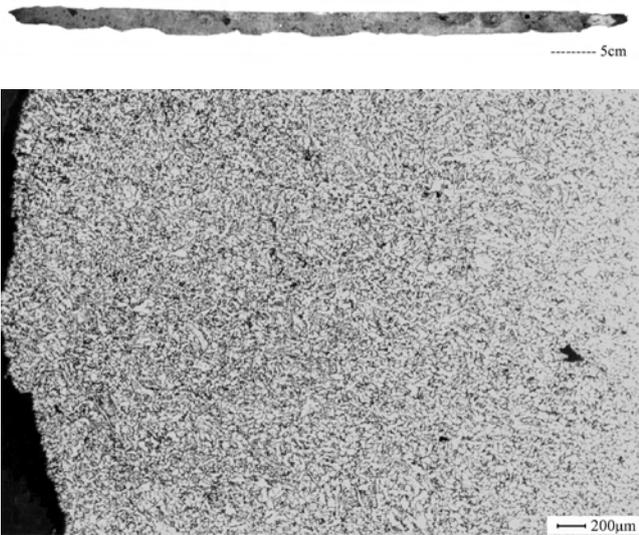
Figure KIS #9
The sabre may be from the 11th century AD and is composed of carburised iron. The hardness at the edge is 189 VPH, while the interior is 167 VPH.
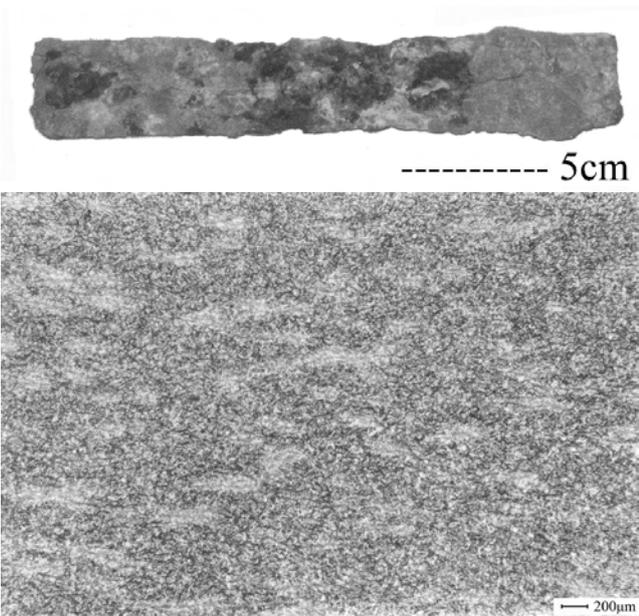
Figure KIS #10
This 7th century fragment of a blade was found in Machte Cemetery. It is made of crucible steel.
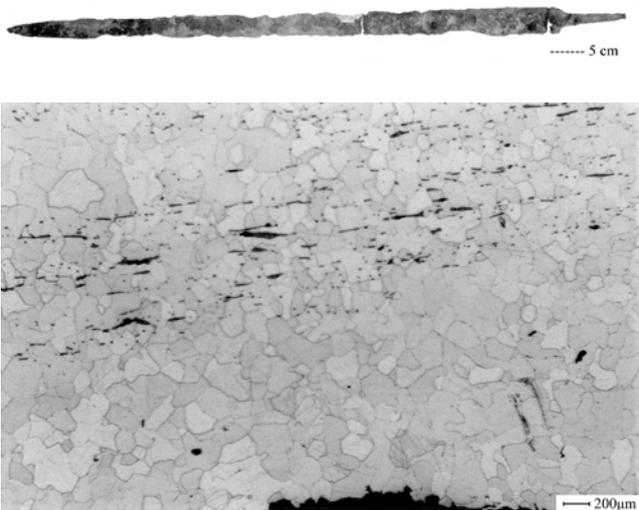
Figure KIS #12
This mid-1st millennium AD double edge sword was found near Kislovodsk. It is primarily composed of large ferrite grains. The percentage of martensite increases towards the exterior suggesting a carburized edge.

Figure KIS #13
This mid-1st millennium AD spearhead was found near Kislovodsk. The section was taken from the tang rather than the blade. The carbon content decreases toward the interior indicated by the decreasing amount of martensite from the edge to the centre, suggesting carburization. VPH 305.
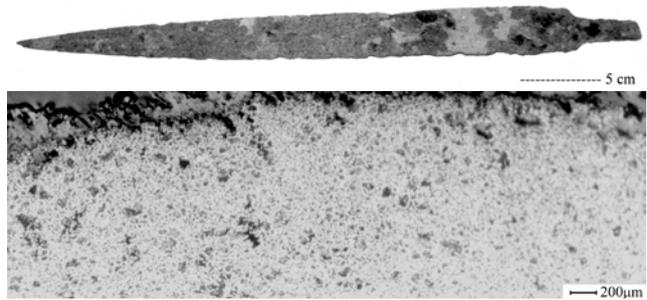
Figure KIS #14
This early 8th century AD double edge sword was found at Lermontovskaya 2. This sword was purposefully bent before being placed in the grave, suggesting a ritual practice of "killing" the sword, also see sample JUM #8. The microstructure reveals relatively large grains of ferrite, some about ½ millimetre across. The sword was probably annealed before bending. The dark elongated areas are corrosion. 102 VPH.
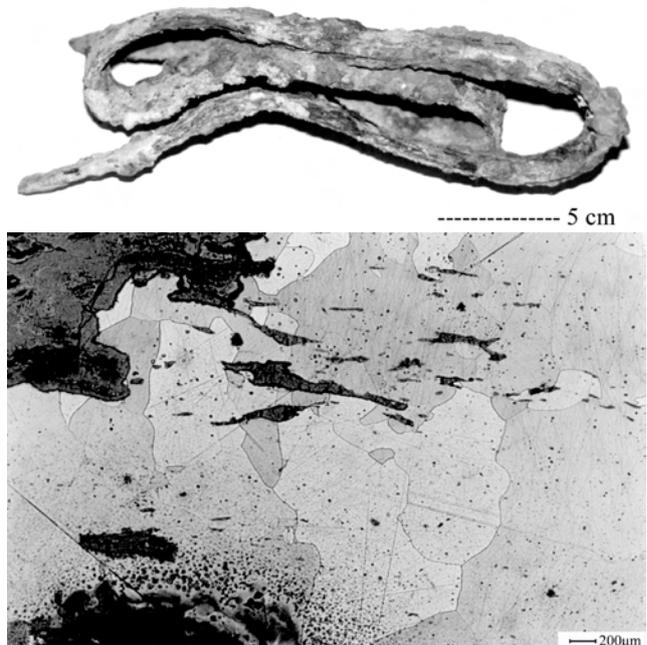
Figure KIS #15
The pieces of a 3rd – 4th century AD double edged sword were found at Klin Yar and are composed of crucible steel.
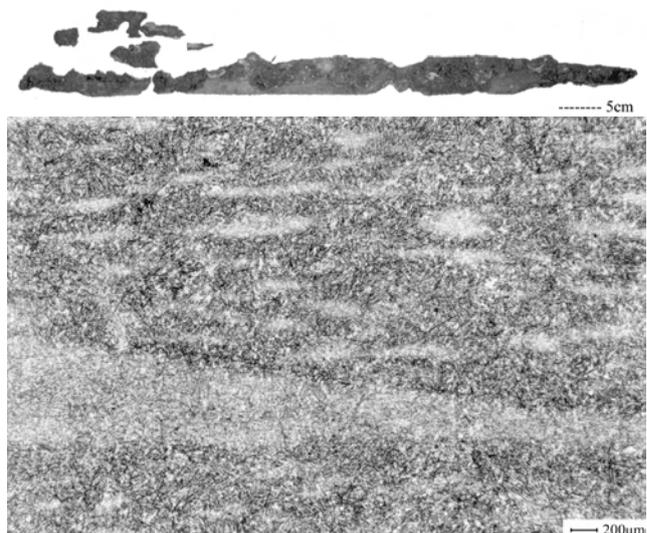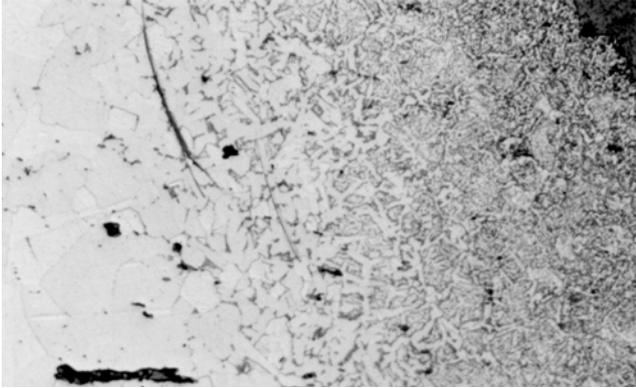
Figure KIS #17
The mid-1st millennium AD sword fragment was found near Kislovodsk. The carbon content decreases toward the interior of the blade, indicated by the decreasing amount of martensite from the edge to the centre indicating a carburized blade that was subsequently quenched. The difference in hardness, from 105 VH in the ferrite region to 315 VH near the edge, indicates a blade with a comparatively soft interior but containing a hard edge.
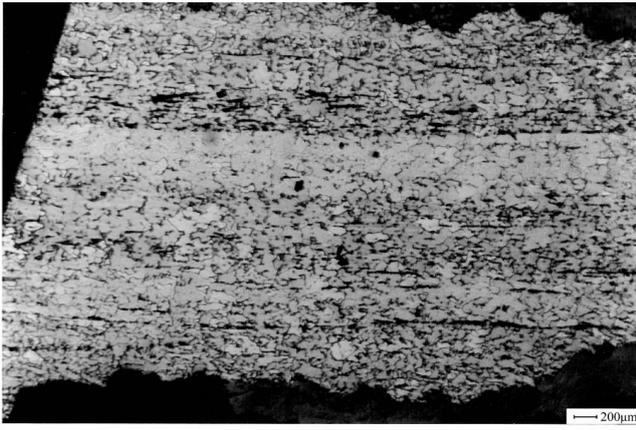
Figure KIS #18
This 7th – 9th century AD knife was found near Kislovodsk. It is composed of low carbon steel. Slag inclusions can be seen along the length of the blade. VPH 206.

Figure JUM #1.

The sabre has a small guard and the handle is a modern reconstruction. The sample is composed completely of ferrite grains with intergranular pearlite indicating low carbon steel. The blade has a relatively homogenous carbon content and very few non-metallic inclusions indicating relatively clean steel, compared to the blades discussed above. This may be due to the location of the sample, or the steel may have been from a carburized bloom.
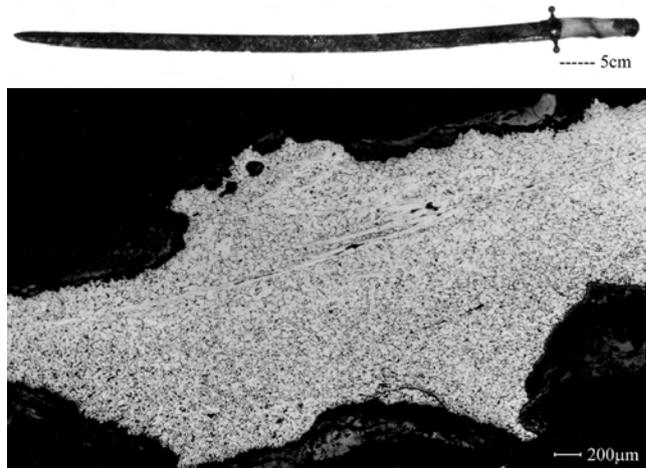
Figure JUM #2.

This is a double edged sword. The gold applied to the sword was attached with adhesive during modern reconstruction. The gold sheet may be from a scabbard, which deteriorated during burial. The microstructure is composed of large areas of upper bainite with laths and plates of ferrite.
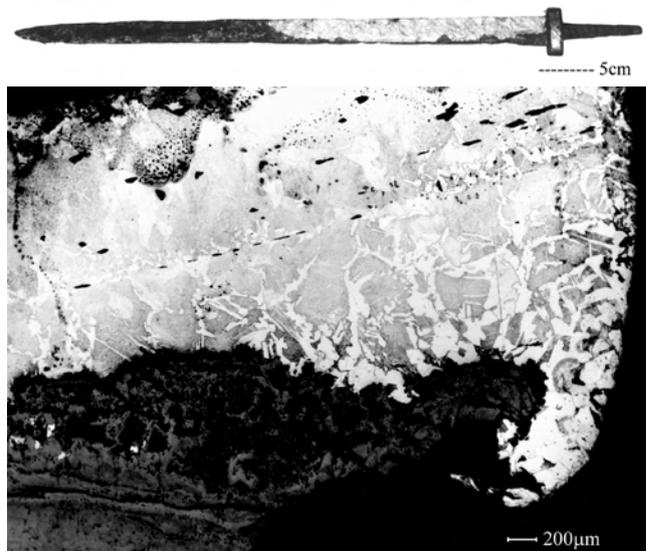
Figure JUM #3

This sample from the dagger is composed of a relatively homogenous low carbon steel. Elongated slag inclusions are also present and distributed throughout the sample. The microstructure consists of ferrite with intergranular martensite.
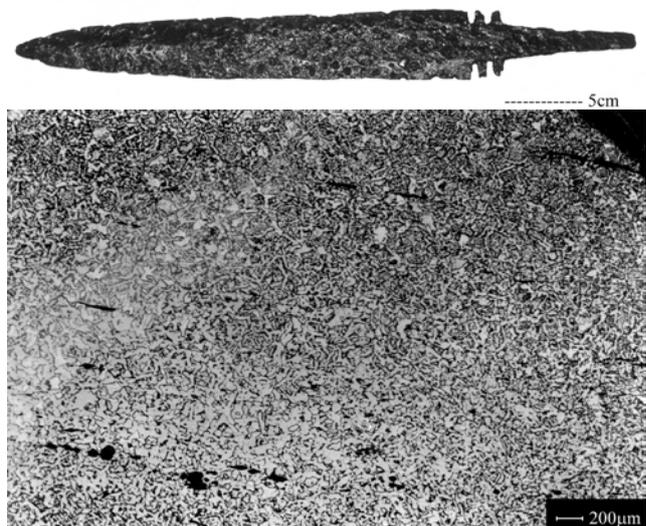
Figure JUM #4
The centre of the double edged sword blade is composed of large ferrite grains. The edge contains a higher percentage of ferrite towards the centre and more martensite towards the edge. There are also elongated slag stringers which appear in a higher concentration in the ferritic area.
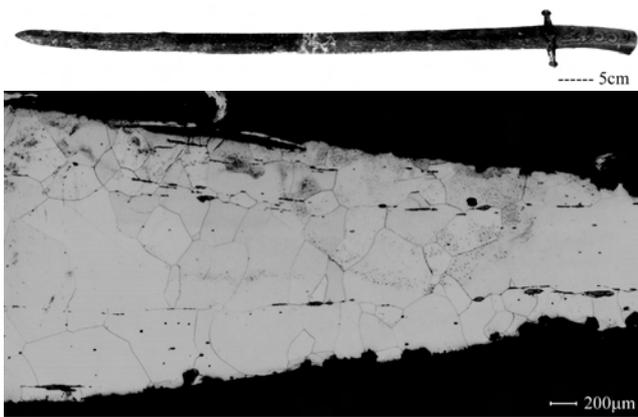
Figure JUM #5
The sabre has a small guard near the handle. The handle is a modern reconstruction.

The area sectioned is mainly composed of ferrite. A broken line of elongated slag inclusions can be observed through the section, from left to right. If there had been a carburised edge, it has completely been corroded in this sample. The edge of the blade and the tip were probably made of steel, although no evidence remains. The small dark spherical spots are etch pits which are associated with precipitates of carbides or nitrides (see Samuels, 1980, 69). Etch pits are found in quenched ferrous products suggesting that the sabre was quenched, further supporting the belief that it probably had a carburized edge.

The lower image shows in detail dark etch pits in ferrite grains (top right and left).
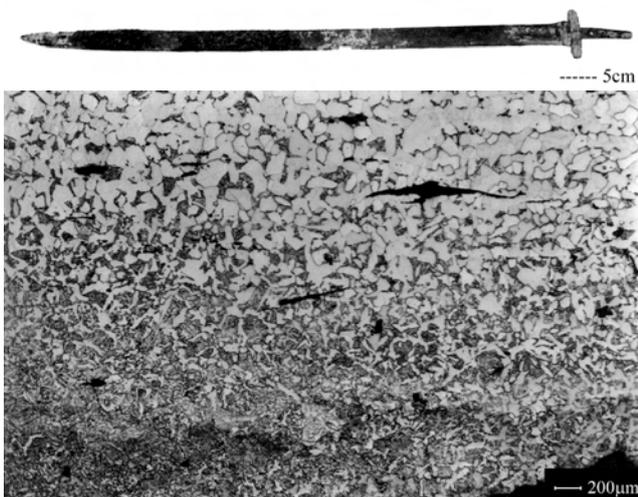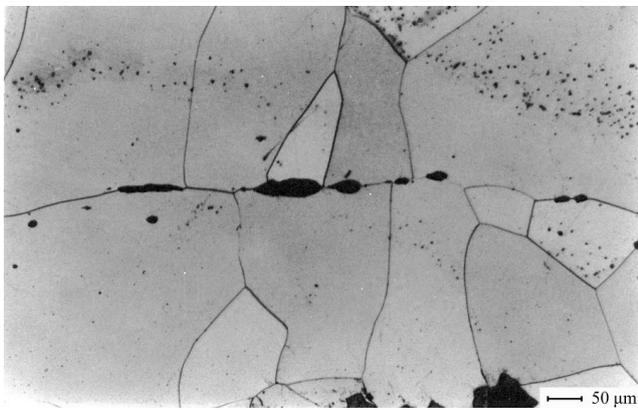
Figure JUM #6
The sabre is composed of carburized steel. The edge contains more ferrite towards the centre and more martensite towards the edge. Non-metallic inclusions and elongated slag are spread throughout the sample.

Figure JUM #7
The sabre is composed of areas of iron with steel at the edges.

Figure JUM #8
The sabre was ritually bent before being buried. The style of the attachment near the handle is also found on 10th – 12th century AD Kirghiz swords (Nicolle 1999, 290 and 477) and sabres from the western Steppes dated to 1150-1250 AD (Nicolle 1999, 281 and 471). The edge seems to be made of piled steel that was then forge welded onto an iron layer. The sword was probably annealed before bending.
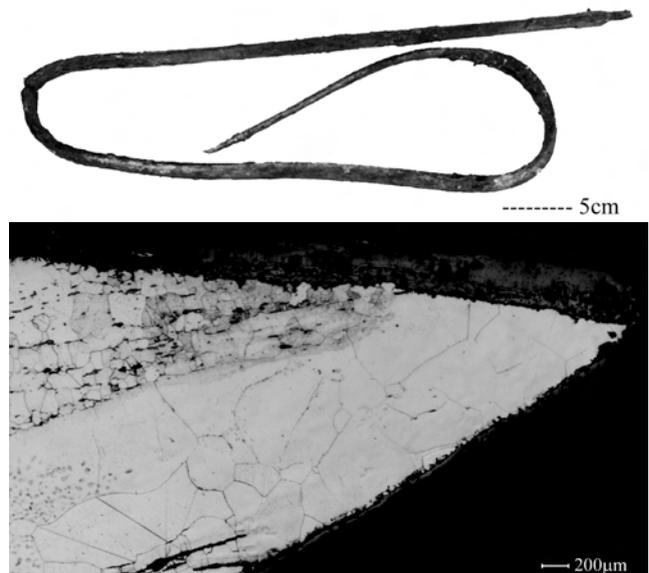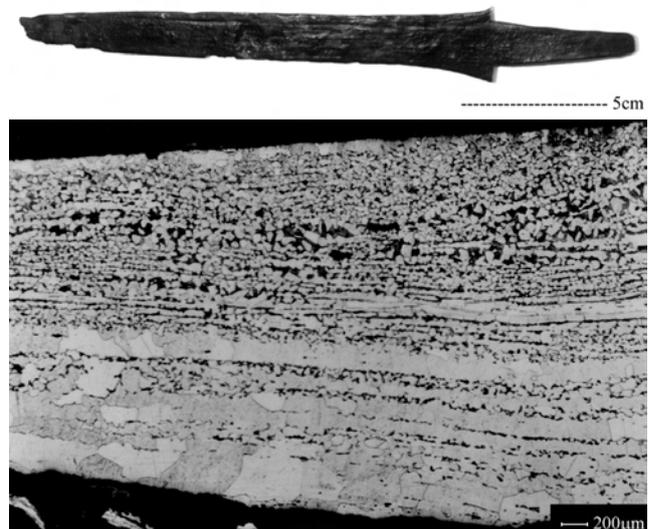
Figure JUM #9
The knife is composed of many layers of iron and steel.
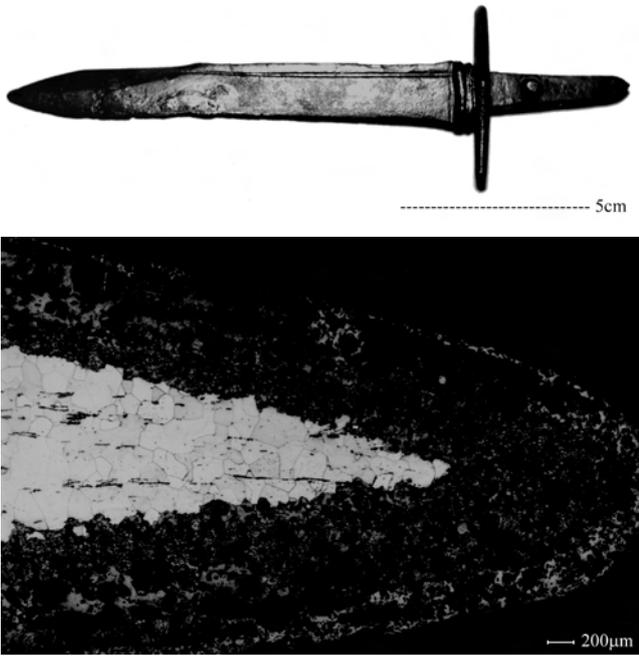
Figure JUM #10
The microstructure of the knife is composed of ferrite with a relatively even outer crust of corrosion. A string of elongated slag inclusions runs along the sample. The tip and edge near the tip might have been made of steel although no evidence for this has been preserved.
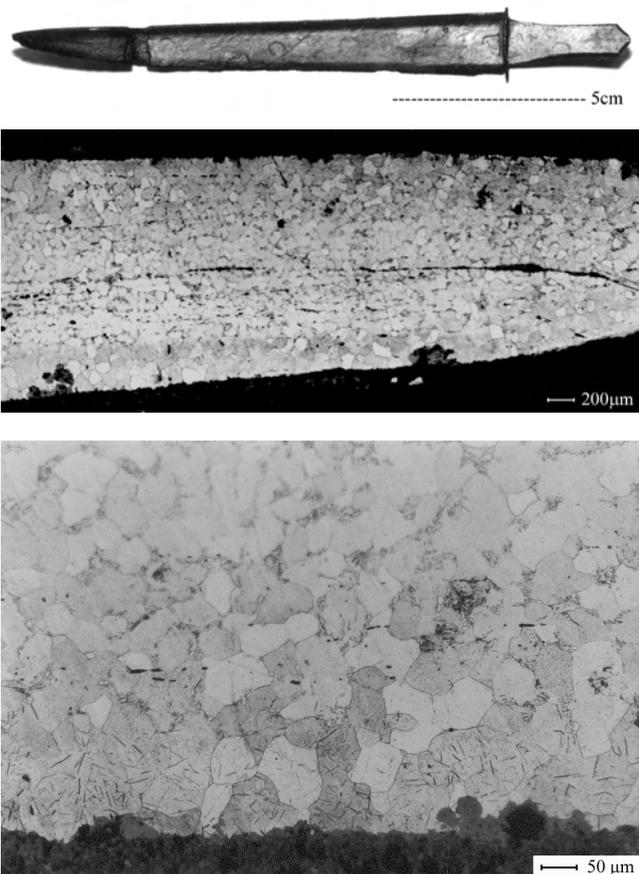

Figure JUM #11
The knife is associated with the Alani culture. The back edge of the knife is raised and flattened, whereas the cutting edge has a sharp angle down to the cutting surface. A line of elongated slag inclusions can be observed in the centre of the blade surrounded by ferrite grains. The sides of the blade appear to have laths within the ferrite grains suggesting that the edge is composed of a low carbon iron that appears to have been quenched.

Figure JUM #12
The knife is composed of a single piece of low carbon iron. The microstructure is primarily composed of grains of ferrite with occasional intergranular pearlite, which appear as dark areas between the lighter ferrite grains. The sample is virtually free from slag and non-metallic inclusions, and therefore may be modern.
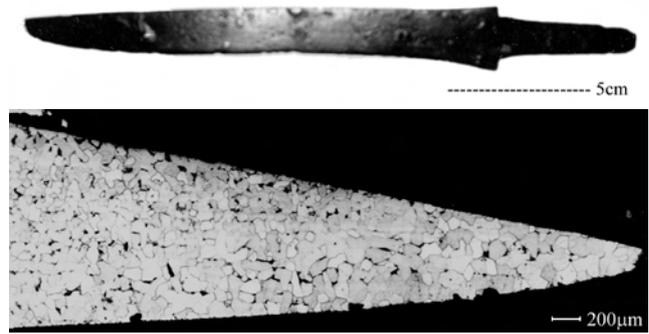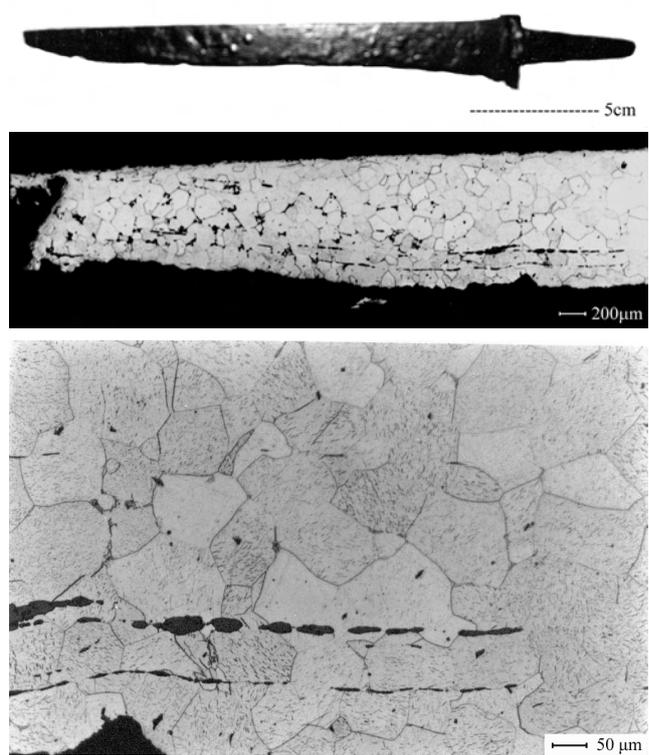

Figure JUM #13
The knife contains elongated slag stringers in a ferritic matrix. The edge of the blade appears to have laths within the ferrite grains suggesting that the edge is composed of a low carbon iron that appears to have been quenched.

Figure JUM #14
The knife is composed of layers of low carbon iron. Intergranular pearlite can be observed between the ferrite grains.
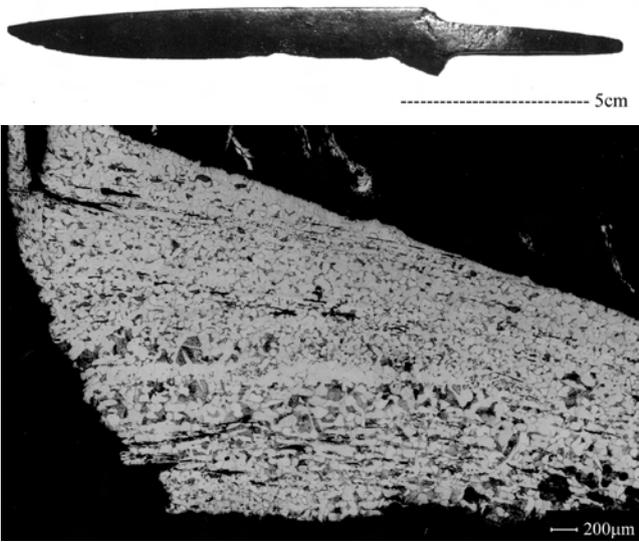
Figure JUM #15
The blade is composed of layers of iron and steel. There are elongated slag inclusions within the steel.
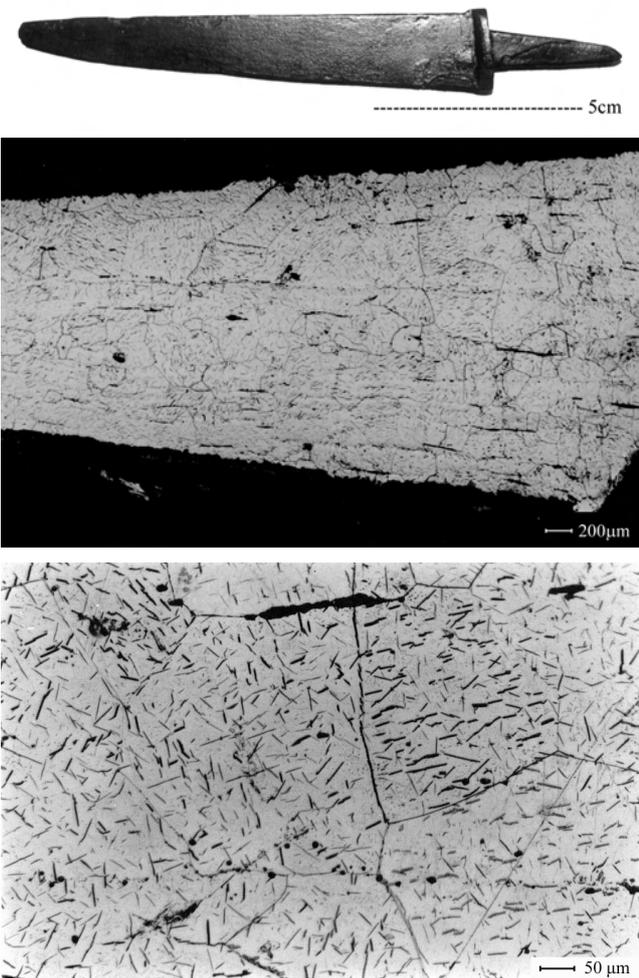

Figure JUM #16
The blade seems to be composed of iron and elongated slag inclusion. The blade appears to have laths within the ferrite grains suggesting that it is composed of a low carbon iron that appears to have been quenched.

Figure JUM #17
The knife is made of a series of layers of low carbon steel forge welded together. At the weld ?joins? pearlite has accumulated producing bands at the forge line.
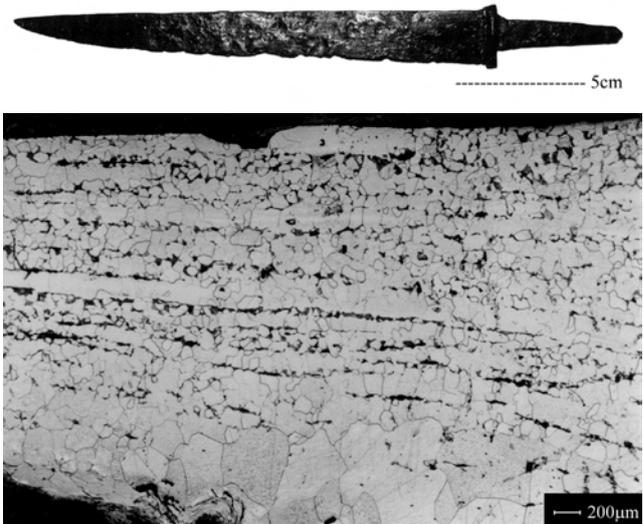

Figure JUM #18
This knife is composed of quenched martensite and lower bainite. The small lines within the grains may be nucleation points (see Samuels 1980, 329). The sample contains few non-metallic inclusions.
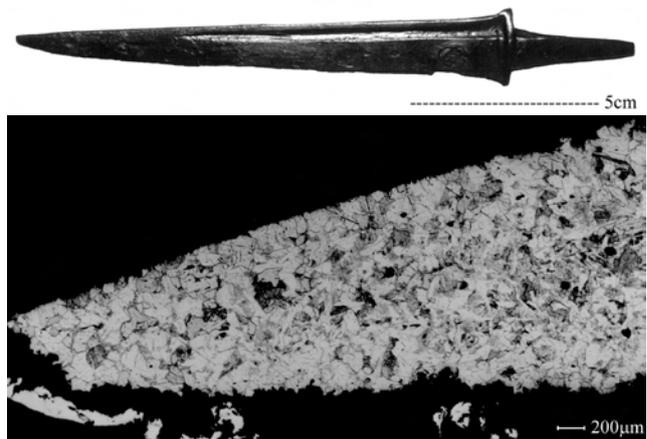

Figure JUM #19
The knife has an interesting shape containing a depressed area on one side of the blade. The other side of the blade is flat. The sample is virtually completely corroded; however an island of uncorroded low carbon steel was observed. The microstructure reveals grains of ferrite with intergranular sorbite/pearlite.