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A LURISTAN SWORD IN THE ALLARD PIERSON MUSEUM
Some metallurgical considerations*

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Introduction

In 1995, the Allard Pierson Museum was donated an elaborate iron sword (inv. no. APM 13317, Fig. 1). It is among the now nearly 90 specimens of the well-known class of such weapons which entered the antiquities market in the 1920s[1]. Literature suggests these swords may have been used either purely functionally in self-defence or show prestige. None of them comes from controlled excavations, their origin is sought in Luristan, central-western Iran. Though an estimation on the basis of typology and decoration dates them between the 11th and 7th century BC (probably near the lower limit), there are, in my opinion, some technological/metallurgical considerations to go against this widely accepted date of manufacture.

Fig. 1. Luristan sword, Amsterdam, APM 13317.

* My thanks are due to Dr. C.W. Neeft and Drs. Ron Leenheer for commenting on drafts of the text, manner and matter. J.J.M. Schepers kindly added a few last minute language corrections.

[1] For this class of swords, see especially Moorey 1971, 316-319, *s.v.* nos. 540-541; Muscarella 1989, 349-366; also *idem* 1988, 185-189, *s.v.* no. 303.

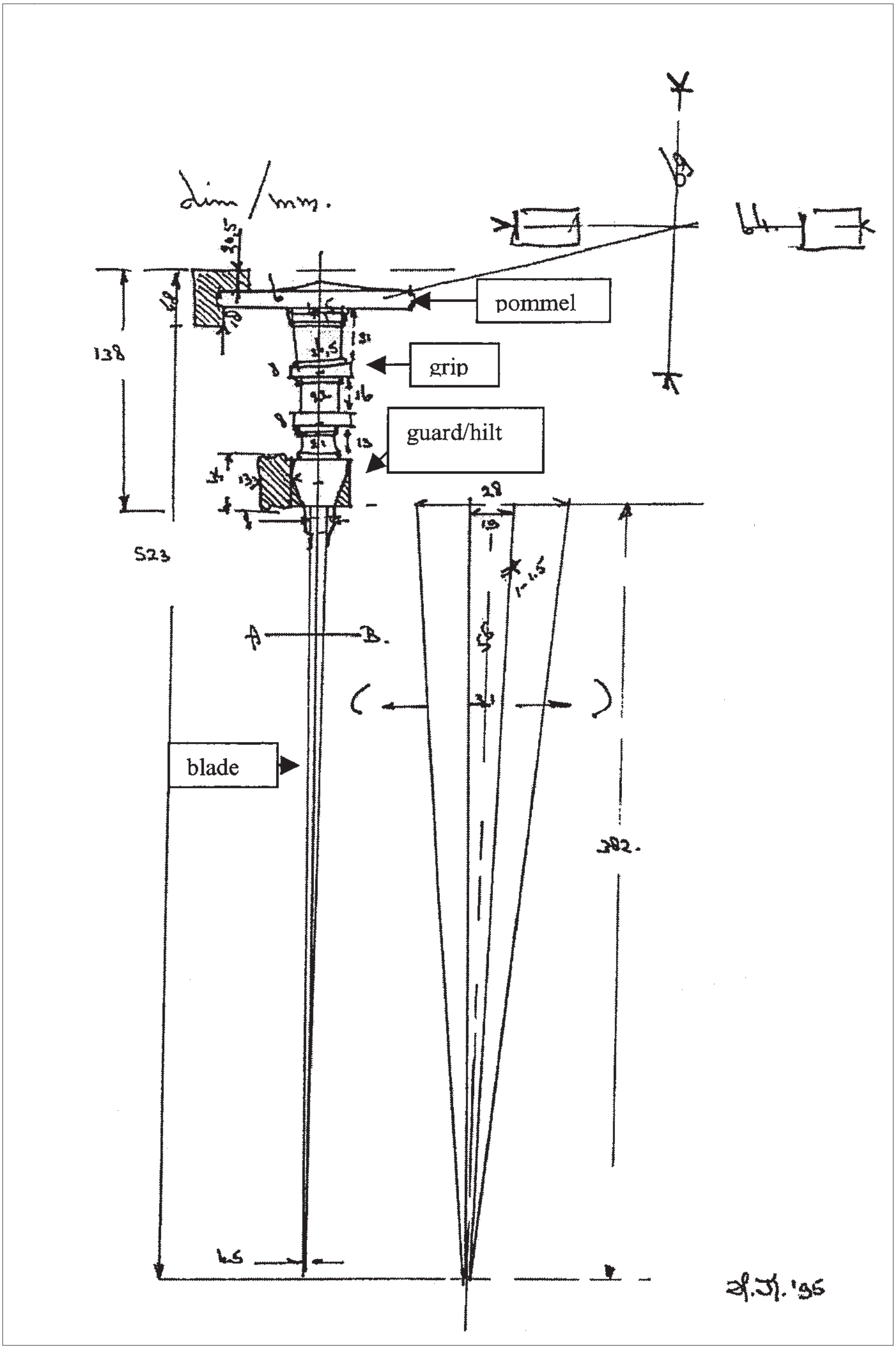

Fig. 2. The ‘Allard Pierson’ Luristan sword. Drawing APM 13317.

Dimensions	**in mm (Fig. 2)**
Total length	523
Blade	382 x 31
Centre ridge	19
Max. blade thickness	7.5
Grip length	78

Typology

Forms and decorations of the swords are clearly identical, showing them beyond doubt to belong to the same class. The swords have a willow-leaf shaped blade, set at right angles to the hilt. The hilt, in turn, has a disc-shaped, flat pommel with a pair of bearded male heads set opposite each other on the edge and parallel to the faces of the blade. The backs of the heads extend towards the centre of the pommel as lion-protomes (Fig. 3). Two rings divide the grip into three sections, the upper one wider than the two lower ones. The guard is decorated with two crouching lions, set opposite each other and parallel to the faces of the blade and facing them (Fig. 4).

Within this general typology, three variants can be distinguished.

1. The composition of the various parts is well-balanced, lending the weapon a harmonious appearance. The ornamental parts – the human heads on the pommel and the crouching lions on the guard – are meticulously formed[2].

Fig. 3.The figure on the pommel.

Fig. 4. Crouching lions at the guard.

[2] Muscarella 1989, 366.

2. The composition is well-balanced as with the first variant. Guard, grip and pommel, however, are covered with bronze sheet[3].
3. In contrast to the other variants, the composition of the weapon is incoherent, as if the various parts do not belong together. The ornamental parts are carelessly formed, at times even beyond recognition[4].

Construction method of the APM sword

Radiography[5] has shown the weapon to be an assemblage of various parts (Fig. 5), a composition earlier observed with several other specimens of its class[6]. The crouching lions forming the guard and the pair of bearded human heads decorating the pommel are caught in recesses made in the metal. Unfortunately, the radiograph does not decisively show the structure of the hilt. Whereas several seams are visible in the bands, it is not clear how precisely the bands have been applied to the grip. Nor does the radiograph ascertain the construction of the pommel, how the pommel is fixed to the grip, whether the grip consists of one piece or is a combination of several parts, and how the blade is joined to the guard.

Maxwell-Hyslop and Hodges rightly remarked that a competent blacksmith will not rely upon rivets, bands and burred edges to hold his work together, but rather use a hammer weld carried out in the hot[7]. They add: "To be blunt, seen in terms of blacksmithing these swords are a mess, and any of them could have been better made by the barbarian smith of Central Europe, certainly by the eight century BC".

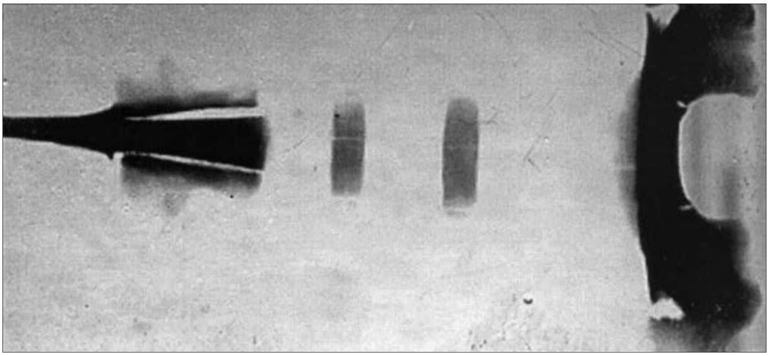

Fig. 5. Radiograph of the 'Allard Pierson' sword.

[3] Cf., e.g., Maxwell-Hyslop/Hodges 1966, pl. XLX, 4-5.

[4] As for the Allard Pierson sword, this is not caused by corrosion.

[5] I wish to take this opportunity to thank Roel Jansen for spending a lot of time listening to my questions and offering his expertise. I am also grateful to the Academic Medical Centre of the University of Amsterdam for putting their radio diagnostic equipment at our disposal.

[6] Maxwell-Hyslop/Hodges 1966, 166 (sword coll. G. Nazar Esq.); Maryon 1961, 175 (sword London, B.M. 123304) and 181 (sword Hamburg, Kunst- und Gewerbemuseum).

Effective weapon or symbolic/prestige object?

In favour of its use as an effective weapon, Ternbach pointed out that the blade is turned over 90^0 to the hilt, that the handle is designed to lie flat in the palm of the hand, and that the blade is perpendicular to the centre of the flat side of the hilt. These highly unusual characteristics led him to interpret the weapons as specially designed daggers that must have been used for stabbing, probably in an overhand thrust[8].

Several characteristics do raise serious question that the Allard Pierson sword and others of its kind has ever been used as a weapon. First of all, whereas the length of the grip of the Luristan sword in the Allard Pierson Museum is 78 mm, the width of my closed hand, of normal size, I presume, is 114 mm. This means that my hand falls partly over the guard. Also, using bar iron for a grip is not a practical, well-considered decision. Sweating hands will soon discolour the metal, while never allowing a tight grip on its smooth surface[9].

The oversized pommel does not have any practical value. A pommel of this size is functional only if a stabbing-point is attached (Fig. 6). The human heads were not made to serve that purpose. Their shape will not very effectively do the job, nor is their connection with the pommel very reliable.

The form of the guard has a decorative purpose (Fig. 7) and does not provide any protection for the hand on the grip. In using the sword as a thrusting weapon – which is what it was designed for[10] – the guard would not prevent the hand from slipping off the grip (cf. also above)[11].

Most remarkable and strongly against interpretation of the sword as an effective weapon is the decrease of the blade-width just below the juncture with the guard (Fig. 8), at the very point of maximum leverage, where the force exerted on the blade while stabbing will be strongest.

Furthermore, the weapon is completely out of balance, the weight ratio between hilt and blade being approximately 3:1, so that handling the weapon in combat would uncomfortably burden the wrist.

Finally, Pleiner acutely observed that "Der Hersteller der Klinge hatte nicht die Absicht ihre Schneide mit harterem Material zu versehen (mittels Aufkohlung, Stahlanschweißen, Abschrecken u. dgl.). Die festgestellten Angaben deuten eher auf eine Kunstschmiedearbeit als auf die Schwertfegerkunst hin"[12].

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[8] Ternbach 1964, 46.

[9] Maryon 1961, 176, suggested that the projecting collars on the hilt were filled by gaily colored coiled and plaited cords or by leather thongs. However, he does not explain why the connections between the grip and the projecting collars then would show a decorative pattern.

[10] Ternbach 1964, 46.

[11] A comparison with rapiers of the Middle Ages (Maryon 1961, 175), which were also provided with a guard – known as ricasso – is irrelevant. The rapier has a long slim blade, so that the force on the guard by an upward thrust at the abdomen or the chest is far less than the force action with the willow-leaf shaped blade of the Luristan swords.

[12] Pleiner 1969, 46.

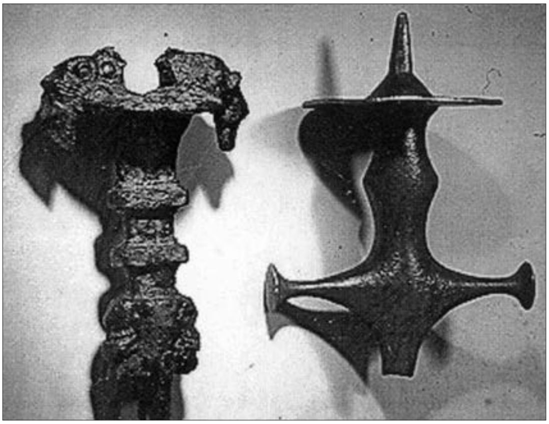

Fig. 6.
The 'Allard Pierson' pommel and a pommel with stabbing point.

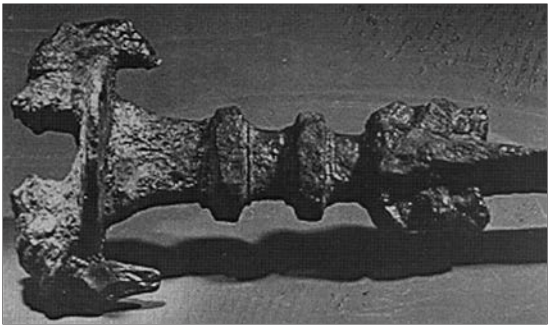

Fig. 7.
Decorative elements.

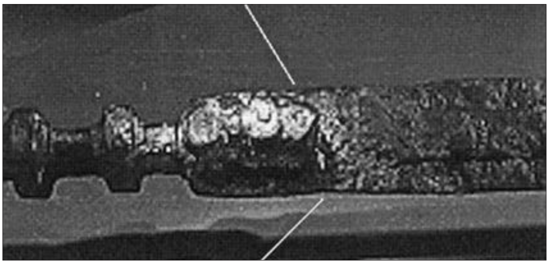

Fig. 8.
Decrease of blade-width below the juncture with the guard.

However, the interpretation as symbolic/prestige object also has its flaws. Although the weapons often are of strongly decorative appearance, their constructions do not quite sustain this. All radiographs of the swords clearly show big gaps between the crouching lions and guards, heads and pommels, bands and grips (Figs. 9-10). Also, on scrutiny, some of the welds on the Allard Pierson sword turn out to be poorly finished, while others do not show signs of hot-welding. The crude joining methods do not point to the work of a professional craftsman.
An interesting characteristic of at least some of the examples of this class of

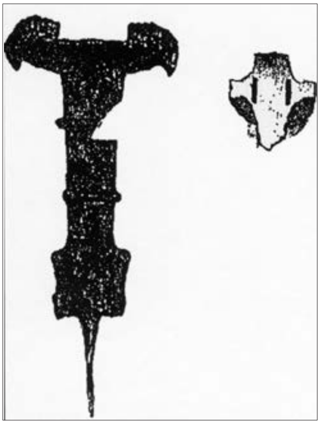

Fig. 9.
Gaps between the band and the grip (after Maxwell-Hyslop/Hodges 1966, fig. 3)

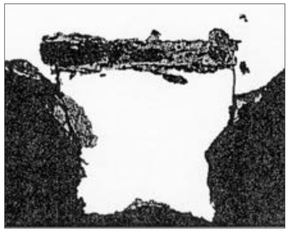

Fig. 10.
Gaps between decorative bands and grip (after Bird/Hodges 1968, fig. 6).

Luristan swords is the bronze-covering of the hilt. Apparently, this was meant to suggest solid bronze, implying that iron was no longer a prestige material at the time of manufacture of these weapons.

Vanden Berge and Muscarella have catalogued as many as 88 of these swords. This large number points to manufacture in a relative short period by workshops serving the needs of more than just merely elite.

Metallurgical examination
Most authors agree that the "Luristan" swords are among the earliest mass-produced iron weapons from the Near East[13].They have been the subject of no less than six radiographic and metallographic studies. All these examinations, but one,[14] were carried out on the pommel,[15] the grip,[16] or on the blade[17] – parts of the weapon that do not call for prime attention[18].

Metallurgical examination of the Allard Pierson sword[19]
For the study of the sword in the Allard Pierson Museum, a section was cut from the rear side of one of the two pommel-head ornaments (Fig.11).

[13] Muscarella 1989, 355; Bird/Hodges 1968, 215.
[14] Maryon 1961, 179.
[15] Maryon 1961, 177.
[16] Bird/Hodges 1968, 221.
[17] Ternbach 1964, 51.
[18] The brief examination of the top of the beard (Leffert 1964, pl. 24) yields only limited information.
[19] I wish to thank Stork FDO B.V., Amsterdam for the use of their equipment and Albert Bank for his support.

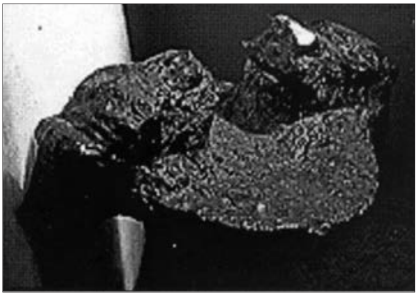

Fig. 11.
Pommel section removed for metallurgical examination.

The section was mounted in a clear methacrylate medium, grounded and polished and a photograph, 50x enlarged, was made. This micrograph (Fig. 12) shows slight corrosion on the edges only and very few inclusions. After etching the section with a 2% Nital, another micrograph, also 50x enlarged, was taken. It shows a low carbon content at the surface, increasing toward the centre (Fig. 13).
The results of the metallurgical examination of the Allard Pierson sword are in keeping with those published for other such swords. Pleiner, Bird and Hodges, and Maryon all point out that the specimens they scrutinized are made of a normalized steel, containing ca. 0.5 % carbon, with the steel decarburized from the surface to an appreciable depth[20].

To conclude, metallurgical investigations, including those of the Allard Pierson sword, have yielded the following characteristics for the iron:
- The base material is a homogeneous, normalized steel of high carbon content.
- The carbon content decreases toward the surface, which is the result of the smith's working of the surface.
- The base material shows only a small amount of non-metallic inclusions.
- Except for some occasional pitting, corrosion has only affected the surface.

Iron production and iron working in antiquity
For a better understanding, some basic knowledge of early iron technology is necessary. The melting point of iron is 1540^0 C., a temperature that could not be obtained until the use of coal in the Late Middle Ages. The only furnace fuel known in antiquity was charcoal. Therefore, iron was extracted from its ore by the so-called direct method. The silicates (melting point 1100-1150^0 C.) were melted from the ore so as to form a slag at the bottom of the furnace. The infusible part, the so-called bloom, remained. Except for a lot of enclosed slag, bloom is a remarkable pure iron of less than 0.1% carbon content.
Its carbon content determines the hardness of the iron. Increasing it will result

[20] Pleiner 1969, 44; Bird/Hodges 1968, 222; Maryon 1961, 177 (sword in the British Museum no. 123304) and Maryon, 1961, 178 (sword in the Royal Ontario Museum).

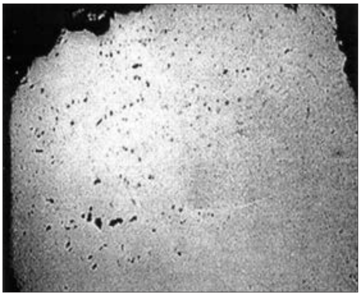

Fig. 12.
Section unetched, showing small amount of non-metallic inclusions and shallow corrosion.

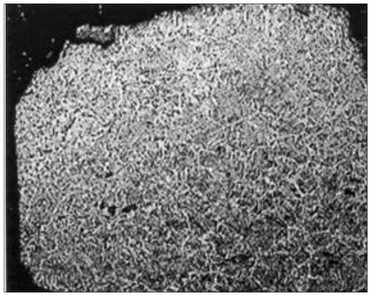

Fig. 13.
Section etched 2% Nital, showing **increase** in carbon content towards the centre.

in harder and more useful iron (Fig.14). Raising the carbon content involves a complicated method, depending on time, forge temperature, and good reducing conditions in the forge. Even when the process is well-controlled, the result will at best show a non-homogeneous carbon content, decreasing from the outside towards the centre of the object (Fig. 6).

Hardening iron

An increase of the iron's carbon content, to make a more or less homogeneous steel, can be achieved by four different methods:

1. Case hardening. This method, by which the ancient smith added carbon to iron, is known as carburization. It consists in prolonged heating of the iron above 900^0 C but below its melting-point, in intimate contact with charcoal

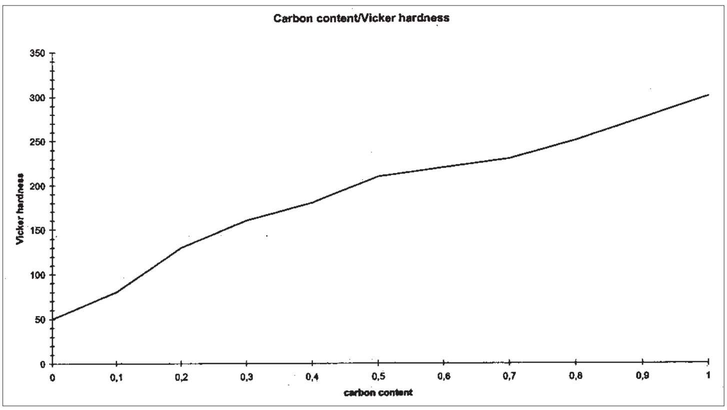

Fig.14. Correlation carbon content and iron/steel hardness.

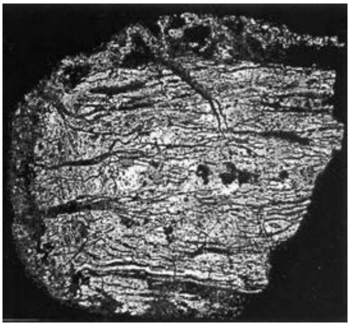

Fig. 15.
Section of a pair of iron tweezers, 7th century BC, showing the **decrease** of carbon content towards the centre, amount of non-metallic inclusions and penetrated corrosion.

and in a reducing atmosphere in the forge. Well-carburized iron will exhibit a high carbon content decreasing from the surface towards an almost carbon-free iron core (Fig. 15).

2. The 'steely ore' method. There is general agreement that 'steely ore' or steelstone is a catalyst to steel-making[21]. Wherever early steel-making techniques flourished, sphathic (siderite) ores appear to have been employed. One of these was chalybite ($FeCO_3$), described by Lazarus Ercker (16th century) as non-magnetic and coloured like a yellow spar[22]. Red and white spathic ores, high in manganese oxide (MnO), were also frequently employed. The reasons for the preference of spathic ores are far from clear. On account of the presence of magnesia, which has a strong affinity with carbon, most likely these ores have facilitated the absorption of carbon in the direct-method furnace.
3. The crucible or wootz steel method - Damascus steel.
   The Scottish metallurgist David Mushet noticed that wootz had melted from powered magnetite and hematite in small, flattish slightly convex crucibles. Wood or green leaves served both as reducing and carburizing agents, calcareous ore as a flux[23]. The content of the flattish crucibles being spread over a relatively large area in direct contact with the charcoal fire, heating was at or near its best.
4. The Bessemer process. Bessemer's first patent, dated October 17, 1855, concerns the principle of steam or air being blown as decarburizing agent over molten iron in crucibles in the furnace. To control the process better, the carbon is first removed while afterwards, by adding anthracite to the molten pig iron, its desired quantity will be effected.
   In 1864, Martin refined the principles of this process in the 'open hearth furnace', while in 1878, Thomas did so in the 'basic Bessemer process[24].

[21] Forbes 1950, 409.
[22] Ercker 1951, 287.
[23] Wertheim 1961, 194.
[24] Wertheim 1961, 289.

Each of these steel-making processes yields its specific base material with its specific characteristics:

	case hardening	steely ore	wootz	Bessemer
1. beginning/ period	12th c. BC/?	8th c. BC/?	2nd c. AD./ 16th c. AD[25]	1855 AD
2. carbon content	increasing toward surface	decreasing toward surface	mixture of carbon-poor and carbon rich iron	decreasing toward surface
3. non-metallic inclusions	high	high	low	low
4. manganese content	low	high	low	low
5. visible surface structure	no	no	yes[26]	no

Comparing the material characteristics of the Luristan swords with those of the steel-making processes:

Material characteristics of the sword	case hardening	steely ore	wootz	Bessemer
1.decreasing carbon toward the surface	—	X	—	X
2. few non-metallic inclusions	—	—	X	X
3. low manganese content[27]	X	—	X	X
4. no visible surface structure	X	X	—	X

The two comparisons will necessary lead to one of two possibilities:

1 As far back as the Early Iron Age, already a steel-making process was used in the Near East, as advanced as the Bessemer process developed three millennia later.

[25] Ypey 1983, 192. “Wootz soll schon von den Römer geschätzt worden sein, doch hat man bis jetzt noch keine römerzeitliche Klinge mit Wootz nachweisen können. Waffen aus Wootzstahl sind wohl kaum früher nachzuweisen als im 15. und 16. Jh.”.

[26] The wavy lines in the steel of the Damascene blades.

[27] Pleiner 1969, 44; Lefferts 1964, 61.

2 The examined parts of the Allard Pierson sword and of four other swords[28] were made of modern steel, showing all the characteristics of a standard production process that was in use from *ca*.1880 to 1940 AD.

Since the first possibility is highly unlikely, we should accept the second. Doing so, the homogeneous, high carbon content and the shallow selective corrosion pattern will appear logical.

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[28] Swords in Das Deutschen Klingenmuseum (Pleiner 1969, 41); private collection (Bird/Hodges 1968, 222); the British Museum (Maryon 1961, 177), and the Royal Ontario Museum, Toronto (Maryon 1961, 178).