Museum of the Terracotta Warriors
and Horses of Qin Shihuang
Lintong, Shaanxi, PR China

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“Technique and Materials of the Polychromy of the Sculptures from Qin Shihuang’s Burial Complex”

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16 January	Arrival of replicas in Munich and begin of painting in the workshop of the Bavarian State Department of Monuments and Sites. Several groups visit the workshop during this time, as Dr. Rothenpieler from the Bavarian State Ministry for Science, Research and Art (24. 1.), a delegation of South African conservators (31. 1.) or director Greipl with students (2.2.).
17 – 26 February	Visit of German delegation in China. Participants: Prof. E. Greipl, Prof. R. Snethlage, C. Blänsdorf, B. Oginski, F. Horn
20 – 21 February	Steering Committee Meeting in Xi'an (Tanghua Hotel)
22 – 24 February	Visit of the Stone Caves in Anyue/Sichuan
25 February	Meeting with Zhang Tinghao in the National Institute for Cultural Relics in Beijing
20 April	Opening of exhibition 'Xi'an – Kaiserliche Macht im Jenseits. Grabfunde und Tempelschätze aus Chinas alter Hauptstadt' in the Art and Exhibition Hall of the Federal Republic of Germany in Bonn
21-23 April	Symposium: 'Unter der Gelben Erde' in the Exhibition Hall in Bonn
21 June	Special tour through the exhibition in Bonn guided by C. Blänsdorf
23 – 30 July	Visit of a German group in China for discussion with the Chinese project partners, visit of new sites and planning of the future cooperation. Participants: Prof. E. Emmerling, C. Blänsdorf, M. Kocher
28 August	Congress organised by the IIC (International Institute for Conservation in London): 'The Object in Context: Crossing Conservation Boundaries', S. Bucher and C. Blänsdorf present their work on August 30th
31 August – 21 October	Exhibition on the project in the Bavarian State Department for Monuments and Sites ('Chinas Terrakottaarmee'), presenting all aspects of the project. The exhibition was planned in the program 'Wissensspeicher' as accompanying program of the IIC congress. The exhibition was prolonged and was also open for the events of
9 September	'Day of the Open Door' (of monuments)
21 October	'Long Night of the Museums', opening time 19 pm to 2 am
3 to 29 November	Work visit of Rong Bo and Zhang Zhijun in Munich (climate monitoring, measurements of salts in stone buildings)

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Painting technique of the polychromy of the sculptures from Qin Shihuang's burial complex, summary of the results 2001 to 2006

Preface

The investigation on the painting technique of the warriors from Qin Shihuang's terracotta army in the early years of the project mainly focussed on supporting the conservation work which was the main aspect of the research. In 1999, a group of kneeling archers was excavated in test area 21, corridor 18 (T21G18) in pit no. 2. The well-preserved polychromy could be consolidated due to the hand-in-hand cooperation of archaeologists and restorers practised here for the first time. Consolidation of all sculptures took years. Meanwhile new excavations had started on the burial complex, revealing terracotta sculptures of civil servants, acrobats, 'musicians' and bronze birds, all of them painted.

In 2001, the investigation on materials was started with the new focus to understand the painting techniques used on the sculptures. Pigment analyses were now made to get an overview on colorants, mixtures and the distribution of colours.
In 2003, the documentation of complete sculptures was started on eight kneeling archers from pit no. 2, T21G18. In the following year, the about 100 fragments of colour (so-called B-number fragments) in soil stored in the storage room of the museum could be examined. Traces of patterns found on five of them were the base of an investigation to understand and reconstruct patterns and the polychromy of the sculptures on which these patterns once belonged.
In 2005/2006 the results of these investigations were used for exemplary reconstructions of the polychromy on replicas of two selected warriors. These reconstructions were presented in the exhibition 'Xi'an – Kaiserliche Macht im Jenseits' in the Art and Exhibition Hall of the Federal Republic of Germany in April to July 2006. This exhibition clearly was one of the highlights in the history of the 'China project'. The reconstructions show the latest state of knowledge, but they are not the end of the research. Analyses on the binding medium and on one special yellow pigment are not finished yet. Properties or qualities of single pigments and typical mixtures are only partly examined. Concerning colour distributions, application techniques and prototypes for painted textiles more questions remain open than three are already answered.

This volume compiles five articles on painting technique from annual reports 2001 to 2005 and contains five new articles from 2006. These ten contributions comprise all relevant research results on painting techniques and materials from the last six years. They also show the development in this field. The earliest articles can already be revised or enlarged due to new research. A short summary and critical evaluation is given here as preface to the full texts of the articles.

Painting technique

Painting technique and painting material of the terracotta army of Qin Shihuang – latest investigations (2001/2002) describes the results of pigment analyses and observations on colours which were collected as part of the conservation work since 1999. Observations on a head of the kneeling archer from pit no. 2, T1G18 (head of fig. 08) during the consolidation work gave new insights into the painting technique. For the first time, application technique of flesh tones and details as painted eyes and hairline could be observed. It also became clear that the paint layers have to be treated with the most possible care during removal of the soil as these fine lines or thin glazes are scratched off easily.

Some of the interpretations have to be revised or corrected meanwhile. The presence of Chinese Blue ($BaSiCu_4O_{10}$) next to Chinese Purple ($BaSiCu_2O_6$) was stated by Chinese investigations on the skirt of one of the acrobats, and blue particles in violet layers found in microscopic slide preparations seemed to confirm the use of at least small quantities of Chinese Blue. Chinese Blue could never be detected by Prof. Heinz Berke in Zurich using Raman and XRD who is researching on the blue and purple barium copper silicates since years. The first conclusion from the microscopic investigations was that the Chinese Blue might be present in a too small amount to detect it with other analysis methods, especially XRD. Meanwhile it became clear that an amount of blue particles is always present in Chinese Purple as impurity of the production process. In this context it has to be stressed out that samples of the Chinese Antiquity contain remarkable few blue particles compared to modern reconstructions of the pigment. Furthermore, there are also barium copper silicon compositions which are Chinese Blue ($BaSiCu_4O_{10}$), but nevertheless bright blue as $BaSiCuO_7$. A deliberate use of Chinese Blue on objects from the QinShihuangling therefore cannot be confirmed yet.

The investigations on the unknown yellow pigment also mentioned in this article turned out to be a rather difficult subject. Also because of extremely small amounts of sample investigation are still going on. The article ‘Identification of Pigments of the Wall paintings of a Han Dynasty tomb in Xi’an’ from 2005 gives the recent states of knowledge.

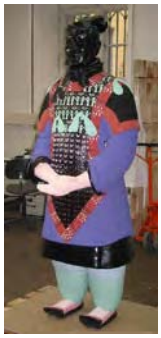
Many aspects on the painting technique touched here for the first time became subject of more profound investigations in the following year, as the questions of colour distributions, pigment mixtures and layer structure of flesh tones. Although there are some imprecise or slightly wrong descriptions – as the assumption that black was only used for smaller areas (later on it became clear that it was also used for jackets) – the observations are mainly still valid. The ongoing investigation of more sculptures made it possible to clear or revise some aspects as possible colours of the iris, but other are still open. For example the consideration if parts might be omitted or simply forgotten to be painted could not be decided yet. For a profound statement on questions as thickness of flesh tones, eye colours or typical pigment mixtures of flesh tones, investigations on a larger number of sculptures would be necessary.

For reprinting the article in this volume corrections of the English language have been made, but the contents were not changed.

New investigations on the polychromy of the terracotta army - Kneeling archers and officers with decorated borders (2004) focuses on colour schemes of whole sculptures and provides the first reconstruction of a border decorated with elaborate patterns. The article was written in German and was translated n to English for this volume.
The contribution has two parts, the first describing colour distribution in the clothes of a group of kneeling archers, the second dealing with the pattern on the armour of co-called 'chariot officers'. The investigation included nine kneeling archers, the last one just being consolidated in October 2004. The distribution of colours in the clothes and the resulting colour scheme are presented. The investigation of flesh tones showed that there are one-layered, double-layered and three layer structures and that hands and feet do not have to match the colour of the faces. For the first time, also two and three layer structures of the clothes were detected, indicating a multilayered system as well as changes or corrections. The nine kneeling archers were arranged as a group which shows the colourful, non-uniform distribution of clothes' colours.
Later investigations () showed that the arrangement of the warriors is wrong and that SH001 is not standing directly in front of the formation of the other eight. Nevertheless, the impression of bright colours in lively contrasts has not been changed by the recent – and hopefully correct – positioning of the sculptures. Also the total number of warriors in this corridor had to be corrected meanwhile (not 40, but maybe 24 warriors).
A detail result that has to be revised is the identification of charcoal black as black. The investigated sample probably contained particles from the charred wooden beams which always can be found on top of the paint layers. Recent investigations indicate the use of bone black as black pigment.
The second part of the article describes the reconstruction of a pattern from colour fragments and sketches made by the archaeologists in the 1970's. Among the 100 fragments of colour in soil, 29 were investigated. Four of five of fragments with patterns showed the same type of decoration. From documentations in colour drawings over the correct positioning to a tentative reconstruction, step by step the decoration of the borders of armour of officers with 'apron-style' armour could be reconstructed. Detail questions remain open; the polychromy of the complete sculptures has not been investigated yet. The article also describes the difficulties of documenting preserved colour fragments and interpreting them for reconstruction of the original polychromy.
Further research is planned, but not started, so the description in this article is still containing this recent stat of knowledge.

The polychromy of clothing and armours of the generals from the terracotta army (2005) is a detailed study on the polychromy of this type of warriors, especially the decorations with various patterns. The system has been the same as described for the 'chariot officers'/'apron-style' armours in 2004: Sketches of colour preserved in soil and information from the excavation reports were evaluated and combined to understand and reconstruct the polychromy. Different from the 'chariot officers' also seven of nine original sculptures could be examined what provided additional useful information. The evaluation of the excavation reports showed that information was recorded incorrect and mistakes in descriptions and also colour reconstructions can be traces back to misinterpretation of primal data. Step by step many colours and patterns could be reconstructed. The 'bird and sun' pattern on the chest of the generals was reconstructed for the first time in a correct way.
Also for the generals, parts of the reconstruction drawings remained blank and a considerable number of questions on details or whole parts of clothes could not be answered yet: There is

no information n the ties of the cap or the shoulder protection parts of or below the armour. The colour of single ornaments is not clear. The possible variation in shape and colour within a set design of pattern could not be answered yet. The possibility to link the painted patterns to textiles excavated from tombs from the Warring States to the Han Dynasty period was touched, but opens a wide field of research not entered yet.



Reconstruction of the polychromy on replicas of terracotta warriors was a project which directly derived from the research in the previous years. Practical work was started in 2005 and was finished in 2006 just before the exhibition in Bonn.

Preparing the replicas (2005) describes the work in Lintong, from the selection of types of warriors and the choice of material of the reconstruction to the lacquer coating. **Painting the replicas (2006)** is the second part of the work which took place in Munich: the painting process including the tests and principal decisions.

The idea of painting replicas in a 1:1 scale emerged as a possibility to recover the painting technique and aspects of understanding the original polychromy. The startling exhibition 'Bunte Götter' in the Glyptothek in Munich in 2003/2004 with reconstructions on replicas of ancient Greek marble sculptures was also an impetus to try something similar for the ancient Chinese sculptures.

The gypsum casts were provided by the Museum of the Terracotta Army and reworked in three weeks to obtain surfaces and detail structures fairly comparable to the originals. Two painters from the Center for Conservation and Restoration of Cultural Heritage of Shaanxi Province applied the *qi* lacquer coating serving as ground layer.

For painting, not only tests for the selection of colorants and binding media were necessary, but also essential decisions as the choice of the colour scheme, dealing with parts without any information or the aspired visual impression in regard of gloss, pureness of colours etc. Principally, the aim was to reconstruct the polychromy of individual sculptures as far as possible in a fresh, not aged state, using only materials available in the Chinese Antiquity. Nevertheless, all parts which had possessed a pigment layer should be painted, resulting rather in an 'ideal' and exemplary than an individual reconstruction of two individual warriors. This meant that a considerable freedom of decision was necessary although an orientation on comparable sculptures was attempted wherever it was possible.

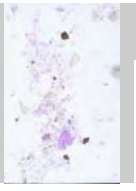
The sculptures were painted using the pigments analysed in original paint layers and a mixture of egg and skin glue as binding medium. The visual impression of the paint layers matches the one of the original paint layers. Although the degree of gloss cannot be reconstructed from the originals beyond doubt, matte or semi-matte surfaces seem to be highly probable for several reasons. Egg as binding medium of the original paint layers was analysed shortly after the decision for egg/glue as binding medium of the reconstructions and seemed to confirm the correctness of this choice. The painted replicas were exhibited in Bonn and afterwards in a small studio exhibition in Munich. They are planned to be presented again in another place soon, but difficulties with transport damages and dust still have to be solved.

From the research aspect the reconstruction of the polychromy on the replicas has solved many questions and resulted in a visual impression of two warriors which does not need corrections (yet). Nevertheless, questions remained open and are subject of the ongoing investigations.

Small archers and model of T21G18 (2006) was part of the reconstruction of the polychromy on replicas. Small replicas of kneeling archers were painted and arranged according to the formation in the corridor G18. It was difficult to find out the correct positioning of the archers and the attribution of individual archers to the positions recorded by archaeologists. The presented solution is suggested compromise. It served as the base for the construction of a box which is a storage and transport box for the eighteen small replicas and a model of G18 at the same time. Cover and walls can be removed in sections, so different views inside the pit are possible.
Eleven of the replicas are painted, showing the polychromy of all kneeling archers which could be investigated and recorded so far. The box is made of wood; the inside is painted to imitate the brick tile floor and the rammed earth walls.

Reconstruction of the polychromy of two kneeling grooms (2006) describes a first examination of sculptures not belonging to the terracotta army: The kneeling grooms were found in the ‘stable pits’ or with the ‘rare birds and animals’. The colours of two grooms were recorded and for two grooms the colour scheme could be reconstructed in a drawing and on small scale replicas. The investigations showed that robes are of the same type as can be observed on the generals. The neckline is decorated with coloured borders.

Plastically applied decorations –technique and reconstruction tests (2006) presents three different groups of sculptures where these special decorations have been used: the skirts of the acrobats, the disc pendent of the charioteer of bronze chariot no. 1 and the bronze birds. The technical realisation was reproduced on black panels, discovering that it is possible to achieve raised decorations with different kind of brushes and a paint mixture on the base of egg and skin glue. There are some ideas what kind of materials these decorations imitate on the acrobats and the bronze chariots, but no definite solution yet. The plumage of the bronze birds technically is the most difficult type of decoration to realise. The reconstructions showed how it might be done, but also how extremely careful and realistic the original plumage had been carried out.



Material analyses

Identification of pigments of the wall paintings of a Han Dynasty tomb in Xi’an (2005) is part of the ongoing research on pigments and painting techniques of the Antiquity in the Xi’an area. Investigations focus on sculpture polychromy, but the unusual bright colours of a Han Dynasty tomb in Xi’an was the reason for investigations on a pictorial layer of a mural.

Xia Yin from the Museum of the Terracotta Army is doing pigment analyses of paint layers of all kinds of objects and all periods all over China. He mainly uses polarised light microscopy (PLM) which is useful, but limited to materials where standard samples exist and which are distinct in their properties.
Two pigments from the Han Dynasty tomb paintings could not be identified with PLM. The yellow pigment very much resembles the still unidentified yellow from the terracotta army. This was the reason to start further investigations during a work stay of Xia yin in Germany. The pigments could be investigations with Raman spectroscopy and micro-XRF by Susanne Greiff in the university in Mainz as well as the Roman Germanic Central Museum. The purple pigment could be identified as Chinese Purple with Raman spectroscopy.
The yellow pigment sample from the Terracotta Army was too small for analysis, but the yellow and orange samples form the Han Dynasty tomb was identified as lead-vanadium composition, probably vanadinite ($Pb_5[(Cl/VO_4)_3]$). Vanadinite is also suspected to be the material the yellow pigment of the Terracotta Army consists of, an assumption which could be supported by a SEM element mapping which proofed that the yellow consists mainly of lead with some vanadium and chlorine.
In 2006 the same pigment could also be identified in fragments of paint layer in soil form small terracotta figurines from a Sui Dynasty tomb near Xi'an (591 AD). This finding strengthens the assumption that the vanadinite was found in local quarry where lead ores were mined during the antique times. Further research is planned on this pigment.

The binding medium of the Terracotta army polychromies (2006) describes the result of the first successful attempt to determine the binding medium in the pigment layers of the terracotta army and other painted burial objects from the tomb area of Qin Shihuang. The analyses were carried out at the University of Pisa by Maria Perla Colombini and Ilaria Bonaduce.
The chemical characterisation was performed through an analytical procedure based on a purification method (which until now had only been used in proteomics), followed by microwave assisted acidic hydrolysis and by GC-MS analysis. The combination of molecular biology technologies and analytical chemistry methods to archaeological science permitted to identify the binding medium in paint layers from terracotta warriors and a white bronze swan as egg.
Parallel to this investigation, the paint layer of a black bronze bird restored by the conservators of the Roman Germanic Central Museum was analysed in the Doerner Institute. Also here, the binding medium was identified as egg. Tests with different kinds of binding media carried out in preparation of the painting of the replicas however suggest that there should be another component serving as thickener and reducing the fatty amount of the medium. Analyses to identify this possible second component in the binding medium are carried out in the moment.
The use of egg as binding medium was not known for ancient China. Therefore the result of the analysis is important not only for the Terracotta Army, but also for the research on ancient Chinese painting techniques.

Year 2001/2002

Painting technique and painting material of the terracotta army of Qin Shihuang – latest investigations

C. Blaensdorf

The conservation of the polychromy has been the main aspect since the beginning of the "China Project". During conservation, also some information about the painting technique and materials has been complied. Since 1999, also pigment samples from the new findings form the burial complex are included, as the acrobats, civil servants and bronze birds. The aims of the investigation are to get an overview on the colorants used for the polychromy and to enlarge the knowledge about the painting technique.

1 Colours and colorants of the terracotta army and terracotta figures from the burial complex of Qin Shihuang

Eight different colours have been found so far on terracotta figures from the Terracotta Army and the burial complex of Qin Shihuang: Blue, green, violet, red, pink, white, yellow, black. Blue, green, red, violet, pink and white are the most frequent colours. There are used in different shades, as dark and light or with reddish or bluish tinges. Yellow is very rare. Black was only seldom used as colour for a whole area. The Qi-lacquer replaces dark brown or black. Table 1 gives a survey of the colours and their shades.

colours	nuances, shades	predominantly used for
blue	light blue (sky blue) darker blue	robes, trousers, leg guards
green	light green dark green	trousers, robes, buttons, leg guards
red	orange orange-red bright red cherry red brownish red	buttons straps on armour and caps, laces straps, hair ribbons, caps/headscarves, robes trousers robes
violet	reddish violet bluish violet light violet	robes collars trousers, laces, leg guards
pink	almost white to reddish pink orange-pink	 robes, i. e. buttons
	many different tones from very pale (almost white) to reddish-brown; mostly bright pink	flesh tone
white	different shades ?	clothes, some caps, trousers
yellow	ochre bright yellow	decoration of sleeve (?), caps of cavalrymen ? B-0107, origin unknown (clothes ?)
black	--	decorations, eyes, some caps; black part of skirt of acrobat no. 3
brown/black	lacquer: medium to almost black	hair, shoe soles, armour plates

Table 1. Survey on colours of the terracotta figures

The shades of colours have used intentionally for artistic reasons; they are not resulting from changing qualities. This can be observed, for example, on a fragment of a hemline decoration preserved in the soil with two reds (dark and light) next to each other (F-014/98; fig. 1) or on a figure with several red nuances next to each other: Bright red was used for the straps of the

armour, a paler orange-red for the small button-shaped stitches and a reddish-brown red for the robe (see. fig. 2).

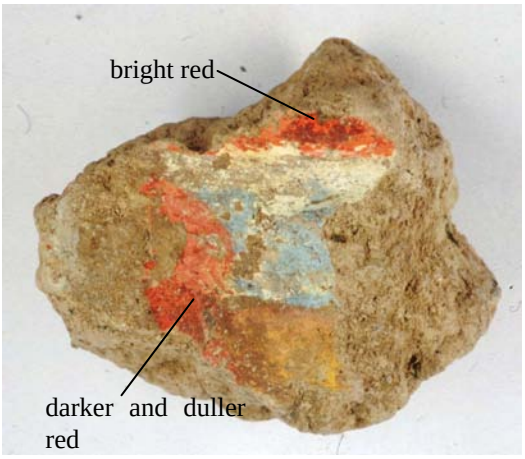


Fig. 1. F-014/98: Polychromy of a hem decoration (?), preserved in soil, with two different shades of red

Fig. 2. Reconstruction of a warrior from pit no. 2 with three shades of red: reddish-brown robe, bright red armour straps and orange red stitches

There are more than 15 different nuances of colours. A detailed investigation on the use and distribution of the colour shades was never carried out, maybe because of the problem of conserving the colours. The conservation of complete polychrome sculptures which is possible since 1999 opens new options for studying the polychromy.

Pigments

The analyses of pigments performed in the last years have mainly confirmed the range of materials already identified in the 1990s. This could mean that the palette and the most common mixtures have been identified now. One exception is the use of Chinese Blue (Han Blue) which was confirmed for the first time in 2000.

Twelve different pigments have been identified so far: Lead white, bone white, kaolin; yellow ochre; cinnabar, red iron oxide, minium; Chinese Purple, Chinese Blue, azurite, malachite, and carbon black. The pigments have been used pure or in mixtures. Calcium carbonate, dolomite, aluminium silicates, quartz, barium sulphate, a low amount of iron oxides and kaolinite are found in most of the samples and can be identified as parts of the surrounding soil which is always present in pigment samples.

Table 2 gives an overview of the pigments identified so far. Articles by Chinese authors from the 1980's and early 1990s also mention other materials as lead thiocyanate, dolomite, umber and ultramarine.[1] Lead thiocyanate was not found in analyses carried out within the project. The colourless, unhealthy material is not known as a pigment. The mention of ultramarine is clearly a mistake: There are no lapis lazuli (ultramarine) deposits in China; the pigment ultramarine was imported to China together with Buddhism from Central Asia[2]; there is no evidence that it had ever used before.

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1 Qin Shihuangling bingmayong keng. Yiaho keng fajue baogao (Excavation report of pit no. 1, 1988), appendix 2, p. 330-340 - Qu/Cheng/Wu 1991. - Jiang Xuanyi, Zhongguo kuina cailiao shi (History of pigments in the Chinese Art of Painting, Shanghai 1984), p. 119-120

2 The use of ultramarine in China is closely linked to Buddhism. The Chinese word for ultramarine, *fo qing* (佛青 Buddha's Blue), comes from the blue-painted hair of Buddha statues.

Name (English, German, Chinese)			formula	analyses within project	reference
white 白					
lead white (cerrussite and hydro cerrussite)	Bleiweiß (Cerrussit)	白 铅 矿	$PbCO_3$ $Pb_2CO_3Pb(OH)_2$	PLM, XRD	1
bone white (apatite)	Knochenweiß (Apatit)	磷 酸 钙 磷 灰 石	$Ca(PO_4)_3OH$ $Ca_3(PO_4)_2$ $Ca_5[(F,Cl)/[PO_4)_3]$ $Ca_5(PO_4)_3(OH)$	PLM, XRD	3 (IR) 3 (XRD)
(calcium carbonate)	(Calciumcarbonat)	（碳 酸 钙）	$CaCO_3$	XRD	
bariumsulfate (baryte)	Bariumsulfat (Baryt)	重 晶 石	$BaSO_4$		1 (XRD ?)
kaolin (China clay)	Kaolin (Porzellanerde)	高 岭 石	$Al_2Si_2O_5(OH)_4$ (kaolinite)	PLM, XRD	
yellow 黄					
yellow ochre	gelber Ocker	黄 赭 石	Fe_2O_3	PLM, XRD	1
?	?	铅 黄	PbO (with vanadium)	PLM, XRD	
red 红					
natural cinnabar	natürlicher Zinnober	朱 砂	HgS	PLM, XRD	
red iron oxide (hematite)	rotes Eisenoxid (Hämatit)	赤 铁 矿	Fe_2O_3	PLM, XRD	1
red lead	Mennige	黄 丹	Pb_3O_4	PLM	3 (in pink)
purple 紫					
Chinese Purple	Chin. Violett	汉 紫	$BaCuSi_2O_6$	XRD, EDX, PLM, Raman	
blue 蓝					
azurite	Azurit	石 蓝	$2\ Cu_2CO_3\ x\ Cu(OH)_2$	PLM, XRD	
Chinese Blue	chin. Blau (Han Blau)	汉 蓝	$BaCuSi_4O_{10}$	XRD, EDX, PLM, Raman	
green 绿					
malachite	Malachit	石 绿	$Cu_2[(OH)_2/CO_3]$ $Cu_2(OH)_2\ x\ CuCO_3$	PLM, XRD	1,2
black 黑					
carbon black	Pflanzenschwarz (schwarze Tusche)	黑墨	C		2
pigments mentioned in earlier articles					
dolomite	Magnesiumcarbonat, Dolomit	碳 酸镁	$MgCO_3$	---	1, 3 (in pink)
lead thiocyanate	Bleithiocyanat	硫 氰 酸 铅	$Pb(SCN)_2$	---	1, 3 (in pink)
aluminium oxide	Aluminiumoxid	氧 化铝	Al_2O_3	---	1
magnesium aluminium sulphate	Mg-Al-silikat	硅 酸 镁 铝	$SiO_2\ x\ Al_2O_3\ x\ MgO$	---	1, 3 (in pink)
umber	Umbra	棕 土	contains Fe_2O_3, Mn_3O_4, Al_2O_3, SiO_2	---	2
ultramarine	Ultramarin	佛 青		---	2

1 Qin Shihuangling bingmayong keng. Yiaho keng fajue baogao (Excavation report pit no. 1, 1988), appendix 2, p. 330-340 (Results in table 4 do not correlate to XRD-graphs in table 1. Not clearly able to identify: baryte, Bleithiocyanat).
2 Qu/Cheng/Wu 1991
3 Jiang Xuanyi, Zhongguo kuina cailiao shi (History of pigments in the Chinese Art of Painting, Shanghai 1984), p. 119-120

Table 2. Pigments determined in the polychromy of terracotta warriors, 1991- 2002

1.1 Use of the pigments

White

Larger white areas are not found very often on the terracotta army. White button-shaped stitches on armours have been found, white caps and some white jackets.[3] There are white areas in decoration of hemlines. An acrobat from pit K9901, fig. no. 3, wears a skirt with black and white areas decorated with a fine geometrical pattern, always in the opposite colour: the same pattern appears black on white and white on black.
For most of the investigated white areas ***bone white*** was identified. Only few samples from the terracotta have been analysed so far. Bone white was found in the white skirt of acrobat no. 1[4] and a sample from a crane's feather[5] from pit no. 7. Bone white was also found in the almost white flesh tones of some of the acrobats.
The white part of the decoration of a hem in F-014/98, however, contains pure ***kaolin***. Smaller decorations as the white geometric patterns on the black part of the skirt of acrobat no. 3 are not analysed yet.
Maybe bone white was the general material for larger areas that should be painted white, while for smaller white areas and white patterns also other colorants could be used. If the slight differences in tint were also used on purpose could not be determined yet.
Lead white was not found in pure white areas, but only as component in pink shades.

Yellow and ochre

It is remarkable how little yellow or yellowish tones have been used. This must have artistic or iconographic reasons. There is only one fragment of unknown origin exhibiting a yellow pigment layer below a pink one (B-0107, see: *Annual report 1999*). The yellow pigment could not be determined yet. Its main component is lead, but its optical properties do not correspond to massicot or litharge (PbO, yellow lead oxide). It is also strange that it had been overpainted again or only served as underground for a pink. This probably means that it was invisible in the final situation. Further interpretation is difficult as the origin of the sample is not known. As lead white and minium have been found, it seems reasonable that also the production of massicot was known in the Qin period. Another well-known and often used pigment was orpiment (As_2S_3) and Mr. Zhang Zhijun from the Museum of the Terracotta Army therefore had the assumption that the yellow of the fragment B-0107 was orpiment. This assumption proved to be wrong as no arsenic or sulphur could be detected in the layer.
There also are only few ochre-coloured areas: One example can be found on the soil lump 014/98, shown in fig. 1, where light ***yellow ochre*** ("gold ochre") had been used. The iron oxide is very pure, homogenous in size, fine-grained and amorphous. The reddish-brown iron oxide added to the colour of some robes, has a similar quality. This means that the earth pigments had been prepared very carefully. The rare use of ochre and brown is surprising as these colours of course were most available and the cheapest pigments: The loess soil is yellow ochre with reddish-brown varieties in some regions of the hills south of Lintong. In some early texts of 1980's, gilded areas are reported. This could not be confirmed.

Red

Red is one of the most frequent colours on the terracotta army: There are bright red caps, straps and stitches on armours, ribbons and laces, reddish robes, trousers and shin protection,

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[3] The meaning of white as colour of death and mourning as nowadays was not common in Ancient China, but white cloths might have been reserved to special aspects or functions..
[4] Analysed by XRD in China; see Research report from the Museum of the Terracotta Army 1999, p. 202, 214.
[5] Analysed in Munich using PLM.

as well as red decorations of all kind. All red areas contain ***cinnabar***. There are at least three shades of cinnabar, a matt looking rather dark variety, a bright red and an almost orange one. In the reddish-brown of the robes of several warriors in pit no. 2, a fine, homogenous ***bright red and brown iron oxide*** was added. The colour partly has a brownish-violet tinge.
Minium was only found in very small quantities and only in pink mixtures of flesh tones.

Blue

Blue is also a very wide spread colour, used for jackets, trousers, shin protections and decorations. There is dark blue and light blue. All investigated blue areas contain only ***azurite***. Some green, brown, black and white particles can be regarded as impurities. The dark blue and light blue colour might be due to quality and preparation of the azurite.
Chinese Blue was only found in purple mixtures (see below).

Green

Green is a very widely used in the terracotta army. It was the most frequent colour on all parts of clothes on the more than 1000 warriors examined in pit no.1 in 1984. For green always ***malachite*** has been used. The particles appear rather coarse. Single particles with another colour are probably impurities.

Pink

Pink can be found as colour for clothes and as flesh tone. There are at least two or three different pink shades for clothes. Various shades of pink have been used for the flesh tones. They depict different types of complexion, from pale to sun-tanned, maybe also indicating age, region of origin, ethnic groups or moods.
All pink mixtures consist of white and red. The small amounts of ochre, brown or black in the samples probably are no deliberate addition, but part of the adhering soil.
The pigment layers of ***pink clothes*** mainly contain ***bone white*** and ***cinnabar***. There are also mixtures containing white pigments: One sample contains ***quartz*** or ***kaolin***[6] instead of bone white. A pink pigment layer on top of a blue layer contains ***lead white***.[7]
The pink layers of the ***flesh tone*** vary in composition and they are different from the pink of the clothes. Often the flesh tone consists of two layers with a considerable difference in colour. Mostly the pigments are ground very fine, especially the cinnabar. As pigments mixtures mostly ***bone white*** and ***cinnabar*** was found in varying proportions so the colour ranges from pink to almost white. Quite often there also mixtures containing ***lead white*** additionally to bone white[8]. The strange grey colour of the white top layer of sample 1/2002 might be caused by discoloration of the lead white or soot from the fire. In two cases minium has been found in the lower pigment layer. There can be also small quantities of other colours added as ***malachite***[9] or ***Chinese Purple***[10], maybe giving variations of shade (list of determination results on flesh tone samples: see table in appendix 2).

Purple

Purple is also a popular colour for clothes. There are several shades; all of them are mixtures of pigments. They always contain ***Chinese Purple (Han Purple)*** and varying quantities of

6 Samples from fragments F-001/2000 and F-003/2000.
7 Sample 008.2.1/92, PP L 7. As the origin of the polychromy preserved in the soil cannot be reconstructed, the pink could have been part of a hem decoration or belong to the flesh tone.
8 Fragments F-003/91, 005/91; pink top layer of F-006/91 and of F-005/92.
9 Sample 6/2000
10 Pink top layer of F-005/92

azurite, cinnabar and ***bone white*** or ***lead white***. Depending on their proportion, the colour varies from almost blue (containing more azurite) to almost pink (containing more cinnabar). All examined samples from the terracotta army contained larger quantities of lead white and were of light colour. A dark violet was not observed during the investigations. On the skirts of the acrobats no. 2 and 3, bone white was detected instead of lead white.[11]
Recently also ***Chinese Blue*** has found in some purple samples (see table 3). The proportion of Chinese Blue is always much lower than the one of Chinese Purple. Probably Chinese Blue is found in the darker purple samples. The examined samples come from the purple sleeve of warrior no. 6 in pit no. 2, T21G18 and from acrobat no. 3.
Comparable purple mixtures have been found in paint layers from burial objects of Han Jingdi's tomb (died 141 BC) Yangling. Two blue samples examined in 2001 contain azurite, some Chinese Purple and some phosphorite ($Ca_3(PO_4)_2$) or apatite. Main colorant is azurite. The purple sample contains Chinese Blue besides Chinese Purple, as well as some cinnabar and lead carbonate.[12]

preparation no.	from sample no.	dsecription	method	result
PP L 108	5/2002	pit no. 2, T21G18, warrior no. 6, sleeve, violet partly a thin white layer underneath the thick violet layer lower layer, yellowish white	PLM	- lead white - cinnabar - (Chinese Blue and Purple, black) - (soil, lacquer flakes) - (iron oxide (from soil ?))
PP L 109	5/2002	pit no. 2, T21G18, warrior no. 6, sleeve, violet top layer, violet	PLM	- Chinese Purple - Chinese Blue (less than purple; 3-7.5 µm) - 1 particle azurite - cinnabar, coarse (15-20 µm) - lead white
PP L 110	7/2002	pit no. 2, T21G18, warrior no. 6, sleeve, violet 1 layer: at 40 x magnification violet and red particles visible lower violet layer	PLM	- Chinese Purple - Chinese Blue (2 particles) - cinnabar, coarse (15-20 µm) - lead white
	PS-006/99	acrobat no. 3 (skirt ?) from pit K9901	XRD	Research Report of the Museum 1999, p. 214
Y 1 PP 2	Y 1 PP 2	Yangling, pits of burial gifts. loose flake from an object, details of origin are unknown	XRD Raman [1]PLM	- Chinese Purple[1] - Chinese Blue[1] - lead carbonate ($PbCO_3$) or basic lead carbonate ($PbCO_3 \bullet 2Pb(OH)_2$) - some cinnabar[1]

Table 3: Determination of Chinese Blue in samples from Qin Shihuangling and Yangling

Black

Black is used in smaller areas and fine lines: There are black geometrical ornaments on the borders of armours and on the belts. In the faces moustache, eye brows, pupils and hairline are painted with fine lines. One of the few pieces of clothes with black ground is the skirt of acrobat no. 3 which is partly white and partly black and totally covered with fine geometrical patterns. Analyses indicate ***carbon black***, which was also used for making black ink.

11 Samples from the acrobats have been analysed by XRD in China. The samples from the terracotta army in Munich.

12 The identification was made by PLM (Munich), XRD (Xi'an) and XRD / Raman (Zurich, *see: Appendix to this text*).

2 Painting technique

2.1 Application of the polychrome layers

The binding media of the pigment layer could not be determined, probably because it had been an aqueous binding media that has decomposed in the humid environment or migrated into the soil. Some information about the painting process can be obtained from the structure and thickness of the pigment layers:

The colours have been applied in rather thick layers and with paint brushes. Often the fine relief of brush strokes are still visible. On fragments from a reddish brown robe also on larger areas no beginning of strokes could be found: On F-002/99 the brush strokes are very well visible (fig. 3 and 4). As all marks of brush hairs run perfectly parallel without overlapping or changes of directions, the paint brush must have been more than 10 cm in width. On the faces the direction of the brush strokes follows the modelling of the terracotta surface. This can be observed for example on the ears (fig. 10) or around the eyes.

The visible brush strokes are part of the surface structure and the artistic impression. For example, they seem to support the impression of textiles in the clothes. The use of broad paint brushes also refer to a mass production where large quantities of figures had to be painted. The observations on the pigment layers allow drawing some conclusion on the painting process: The paint was applied in a single quite thick layer. There are traces of broad paint brushes used for the robes and other large areas. Smaller ones were used for the connecting straps and stitches of the armour: the rows of red straps have been painted with one single brush stroke each, the little stitches with one single dot of paint. The consistency of the paint must have been rather viscous and fast-drying without loosing much volume.

It is noticeable that the thickness of the pigment layers varies in the different pits. While the thickness seems more or less uniform in the pits of the terracotta army, it is thicker on the acrobats, but thinner on the robes of the civil servants in pit no. 6. On the latter the polychromy appears to be also less careful and detailed, while the heads have a thick double layer of flesh tone and are carefully painted.

On some objects white paint has been used to influence the surface structure: On the shield of the bronze chariot no. 1, the white is applied in little dots. On the bronze cranes the thick white polychromy is modelled to imitate feathers, depicting the quill with a ridge and the feather structure with fine brush strokes departing from it. This kind of surface structure with a painting material reminds of the use of *pastiglia* in Europe. Pastiglia was used as raised decoration, applied with a paste of white ground layer during the preparation o the gesso ground. It normally consists of the same or a similar mixture as the gesso ground itself, what means animal glue and calcium carbonate (chalk) or gypsum.

The colour seems to have been always matt, what also an indication for the binding media, because it excludes the use of lacquer, drying oils and resins.

In 2002 an attempt was made to reconstruct the polychromy schematically on a lacquered terracotta tile.[13] As models for the reconstruction served a fragment of an armour (F-004/00) that was stored in Munich during that time (fig. 5 and 6) and a colour picture of a richly decorated border of a general armour (fig. 7 and 8). Peach gum was used as a classical Chinese binding media for paintings. Already a thin pigment layer covered the lacquer sufficiently and gave a bright impression, but the peach gum does not allow applying thick layers. To reach a thickness that is still much below the original one, at least three layers had

13 The reconstruction was made by Barbara Emmer in March 2002.

to be applied on top of each other. A thicker application was difficult without dissolving the first layers again. Brush strokes are not visible. *Pastiglia*-like structuring of paint is not possible with tree gums which are more suited as a binding media for water-colours.

2.2 Flesh tones

The conservation work on a head in autumn 2002 gave the opportunity to study the painting techniques closely. The course of the work can be reconstructed as follows:

- the head was coated with lacquer together with the body of the figure
- the thick pink flesh tone was applied
- details as the hair line, moustache, eyebrows and eyes were carried out in black and the hair tie was painted red.

This face shows only one pigment layer of rather light pink. More often, the faces and sometimes also the hands have two pigment layers of different colour. Often the second layer seems to have a lighter pink or almost white tint – a proceeding which appears comparable to the structure known in European paintings and sculptures for achieving a realistic impression of skin - but there are also examples where a white layer is below a darker pink one.
There were several suggestions for expalining the double pigment layers of different shade: One idea was that the dark lacquer underneath requires a thicker application for the light colours. This seems wrong because light pink colours in the robe have a “normal” thickness and also the reconstruction showed that it is not necessary to apply light colours much thicker than dark ones. Another idea was that heads and hands might have been painted separately in kind of a mass production using a ground shade that than had to de differentiated to match hands and faces. This could also be proven to be wrong, because they have been lacquered and painted together with the bodies: The lacquer shows a priming barb at the throat where it touched the collar. This can be observed clearly on the head treated in 2002 (fig.9).
The paint layer is applied rather thick with visible brush strokes (see fig. 10). The pink flesh tone followed the hair line roughly and also covers the beginning of the parting on the hair in the centre of the forehead. The centre of the eyes might have been omitted as it was supposed to be black. The thick layer covered fine surface structures of the terracotta as the thin, incised lines indicating the moustache. The hairs of the moustache were painted again on top of the pink paint layer. The painted lines do not follow the incised (fig. 13). Moustache and hairline have been painted with very fine black lines. It looks as if a rather hard, flat and almost dry paint brush had been used (fig. 11). Iris and pupil are not differentiated in colour. This is very frequent on the terracotta army, though there seem to be sculptures were the iris is not as dark as the pupil. The black of the eye is clearly painted on top of the pink around the margins of the iris, but there seems to be no pink in the centre of the eye (fig. 12).
On the face of the head/2002 the surface is darkened by adhering soil and flakes of polychromy that belonged to another part of a figure, as the greenish blue spot above the right eye (see fig. 12) and the bright red spot on the left cheek. However, the cheeks and ears seem slightly redder than forehead, sides and neck. A realistic differentiation of shades in the faces was assumed on other figures before as the civil servants and some figures form pit no. 2, but the damages of the surface caused by the removal of the adhering soil and as well as discolorations by remaining soil and soot make it difficult to reconstruct the colour of the original surface.[14] The double layer could have given a possibility of coloured modelling of the flesh tone. This kind of technique is very common in Europe, but it seems not to be known in China so far: Sculptures as well as painted figures on murals or scrolls do not show a “natural shading” of flesh tone produced by overlying half-transparent layers. Usually the

[14] Often the paint layers are thinned on the elevated parts as cheeks, nose tips or forehead. If there is a two-layered structure with the darker pink covered by a light pink, this results in a more reddish tinge of these areas. Though this appears realistic, it might be an artificial effect caused by the loss of the original surface.

whole face is painted with pink without any differentiation. Eyes, eyebrows and maybe moustache or nostrils and lips are applied graphically with single lines. Cheeks might be highlighted with red circles.

Eyebrows and moustache are dark grey today, but this might be a discoloration. It is remarkable that no traces of red could be found on the lips. On other figures the lips are red, but the moustache is not painted. It looks as if they had just been forgotten by accident. The white of the eyes is just painted pink – not very disturbing on a face with a light pink flesh tone. For the same reason, on light pink hands the fingernails sometimes are not painted white.
This kind of execution of the flesh tones seems to reflect the manner of a very efficient, time-saving work, carried out by well-trained artisans, combined with care about little details.

3 Conclusion

The palette of the pigments used for the polychromy of the terracotta army and other sculptures from the burial complex of Qin Shihuang is mainly known. New investigations still reveal divergent mixtures and new findings concerning the painting technique. These differences might be explained by artistic intentions which are only partly understood so far. For the interpretation an investigation on much more figures would be necessary that has not been carried out systematically so far.

Also the influence of mass production has to be concerned. There might have been a larger number of workshops and artisans involved which favoured different materials and techniques. Some differences might be also explained by economic reasons: Maybe cheaper pigments or mixtures with cheep materials have been used for large areas, reserving the expensive pigments for small areas and decorations.

Overall, the use of pigments and the technique seems so homogenous that there must have been a well organised plan for the polychromy. Probably there was a model for the technique that had to be copied. Pigments and painting materials might have been bought in large quantities and supplying the artisans according to their actual need.

Also the recognisable course of the painting process seems to reflect a mass production and a rationalised strategy carried out by well-trained artisans: There were paint brushes exactly of the right size, making it possible to apply paint with only one strike. There are hardly any mistakes visible and no corrections were made. On the same time, many details are carried out carefully and with a feeling for the small accents that give the sculptures a vivid expression, as the finely painted hairline or the accuracy in painted decorations.

The binding media is still not determined by scientific analyses. However, conclusions are possible form the type of ageing and the way of application: It must have been an aqueous medium, resulting in matt surfaced pigment layers. The binding media allowed to apply thick layers and dried fast, so the brush strokes remained visible and there are no drops of run-down colour.

Reconstruction tests showed that peach gum seems not suited. Another possibility would be glutin glue made from bones, skins or fish bladders. Animal glue is also a traditional binding media in China. It is in use to paint sculptures until today. A reconstruction using animal glue is planned.

Figures

Fig. 3. F-002/99, detail of visible brush strokes, h. ca. 3 cm

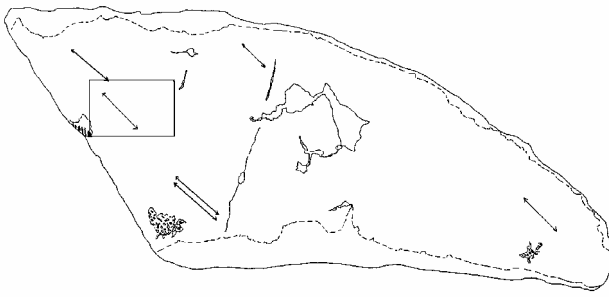


Fig. 4. F-002/99, max. size: 23.5 x 9.5 cm. The arrows indicate the direction of the brush strokes; the square indicates the area shown in fig. 3.

Fig. 5. F-004/00 after conservation of the polychromy. Most of the lacquer is already missing.

Fig. 6. Reconstruction of the polychromy of F-004/00 on a flat terracotta tile

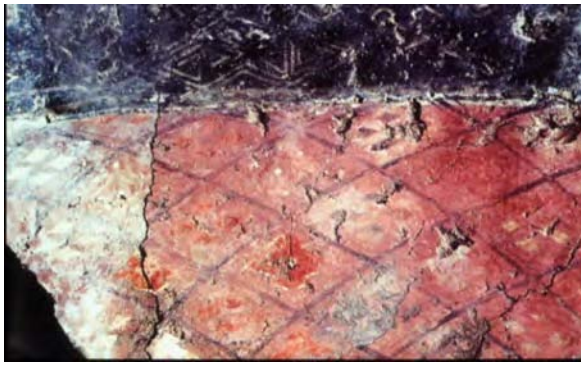


Fig. 7. Picture of a border of a generals armour decorated with a rhomb pattern on red ground. The polychromy is preserved in the soil and is seen from the backside.

Fig. 8. Reconstruction of a rhomb pattern, based on colour plates as fig. 8.

Fig. 9: Head/2002 – priming barb at the throat following the line of the collar

Fig. 10. Visible brush strokes following the modelling of the ear

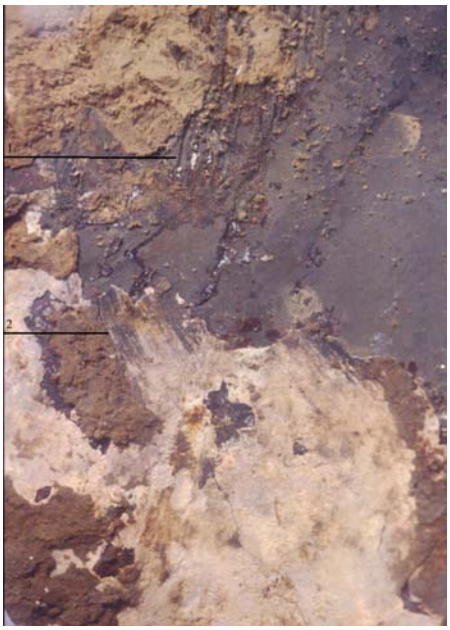


Fig. 11. Head /2002: Hairline at the back of the head: 1 (upper line) shows the hair incised in the terracotta; 2 (lower line): hair line painted on the pink

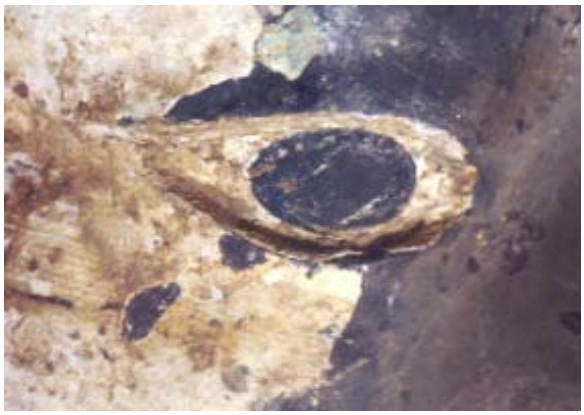


Fig. 12: Head/2002, right eye: The white of the eye is simply painted in the pink flesh tone, iris and pupil are not differentiated. The black is painted on top of the pink, giving the eye the perfect round shape.

Fig. 13. Head/2002: The moustache shows a fine structure of crossing lines incised into the terracotta. This structure is completely covered by the thick flesh tone layer. The in painted moustache the hairs show in another direction than the incised ones.

Appendix 1: Auszug aus dem Bericht von Prof. Heinz Berke zu Proben aus Yangling

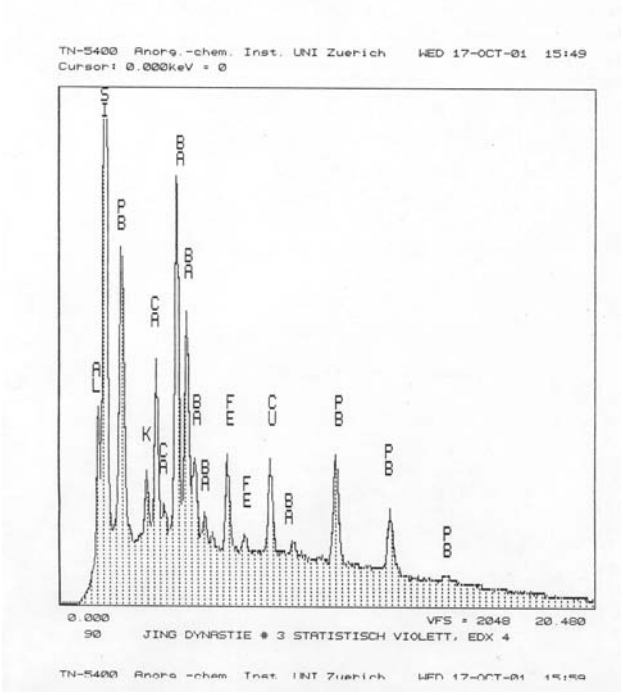
Yangling Probe 3 (von Y 1 PP 2), violette Scholle, aufgesammelt in der Grabung

Elektronenmikroskopie - EDX

Dominierend sind die Elemente der Pigmente Chinesisch Blau und Purpur (Ba, Cu, Si) einschliesslich dem Begleitelement dieser Pigmente Blei. Ausserdem findet man geringfügige Anteile von Aluminium, Calcium, Eisen und Kalium.

Raman

Hauptkomponenten sind Chinesisch Blau ($BaCuSi_4O_{10}$) und Chinesisch Purpur ($BaCuSi_2O_6$). Die Spektren zeigen ausserdem in geringen Mengen die Anwesenheit von Bleicarbonat ($PbCO_3$) oder basischem Bleicarbonat ($PbCO_3 \bullet 2Pb(OH)_2$).

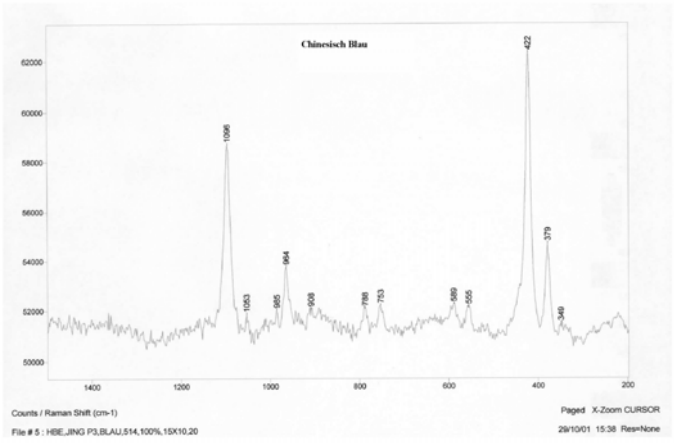


EDX-Anaylse von Probe 3

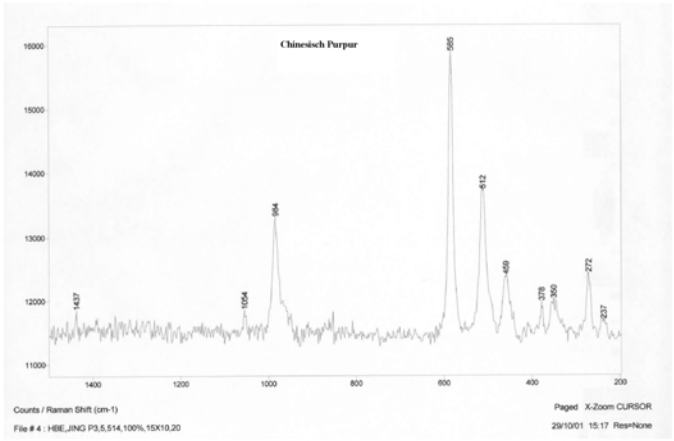
Schlussfolgerung

Probe 1 und 2 sind Blauproben, die auf Azurit basieren. Darin enthaltene Weissanteile sind bei Probe 1 wahrscheinlich Feldspäte und bei Probe 2 möglicherweise auch etwas Feldspäte, in grösserem Umfang aber Phosphorit ($Ca_3(PO_4)_2$) oder Apatit.

Probe 3 unterscheidet sich von Probe 1 und 2. Sie zeigt nach Ramananalyse eindeutig Chinesisch Blau und Chinesisch Purpur und kein Azurit. Wie bei allen antiken Chinesisch Bau- und Purpurproben findet man stets Bleigehalt, welcher in Form von Resten von Bleicarbonaten Raman-spektroskopisch sichtbar ist.



Ramanspektroskopie: Chinesisch Blau



Ramanspektroskopie: Chinesisch Violett

Appendix 2: Samples of flesh tones examined 1991-2002

fragment no.	area	description of pigment layer(s)	analysed pigments	sample	Cross section
B1 (1991)	flesh tone	2 light pink 1 dark pink	2 apa, cin		
B2 (1991)	flesh tone	2 light pink 1 dark pink			
B5	hand or thumb	? white			
003/91	thumb, detached flake	single layer	apa, cin, cer	003-2	003a
005/91	finger	double layer	apa, cin, cer	005-1	CS 005-1
006/91	left hand	2 thick, pink 1 thin, white	2 apa, cin, cer 1 apa, cer, (min ?)	006-2, 006-1	006b, 006c, 006d
002/92	hand finger nails	2 finger nails: white 1 pink	1 apa, cin		002.1-4
005/92	thumb	2 thick, pink 1 thin, orange	2 apa, cin, Pb carb., Han 1 min ?		005.1-2
004ab/95	finger / 2 fingers	2 pink 1 white			
008/95	hand without fingers	2 pink 1 white			
F-005/98	fingers	2 thin, white 1 thick, orange- pink	2 apa, cin 1 apa, cin, brown Fe_2O_3, (azu)	2: PP L 30 1: PP L 28, 29	CS 4
F-005/98	fingers	white top layer ??	- kaolin - bone white - cinnabar (very few)	PP L 32 (005.98.2)	
F-005/98	fingers	pink bottom layer	- bone white - cinnabar, very fine	PP L 31 (005.98.1)	
6/2000	hand (isolated flakes)	pink layer with green particles	- bone white - malachite - cinnabar	PP L 59 - L 63	
pit no. 2, Fig. 2, T21G18	hand, isolated flake, picked up from the figure in Nov. 2000	??????	- cinnabar, very fine - bone white	PP L 94	
3/2000	face, one layer: pink layer with bright red, violet and orange-yellow particles, some lacquer	only one layer ??	- bone white - cinnabar - soil - lacquer	PP L 54	
1/2002	pit no. 2, T21G18, hand, middle of the back of the hand	2 grey (or white with dirty surface) 1 light pink	2 apa, lead, cin (little), (charcoal) 1 apa, cin, (soil)	2: PP L 102 1: PP L 101	
2/2002	(same as 1/2002)	2 white 1 light pink	2 apa, (cin) 1 apa, cin (fine, ca. 2.5µm), (soil)	2: PP L 104 1: PP L 103	
3/2002	(same as 1/2002)	2 white or grey 1 light pink	2 1 apa, cin	2: 1: PP L 105	
3/2002	pit no. 2, T21G18, another hand	2 white 1 light pink	2 apa, cin, (soil) 1 apa, cin, (lead white or minium), amorphous particles	2: PP L 107 1: PP L 106	
PS-009/00	leg of acrobat no. 7 from pit K9901		apa, cin	Research report of the Museum 1999, p. 202, 214	

apa	apatite / bone white	min	minium
cer	cerussite	Han	Han Purple
Pb carb.	lead carbonate	azu	azurite
cin	cinnabar		

Year 2004

New investigations on the polychromy of the terracotta army - Kneeling archers and officers with decorated borders

Catharina Blänsdorf

The investigation on the colours of the terracotta warriors was accompanying the conservation work on the paint layers since 1991. Many individual results were obtained this way. The pigments and frequently used mixtures are known to a large extent. Examination of those original fragments which were used for the conservation tests provided information on the colours of single areas. In these examinations only data was gathered without the attempt of interpretation in a larger context. In 2004, for the first time systematic investigations of painting technique and colour distribution and, based on this, considerations on the original appearance of individual sculptures or groups of sculptures were carried out.

1. Kneeling archers

In October 2004 another sculpture of a kneeling archer was salvaged from pit no. 2, excavation area 21, corridor 18 (T21G18) to the workshop of the museum. This sculpture was lying faces down on the floor and the back was already exposed since the test excavations in 1977. When the sculpture was lifted in 2004, surprisingly there was still colour on the front side. The head was broken off and hidden below the body. The polychromy was still more or less adhering to the terracotta, but the conservation proved to be very difficult because of the advanced state of drying: the major part of the polychromy remained in the soil and was lost this way. This kneeling archer, provisionally numbered as SH001, was the last but one kneeling archer in this part of the corridor. Now there is only one sculpture, partly covered with soil which is standing in the corridor, next (to the north) of warrior no. SH001.
Including sculpture no. SH001 there are nine kneeling archers with preserved polychromy form the corridor 18 now. These sculptures became the base for a detailed investigation of the colours and the painting technique of the sculptures. Partly pigment determinations have been performed during the consolidation treatment. As on all of these sculptures the polychromy was preserved, the sculptures possess much more polychromy as any other sculpture. Together they represent a segment of corridor 18 – only a small part of the altogether 40 sculptures, but a complete formation of four rows. This allows a first interpretation of a cohesive group of warriors.

In May 2004 the polychromy of the eight already consolidated kneeling archers was documented in colour sketches. The preserved colours were recorded using gouache colours and a schematic drawing of a kneeling archer in four views (front, back, left and right).[1] The colour tones were recorded as they appear today, but obvious discolorations were omitted.
These colour sketches showed that the principal distribution of colours is easy to understand: Robe, trousers and shin protection are unichrome. Shin protections modelled as two-part types are also painted in two colours. Sleeve cuffs and collar can have up to three colours arranged in stripes; they are always designed as equivalents, what probably means that they belong to the same garment. The connection straps of the armour plates, hair ribbons and, as far as existing, shoe laces are yet another colour accents.

[1] The drawing was prepared by Xia Yin, museum of the terracotta army, Lintong.

On the base of this knowledge also small rests of colour are sufficient to reconstruct the colour scheme and in this way the original appearance with a high probability. This can be seen on a kneeling warrior (fig. 1) who only has small fragments of colour as the polychromy was not consolidated. Furthermore retained particles of polychromy are discoloured by adhering soil. Nevertheless on the base these small fragments the polychromy could be reconstructed in the following way:

Fig. 1. Kneeling archer no. 02812 in the storage room and reconstruction of the colour scheme

1.1 Painting technique

The ***determination of the pigments*** on the nine sculptures gave the following results: bone white, lead white, cinnabar, red iron oxide, yellow ochre, azurite, malachite, bone black. This confirmed the already known pigments (except for bone black), but they are used in a larger range of mixtures than thought before. Especially the pink and reddish brown colours show a large variety of mixtures. These can be explained by the many artisans involved, but also on the fine differentiation in nuances.

As ***colour tones*** green and red to reddish brown are the most frequent tones. Both are used for large areas (as jackets or shin protections). Blue, purple, red, white and black are rarer and are preferably used in smaller areas. The choice of colour might be related to the availability, artistic considerations or the meaning of special colours. Certain colours might be reserved to special ranks; or the colours were selected depending on the contrast to the lacquer and to each other. Also economic reasons might have been of importance: Azurite and cinnabar were more expensive than other pigments. Azurite additionally is problematic in use in many binding media. Also Chinese Purple might have been one of the more expensive pigments.

The ***flesh tones*** can have one layer (warrior no. T21G218:08), two layers (T21G18: 02, 04, 05, 06) or even three layers (T21G18: 03, 07).
Double layers are very frequent, mostly with the lighter pink on a darker one. This structure might have artistic reasons: It is equivalent to the technique used in Europe to underpaint flesh tones in darker reddish tones to achieve the impression of natural flesh tones. However, on the terracotta army mostly the layers seem too thick to be transparent.
The application of three layers seems to be a correction in the work process: On the first, very smooth (maybe polished) light pink layer, the features of the face were already painted rather schematic with broad black lines. The upper layers (light pink on darker pink) have more impasto. Hairline and brows are painted as fine single lines, not with one broad stroke. If here also different ‘styles’ become visible has to be investigated on a larger numbers of sculptures.
Colour and structure of paint layers on the faces are often not equivalent to the hands and feet: Pale faces are combined with stronger coloured hands and vice versa. A correction caused by a damage is only visible on one sculpture (T21G18:08): After already being painted, the right thumb was broken off. The left hand fell out of the sleeve and could not be pushed back as far as before anymore. The joint of the glued thumb and not yet painted stripe around the left wrist were repainted. The colour is lighter than the original one, but the difference is so small that the repair is standing out much.

The paint layers of ***garments*** are mostly applied in one layer. The purple jacket of T21G18:07 has a white underpainting. The brightness and intensity of the purple is increased. Cross sections show that the layers have no clear separation, what probably means they are applied ‘wet in wet’. Other areas with two or three layers are more difficult to interpret: they might be changes of the concept rather then a deliberate structure as they do not seem to aim at a special artistic effect. One example is the lower part of the shin protection of T21G18:08 which shows green (as first layer), white and blue on top of each other.

Fig. 2. Reconstructed polychromy of kneeling archers in pit no. 2 T21G18, view from east

Changes of the colour within the same part of clothes can be observed on sleeve cuffs and collars, sometimes also on shin protections and trousers. Especially bleu and green are interspersed with light ochre segments or blotches. Some of them appear rather unmotivated, and sometimes the differentiation between ochre colours and adhering soil is also not clear, but at least the changes from blue to ochre on collar and sleeve cuffs of T21G18:01 obviously is part of the artistic concept. The ‘gold ochre’ is different in tone from the adhering soil; the ochre layer has the same structure of brush marks as the blue. Cross sections show that the ochre layer, line the blue one, is covered with a thin layer of soot which can be traced back to the pillage of the pits in 206 BC, the SEM identifies the particles of the ochre layer as iron oxide. This means that the ochre layer was already there before the fire and before soil covered the surfaces. The ochre therefore cannot have developed out of the soil now covering the sculptures. A collar with a similar distribution of two colours could be observed on a standing infantryman with armour from pit no.1 (warrior no. 02528). Like on the kneeling archer T21G18:01, there is a horizontal borderline in the middle of the back where the colour changes completely. On the side it runs out in vertical streaks, so in the front only blue is visible. The only difference between the two collars, except for the mirror-inverted arrangement of the collars, is that on warrior 02528 the second collar is not ochre but purple.

Discolorations can also not be excluded. In many areas colours between yellowish white, pink and ochre cannot be distinguished with certainty from the adhering soil. The bluish green jacket of T21G18:03 is covered with a thin ochre brown layer. It was not possible to say if this is soil or a complete overpainting with ochre. The same applies to the shin protection of T21G18:02, on which ochre coloured areas with visible paint brush pass into brownish layers which clearly are soil without a clear border.
Another discoloration is the yellowish impression of the flesh tones. Although this seems rather natural, it is only caused adhering soil: Inside the layer there is only white and red in different ratios. The original colours ranged between pink and almost white.
Definitely no discoloration is the colour of the green face of warrior T21G18:01. The layer, as all green areas, only contains malachite. The back of neck including the back of the ears, the parting of the hair, as well hands and feet are pink. This probably means that the green is make-up, maybe some kind of ‘war paint’. On the lips only traces of white are preserved on top of the green. They can be interpreted as remnants of a white polychromy or the underpainting for a natural red.[2]

1.2 Distribution of colours

In general bright colours and combinations rich in contrast have been preferred. When broken colours or nuances of the same tone have been used, they are not directly next to each other, but separated by another colour. An attribution of colours to special areas does not seem to exist. Only the long stitches on the armour plates which where bright red on all infantrymen examined so far. Red also seems the preferred colour for hair ribbons, but there are pink ones as well. The colours for the button-like small stitches can vary: white, yellowish white, ochre or not painted were found on the kneeling archers, on other infantrymen also orange-red, red, green and black have been found. Shoe laces seem to occur in all possible colours.
The comparison of all nine warriors (fig. 2) also shows that each warrior was painted differently. Even if the colours in the main areas as jackets and shin protections are the same or similar, the colours of the smaller areas as collar or trousers always differ. An arrangement according to the main colours as anticipation of later uniforms seems not to exist. On the contrary, at least for these nine sculptures the most variegated array seems to be chosen.

[2] As the red of the lips normally is applied in thin glazes, it would have appeared brown if applied directly on the green.

2. Standing archers and cavalrymen

During the work the storage room of the museum, also several sculptures of other type could be examined which still had traces of colour.

Two ***standing archers***, both from pit no. 2, seem to be dressed mainly in green:
Warrior no. 02816 wears a green jacket with green cuffs and a green shin protection.
Warrior no. 02817 wears a green jacket contrasted with red collar and sleeve cuffs and green trousers. The hair ribbons in both cases are green; the square hair pins are white.

The polychromy of a ***cavalryman*** from pit no.2, T13, could be reconstructed using photographs from the excavation: The jacket is reddish brown, the sleeve cuffs and the collar are red and the long trousers are green. The cap is bright red. The armour has red long-stitches and white button-like stitches. The belt shows a rhomb pattern painted with fine black lines on the lacquer. The belt hook in the shape of a flying bird is painted white.
A reconstruction drawing by the museum of the terracotta army shows another cavalryman with green jacket and red sleeve cuffs and collar. The armour has bright red long stitches and light button-like stitches[3]. The belt is bright red without pattern. The brown cap shows a pattern of clusters of three red dots. The boots appear green with red laces. The trousers look greyish on the print and could have been light purple on the original drawing.

Fig. 3. Cavalryman, pit no. 2, T13

Other sculptures of both types could not be examined yet. They are also not described in the Chinese publications. The interpretation of the results is therefore difficult. Maybe important is the dominant character of green and reddish brown/red. The frequent use of green and (cinnabar) red was already observed on sculptures from the eastern sectors of pit no. 1.[4]

3. Colour fragments in soil and sculptures with decorated borders

In the storage room for terracotta objects of the museum of the terracotta army there are 171 fragments of soil stored in shelves. Different kinds of materials have preserved in these soil fragments as imprints of mats, weapons but also layers of polychromy from the terracotta sculptures. The soil fragments are numbered with ‘B’.

[3] Colour is not clear.

[4] Excavation report: 陕西省考古研究所，始皇陵秦俑坑考古发掘队 Shaanxi sheng kaogu yanjiusuo/ Shihuangling Qin yong keng kaogu fajuedui (ed.), *秦始皇陵兵马俑坑。 一号坑发掘报告 1974-1984. Qin shihuangling bingmayong keng. Yihao fajuedui 1974-1984*. 2 vols. Beijing 1988.

About 100 of the fragments contain paint layers. 29 of these were recorded concerning the colours; the pigments were analysed. At least five nuances of blue and three shades of red could be observed on these fragments which are realised by different fineness or qualities of the pigments as well as mixtures with white. Five of these soil fragments show decorations of ornaments.

3.1 Documentation of the ornaments

With the help of an examination in raking light and under the microscope colours and system of the patterns could be recorded in colour drawings using gouache. Fig. 4 shows one of these fragments as photograph of the actual situation and the drawing. It is obvious that photographic documentation or descriptions are not suited for documentation in this case. Therefore all colour fragments and attempts of reconstructions were recorded as colour sketches.

Fig. 4. Fragment B-0113 and reconstruction of pattern and colours (drawing as ‚negative’ in the soil)

The fragments were recorded in the scale of 1:1 as documentation of the preserved parts, but with reconstruction of the fresh, unchanged colours. The drawings show the fragments from the side where originally the terracotta has been. This view is called ‘negative’ in the following text, while the view on the original surface is referred to as ‘positive’.

3.2 Attribution of the pattern fragments

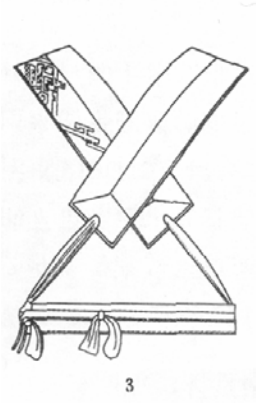
Four of five fragments showed a similar pattern. The next question was where these types of patterns originally were located. As a first step the tape of sculpture had to be determined. In general, there are three types of sculptures which are described to have decorations with patterns. These patterns are always found on the borders or smooth parts of the armour:

a. Generals
b. Officers with ‘apron-style’ armour
c. Officers with vertical lower border of the armour

Type I Type II

a. Generals
Generals are marked by the special cap. There are three different types:
Type I, with arms crossed in front of the belly, has an armour with shoulder pieces.
Type II, has straight arms and no shoulder pieces.
Type III does not wear any armour.
There are two different patterns, one on the border and the other on the chest part of the armour of type I and II. Type I might have had additional patterns on the shoulder pieces, but there nothing is preserved of these parts.
Generals are the commanders of chariots in pit no. 1 and 2, but one was also found standing on the floor in a group of infantrymen in pit no 2.

b. Officers with ‘apron-style’ armour (‘chariot officers’)
These officers seem to be special high-ranking officers as two of them are placed on chariots in pit no. 1 as equivalents to generals. The caps are attributing them to a lower rank, but as chariot officers they seem to be in an important situation. The armours are designed like aprons with a front part and straps over back and around the waist. The broad straps are crossed in the back. Thinner straps are attached to them and tied in the waist. The armour has one border running round the neckline, the other round the lower edge of the armour. They have different patterns. On the back straps both borders are combined.



c. Officers with armour with vertical lower border (‘minority officers’)
This type of officer has a special type of armour. The lower edge is not pointed in central axis, but vertical. The armour is only open on the left shoulder, but on the whole left side and is fastened by overlapping of the borders. As on the generals’ armour the chest part is smooth without scales. Armour and square shoulder pieces are surrounded by borders. All sculptures of this type found so far come from the front part of pit no. 1 where they were integrated in blocks of infantry officers. Due to the ‘exotic’ type of armour, they are also interpreted as representatives of Non-Chinese minorities.

The generals and the two types of officers represent warriors in high-ranking positions. There are only few of these sculptures. From all sculptures excavated so far, nine are generals, five ‘chariot officers’ and four officers with armour with vertical lower border. Without the two generals who do not wear armour, this means that 16 of about 1200 sculptures are decorated with painted decorations.

3.3 ‘Chariot officers’ with ‘apron-style’ armour

The patterns have been recorded by the Chinese archaeologists in drawings. However, the black and white line drawings appear confusing; they partly are not very accurate concerning patterns and attribution of colours. Additionally it is difficult for the understanding that the drawings in the publication are printed tilted or upside down. Nevertheless, basic types can be distinguished. On the borders of the armour of the ‘chariot officers’ there are two different types of decorations which are united on the back straps in a double border (fig. 5). One of the decorations is also used on the borders of the officers with armour with vertical lower border (fig. 6).

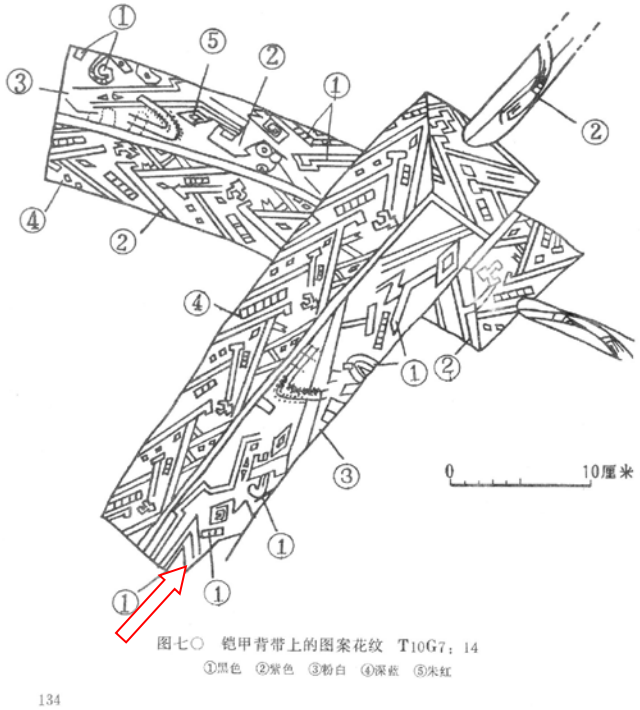


Fig. 5. Back straps of armour of chariot officer T10G7:14 with two borders of different decorations. The red arrow marks the ornament which reappears on the officers with armour with vertical lower border (fig. 6).

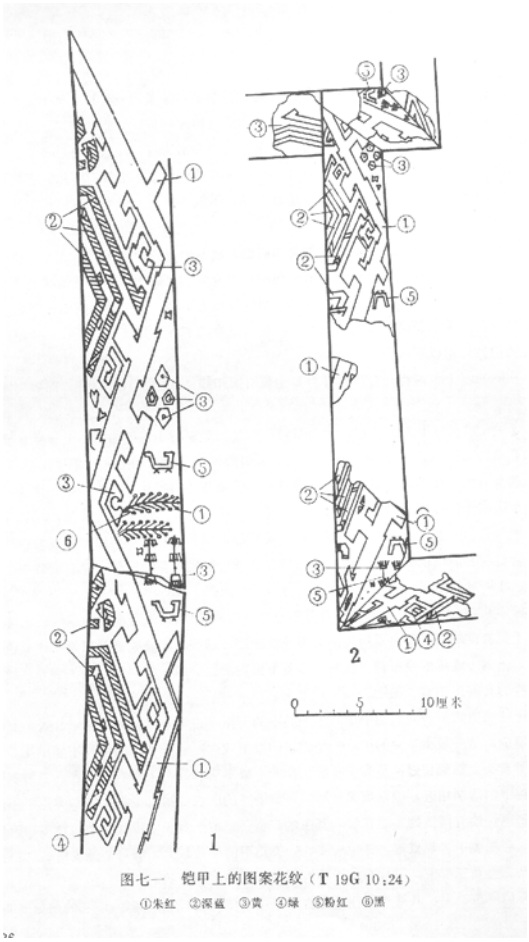


Fig. 6. Border of armour of officer T19G10:24 with armour with vertical lower border. The pattern is clearer visible than on the back straps of T10G7:14.

Four fragments of ornaments in soil belong to the decorated borders of armour from these types of officers. Three of them definitely belong to a ‘chariot officer’ because both ornaments are preserved next to each other (fig. 7: fragments 2, 3, 4). On two fragments parts of a green jacket are preserved (fig. 7: 2, 3). Three fragments are preserved as ‘negative’ (fig. 7: 2, 3, 4), one as ‘positive (fig. 7: 1), but in a very poor condition. Because of missing information it is still not possible to say which sculpture these fragments could be attributed to or if they all belong to one sculpture. Nevertheless an attempt was made to arrange the four fragments into a fitting situation on the crossed back straps:

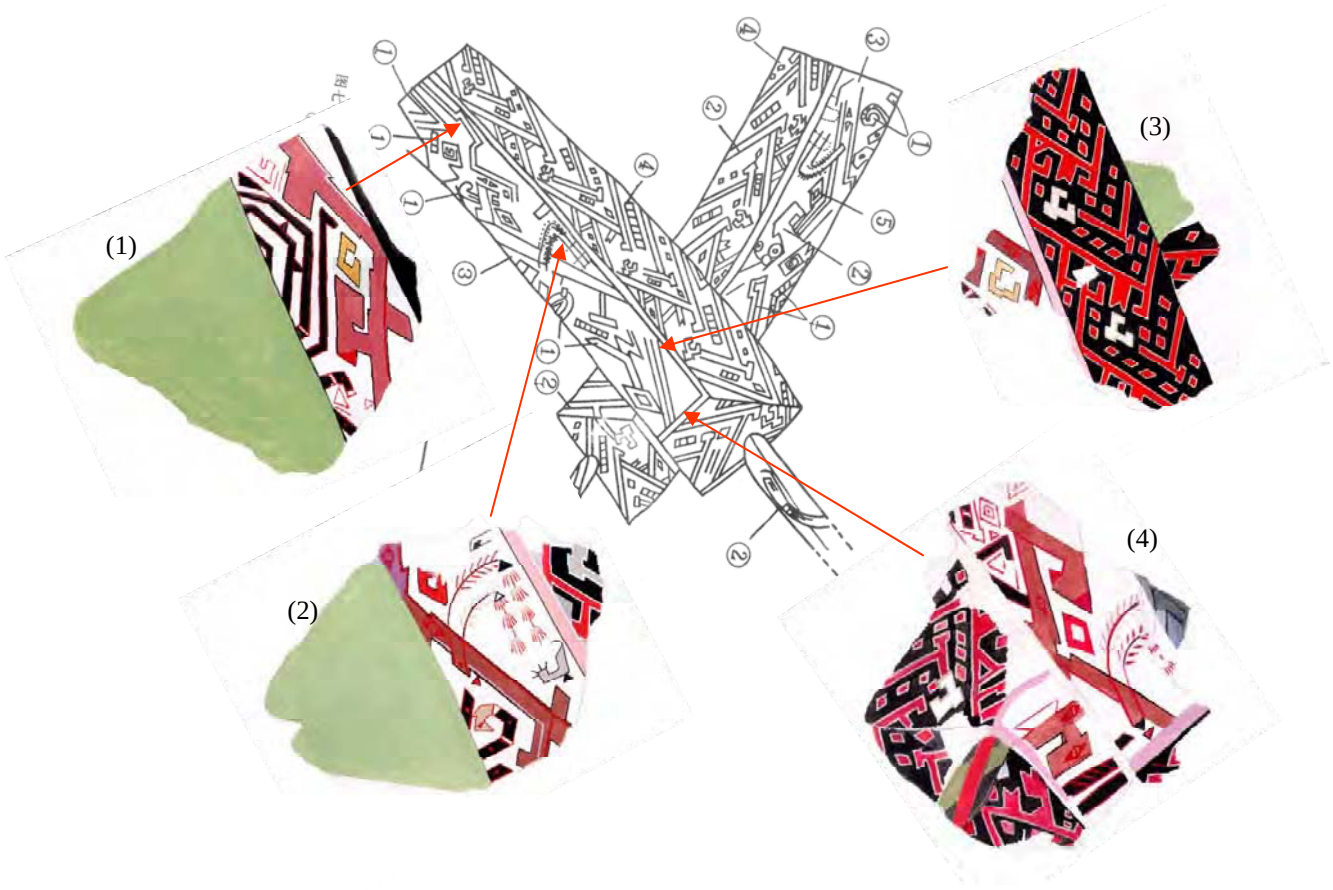


Fig. 7: Drawing of back straps and attribution of preserved colour fragments.
Centre: Line drawing of chariot officer T10G7:14 from the excavation report of the 1970’s [Yuan 1990, p. 294.]. The drawing shows the straps as ‘negative’ (i.e. colour in soil). The jacket of this warrior was reddish pink, what means that the fragments are not belonging to this specific sculpture, but from the equivalent sculptures there are no drawings of the decorations.
(1) Fragment No. B-0145, paint layer on gypsum (‚positive’), decoration with white ground with zigzag band and black pattern of bent lines
(2) Fragment No. B-0114, paint layer in soil (‚negative’), decoration white ground with zigzag band, ‘hanging umbels’, part of the black bent line pattern; pink separation line; small part of decoration on black ground
(3) Fragment No. B-0113, paint layer in soil (‚negative’), decoration with black ground, red pattern with white interspersed ornaments; pink separation line; part of decoration on white ground. The decoration with black ground appears a second time on the left side, because the two straps overlap in this area. Fragment (2) and (3) might come from the same sculpture as they seem to fit one to the other.
(4) Fragment No. B-0111, paint layer in soil (‚negative’), crossing of the ends of the two straps. The decoration on black ground is edging the one on white ground. The pink separation line is visible. On the right part a longer strip of the ornament on white ground with zigzag band and ‘hanging umbels’. On the left black ground decoration, the beginning of the thin straps are preserved showing a black strap with red and green decoration stripe.

Combined with the fragments of colour the drawings became much clearer. On the other hand, the position of the fragments could be attributed very well.
The two borders show different geometrical decorations. The one running around the lower border of the armour has a white ground, the one running around the neckline a black ground. They re separated from each other by a pink line.
The ***decoration on white ground*** is subdivided into triangles by a jagged zigzag band in reddish brown. From the geometrical fillings, the ‘twigs’ with ‘hanging umbels’ in red and black are the most prominent ornaments which are arranged in the triangles facing the central separation line. The triangles facing the green jacket show patterns of bent black lines with red outlines. Red dots in the bent-off end pieces resemble ‘heads’.

The ***decoration on black ground*** shows a geometrical red pattern of bent lines and rhombi with light ochre outlines. The red lines are interspersed with isolated white patterns with light ochre outlines.
By a lucky coincidence on the four fragments almost all parts are preserved which are necessary to reconstruct the whole straps: The end of the border is preserved, the crossing and the separation line. Even a part of the thinner attached strap is preserved. In the pattern repeat of the ornament on white ground only small filling patterns are missing which partly can be taken from the drawing of T19G10:24 (fig. 6). One problem is that the general arrangement seems to have been definite, but the small filling ornaments could be varied freely: ending of lines small ornaments, the direction of twist are different in each section of pattern repeat.
One possible reconstruction is given in fig. 8.

Fig. 8. Reconstruction of the back straps after combining the drawing with the four preserved fragments and completion of small elements from other drawings. View as ‘negative’ (colour in soil).
Rekonstruktion des Musters durch Zusammensetzen der vorhandenen vier Fragmente und Ergänzung der fehlenden Partien nach den Zeichnungen der Archäologen, als Negativ in der Erde.

All lines in the ornaments are remarkably accurately drawn. Fine lines as the outlines are 0.5 mm wide and perfectly straight and homogeneous in width. There are almost now traces of construction marks. Only on the reddish brown zigzag band there is a red line below the reddish brown which might have been an auxiliary line for the run of the zigzag.
Both decorations are characterised by the edgy ornaments. This gives the impression of a woven textile pattern. Only the ‘twigs’ and ‘umbels’ have a rounded course and appear line embroidery stitches. The realistic impression of the decorations is further increased by the fact that the pattern is distorted slightly, exactly a fabric would do over the rounded parts of a body.

As a last step in the reconstruction the whole part was inverted to a ‘positive’, so it is visible as it originally was when looking at the sculpture. Fig. 9 shows the reconstruction and a photograph of a back of a ‘chariot officer’.

Fig. 9.
Back of a ‘chariot officer’ (above)

Reconstruction of the polychromy of the back straps as ‘positive’ (right)

3.4 Problems of the documentation

For the documentation the colour tone should be recorded in their ‘fresh’, ‘original’ appearance. Discoloration by soil and consolidants should be excluded as far as possible. Therefore fracture edges and damages in the surface were examined under the microscope. The comparison with pigment analyses nevertheless proved that shifts towards more yellowish tones unintentionally still had happened. Greens always consist of pure malachite, additives or impurities are white or blue (azurite), but there never is any ochre. All types of malachite are much more bluish than the documented colours.

When the colours were recorded in China as they are appear today, a considerable amount of ochre had to be added. Even for the ‘fresh’ colours black and white had to be added. This also refers to the change of impression caused by the loss of the binding medium. Without binding medium the colours appear opaque and whitish.

One problem for the investigation on the colours was that the fragments in soil and also the colours on the sculptures are rather poorly recorded. Therefore it is difficult to attribute preserved colour fragments to individual sculptures or to their respective places on these sculptures. A similar problem is that sculptures with storage room numbers cannot be traced

back to the excavation numbers (which indicate the position inside the pit). Reference lists for numbers are not available or (ostensibly) not existing. Excavation reports, photographs or drawings can also not be seen or found. What is available in the archive dated back to the 1990’s only and is also incomplete. A data base on the sculpture is just set up recently and still too incomplete, even to identify the generals.
Another problem is hat sculptures as well as colour fragments are often contaminated or even covered with fine dust. Soil adhering to coloured surfaces hides the original colours. Unrecorded consolidation measurements with unknown materials have changed the visual impression and resulted in an inseparable commingling of pigments and soil/dirt. The recognition of the original colours therefore is not easy in many cases: the jacket of kneeling archer T21G18:01 for example, nowadays looks indefinitely light-coloured, in some areas greyish to greenish in others brownish. On the base of the pigment analysis this jacket could be identified as originally light pink.
On the fragments in soil an additional difficulty is that the paint layers are visible from the back. This complicates interpretation and understanding of the patterns. Often fine details are covered form the still preserved ground layer which, of course, cannot be removed.
On the sculptures as well as on the colour fragments not all questions could be answered without doubt. Some colours are unclear, some areas too damaged. In some cases alternatives were sketched concerning nuances or colours of complete areas.
On the background of these difficulties the examinations resemble a puzzle on which with ongoing observations and new findings corrections will be necessary again and again.

4 Perspective

The investigations since May 2004 have proofed that although the pigments are probably all known by now, there are much more mixtures and colour nuances than known before. Surprisingly many areas of the robes of the kneeling archers seem to have a two-layered a structure, although a single-layered structure was always described for the clothes. Mixtures, nuances, multilayered structures and the use of glazes are planned to be investigated further.
The documentation of as many sculptures as possible seems reasonable even in respect of high total number, as most sculptures have only traces of colour preserved. But piece by piece gaps in knowledge can be closed by comparison. The compatibility of the colour schemes on other sculptures of the same type for example enables us to include even isolated results into an overall view. Every additional examination has resulted in new cognitions so far. Using prefabricated forms even the time consumption is acceptable. With more time drawings of individual sculptures can be made using the documented colour indications.
For the sculptures with decorated borders a reconstruction as colour drawings is planned. Because of the accuracy of the painted decorations the search for textile prototypes seems reasonable as well as searching for formal prototypes which could explain the meaning of the stylised ornaments.
Furthermore it is planned to reconstruct the polychromy of selected sculptures on replicas in the scale of 1:1. These replicas shall be presented in the exhibition in Bonn next to the originals. The reconstruction using replicas has the advantage that a modelled surface, gloss and surface structure can be reproduced which cannot be depicted in gouache colours. However, so far there is still important information missing like the colours of special areas or the binding medium which are necessary to produce a scientifically confirmed reconstruction of the polychromy.

Year 2005

The polychromy of clothing and armours of the generals from the terracotta army

Catharina Blaensdorf

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4 Summary and conclusion

Introduction

So far nine generals' have been found, representing the highest military rank in the terracotta army. All sculptures merely show traces of colours, mostly tiny fragments retained in some incisions in the terracotta surface. Though colours are listed roughly in the appendix of the excavation report[1] and some fragments of patterns were documented by drawings or colour photographs, a systematic analysis of the patterns was missing until 2003. Not even the simpler pattern units had been thoroughly reconstructed so that the water colour drawings of painted generals represent rather a free interpretation of the polychromy than a scientific analysis.
The aim of the investigation on the generals was (i) to understand - as far as possible - the selection and arrangement of colours and (ii) to reconstruct the types and colours of patterns. During the time of August 2003 to August 2005, all colour traces were recorded systematically for the first time. The pattern units could be reconstructed and interpreted. Besides the research aspect, the results were the base for painting a replica of a general in the original technique in January 2006.

1 Existing material: sculptures, colour fragments and related information

The sculptures of the generals have lost most of the polychromy after excavation. Preserved fragments of paint layers are too small to give information about colour schemes or patterns. Therefore, other sources are necessary to understand and reconstruct the original polychromy.
These sources mainly are the excavation reports from 1988 and 1990, some colour photographs and colour reconstructions done by the Chinese archaeologists. The excavation reports contain descriptions of selected sculptures, tables with a rough overview on colours as well as drawings of fragments of patterns with some colour annotations. There are no photographs in these reports, probably because of the poor printing quality at that time and because almost all pictures were black and white.
Especially since 1999 colour photographs of better quality appeared in illustrated books on the terracotta army. Four of them show details of patterns.
Another very important sources are fragments of polychromy preserved in the soil: one small piece mounted in plaster and a large part of a back of a general which is still inside pit no. 1.

1.1 The types of generals

The military ranks in Qin Shihuang's terracotta army are defined by the types of the caps. The infantrymen do not have caps of rank at all, but partly wear soft textile caps over a hair bun on top of the head. Caps indicating ranks were stiff structures, probably made of leather or a strong fabric immersed in *qi* lacquer. The archaeologists have defined three ranks: lower officer, middle-ranking and high ranking officers or generals. The generals wear a "pheasant-feather cap" with two rolled-in strips pointing upwards on top of the head. Charioteers are middle-ranking officers; cavalrymen wear round caps which are specially designed for riding.

The first aim for investigating the polychromy of the generals was to identify the sculptures and to attribute the existing material to each of them. One difficulty was that the numbering system has been changed: The 1980's reports use numbers depending on the excavation

[1] Shaanxi sheng 1988, p. 376-432.

position (‘T-G-numbers’ with T = excavation sector, G =corridor, Z=individual number). A little confusing, for pit no. 2, the letter “T” is not referring to an excavation sector, but to test areas of the 1977 excavation campaign. Later on a system was established using continuous numbers (like 002831) which might be easier for administration and databases, but do not have a relation to the position anymore. There is no list correlating these two types of numbers. Additionally, there often other numbers are written on the sculptures, fitting in one or the other system, but not one of the given numbers. This looks like there might have been changes or confusion.
In this text, T-G-numbers are used though they are the “old-fashioned” system, because they allow identifying the sculptures clearly. They are taken from [Yuan 1990].

The nine generals come from pit no. 1 and 2. There are no generals in pit no. 3, though this is said to be commanders’ stand. Besides the special caps, generals wear a double long-jacket and armours with borders and tiny plates which further single them out from the others with just wear one jacket and armours made of large leather squares. Most of the generals belong to chariot crews and commanding infantrymen, probably also the two from pit no. 1 of whom the position is not clear. Only one general (pit no. 2, T4:1) is definitely not from a chariot, but standing in the second (i.e. the rear) row of a group of 2x 14 warriors.

The generals can be classified into three types according to posture, armour and style of beard. This classification as
- type 1 = armour with shoulder protections, hand crossed
- type 2 = armour without shoulder protection, arms stretched out
- type 3 = no armour

has been introduced by me to identify these three types.

Interesting enough, the three types also have different styles of beards (fig. 1).

type 1
two tufts on the chin

type 2
full beard

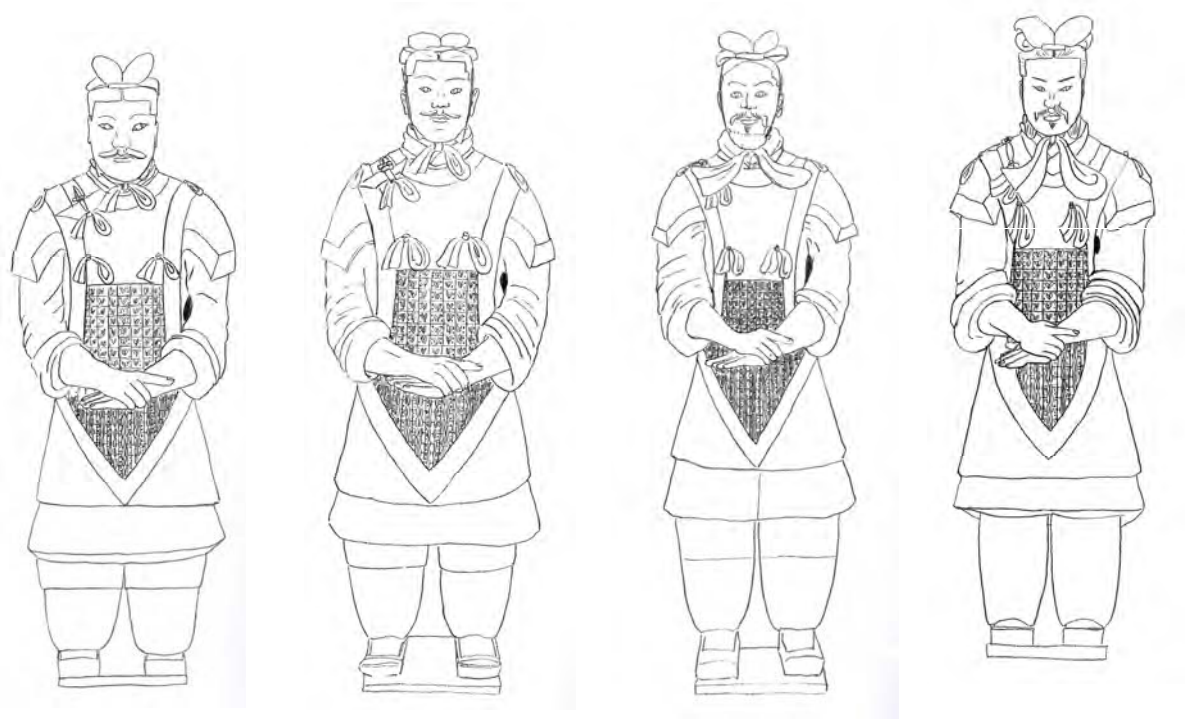
type 3
one small tuft below the lips

Fig. 1. Different types of beards of the generals (additional to the moustache)

Type 1

pit no. 1: T2G2:97, T20G10:97, T12G7:H93
pit no. 2, T4:1

Fig. 2a-d



Pit no. 1, T2G2:97 Pit no. 1, T20G10:97 Pit no. 1, T12G7:H93 Pit no. 2, T4:1

Identification:
Posture: hands crossed in front of the belly, palms facing downwards as if resting on something
Garment: armour with shoulder pieces
Features: moustache and a small tuft on both sides of the chin

Position in the pits:
Pit no. 1, T2G2:97 and **T20G10:97** in equivalent positions on the second chariot of the second corridor from north and south.
Pit no. 1, T12G7:H93: position not clear, maybe from the third chariot of the formation
Pit no. 2, T4:1: corridor K2, west of (i.e. behind) formation of archers; second row, behind corridor no. 20 (i.e. the second block from north).

Type 2

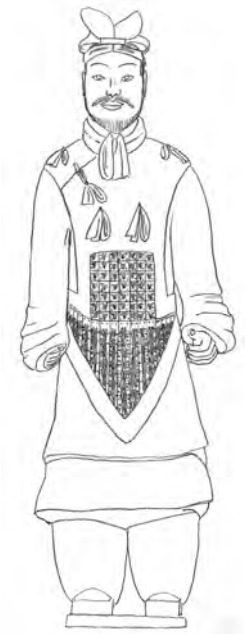
pit no. 1, T10G5:15, T22G9:1
pit no. 2, T9:1

Identification:

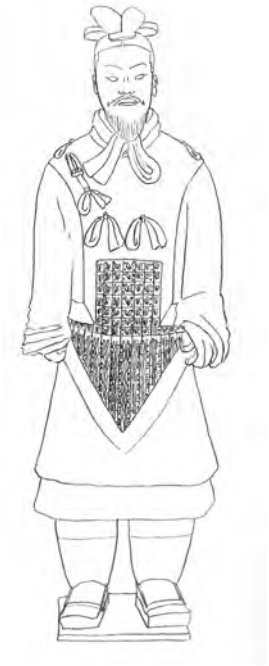
Posture: arms stretched out, one hand clutched as if holding something, the other one hidden in the sleeve, only parts of the fingers visible
Garment: armour without shoulder pieces
Features: moustache and full beard

Position in the pits:
Pit no. 1, T10G5:15: first chariot of fifth corridor from north; counterpart to officer with "apron-style" armour (T10G7:14)
Pit no. 1, T22G9:1: Position not clear
Pit no. 2, T9:1: corridor G4, sixth chariot (i.e. last one in the row), formation of infantrymen

Fig. 3a-c



Pit no.1, T10G5:15



Pit no. 1, T22G9:1

Pit no. 2, T9:1[2]

Type 3

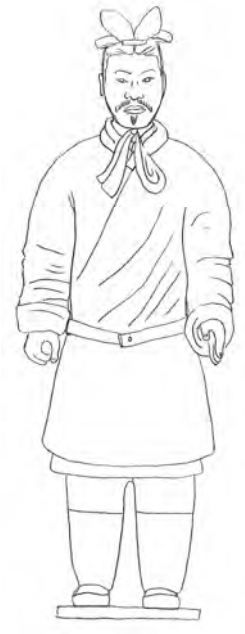
pit no. 1, T1G3:15, T19G9:13

Identification:
Posture: arms stretched out, right hand clutched as if holding something, left hand stretched out
Garment: no armour

Features: moustache and small tuff of beard below the lower lip

Position in the pit:
Pit 1, T1G3:15 and **T19G9:13** are standing on chariots in equivalent positions: the first chariot in the third corridor form south or north

Fig. 4a-b



Pit no. 1, T1G3:15

pit no. 1, T19G9:13

Fig. 5 [

Bronze chariot no. 1, standing charioteer [Qin Shihuangling tong che ma 1998, vol.1, p. 58]

[2] In this case "T" is not referring to the corridor, but to the test areas of the excavation of 1977. In lack for a more systematic and logic numeration, these numbers are used here. They are taken from [Yuan 1990].

As far as the position can be located from the excavation plans[3], it seems that in pit no. 1, the single types are arranged in mirrored positions. This might indicate that they were not equal in rank or had special duties according to their position. One general of type 2, T10G5:15, has an officer as counterpart who according to his cap should only be of low rank, but is dressed in special "apron-style" armour (T10G7:14). As all the officers with this type of armour are in special positions as well, often on chariots, they might be a rank just below the generals. This could indicate that a general of type 2 might have been of a lower rank than type 1.

The charioteers on the two bronze chariots can be identified as generals as well, dressed in the same type of double long jackets and wearing the same type of cap. They do not wear a suit of armour (Fig. 5).

1.2. Descriptions and tabular lists in the excavation reports

There are two basic books which are the main sources for all investigations concerning the terracotta army: the first excavation report from 1988 (Shaanxi sheng 1988) and the ensuing publication on the terracotta army from 1990 (Yuan 1990).

Shaanxi sheng 1988 is the report on the excavation of pit no. 1 between 1974 and 1984. The text itself gives a rather short introduction on colours[4]. A table (vol. 1, p. 139-140) lists up how many garments or parts of them have which colour. The types of warriors are classified as 'infantrymen', 'chariot adjutants to the right' (to the charioteer), 'officers'. As colours vermilion red, date red, light green, sky blue, light purple, white, brown (=lacquer) are listed. Colour distributions or colour scheme of single sculptures cannot be reconstructed from this list.

In the appendix (vol. 1, p. 396-432) there is a table of (almost) all excavated sculptures listing the colours of the main parts, as far as they could be recorded during excavation. Vol. 2 contains photographs, but there is nothing about colours, maybe because most of them are black and white.

Yuan 1990 was published only two years after the excavation report. It is less detailed, but more comprehensive in matter, as it also includes the finds from pit no. 2 and 3 as well as the other pits with burial objects from Qin Shihuang's tomb. It seems that the archaeologists paid more attention on the polychromy in this publication – a fact that might be reflected also by the choice of a drawing of a general with reconstructed polychromy for the dust cover. This interest might be inspired by new findings in pit no. 1 and 2 in the 1980's with substantial remains of polychromy.[5] Chapter III on hairstyles, armour and clothing contains more information on colour than the equivalent part of Shaanxi sheng 1988. Each pieces of clothing is described, including a listing of typical colours (e.g. 88 % are blue, 5 % red etc.)[6]. The next paragraph (III. 3.2) describes colour schemes for selected sculptures as representatives of different ranks (high ranking officers; middle ranking officers; junior officers; charioteers and adjutants; cavalry and infantrymen; figures form other pits). Three generals (pit no. 1, T2G2:97; pit no. 2, T9:1 and T4:1) are described here. Additionally the colours of the clothes of the two bronze charioteers are specified which are generals as well.[7]

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3 The published plans just show the situation of 1984 or 1988. As more recent plans are not available (or not existing?), the position of sculptures excavated after this date, can only be determined roughly. The plans are published in Shaanxi sheng 1988, p. 6/7 (pit no. 2), p. 52 (pit no. 1).

4 Shaanxi sheng 1988, p. 162 (English translation: AH 83, p. 93 and 95).

5 For example T4:1 from pit no.2 or T22G9:1 from pit no. 1 (excavated in 1986). The polychromy is lost today.

6 Yuan 1990, p. 255-269.

7 Yuan 1990, p. 269-273.

All these descriptions are rather summary. Small details, the exact distribution of colours, patterns, the nuances of colours and all technical description on the structure of the polychromy are missing completely. Nevertheless they are a valuable source for the distribution of the main colours on the described sculptures and a useful base to understand colour schemes.

1.3 Drawings of patterns

The complicated patterns are difficult to describe. There are descriptions of shapes and colours in the written text of the excavation reports Shaanxi sheng 1988 and Yuan 1990, but the explanations are not easy to understand. Sketches were used by the archaeologists to record the fragments of patterns they found in the pits. They are black and white with lines indicating the outlines of single elements. Colours annotations were marked with numbers pointing to the respective area. Shaanxi sheng 1988 contains seven drawings (p. 133-138). Three fragments are from two generals, all belong to T20G10:97 (fig. 5-7). In Yuan 1990, there are four additional drawings of pattern fragments from the two generals from pit no. 2 (T4:1, p. 293 and T9:1, p. 296; fig. 8-10 of this text).

Fig. 6. Shaanxi sheng 1988, p. 138
T20G10:97 - right shoulder

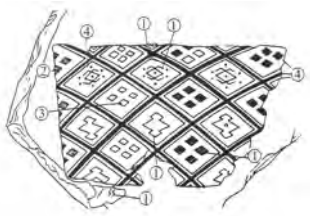

Fig. 7. Shaanxi sheng 1988, p. 137
T20G10:97 - border

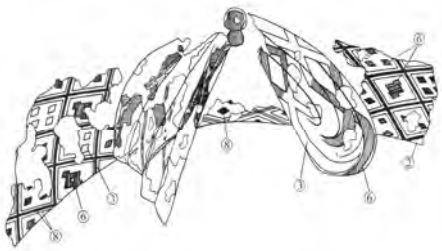

Fig. 8. Shaanxi sheng 1988, p. 137
T20G10:97 - left shoulder

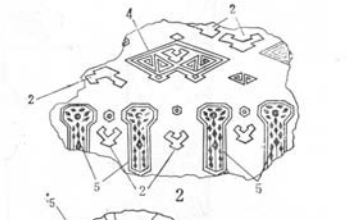

Fig. 9. Yuan 1990, p. 293
pit no. 2, T4:1 – ‘bird pattern’

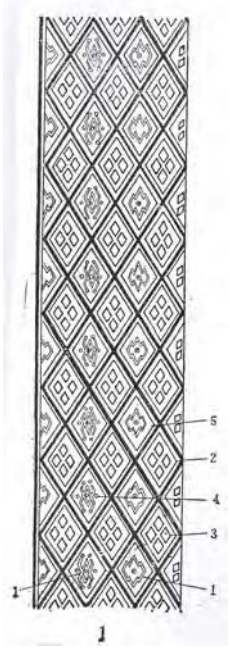

Fig. 10. Yuan 1990, p. 293
pit no. 2, T4:1 – border

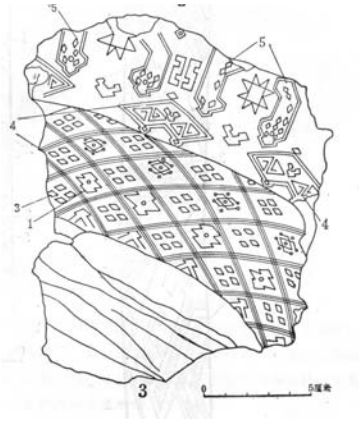

Fig. 11. Yuan 1990, p. 293
pit no. 2, T9:1

Additionally there is one drawing of a general which also indicates patterns. Normally only the shape (i.e. the terracotta) is depicted in these archaeological drawings. But in Yuan 1990 the drawing of general T4:1 is published showing a rhomb grid on the borders of the armour and a decoration on the shoulder pieces (fig. 12).

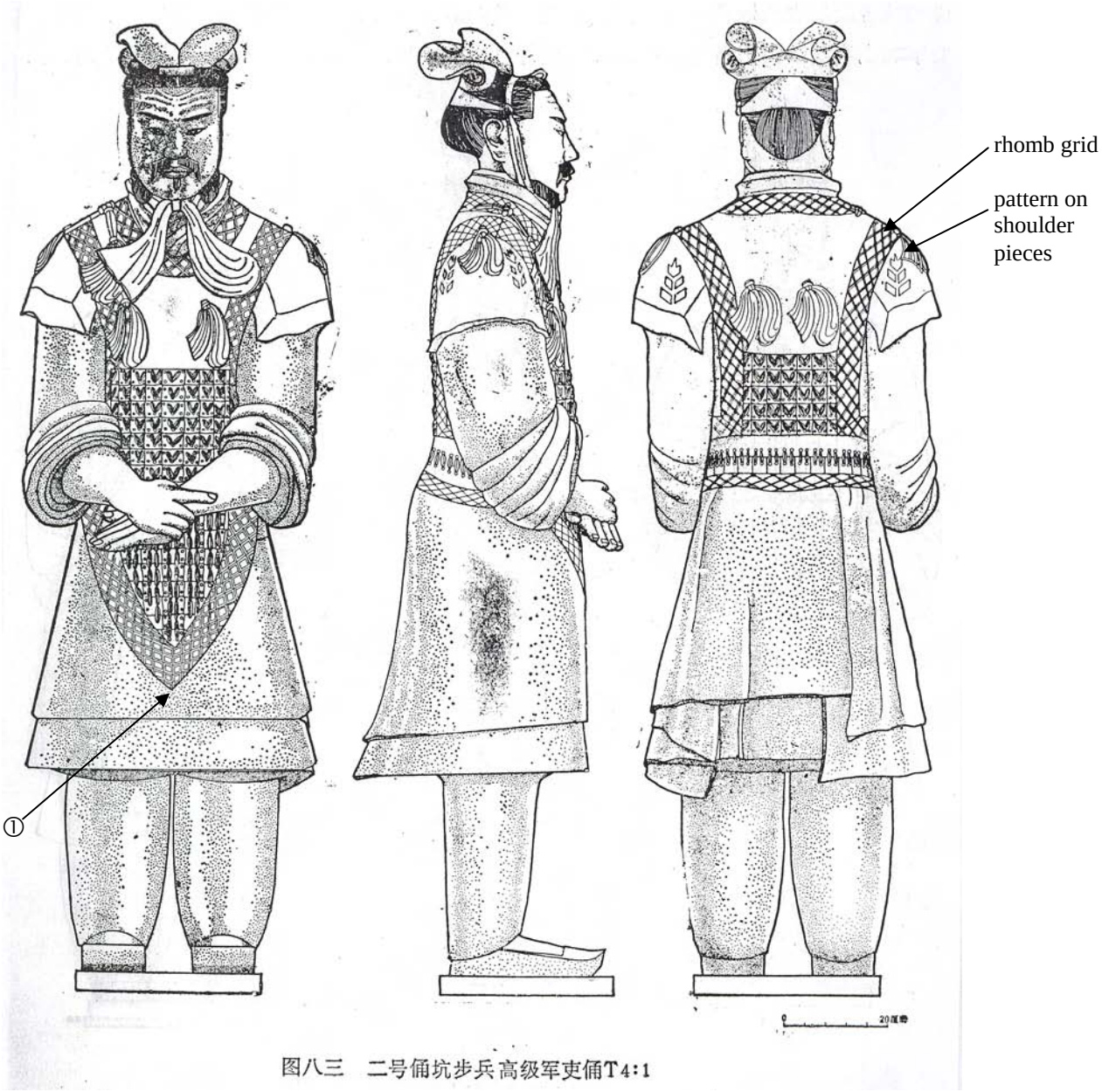

Fig. 13. Drawing of general T4:1 from pit no. 2 [from: Yuan 1990, p. 145]

The way these patterns are drawn here seems to indicate that there was still a considerable amount of polychromy on the sculpture after excavation, allowing to document even details of the rhomb grid like the joint of the two borders on the point of the triangle apron section in the front part of the armour (fig. 12, ①). Today there seems not much colour left on the sculpture. Unfortunately there are no photographs, records, drawings or other documentation material on this sculpture accessible in the museum, so it is not possible to say how the sculpture looked like when excavated. The patterns on the shoulder protection parts are the only hint what kind of decoration might have been painted on these parts.

1.4 Photographs

Since the 1990's number and quality of colour plates in Chinese publications has extremely improved. There are more and more illustrated books showing sculptures with remnants of colour or the kneeling archers with polychromy preserved since 1999. One of the first illustrated books in this high quality[8] also shows four details of patterns. Three belong to generals, one is a detail of fragment B-0101, the others are details from the back of T22G9:1. The polychromy of T22G9:1 appears in a much fresher and less dusty condition than today.

1.5 Colour fragments in soil ('B number-fragments', B-0101)

In the storage room there are about 160 fragments of materials preserved embedded in the soil of the pit. There are imprints of mats, wooden beams and other wooden objects, traces of basket-work quivers and bamboo weapon shafts. About 100 pieces are polychrome layers which remained in the soil when the terracotta shards were lifted from the clay inside the excavation site. Most fragments are lumps of soil mounted in gypsum, what means that the polychromy is visible from the back (as 'negative'). A few also are examples where gypsum was cast in the void left by the terracotta and the soil was removed, so the mostly poorly preserved polychromy is visible as originally on the surface (as 'positive').
The numbering system of these fragments follows system (inv. no. with B-0xxx) which is not linked to sculpture numbers or excavation positions. Also here, no list with data is available and mostly no information is written on the fragments themselves or the plastic bags used for wrapping. This means that for most of the fragments an attribution to a special sculpture is not possible. The part of the body can sometimes been concluded from the shape of the fragment.
From the five fragments with patterns four belong to officers with decorated armour borders (three 'negatives', one 'positive'). At least two belonged to the same figure, an officer with 'apron-style' armour and green jacket (see Annual report 2004). Concerning the sculptures with decorated borders of the armour, the distinction between 'positive' and negative' is important as patterns appear mirror-inverted in the 'negative'.
Only one of the fragments, B-0101, belongs to a general. It is a 'negative' in soil. As there is a drawing of this fragment in Yuan 1990, it can be attributed to general T9:1 from pit no. 2 (fig. 11 and 13).

Fig. 13. B-0101, June 2005

The fragment shows a part of the collar with a green and violet part, the rhomb grid pattern on reddish brown background. The pattern on black ground below the rhomb grid border can be identified as part of the upper body where the armour is smooth and without plates. During the investigation, this fragment could be attributed to the back of the general.[9]
The quality of this fragment indicates that also on the general T4:1 parts of the polychromy had been preserved in perfect state.

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8 Qin Shihuang bingmayong bowuguan 1999.

9 The pattern of the armour (on the black background) shows that the fragment is from the central axis of the figure, what means centre of chest or back. If it had been from the chest, the crossing of the collar halves would be visible in this area. As the folds of the collar run horizontally, the fragment can only come from the back.

1.6 Colour in soil inside the pit (T22G9:1)

Some imprints of objects or pieces of polychromy in soil were not taken out, but left in on-site, especially when these fragments are rather large and the layer of soil below is so thin that is piece is likely to break apart if the soil is separated from the floor. Most of these imprints are traces of wooden objects as chariots, weapons or quivers. In pit no. 1, T22G9, one large fragment of polychromy was preserved that way after being excavated in 1986. They belong to T22G9:1, a general of type 2.

One photograph of the generals' polychromy could be identified as detail of T22G9:1 (fig. 14) – and then it was possible to see this fragment inside the pit. In June 2005, the fragment could be investigated. It is protected inside the pit with a perspex construction covered by a plastic foil. Before work could be started, the cleaning of the very dusty floor and surrounding was necessary and a daylight lamp had to be carried into the pit (including 85 m of extension wire). Though the covers keep most of the dust out, the paint surface appears much paler than on a photograph taken before 1999 (fig. 15).[10]

Fig. 14. Detail of colour in soil from the back of T22G9:1, excavated in pit no. 1 in 1986. On the photograph the colours appear much brighter than 2005, so it might have been taken some years ago.
[from: Qin Shihuang bingmayong bowuguan 1999, p. 156]

Fig. 15. The same detail, situation in June 2005. Although still preserved, the pattern is less clear due to fine dust on the surface.

[10] The photograph can be found in an illustrated book on the terracotta army published in 1999 [Qin Shihuang bingmayong bowuguan 1999] by the museum of the Terracotta Army in Lintong.

Especially one part shows a crack system in the surface, caused by the drying of the loess soil. A thin layer of soil detaches superficially (about 2mm thick), forming small ‘cupping’ flakes which break easily (fig. 16). Besides dust and these cracks the surface is well preserved.

Fig. 16. T22G9:1. Part of back below the right shoulder, June 2005: Cracks and detached flakes.

The preserved polychromy (fig. 17) consists of six parts. They probably correspond to six terracotta shards as differences in level and displacements are recognisable. Especially the parts of the armour plates additionally show distortions which might result from lifting the terracotta shards from the soft clay. Below the polychromy, there are the feet of a sculpture with round-edged shoes which probably belong to another sculpture.[11]

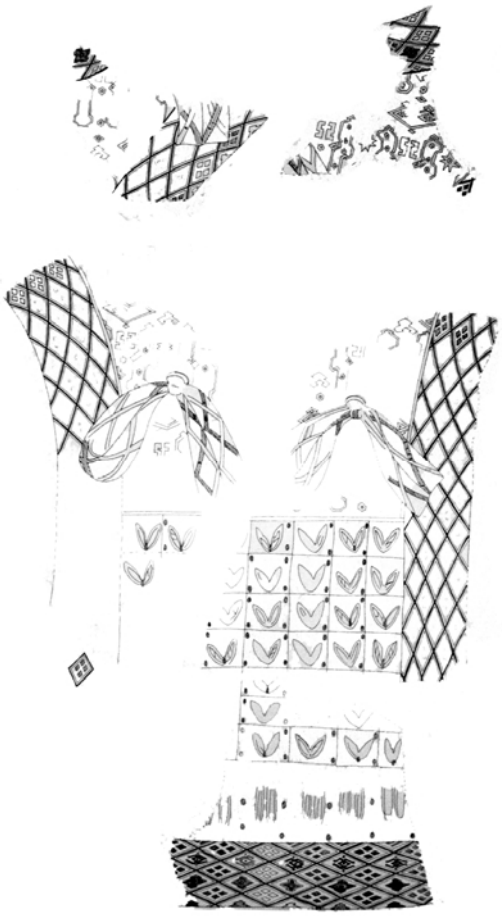
All parts were documented by transferring patterns and colour annotations on a transparent foil (‘Hostaphan’). Two parts of the shoulder area are now lying upside down, right and left above the part of the back. Both could be identified as adjoining pieces of the left shoulder. After correcting some of the distortions and adjusting the positions of the fragments (fig. 18), almost the complete back of the sculpture from the lower end of the jackets to the collar and including the right arm are visible (fig. 19 and 20). Feet, right arm, collar and head are missing as well as some central parts of the upper back part.

The sculpture of the general is on display in Xiamen for at least two years and thus could only be evaluated from a photograph[12]. It shows that there are traces of paint on the sculpture itself.

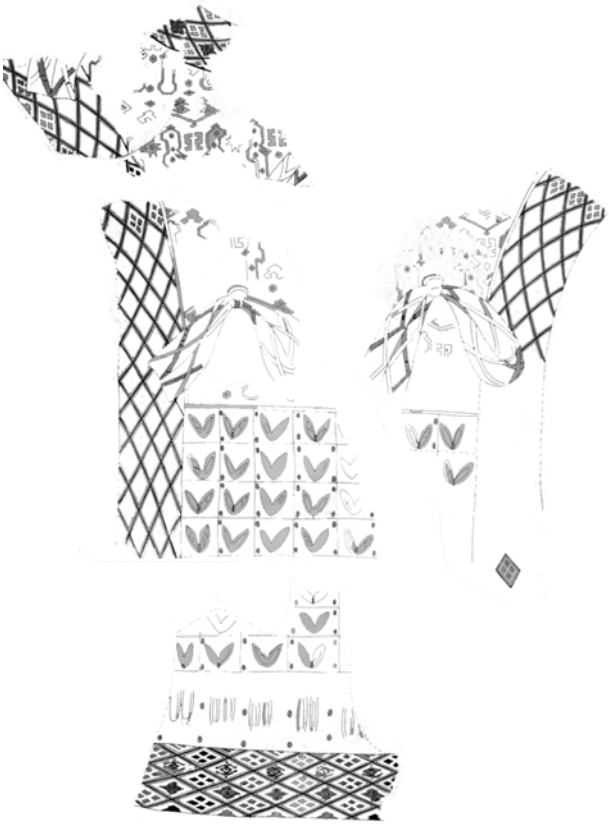
[11] Although round-edged shoes with coloured borders and violet laces should belong to a higher ranking soldier, is seems unlikely that the feet belong to the general himself. The position rather indicates that they belong to the person standing behind him on his right (in the case of a chariot crew this might be the adjutant as the charioteer would be on the left side or in front of both; more likely it is one of the officers of the first row behind the chariot). – On a photograph the shoes show angular edges, but it is not possible to decide if feet and legs are original parts or might be complemented.

[12] in: Qin Shihuang bingmayong bowuguan 1999, p. 88.

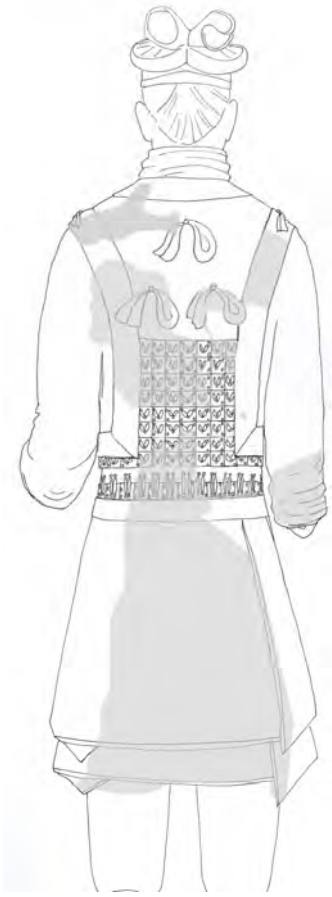
▲17



18 ►



▲19



20 ►

Altogether, descriptions, drawings and photographs can give a lot of information which can support and complement the observations made on sculptures and colour fragments in soil. Table 1 lists the existing material for all nine sculptures again.

inventory number	*excavation reports*			*on sculpture*		*colour in soil*	*patterns*	*colour photo-graphs*
	description in text[13]	*listed in table of colours*[14]	*sketch of pattern*	*present in 2003-06*	*remains of colour*			
T2G2:97	Yuan 1990 (AH 83, p. 215)	p. 396	--	storage room	x	--	traces of pattern on chest an back	--
T20G10:97	--	p. 427	Shaanxi sheng, 1988, p. 138: 1. right shoulder (rhombi, tie, collar) p. 137: 2. rhombus border 3. left shoulder (rhombi, tie)	show case in pit no. 2	x	--	--	--
T12G7:H93	--	--	--	storage room	few	--	--	--
T4:1	Yuan 1990 (AH 83, p. 215)	--	Yuan 1990, p. 293: 1. rhombus border 2. bird pattern p. 145. drawing of figure with rhombus pattern border	-- (in Leipzig)		--		--
T9:1	Yuan 1990 (AH 83, p. 215)	--	Yuan 1990, p. 296 1. collar part back (rhombi, birds) (B-101)	storage room	x	B-0101	B-0101	B-0101
T10G5:15	--	--	--	storage room	few	--	--	
T22G9:1	--	--	--	-- (in Xiamen)	x	back, in pit	back, in pit	detail of colour in soil
T1G3:15	--	p. 397 (incorrect)	--	storage room	very few	--		--
T19G9:13	--	p. 417 (incorrect)	--	storage room	very few	--		--

Tab. 1. Overview on all existing material on the generals' polychromy

◄

Fig. 17. T22G9:1, Paint layer of the back in pit no. 1, situation in June 2005

Fig. 18. Drawing of the back: Part of armour, two fragments of the shoulder (top part) already turned

Fig. 19. Drawing of the fragments rearranged and mirrored to a 'positive' image

Fig. 20. Position of the preserved polychrome areas on the back of the general

[13] Yuan 1990, translated into German in [AH 83].
[14] Shaanxi sheng 1988, vol. 1, p. 396-432.

1.7 Colour reconstructions by Chinese archaeologists

There are some water colour drawings of reconstructed polychrome sculptures published between 1982 and 1999[15]. Among them, there are two of generals:

- General of type 1: The drawing (fig. 21) is based on the drawing of T4:1 form pit no.2. According to Prof. Yuan Zhongyi[16], the colour selection is a combination of T2G2:97 and T4:1.
- General of type 2: The drawing[17] (fig. 22) is not based on the drawing of the archaeologists, but on an individual sketch, maybe by an artist. There is no information which sculpture was the base for the colouring, but it might have been T9:1 from pit no. 2 as T22G9:1 was not yet excavated at that time. Though published in only in a non-Chinese publication, the drawing seems to come from the museum in Lintong as well, as there is a painted replica in the basement of the laboratory which is clearly inspired by the drawing (fig. 23 and 24). The colours are the same for most areas. The parts with patterns show the same (incorrect) interpretation of the decoration: the border of the armour has a white ground and the rhomb grid is orientated horizontally. The ties have a white or light greenish ground with red stripes as well.

1.8 Interpretation of the existing information

All existing data was collected and combined before and during the examination of sculptures and colour fragments. They provide a lot of valuable information on parts of the polychromy which are completely and irretrievably lost.
Understanding and evaluating the existing information was rather difficult. The confusion of numbering systems and the problem of assigning fragments and information to specific sculptures has already been mentioned.

a. Descriptions, tables, drawings
Descriptions of colours are too general to understand details. For example: What is a ‘coloured scale armour’? If you happen to know that chest and borders can be decorated with patterns you might assume that this is one of these armours, but unfortunately it does not tell anything about the types of patterns or the colours.
In the tabular lists was no space to describe details as coloured stripes, patterns etc. All description about faces is that they are ‘pink’. Examination on preserved flesh tones shows that there are various tones of pink, two- and three-layered structures, that eyes, lips, moustache and brows can have different styles and colour as well. Some of the sculptures are missing in the list though they were excavated already at that time. In the existing specifications are some obvious mistakes – quite understandable at a total number of over 1000 figures, but a difficulty for evaluation: If there are ‘red long-stitches’ mentioned for a general without armour (T1G3:15) or ‘pink trousers’, when there are no trousers (T19G9:13), what about the other details: are they reliable or do they all belong to a different sculpture?
And what about the parts which are not mentioned at all? Was there no colour left or were they just not integrated into the description for some reason?

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[15] The first ones published are in: Capon 1982, p. 51. More were presented by Prof. Yuan Zhongyi on his presentation in the international symposium *The Polychromy of the Antiquity and the Terracotta Army of Qin Shihuang*, March 1999 in Xi’an.
[16] Personal information in June 2005 in Xi’an.
[17] Published in Capon 1982, p. 51.

21 22

Fig. 21 and 22. Water colour drawings of the reconstructed polychromy by Chinese archaeologists of the Museum of the Terracotta Army: fig. 21: type 1; fig. 22: type 2

23

24

Fig. 23 and 24. Gypsum replica of a general of type 2 in the storage area in the basement of the laboratory building

Drawings of ornamental patterns have been often published upside down and without clear description, so it was not easy to understand what they showed: sometimes it was enough to turn them over, but often it was very difficult to find out if was a ‘positive’ or a ‘negative’ of the polychromy or which part they really came from. Colour annotations mostly are not complete and sometimes it is also not clear where the lines point at: The line, the background or the filling of an ornament? During the evaluation it also became apparent that there are inaccuracies in the drawings which make it difficult to understand the shapes of the ornaments.

b. Sculptures and colour fragments in soil

Not all sculptures were present in the museum during the time of 2003-2005. Two sculptures were on display in other museums[18]: Both sculptures would be very interesting to examine.
Colour fragments cannot be attributed to the sculptures anymore and also often are darkened by soil or consolidants. The back of general T22G9:1 preserved in the soil in pit no. 1, seems to be the only one of this kind still preserved today. Though covered with Perspex and plastic foil, the surface is grey from fine dust and shows losses caused by the drying of the soil. This large fragment is the most valuable information on the polychromy of the generals. It is the only one where not only the outlines of the patterns, but also fine details can still be observed. And at least for this one sculpture, the distribution and combination of colours can be reconstructed for major parts of the armour and jacket.

c. Interpretation of texts

Descriptions, tabular list and drawings are three possibilities to find and combine information on sculptures. A problem is that sometimes the data does not really match. To give an example: According to the description in the text of Yuan 1990, p. 271,

> *T2G2:97 […] wears a violet long coat. […] a pink and pale blue scarf and his sleeve cuff borders are pale blue. This officer has red trousers and violet puttees and coloured armour plating*[19]

The lists of colours in the appendix of the excavation report Shaanxi sheng 1988, p. 396 contains the information

> *jacket: light red/pink and light blue; sleeve cuff: azure (sky blue); trousers: light red/pink shin protection: light purple; long stitches connecting the armour plates: light red/pink*

In some aspects, the two descriptions complement each other, but in others they are contradictive or at least not clear enough to understand how the colours had been distributed.

d. Problems of identifying and describing colours

A principal problem for the documentation of colours is recording them. The problem has two aspects: 1. Identifying the colour correctly; 2. Recording them in an ‘objective’ way that can be understood and reproduced by others

Identifying the original colour partly is very difficult. One the hand, light conditions inside the pit are rather poor and in the storage room there is only artificial light. On the other, the preserved fragments of colour on the sculptures are often discoloured by the soil, dust or sometimes consolidants. Partly it is difficult to distinguish between thin layers of soil and paint layers of yellowish, whitish or light pink colour. Additionally, modern additions as

[18] Pit no. 2, T4:1 was in the exhibition in Leipzig Markkleeberg until April 2006; pit no. 1, T22G9:1 is in Xiamen, based on a long-term arrangement.

[19] Translation taken from: AH 83, p. 221

fillings, retouches, drops and flakes of colour from transport boxes or white gypsum from casting the sculptures impair the original surfaces. They partly cover original colour traces and complicate the legibility of the remaining colour fragments.

Describing colour shades is always linked to individual sensations: If an area is ‘light red’ or ‘red’, if it is ‘ochre’ or ‘yellow’ at least partly is a personal impression. Additionally there seems to be a difference in the use of colour terms between China and Germany. For example, dark areas are often described as ‘dark violet’ or ‘dark blue’ in Chinese reports. In fact, they are black – a circumstance I only realised because there is no dark blue at all in the terracotta army.[20] This shifting from black or very dark to blue is also visible on the reconstructions of the generals: Fig. 18 shows the drawing of a general of type 2 with dark brown chest part. The interpretation in a drawing of a general of type 1 (fig. 17) transformed dark brown into dark blue. The implementation on a gypsum replica (fig. 20) further converted dark blue into medium blue, maybe realising that using azurite – the only blue pigment used on the terracotta army – this is the darkest blue which can be obtained.

As the black lines of the rhomb grid of the borders are marked as ‘black’, ‘dark purple’ and ‘blue’ in different drawings, it took some experience to decide that in fact they are always black.

Other examples for descriptions which often diverge from the German view are
- ‘purple’ for reddish brown,
- ‘purple’ for ‘pink’ and vice versa,
- ‘light green’ for ‘light ochre’.

These difficulties were one reason to use self-made colour charts for the documentation and record the colours in drawings of each figure either during the investigation or right afterwards. Photographs have only been used as support for the memory and to record traces of patterns. The small, discoloured remnants of polychromy on the sculpture T2G2:97 could be described in the following way[21]:

T2G2:97

outer jacket, outside: light purple
collar of outer jacket: bluish violet
collar of inner jacket and sleeve cuffs: black stripe (next to the bluish violet), white stripe (edge)
inner jacket: collar completely lost; trimming on the lower seam: light pink, 1 cm wide
inside of inner jacket/underneath: white (?)
shin protection: upper part: light pink, lower part: light pink on top of white ?
chest and back: ‘bird and sun pattern’ as ‘negative’ by remaining lacquer where the double layer (lines of pattern on background) had been applied
ties on the armour: white (?) ground with black (?) and green (?) stripes
shoulder protections: black with traces of yellow white (pattern ?)
shoes: lacquered, borders painted, but colour lost
base slab: not lacquered
face: two layers, both almost white

without traces of colour: cap, hair, eyes, lips, moustache, brows; inner jacket; armour plates, long stitches, short stitches, border of shoulder protection, border of armour

Fig. 25. Reconstruction of polychromy using all available information

[20] Lapislazuli was not known in pre-Buddhist China. Organic dyestuffs as indigo were never detected in the polychromy of the terracotta army.

[21] The sculpture was examined in the storage room of the museum. A daylight lamp was used as light source.

In the end, the traces of colours of the sculptures and especially the fragments in soil turned out to the clue to understand and reconstruct the generals' polychromy and the patterns. Examinations on these 'primary sources' were the base of the investigation, completed by the records, drawings and photographs of the Chinese side.

1.9 Information from outside of the terracotta army

Besides information on and about the generals from the terracotta army, there are the some other sources which could be evaluated, because they might give further hints on the colour design of the generals. These are:

- Charioteers of the bronze chariots: as already mentioned above, the charioteers are generals as well and therefore can be regarded as two more generals of type 3. Especially the patterns of belts, hems of outer jacket and the strap or tie holding the sword are of interest as they might show elements which are lost on all terracotta sculptures. The colours of the clothes cannot be recognised on photographs or by observing the originals inside the showcases, but there is a description in Yuan 1990.[22]
- Sculptures from other pits as civil servants or grooms, as the cut of the clothes is the same.
- For understanding the type of jackets and clothes, comparisons with other terracotta army, as the ones from Yangjianwan[23] are interesting as they are dressed in a similar way: No uniforms, but armours made of dark brown square plates. The hems of the jackets are at least partly decorated with geometric patterns.
- Comparison with archaeological textiles: findings of textiles in tombs of the Warring States and Han Period show which colours, patterns and cloth designs were fashionable and allowed at that time (according to rites and regulations). The findings with a greater number of well-preserved textiles are ladies' tombs as the one in Mawangdui[24] or Mashan[25], but as the style of man and woman did not differ much at that time, they can also serve as indication for what is depicted on the terracotta army. More difficult is the fact that all findings – as far as it is known – do not come from the state of Qin, but from state of Chu (as Mawangdui, Mashan or Zuojiatang), states in the East (as Mancheng in Hebei or places in modern Henan or Shandong) or later on the garrison cities in Xinjiang (Western and especially Eastern Han Dynasty). The Qin Dynasty was short, ended in the total devastation of the capital and organic materials decompose in the wet, humid soil. So there is not too much hope that well-preserved textiles will be found, if not in tombs related to the Imperial family. And these are out of discussion for being excavated in the next generation. There is only one fabric published from the Imperial Qin court: It is the trace of a belt (?) pattern found in the burnt ruins of a Qin Palace in Xianyang. The black and white drawing (without scale or colour annotations) shows a zigzag forming rhombi with small birds and tigers.[26]

These sources of information have been partly used for interpreting the colour remnants on the generals, but this part of the work is not finished yet and will be continued at least in 2006.

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22 English translation: in AH 83, p. 223.

23 The army has 1965 infantrymen, 583 cavalrymen (on horses) and 410 shields, all made of painted terracotta. The standing warriors are about 40 cm high. The 13 pits excavated in 1965 near the grave mound Changling are interpreted as burial gifts for the First Han Emperor Gaozu (Liu Bang, died 195 BC) who is buried in Changling together with his two wives.

24 Mawangdui, near Changsha in Hunan Province, tomb no. 1 of the Marquise of Dai, who probably died in 168 BC. She was buried, dressed in layers of clothes with more textiles as burial gifts, altogether 14 robes. The tomb was excellently preserved when found in 1973.

25 Mashan near Jiangling in Hubei Province, tomb of a 'middle-class' lady, died in 330-320 BC.

26 Zhao Feng 1992, p. 110.

2. Colours of Clothes

The first step for reconstructing the polychrome scheme was to understand the cut or design of the clothes. The visible parts of clothing consist of jackets (undergarment and two long jackets) and shin protections, caps and shoes. On generals without armour (type 3) also the belt is visible.[27]

2.1 Jackets and undergarment

The generals wear two jackets one upon the other. The inner one is only visible at the lower hem as it is longer than the outer one.
The connection of sleeve cuffs and collar to the jackets is more difficult to understand. A look on other sculptures shows that all terracotta figures wear a jacket with plain hems. If edged with a border, this is a narrow flat strip of fabric. From a layer underneath a thick folded collar is visible. It mostly has two or three coloured stripes. Mostly the same colours reappear on the sleeve cuffs. This indicates that sleeve cuffs and collar belong to the same garment.[28] The two colours could be the one of the garment itself and an applied border part.

Regarding this system, the clothes of the generals can be interpreted as follows:
1. Undergarment of which long sleeve cuffs and collar parts which fold up to thick coils
2. Inner long jacket which is only visible at the lower hem
3. Outer long jacket with rather short sleeves (not coming down to the wrists) and rather wide neck, allowing the thick cuffs and collar of the undergarment to stick out

undergarment inner long jacket outer long jacket

Fig. 26. General from bronze chariot no. 1: System of clothing

[27] For the following explanations fig. 30 at the end of this chapter showing five reconstructed generals can help to visualise the descriptions.

[28] Yuan 1990, p. 267 (English translation in: AH 83, p. 209) discusses that the collars (or some of same) in fact as scarves. Though the modelling gives no definite information, the relation of colouring makes it implausible that the collars are parts separate from the sleeve cuffs.

The long jackets appear to be wadded as they are of considerable thickness. The lining inside is only visible "underneath" (i.e. were the legs start or at the overlapping tails of the jackets).
The system of cloth can be demonstrated very well on the general of the bronze chariot no. 1 (fig. 26).

The colour of the **outer jacket** can be identified on five generals: Three generals of type 1 wear purple jackets[29], two generals of type 2 wear green jackets[30]. The third figure of type 3 (T10G5:15) maybe wears a brownish pink jacket. The colours on type 3 are not retained.
The colour of the **inner jacket** is only preserved on two sculptures: in one case it is green[31], in the other red[32].
The **sleeve cuffs** show at least two stripes of different colour. The same colours reappear on the **collars**. As combinations red (second colour missing), black and white, blue and pink, purple (and white), purple and blue, brownish pink (second colour missing)[33] can be identified.
The outer jacket of the generals is the largest colour unit on the sculptures - even if they wear a suit of armour which partly covers the jacket. The inner jacket is only a small colour strip between outer jacket and legs. In general, it seems that inner jacket and outer jacket mainly have different colours. If they do not, as on T22G9:1, there is coloured line in between to separate the two areas. Sleeve cuffs and collars have colours different from the outer jacket and probably also from the inner one. The same system is visible on the bronze charioteer: he has a white collar/sleeve cuff, a green outer and a red inner jacket.

2.2 Borders of jackets

Outer and inner jackets can have borders along the hems of a different colour. On the outer jacket these borders run around sleeves and the neck and end in the waist. The lower part of sides and the lower hem are not decorated. The same type of robe can be observed on the half-life size kneeling grooms and the bronze charioteers. Jackets of this type also have been found in tombs.[34] As colours of the border black and bluish purple have been identified.[35] In both cases a colour different from the outer jacket, inner jacket and sleeve cuffs/collar. Also on the grooms the border is different in colour from jacket and collar.
The inner jacket can have a narrow coloured borders as well. They are running around the lower hem and the sides, where they become visible. This was found on one sculpture (T2G2:97). Though the colour of the jacket and the maybe light pink border are almost completely lost, the line of the decorated hem is still well visible.

29 Pit no. 1, T20G10:97, T2G2:97; pit no. 2, T4:1.
30 Pit no. 1, T22G9:1; pit no. 2, T9:1.
31 Pit no. 1, T22G9:1.
32 Pit no. 2, T4:1.
33 Arrangement of colours from jacket to skin: red (second colour missing): pit no. 1, T20G10:97; black and white: pit no. 1, T2G2:97; blue and pink: pit no. 1, T22G9:1; purple (and white): pit no. 2, T9:1; purple and blue: T10G5:15; brownish pink: T1G3:15.
34 For example an unlined white robe from Mawangdui, tomb no. 1 and an embroidered robe from Mashan.
35 Black: pit no. 1. T22G9:1; bluish purple: pit no.1, T2G2:97.

The lower part of the right sleeve of T22G9:1 is preserved in pit no. 1. The green jacket is edged with a 3 cm wide border at the cuff. Where the black layer is damaged thin red lines can be distinguished orientated in both directions in ca. 45 ° angle. Obviously some kind of decoration was painted on the black with straight red lines. As the black ground (which is on top now) mainly covers the red, it is not possible to reconstruct the decoration.
An idea what this might be can be gained looking at the general from the bronze chariot no. 1. He wears a green outer jacket a white border. Geometrical ornaments decorate the border (fig. 27). According to the archaeological reports they painted in black and vermilion red.[36] Drawings[37] show two superimposed rows of patterns: the first ones are angled 'pincer'-shaped ornaments, the second small 'double Z'. Both ornaments remember textiles with scattered geometrical patterns from this period.

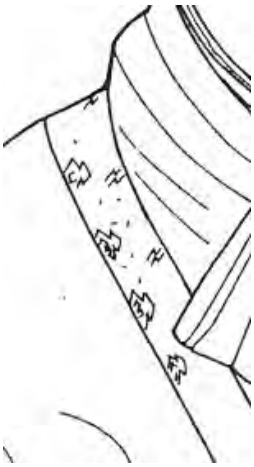

Fig. 27. General from bronze chariot no. 1
Geometrical pattern on border
[Qin Shihuangling tong che ma 1998, vol. 1, p. 58

2.3 Trousers and shin protections

Looking at the legs, from the modelling it is difficult to decide if trousers or shin protections are depicted. As Shaanxi sheng 1988 names colours for 'trousers' it is the question if there are trousers, and if, which part they are.
Except for one sculpture[38], the leg part is divided into an upper and a lower section as it is often the case on shin protections. As the long jackets already cover the knees, only the lower legs are visible. Therefore the trousers which normally are just knee-long should be hidden below the inner long jacket. Nevertheless, the upper part of the divided sections could be regarded as 'trousers'. But it seems more likely that the generals either wear thick two-part shin protections (like the kneeling archers) or long trousers coming down to the ankles. Comparing these sculptures to others, it is more likely that they wear shin protections.
The two-part ones show two colours and at least the upper colour is different from the inner jacket (i.e. the adjacent area). As colours light pink (top), light blue (top), green (total), purple (top) and green (below), black (lower part), bluish purple (top) and reddish purple (lower part)[39] appear which seems to indicate that al colours and all colour combinations were possible here.

2.4 Shoes

Seven of the generals have shoes with decorated borders, but no shoe laces. The borders are a little thicker than the shoe itself so it looks like the leather of the shoe was edged with a textile border. Just one general wears shoes without borders.[40]

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36 Yuan 1990, p. 267 (English translation in: Ah 83, p. 209
37 Qin Shihuangling tong che ma 1998, vol.1, p. 58
38 Pit no. 2, T4:1
39 Colours of shin protections: light pink (top): pit no.1, T2G2:97; light blue (top): pit no. 12, T20G10:97; green (total): pit no. 2, T4:1, purple (top) and green (below): pit no. 2, T9:1; black (lower part): pit no. 1, T10G15:5, bluish purple (top): pit no. 1, T19G9:13; reddish purple (lower part): pit no. 1, T1G3:15
40 Only the general T19G9:13 has no borders at the shoes. The feet of T12G7:H93 are not original, but completions.

The colours of the feet are extremely bad preserved: It is only possible to say that the borders were painted as the remnants of lacquer look different in these areas. As colours green (T1G3:15) and maybe light pink (T4:1) could be determined, on T2G2:97 it was a very light colour as white or light pink. It seems likely that also these textile applications might have pattern decorations for the high ranking officers, but there are no traces big enough left. The tiny remnants are also not thick enough anymore to still exhibit the original surface.

2.5 Belts

Belts are only visible on generals of type 3 because the suit of armour covers the waist completely. No colour is preserved on the belts of the two sculptures of this type, but only tiny remnants of lacquer. While the belt of T1G3:15 is smooth and has a very simply button-like belt hook, the belt of T19G9:13 shows a rhomb pattern in relief which seems to have been imprinted with a roll-shaped die (fig. 28). Compared to other imprinted or painted belts (fig. 29) the decoration of this belt seems extremely simply, especially for a general. There are no indications of how or if it had been painted. The drop-shaped belt hook was white.

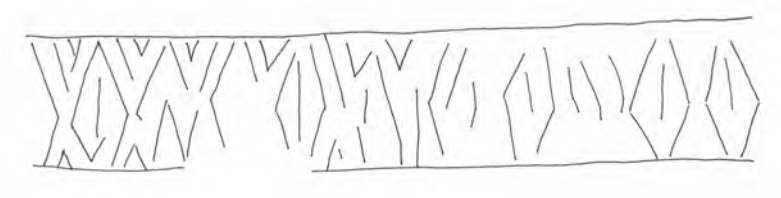


Fig. 28. imprinted pattern on the belt of T19G9:13; the lines are the ridges of the pattern (width of belt: 3.5 cm)

White belt hooks were also discovered on cavalrymen (fig. 29). The choice of white colour seems surprising because the original belt hooks of the time of the Warring States to the Han Period were made of bronze. The more elegant have inlays of silver. Therefore one would expect something yellowish as imitation of a polished bronze. If the white colour is thought to imitate metal, it might be polished silver.

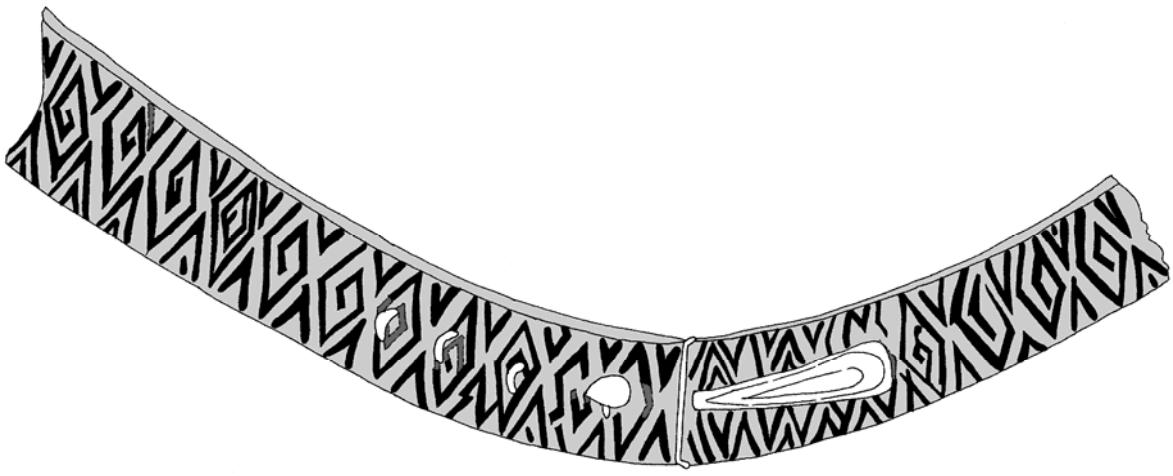


Fig. 29. Belt of a cavalrymen with decoration painted in black on the lacquer and white ‘drop’-shaped belt hook

2.6 Parts without any information – caps and tie of cap

Among the parts without any traces of colour one all nine figures are the caps. Some sculptures show some white traces on caps and ties holding the cap, but as there is white in the hair as well, this seems to be caused by making a gypsum cast. The caps are interpreted to be made of fabric immersed into lacquer. So it seems likely that the cap itself was not painted, but only lacquered. The tie holding the cap consists of two parts: one is holding the cap on the back part of the head and is bound into a tie below the chin. To this tie another is knotted that runs over the front part of the head.
There are traces of colour on the ties of the caps of lower ranking officers, all of them next to the cheeks. This indicates that the ties were originally painted. As they consist of two parts, they could also have two colours. They could also be decorated with a pattern, similar to the ties on the armour (see 3.3), but the traces of colour are too tiny to give any indication.

All information was recorded as descriptions and with the abbreviations of the self-made colour charts. Colour remnants were indicated with water colour and descriptions into sketches of the sculptures. As it is difficult to visualize an impression of the coloured sculpture, reconstruction sketches were made. All reliable information on the single sculptures was used. Additionally also parts without information were painted as far as they can be concluded without doubt from other examples (e.g. that the lips are red, hair and shoes are lacquered).

For five generals, these reconstructions resulted in a rather complete impression of the polychromy though parts are missing on every sculpture. For the other four generals, large cannot be reconstructed or the original colour is so unclear that a visualisation is not possible or reasonable yet. Fig. 30 shows the five generals which could be reconstructed for larger parts.

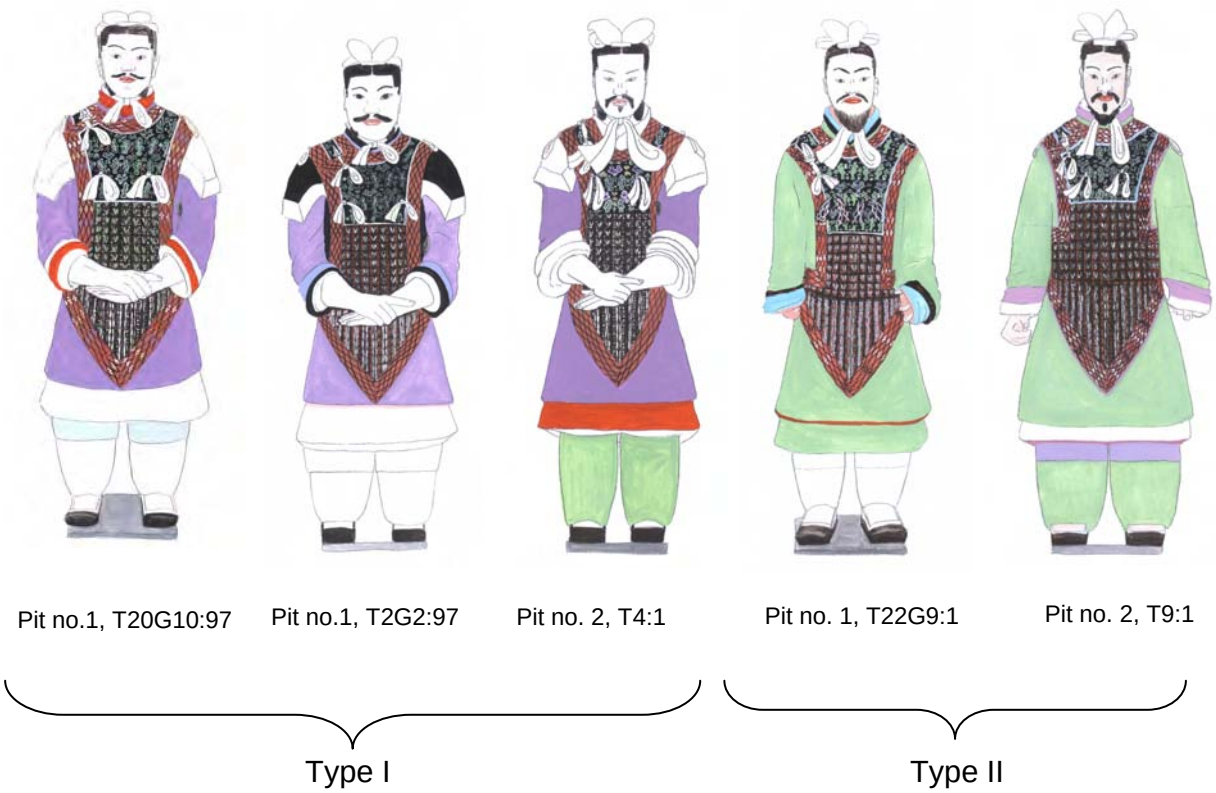


Fig. 30. Colour drawings of the generals whose polychromy could reconstructed in large parts.

3. Suits of armour

The generals wear armours different from all other types of warriors in shape and design: The back ends in the waist, but the front has a pointed apron hanging down almost to the knees. Only the part over stomach and back has plates while the upper part covering the chest is smooth. The plates are linked like on the other soldiers, but additionally show V-shaped stitches which probably are decoration. The edges of the armour are edged with 5 cm wide borders which run around neck, arm holes and lower edge. The armour can be with shoulder protection parts (type 1) or without (type 2).
The decorated parts are: the borders along the edges; the chest part; smooth parts of shoulder protection; border of shoulder protection. Also the ties on chest and shoulders and connecting stitches of the armour plates are painted.

3.1 Borders along the edges of armour – Rhomb grid pattern

Not on one single sculpture the borders still show traces of polychromy today. Colours and design of these borders are preserved in fragments in soil of two sculptures (fig 26).[41] The borders of two more sculptures are recorded as black and white line drawings in the excavation reports (see fig. 6-8, 10, 11).[42] As the pattern is the same on these five generals, one can assume that the pattern of the border was the same on all sculptures.

3.1.1 Description of the pattern

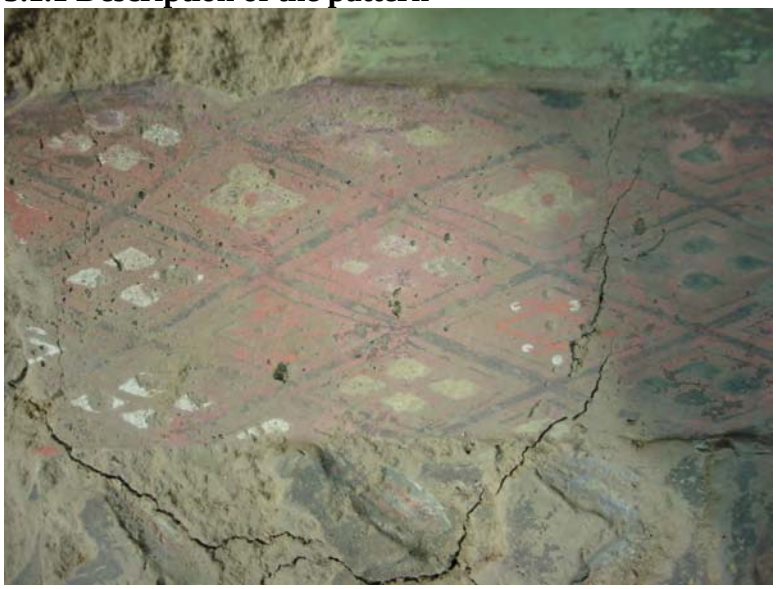


Fig. 31. Detail of rhomb pattern of colour in soil in pit 1 from T22G9:1

The borders show a rhomb grid which is filled with geometrical ornaments.
The **ground** is reddish brown with a purplish tinge. Colour fragments on pit no. 2, T9:1, from the incision at the transition of armour to jacket look bright purple while the area on the soil fragment B-0101 from the same sculpture is reddish brown. As reconstruction tests showed later on, a considerable addition of Han Purple is necessary to mix this colour from the analysed palette of pigments.

The **grid of intersecting black lines** forms a **rhomb** structure. Regarding the border as a horizontal band, the rhombi are “lying”, i.e. the obtuse angles are on top and bottom, the acute angles on the side.

[41] Soil fragment B-0101of pit no. 2, T9:1; colour in soil of pit no.1, T22G9:1

[42] Pit no. 1, T20G10:97, in: Shaanxi sheng 1988, p. 137 and 138, see fig. 5, 6, 7 of this report. Pit no. 2, T4:1, in: Yuan 1990, p. 293, see fig. 9 of this report.

The rhomb grid was contoured with very fine black lines, before the geometrical **fillings** were painted. There are three main ornaments: Four small lozenges arranged in vertical rows are interspaced with broken lozenges and a line and dot pattern in horizontal rows. The half rhombi along the edges are filled with two more geometric patterns which are only partly visible.

3.1.2 Construction of rhomb grid

Comparing the preserved and sketched grids it became obvious that the size of the rhombi is not varying. On curved parts of the border (i.e. the bigger part of the total length), also the rhomb grid is bent. The rhombi are compressed or stretched slightly here, but the average length is always the same. There are always three rhombi on top of each other (sometimes three and a half), and the central rhomb always remains in the middle. The 1mm wide lines are drawn freehand without a ruler though they are extremely regular and straight.
Even if the painter had a lot of experience this kind of regularity indicates that there was a construction system. But it must be an invisible one, as the painting system makes corrections or changes impossible.

The average length of a rhomb is 34 mm, the height 16 mm. The angles measure 50° and 130°. As the borders are 5 cm wide, exactly three complete rhombi can be arranged on top of each other. The interspaces show two complete and two half rhombi:

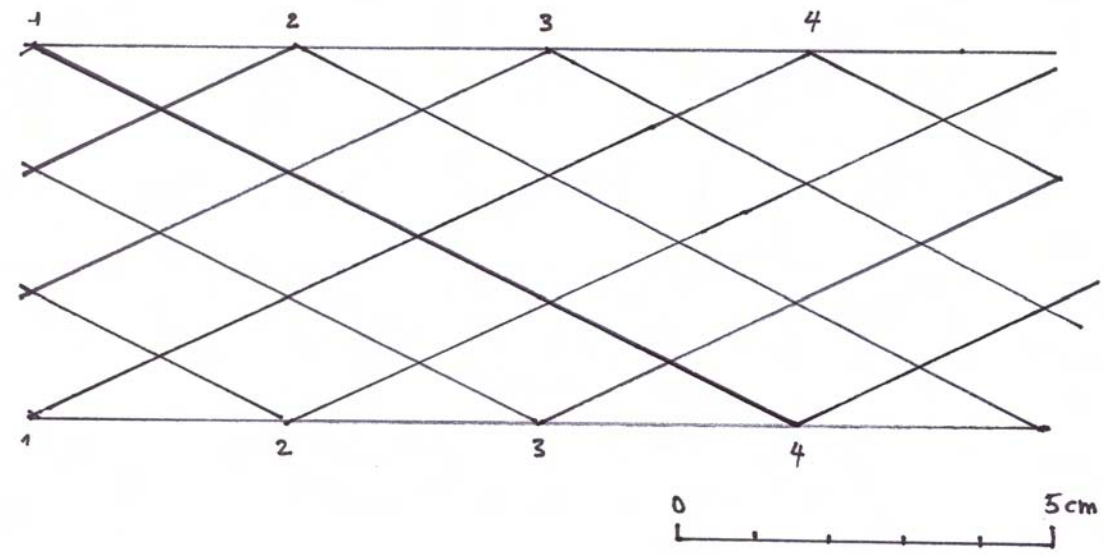
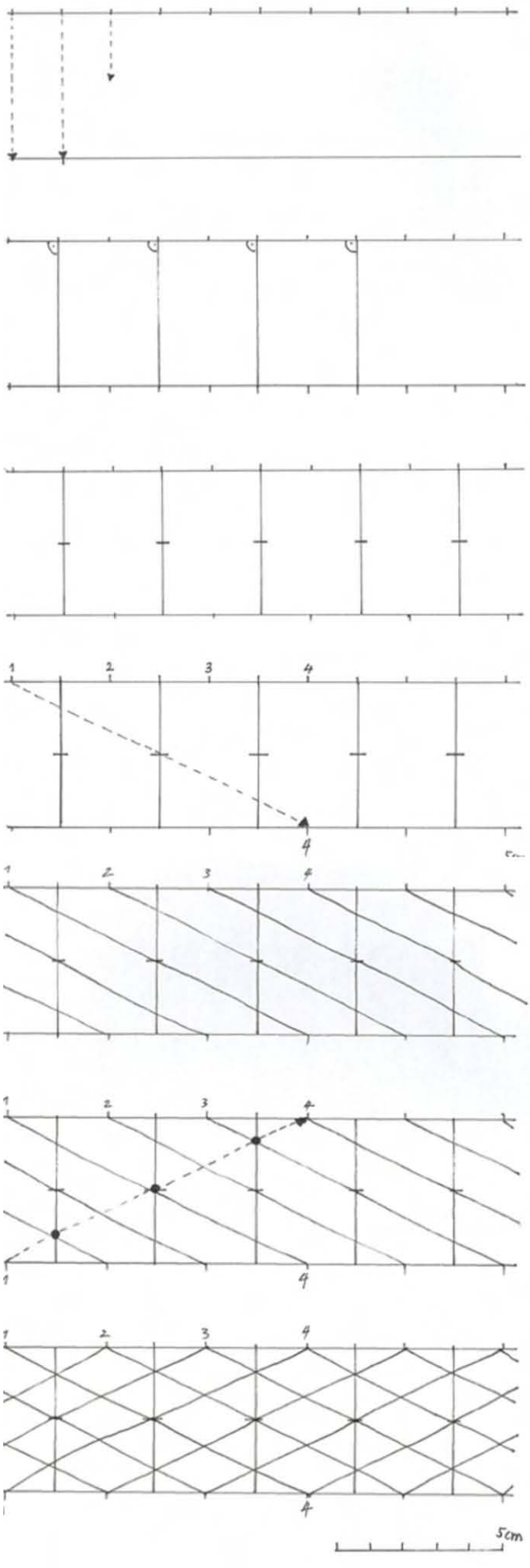


Fig. 32. Rhomb grid

A grid with three rhombi on top of each other can be easily obtained: The length of the rhombi is marked along the border. Then the first mark on the top (1) is connected to the fourth on the bottom (4). This 1 to 4 system on a 5 cm wide strip with a distance of 34 mm between the marks creates rhombi of the fitting size.
A construction system easy to apply the rhomb pattern on the sculpture on which almost all surfaces are curved in at least one direction emerged during the reconstruction of the polychromy on a replica of a general[43] (fig. 33). Intersection points created by a system of subsidiary perpendiculars help to draw regular lines in the correct distances. It also works when the border strip is bent so that the rhombi are distorted. (fig. 34). The result is that the border looks like textile band with woven pattern which distorts when following the shape of the body.

[43] This system was developed together with the conservator Carolin Roth while painting the replica.



1. Along the edge the half length of the rhombi (17 mm) are marked. The corresponding point on the opposite edge is marked as well.

2. On every second mark a line is drawn perpendicular to the edge.

3. The centre of the perpendicular is marked.

4. The rhomb grid is started by connecting mark 1 to mark 4.
Starting at 1 on the upper edge, the line crosses the centre of the perpendicular at 2 ½ and runs into 4 on the opposite side.

5. All lines in one direction are drawn like this.

6. The crossing lines are drawn in same way: Starting at 1 on the lower edge, the line crosses the lines running in the other direction at 1 ½, 2 ½ (=centre of perpendicular) and 3 ½ and than meets 4 on the upper edge.

7. After all lines are drawn like this, the grid is finished.

Fig. 33. Construction of rhomb grid on a straight part of the border

In the same way rhombi can be constructed however the border is curved.

1. Marks in the distance of 17 mm are applied on the edge. Here it is important to start marking on the curved-in (i.e. shorter) side. When the curving changes, a perpendicular has to be drawn to the opposite site and the marking continues there.

2. Perpendiculars are drawn starting from the marks.

3. The centres of the perpendiculars are marked.

4. Start drawing the lines from 1 on the upper edge, crossing the perpendicular at 2 ½, ending at 4 on the lower edge.

5. Draw all lines in one direction

6. Draw the lines in the opposite direction by starting at 1 on the lower edge, crossing the lines of the other direction at their intersection perpendiculars at 1 ½, 2 ½ and 3 ½, ending at 4 at the lower edge.

7. Draw all lines of the second direction.

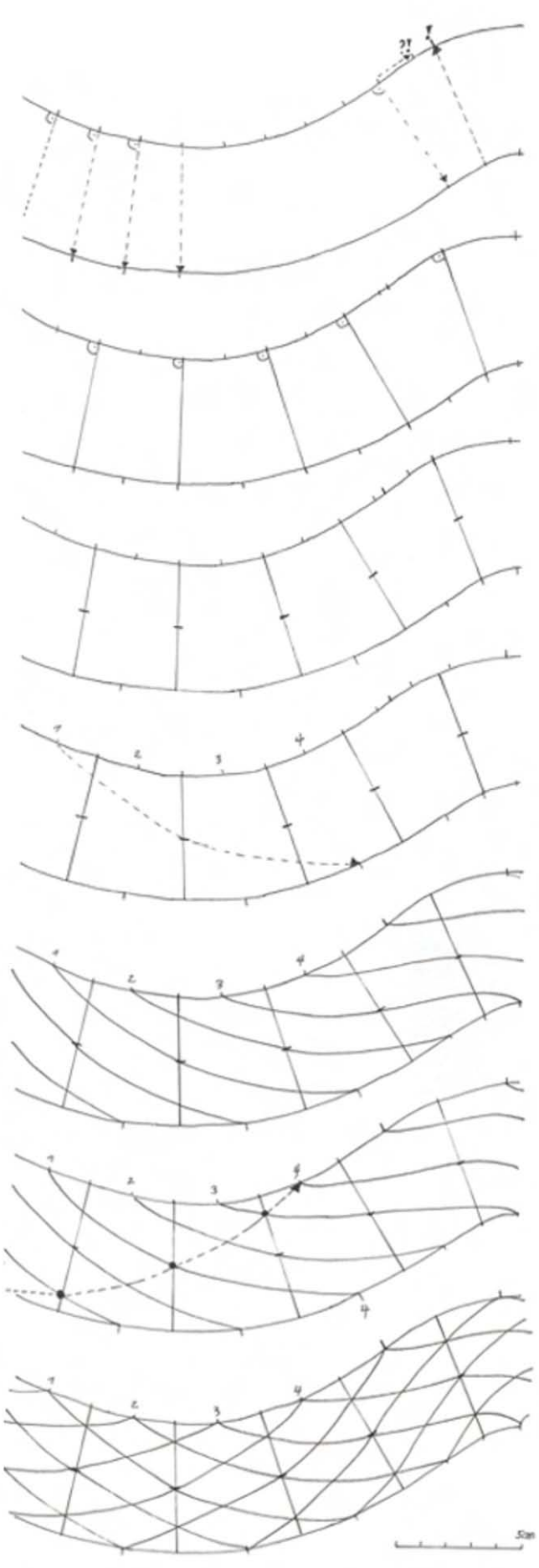


Fig. 34. Constructing rhomb pattern on a bent part of the border

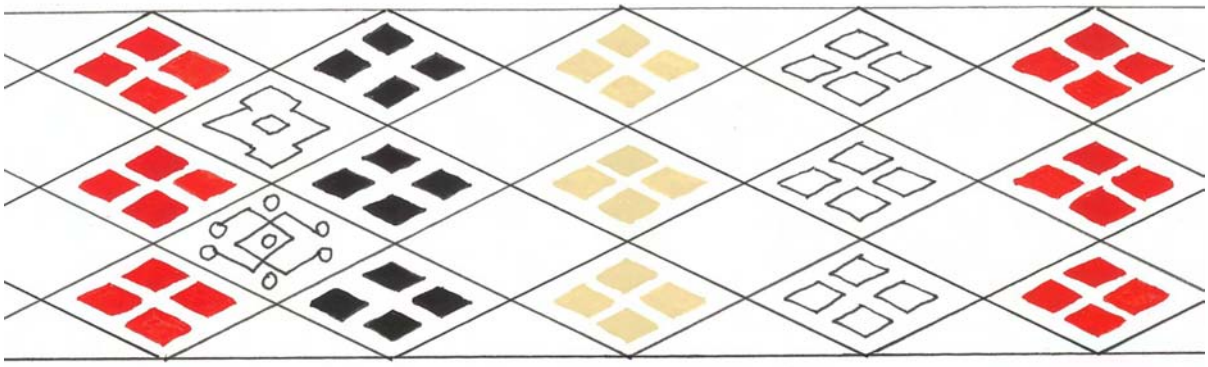
3.1.3 Four lozenges ornament

The filling of the rhombi started with the ornament of for small lozenges. The lozenges are placed into the rhombi which are complete, so that three lozenge fillings are in a vertical row. Each vertical row of lozenges has a different colour. After four lozenge fillings the colours are repeating. The sequence of colours is the same on all documented fragments. The fact that red and white are exchanged in one case[44] can be interpreted as 'mistake' or free interpretation of the painters who allowed interspersing minor alternations in many places.
To understand the arrangement of colours, the orientation of the border is important. For all following descriptions, the border is regarded in this way:
- border runs horizontally
- above border: side facing jacket or collar
- below border: side facing the armour
- the pattern is regarded as 'positive' (i.e. as if looking onto the sculpture).

In this case the sequence of colours is:

red – black – light ochre – white – red …..

jacket, sleeve, collar



armour plates, chest pattern

Fig. 35. Sequence of colours of four lozenges-ornament

3.1.4 Broken lozenges ('ear cup') ornament

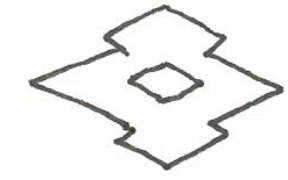
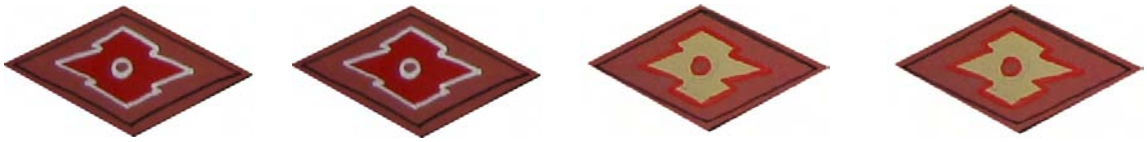


Fig. 36. Broken lozenge ('ear-cup' pattern)

The interspaces of the four small lozenges are filled two types of ornaments horizontal rows. The top row shows an ornament of broken lozenges, a very wide-spread ornament at that time. This nameless ornament was tentatively called 'ear-cup' (杯纹) pattern by Zhao Feng 1999[45], following the mentioning of 'ear-cup motives' in the *Shiming*. The term is not common or accepted, but appears useful as it helps to distinguish these broken lozenges from other lozenge based ornaments.
The broken lozenges are always two-coloured: The ornament has one colour and the outlines are traced in a second colour. There are different variations of colour sequences and combinations. After four lozenges the sequence is repeated so they stay in rhythm with the four lozenges-ornaments. The first red lozenge is placed left to a white four lozenges-ornament. The basic type seems to be

[44] On the left shoulder of T20G10:97, according to drawing in Shaanxi sheng 1988, p. 137 (fig. 8 of this report).
[45] Zhao Feng 1999, p. 48. The identification as 'ear-cup' is based on the idea that this broken lozenge looks like an edgy stylised ear-cup seen from the top.



red
white outline

red
white outline

ochre
red outline

ochre
red outline

Fig. 37

Variations are:
- outline the first red lozenge with ochre (T22G9:1)
- replace the first ochre lozenge by a violet one with red outline (T9:1, T20G10:97).

There are several places where the sequence is mixed or the lozenge rows are shifted compared to the four lozenges. This probably means that the pattern had not to be followed too strictly concerning sequence of colours and starting point of the sequence.

3.1.5 Line and dot ('frog') ornament

The row below the broken lozenges is filled with ornaments consisting of lines and dots. The lines form two overlapping lozenges open on the outer edges and dots are places on the ends, in the centre and below and above (seven dots all together). To make it easier to talk about this pattern, I provisionally called it the 'frog' until a better term is found.

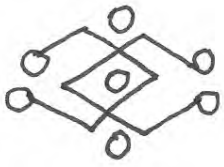


Fig. 38. 'Frog' pattern

The lines and dots are painted separately using three colours (red, ochre and white) in sequence of four colours: red – ochre – white – red – etc….. The system here is

1. paint the legs of the first 'frog' with one colour

2. take the second colour and paint the dots of the 'frog' and the legs of second 'frog'

3. take the third colour and paint the dots of the second 'frog' and the legs of third 'frog'

4. take the fourth colour and paint the dots of the third 'frog' and the legs of fourth 'frog'

5. take a first colour and paint the dots of the fourth 'frog' and the legs of next first 'frog'

Fig. 39. Constructing the 'frog' pattern

etc. (repeat step 2 to 5)

The start of the sequence seems to be not linked to the broken lozenges or the four lozenge ornament. It is also shifting on the same figure, e.g. it is different on the arm holes and the lower border of T22G9:1.

3.1.6 Bevelled border ornaments

The ornaments in the half rhombi along the edges above and below broken lozenge and 'frog' cannot be understood clearly.
Above the broken lozenge there is something that can look like a half lozenge without outline[46], but can also have an outline[47].
Below the 'frog' is an angled line, partly accompanied by a second[48], but there also two small lozenges[49], a broken lozenge without outline and centre or a U-shaped ornament are reported.[50]
The colours of these bevelled ornaments is always linked to the four lozenge rows: The ornament above the broken lozenge right to the four lozenges and the ornament below the 'frog' left to the four lozenges have the same colour as the lozenge row. Regarded in the painting process this could mean: Take on colour and start at the lower border with a cut-off angled ornament; proceed to the right and paint a vertical row of four lozenges; proceed to the right and finish with a cut-off broken lozenge.

Describing all these details sounds confusing, but is necessary to understand the system. The reconstruction of a complete pattern looks like this which is one of four reconstructed borders:

green jacket

chest part of armour

Fig. 40. Reconstruction of rhomb pattern border based on the collar of T9:1 on fragment B-0101

[46] Pit no. 1, T20G10:97; pit no. 1, T22G9:1; pit no. 2, T4:1.
[47] Pit no. 2, T4:1.
[48] Pit no. 1, T22G9:1; pit no. 2, T9:1
[49] Pit no. 2, T4:1, drawing of the archaeologists in Yuan 1990, p. 293 (see fig. 9 of this report)
[50] Pit no. 1, T20G10:97, drawing of the archaeologists in Shaanxi sheng 1988, p. 137/8 (see. fig 6 to 8 of this report).

3.2 Chest part - ‘Bird and sun’ pattern

The chest part of the armour is modelled as a smooth area. It is edged by the rhomb grid border towards collar and arms. Below the chest part, the armour plates are on a slightly receding level. The modelling thus looks as if the chest part is one layer overlapping the armour plate. Both parts then when edged with the rhomb grid borders. The chest part was decorated with a painted pattern.

3.2.1 Preserved fragments and information

There are no descriptions or interpretations of this pattern. The three drawings in the archaeological reports (fig. 6, 9, 11) showing fragments of the pattern are difficult to understand as there is no description where they exactly come from.
The most valuable sources for reconstructing the chest part of the armours are the fragments in soil, B-0101 from T9:1 and the back of T22G9:1 in pit no. 1. After B-0101 had been examined and documented carefully (fig. 41 and 42), the drawings and photographs of the pattern became comprehensible.

Fig. 41. Fragment B-0101, colour fragment in soil, mounted in plaster

Fig. 42. Colour drawing of B-0101

It turned out that they are published upside down or turned to the side. After bringing them to the correct orientation, also their approximate position on the sculptures could be identified:
- One fragment (fig. 42) clearly shows fragment B-0101. As it is described as part of T4:1 in the caption, the fragment could be attributed to this general.
- The next one (fig. 43) can be identified as part of the shoulder as the tie on the rhomb grid border is visible. According to the caption it comes from T20G10:97. The ties have only one loop which is hanging down on one side and two loose ends hanging down on the other. As the ties on the shoulder all seem to be arranged in that way that the loops point to the front and the loose ends to the back, the fragment should come from the backside of the right shoulder.
- The last one (fig. 44) is part somewhere from the inner part of the pattern. The caption attributes it to the general T4:1. Although the specific spot cannot be determined, it is clear that it was published upside down.

The drawings document outlines and some of the colours of the ornaments. The colour of the ground is not mentioned.

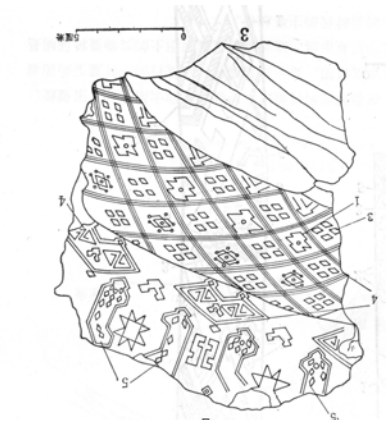


Fig. 43. Yuan 1990, p. 293
pit no. 2, T9:1, B-0101

Fig. 44. Shaanxi sheng 1988, p. 138
T20G10:97 - right shoulder

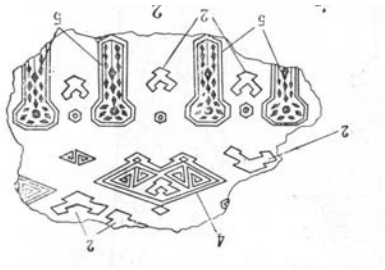
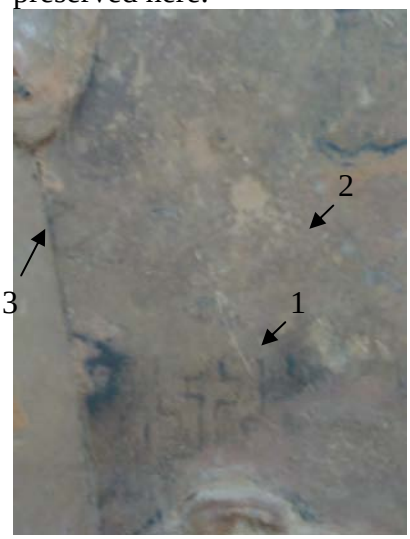


Fig. 45. Yuan 1990, p. 293
pit no. 2, T4:1

The large fragment of the back of T22G9:1 was mentioned already (chapter 1.6; figures 14-20). It became the most important source of information as almost all parts of the armour are preserved here.



Not on one of the sculptures the polychromy of the chest part is preserved, but during the examination of T2G2:97 traces of the patterns were found on the chest part (fig. 46): The outlines of the ornaments have survived as thin lines of lacquer visible on the terracotta. Probably the thicker application of paint in these areas has caused this phenomenon.

Fig. 46. Outlines of ornaments visible as black lacquer lines on the chest of T2G2:97 (1: 'SZ'; 2: '*huang*'; 3: small lozenge filling)

3.2.2 Reconstructing the pattern unit

Fragment B-0101 showed that the chest part has a black ground. Ornaments are painted on this with thin greenish lines (fig. 47). Below the border first a row of angular ornaments is visible drawn with fine lines (①). Below is a row ornaments painted in green with greenish outline and black hexagonal spots (②). In between there a six-pointed ornaments (③) and an 'SZ'-shaped ornament in thin lines (④). Angular ornaments resembling pincers (⑤) are interspersed between the two lines.

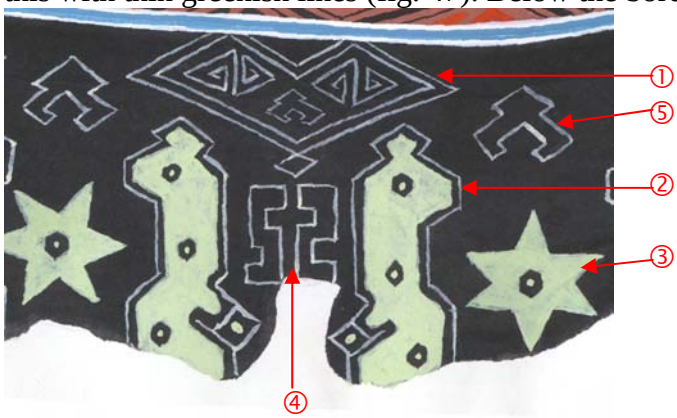


Fig. 47. Pattern on B-0101

The green ornaments are cut off, the pattern unit is not complete.

The other sketched or preserved pattern fragments come from four different generals. Thus fragments from five of seven generals are preserved. A comparison showed that they basically contain the same ornaments. As on the rhomb grid pattern, also on the chest part the same

pattern seems to be used on all generals. This means that all fragments can be used to reconstruct the pattern unit.
When the fragment from T4:1 is placed below B-0101 (fig. 48) almost the complete pattern unit is visible: On the lower fragment the second row of the angular ornaments is visible. Although there are minor mistakes in the drawings, the pattern could be reconstructed (fig. 49). It shows pairs of stylised birds, between them an eight pointed (or, in B-0101: six-pointed) ornament and in their back the 'SZ'-shaped ornament. Between the rows of birds there are large angular ornaments. Smaller 'pincer' shaped ones, hexagonal dots and small lozenges fill the interspaces. They are also arranged on defined positions.

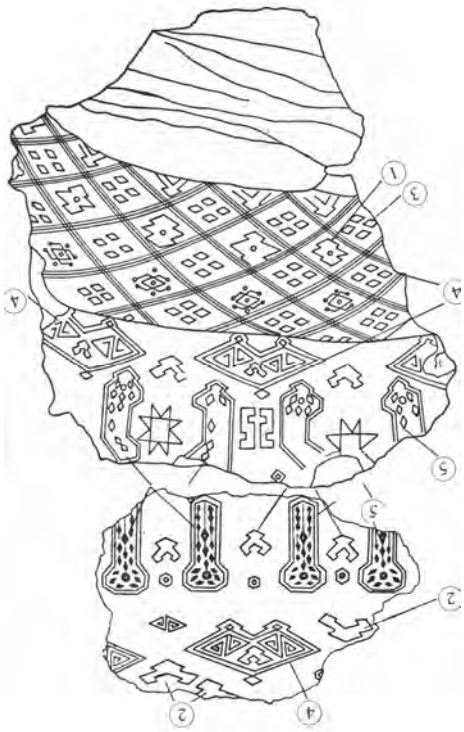


Fig. 48. B-0101 and fragment from T4:1 [drawings from: Yuan 1990, p. 293]

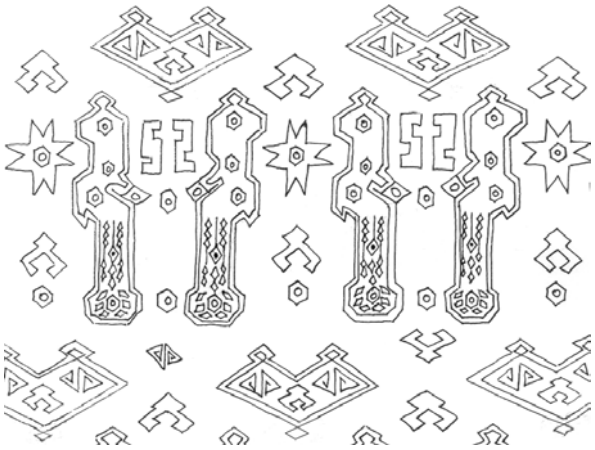


Fig. 49. Reconstructed pattern

There is also a reconstruction of this chest part by the Chinese archaeologists, as part of the colour drawing of a general of type 1 as already mentioned above (fig. 21). It shows geometrical ornaments on a purple-blue ground (fig. 50): rows of the angular ornaments in pink, followed by green ones resembling modern keys and clearly are inspired by the drawing of the fragment of T4:1. There are smaller yellow 'pincer'-shaped scattered between them.
The jacket in this reconstruction is black although the sculptures T2G2:97 and T4:1 which served as models wear purple jackets.
This confusion between purple and black (on the jacket as well as for the background of the pattern) might be another example of colour sensation and the problem to communicate this sensation 'objectively' to others.

Fig. 50. Back of general of type 1, detail of fig. 17

A comparison with the reconstruction in fig. 45 also shows that the pattern in Chinese reconstruction is arranged upside down. It seems that the findings were not really understood and information was passed on incorrectly.

The reconstructed pattern clearly shows one row of birds bordered by a row of the same geometrical ornaments on both sides. Below the birds the ornaments are shifted: Instead of between the heads, they are located between the tails now. The preserved fragments were to small and the drawings not clear enough to confirm what would be in the following row below the ornaments.
Only when the much larger areas on T2G2:97 (fig. 52 and 53) and the colour in soil of T22G9:1 (fig. 54) could be examined during the following stay in Lintong the full pattern unit could be confirmed. The sequence consists of rows of birds separated by rows of geometrical ornaments. Both, birds and geometrical ornaments are repeated without changes (except for minor variations of details). Every second row is shifted so that below a bird looking to the left side, there is a bird looking to the right side. Birds and geometrical ornaments form a unit. In the second row the unit is shifted about the half breadth of a bird pair. Fig. 51 shows the full reconstructed pattern unit.

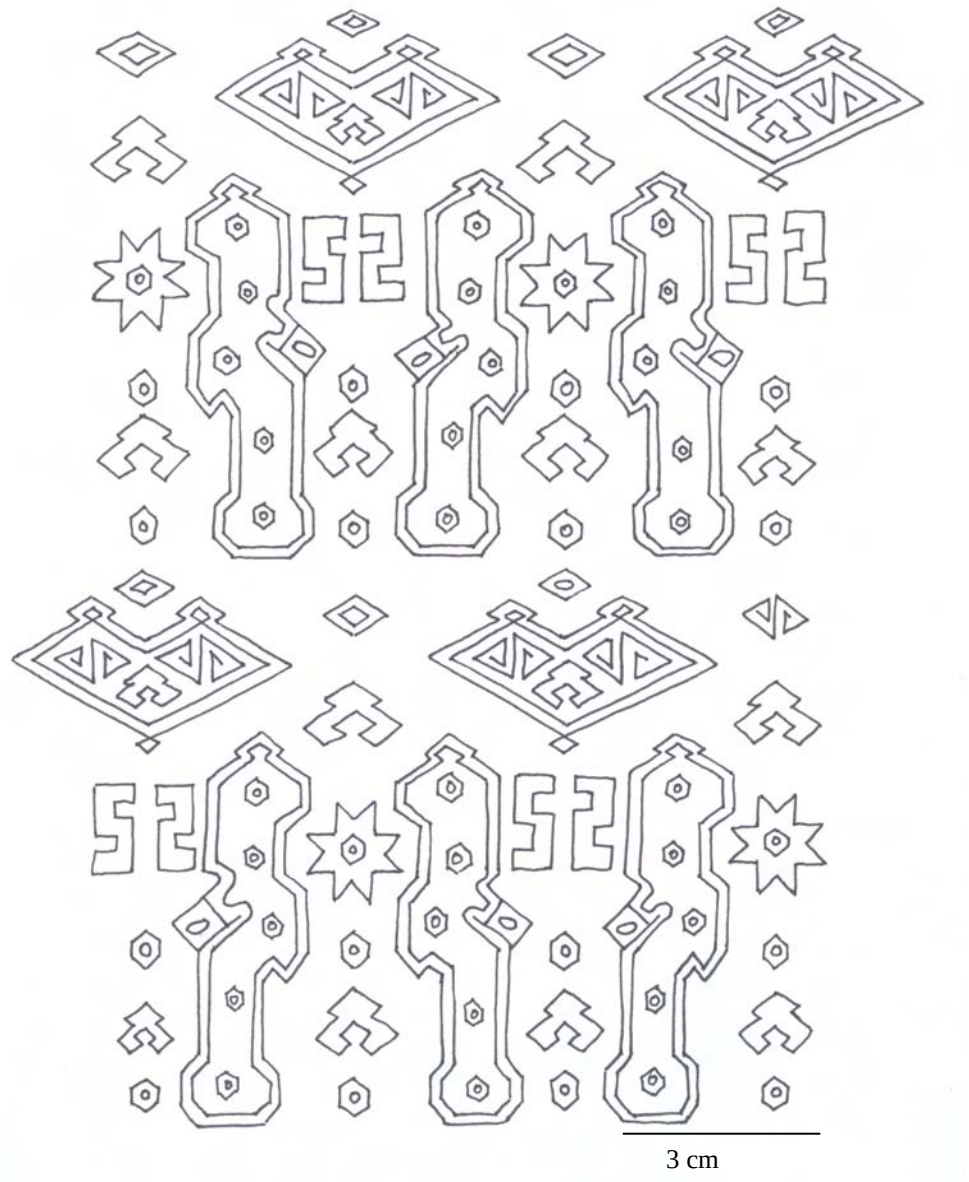


Fig. 51. Reconstructed pattern unit of the ‘bird and sun’ pattern

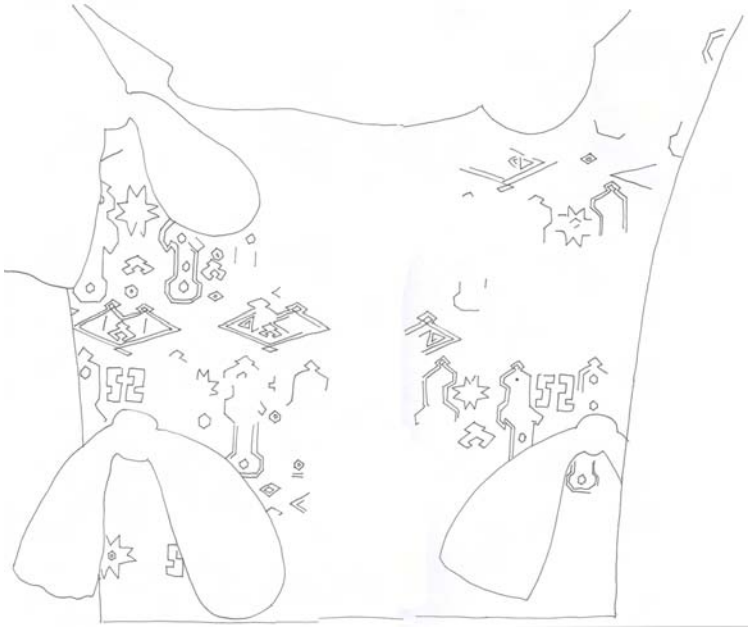


Fig. 51. Drawing of T2G2:97, front part

Fig. 52. Drawing of T2G2:97, back

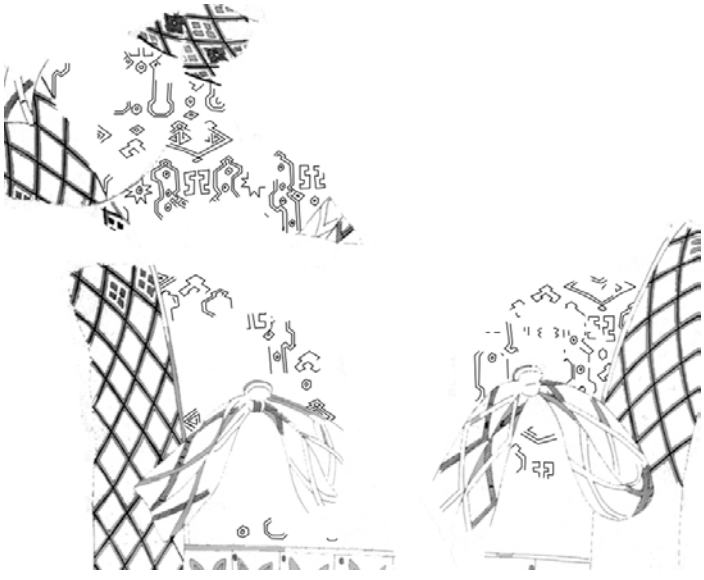


Fig. 53. Drawing of T22G9:1

3.2.3 Types of ornament

a. Birds

Fig. 54. Reconstruction of bird pattern (painted replica)

The main elements of the pattern surely are the pairs of birds with the eight pointed ornament between them. They are most dominant as also the area inside the ornament is painted green, while the other ornaments just consist of light green outlines.
The birds in total in average measure 5.8 cm in height and maximally 1.9 cm in width (chest to wing). They can be imagined as seen in profile: On the head there is 'crown' like a peacock; the beak is blunt and broad. There is a stubby little wing and on the opposite site a hook which might be seen as foot. A long tail is hanging down. Hexagonal dots indicate the eye and maybe a pattern of the plumage.

In one example (T4:1), the drawing of the archaeologists (fig. 45) documented a design inside the tail. This lets the stylised animal look even more bird-like: A long tail seems to hang down, showing a cascade of feathers like a peacock. The fact that these feather designs were only executed in one example might indicate the range of variations. Maybe it was also a concept which was abolished: It might have been too much effort to paint 18 additional little dots on a bird tail which is only 2.5 cm long and 0.8 (upper part) to 1.2 cm (lower end) wide.

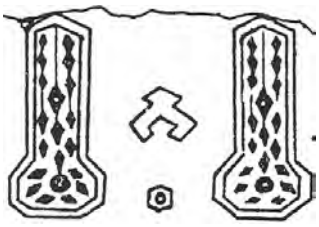


Fig. 55. 'Key' shaped bird tails in drawing of T4:1 (detail from fig. 48)

Fig. 56. Reconstruction of bird from T4:1

b. ‘Sun’

The identification or interpretation of the geometrical ornaments is not easy, as there are no standard terms for them. Ornaments with a number of points, mostly six or eight, are generally identified as celestial bodies. Often they are called ‘sun’, but can also represent a star. They are extremely old ornaments already found on Neolithic pottery. The interpretation of the ornaments has got very far yet, but it is already possible to say ‘suns’ and birds, which generally are interpreted as phoenixes, are combined very often in decorations, especially on textiles.[51]

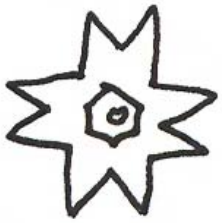


Fig. 57. Eight pointed celestial body (‘sun’)

c. ‘SZ’

The identification or interpretation of the geometrical ornaments is not easy, as there are no standard terms for them. Ornaments with a number of points, mostly six or eight, are generally identified as celestial bodies. Often they are called ‘sun’, but can also represent a star. They are extremely old ornaments already found on Neolithic pottery. The interpretation of the ornaments has got very far yet, but it is already possible to say ‘suns’ and birds, which generally are interpreted as phoenixes, are combined very often in decorations, especially on textiles.[52]

Fig. 58. ‘SZ’ ornament

This ornament seems to be the counterpart of the ‘suns’. It is a rather unusual ornament and its meaning is unclear. It could be linked to ‘S’- or ‘Z’-shaped ornaments often found on textiles. Different from the textiles however here an ‘SZ’ is combined. Textiles usually show the same ornament twice as ‘SS’- or ‘ZZ’-shaped arrangement.

d. ‘*huang*-shaped’ ornament

The identification or interpretation of the geometrical ornaments is not easy, as there are no standard terms for them. Ornaments with a number of points, mostly six or eight, are generally identified as celestial bodies. Often they are called ‘sun’, but can also represent a star. They are extremely old ornaments already found on Neolithic pottery. The interpretation of the ornaments has got very far yet, but it is already possible to say ‘suns’ and birds, which generally are interpreted as phoenixes, are combined very often in decorations, especially on textiles.[53]

Fig. 59. ‘*huang*’ ornament

The large angular ornament between the rows of birds and sun is also very common ornament in the Warring states to Han Period. It sometimes is called ‘*huang*-shaped’ by Chinese authors as it resembles (upside down) a chime stone or jade pendant called *huang* (fig. 60). In this case the *huang* would have been depicted upside down. There are also associations to ‘butterflies’ (also upside down here) or ‘bats’ (like ‘bat’ eave tiles, same orientation). Inside the *huang* is filled with two triangle double spirals and a ‘pincer’-shaped ornament.

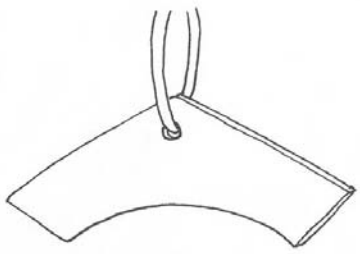


Fig. 60. Hanging chime stone

[51] see chapter 2.3.6.
[52] see chapter 2.3.6.
[53] see chapter 2.3.6.

e. Small filling elements

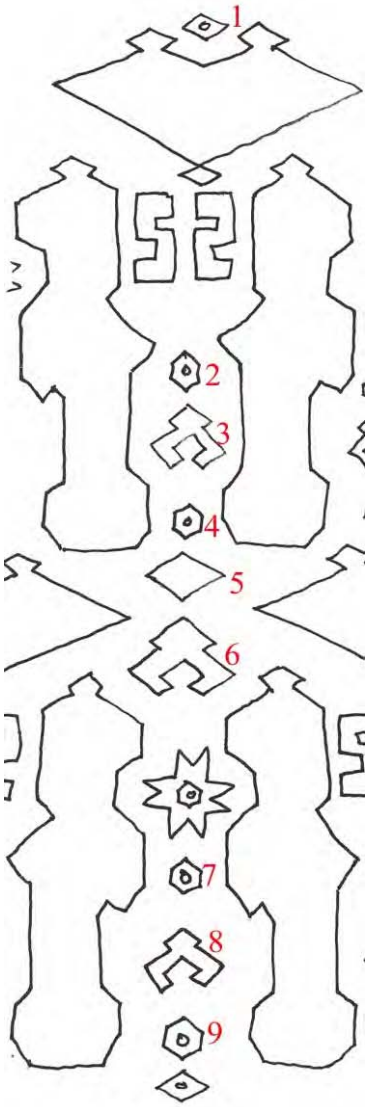


Fig. 61. Sequence of small interspaced geometrical ornaments

Between the large ornaments, there are smaller ones to fill interspaces. Nine ornaments can be found in a vertical row on the middle axis between the birds (stretched over two rows of birds, fig. 61). Three shapes can be distinguished: an angular 'pincer'-shaped ornament (fig. 62), hexagonal dots (fig. 63) and rhomb shaped dots (fig. 64).

At least on position 5, different variations are possible: The rhomb dots can be smaller or bigger, with second small rhomb instead of a dot in the centre (fig. 65). The drawings in the excavation reports depict additional shapes which replace the rhomb dot in position 5: 'pincers', double spirals (fig. 66) and upside-down 'pincers' (fig. 67).
Probably small variations of details of the patterns were tolerated as they can be found everywhere. Furthermore, the variations might be introduced deliberately to make the quite strict pattern more interesting.

Basic shapes:

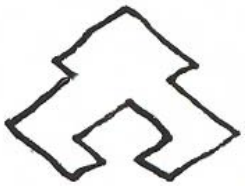


Fig. 62. 'pincer'-shaped ornament

Fig. 63. Hexangular dot

Fig. 64. rhomb dot

Variations:

Fig. 65. double-rhomb dot

Fig. 66. Double spiral

Fig. 67. Upside-down 'pincer'

2.3.4 Colours of the ornaments

Only the preserved fragments (B-0101, T22G9:1 as well the tiny fragments on T2G2:97) of the polychromy are really reliable concerning the colours. In these cases the ground is definitely black.
The colour of the ornaments is less easy to determine. As the fragments in soil are seen from the backside today, the black ground partly covers the ornaments which often appear discoloured. It is very difficult to distinguish between light green, greenish ochre and a 'dirty' white. Sometimes the colour seems to change in the half of a line (what is impossible). Possible nuances of colour thus are not clear yet.
Mainly the ornaments are light green or greenish ochre. This is dominant colour on the preserved fragments and also the one mentioned most often in the excavation reports. All ornaments can be painted totally in light green: In T22G9:1 and B-1010 no other colour could be detected. In some areas it looks as if the outlines are lighter in colour than the green parts inside.

The excavation reports additionally mention yellow for ‘pincers’ in the positions 3, 5 (upside down) and 8. If this is an interpretation of the greenish ochre cannot be evaluated anymore. There is only one example where a colour is mentioned which cannot be confused with the light greenish tone: For T20G10:97 the ‘pincer’ in position is marked as reddish brown. AS the fragment is not preserved, this cannot be checked anymore and might also be a mistake in the documentation. But principally some colour accents seem possible.

2.3.5 Placing the pattern on the armour

The arrangement of ornaments in the ‘sun and bird’ pattern is very strict, but complicated. The comparison of the preserved fragments shows that the size and position of the ornaments varies very little. Even for a skilled painter this seems difficult without a construction system. On the polychromy almost no visible traces of construction lines could be found.

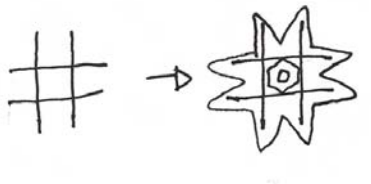


Fig. 68. Construction lines for the ornament of the ‘sun’

On the generals’ polychromy there is only one small example which also belongs to a tiny ornament[54]: To paint the ‘sun’ ornament a grid of lines was drawn first with the same colour which is still visible from the back of the polychromy because of the thicker application of the paint. As on the rhomb borders an invisible system must have been used to construct the arrangement of the pattern.

Fig. 69. Sun with construction lines (detail of fig. 14)

The pattern can be divided into segments using a grid of subsidiary lines. One segment (red lines in fig. 70) is the basic unit which is necessary to build the pattern unit (four segments). The segments are 8.5 cm high and 3.2 to 3.4 cm wide. Additional lines (light grey in fig. 70) can be drawn at the end of the tail and top of the bird’s head. These lines mark relevant spots and meet the centres or points of many filling ornaments. They also give a regular sequence of 2.5cm – 3 cm -2.5 cm.

The observation on the generals showed that the width of grid varies depending on the girth of the general: On thicker ones a sequence of eight birds in the middle row is stretched on 27 cm, while on leaner ones it only needs 25.5 cm. This means the pattern was flexible to some extent what also can easily be reached using such a grid.

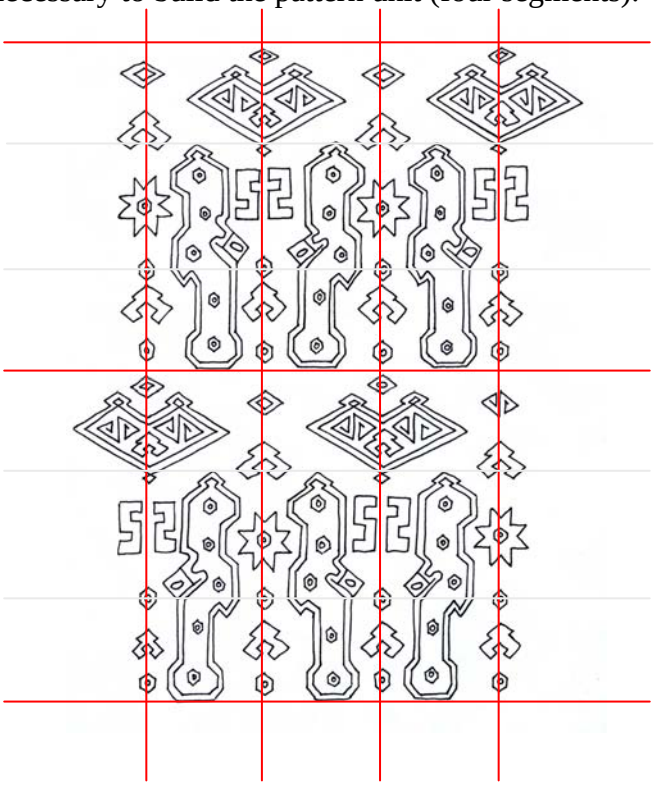
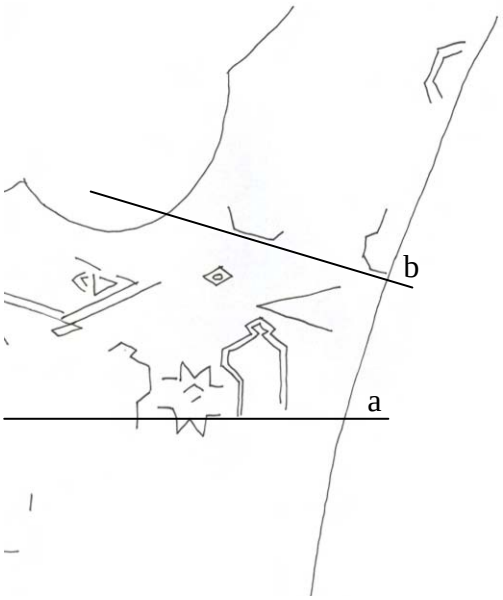


Fig. 70. Construction grid for the pattern

[54] Shoulder part of T22G9:1.

Observation on the sculptures also showed that the pattern was applied starting with a '*huang*' in the centre below the collar. In this way, three rows of birds are visible in the central part of the armour. As all the chest parts are not perfectly symmetrical, the pattern might end slightly lopsided, the last row of birds might be cut off and often a bird is the centre (instead of the interspace between two birds).
The birds are upright on back and chest. This means that - different from the grid border which runs around the armour without interruption and has no top or bottom orientation - , there has to be a seam on the shoulders. On the side of the armour fastener the pattern is interrupted anyway, but on the left shoulder back and front part meet. Different from the rhomb grid border, the seam is not incised in the terracotta.



Furthermore, the pattern is slightly distorted towards the borders on the side and on the shoulders the base line of the pattern does not run horizontally anymore, but is bent downwards to the side (fig. 71). This can only be interpreted as the attempt to depict the distortion a fabric does on the shoulders of a person. In this way, the pattern appears realistic and not like stencilled on the chest without relation to the body.

Fig. 71. Distortion of pattern on the shoulders (T2G2:97, left shoulder, front):
a. horizontal arrangement of pattern
b. distorted base line of pattern

2.3.6 Comparison with historical textiles

The angular ornaments and the distortion of the pattern on the curved parts of the body suggest the impression of a fabric.
All ornaments are angular. Even the dots are hexagonal or rhombic. Outlines often are parallel to each other or in often repeated angles. It was not 'the' Qin style as a comparison with other objects from Qin Shihuang's tomb shows: On the artists' skirts and on the bronze chariots patterns with rounded and complicated arranged, intricate ornaments are painted. Thus the decision for this 'stiff', angular style was made by purpose. The only reasonable explanation seems to be that these patterns imitate woven fabrics. The fact that not only the typical distortion, but also the angular shapes of the patterned have been imitated raises the question of possible models for these painted textiles.

A considerable number of textiles have been excavated from tombs of the Warring States to Han Dynasty (and more are still discovered in ongoing excavation campaigns). Unfortunately there are not any from the state of Qin or the Xi'an area. The best preserved textile findings come from the state of Chu[55] in southern China, especially from Zuojiatang and Mawangdui

[55] Chu was a big state with the Yangzi River in the center. It was neighboured by Yue in the south, Qin in the northwest and Han, Wei, Song and Qi in the north. Form 350 BC on, Qin expanded seizing larger areas of north western Chu. The areas were the textiles were found were still autonomous until 221 BC.

near Changsha (Hunan) and Mashan in Jiangling (Hubei)[56]. Beautiful Han dynasty textiles were discovered in Xinjiang and Inner Mongolia.
The search for archetypes and the comparison with antique textiles has just begun. A detailed discussion will be given in one of the following reports. Here only a glimpse into this matter shall be given to understand the depicted patterns. Especially the textiles from the State of Chu show interesting similarities with the ones painted on Qin Shihuang's terracotta sculptures. While silk gauzes found in Mawangdui resemble the design of the acrobats skirts, for the 'bird and sun' pattern, the textiles with animals from the Warring States (*zhanguo*) Period are of special interest.
There are different weaving techniques for plain and patterned silk fabrics. The most beautiful was the *jin*, a term often translated as 'brocade'. *Jin* silks are warp-faced compound tabbies with up to five colours. They were extremely valuable.

A Warring State *jin* found in Zuojiatang near Changsha [57] is a fine example of textiles of this period and style (fig. 73). It shows two types of animals which are interpreted as phoenix and dragon. In between there are geometrical ornaments, among them 'ear-cup' type broken lozenges and a six pointed ornament. The ornaments are light brown on dark brown. As result of the three-coloured warp, medium brown and cinnabar-'died', bright red stripes are interspersed.
On a close-up of the textile structure the slightly stiff and angular shapes re clearly visible. In the body of the phoenix there is exactly the same type of hexagonal spots as in the birds' body.

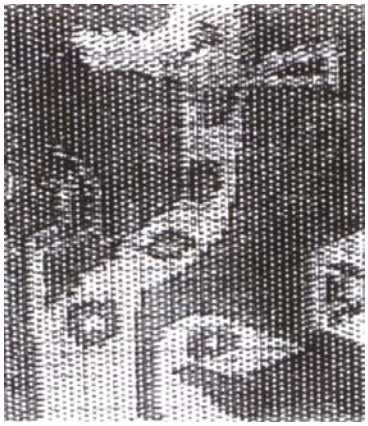


Fig. 72. Detail of the phoenix [Huang/Chen 1999, p. 54]


Fig. 73. Colour drawing of 'dragon and phoenix' textile from Zuojiatang [Huang/Chen 1999, p. 55]

[56] Zuojiatang 左家塘, Changsha (Hunan Province), tomb no. 44, Warring States
Mawangdui 马王堆, Changsha (Hunan Province), Western Han, tomb no. 1 Marquise of Dai, died in 168 BC; tomb no. 2 and 3
Mashan 马山, Jiangling 江陵, Hubei Province, late Warring States, 'middle class lady', died 330-320 BC. – Another important findings are the tombs of Mancheng, Lingshan, (Hebei Province) from the Central Plane east of Xi'an, Western Han, tombs of Dou Guan, died in 118-104 BC and Liu Sheng, died in 113 BC

Also the colour distribution is principally similar to the ‘bird and sun’ pattern of the general: The ornaments are visible in a light tone on a dark ground. The presence of coloured stripes allows two conclusions for the generals: either there are really coloured geometrical ornaments interspersed (as recorded by the Chinese archaeologists) or a rather ‘simple’ two-coloured *jin* was depicted. In any case, the design means that the generals’ armour was lined with a fine, precious silk fabric.

Animals are often found on Warring States to Han Dynasty textiles and decorations. Warring states textiles show animals with long bodies, tails and head. Sometimes wings or feet can be made out, but the stylisation makes it hard to identify the species of animal: They might be phoenixes and dragons, but some look like tigers or are only fantastic. In Han Dynasty animals are easier to identify, but dragon and phoenix pattern dissolve into abstract geometrical spirals, sometimes seen as floral elements.[58]
The animals often appear in combination with geometrical ornaments. ‘Dragon’ and ‘phoenix’ are mostly accompanied by the ‘sun’ ornament. Fig. 73 and 74 show two examples from the Han Dynasty. Peacock- and rooster-like birds are depicted. The first is combined with the ‘sun’, the other with numerous geometrical elements. The ‘SS’ and ‘ZZ’ shapes accompany ‘pincer’ ornaments. Broken lozenges and angular spirals are also visible.
The meaning of these patterns is not investigated yet, but it seems likely to classify the ‘bird and sun’ pattern of the generals as a design which was fashionable at that time.

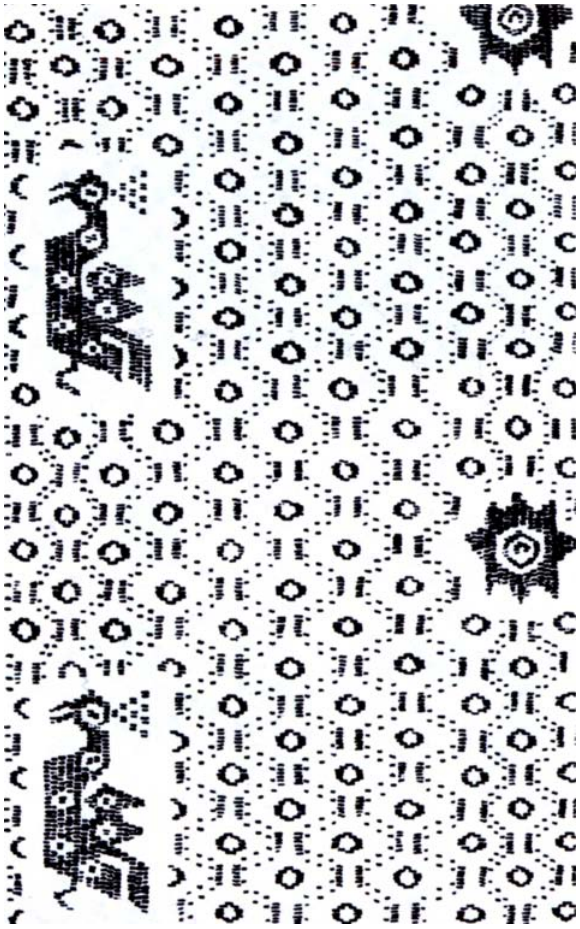


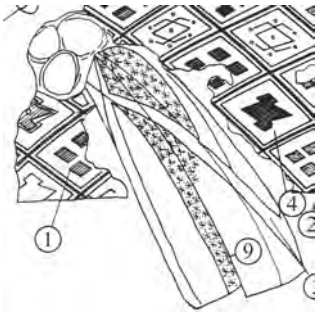
Fig. 73. Mawangdui, tomb no. 1 [Shen 1997, p. 168]


Fig. 74. Han Dynasty [Shen 1997, p. 164]

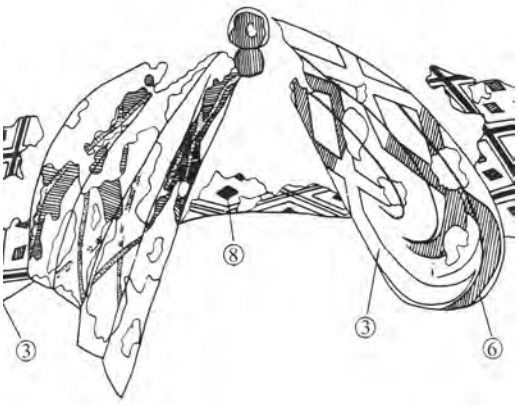
[57] Zuojiatang, tomb no. 44, excavated in 1957, fragment of textiles, in the collection of Hunan Provincial Museum
[58] The development of dragon and phoenix pattern is described in Prüch 1997. A comparable development can be observed on textiles.

3.3 Ties on the armour

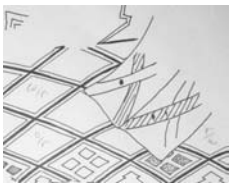
The armours are decorated with nine large ties. There are three on the chest part (front and back), one on each shoulder on the rhomb grid border and one on the armour fastener. It is difficult to say if these ties have any function or if they are just decorative. Drawings, remnants of paint layers on the sculpture as well as in soil give evidence (fig. 76):
- T20G10:97, excavation reports: two drawings from the ties on the shoulders (fig. 6 and 8)
- T2G2:97, sculpture: tiny fragments on two ties of[59]
- T22G9:1, colour in soil: parts of the three ties on the back and the one on the left shoulder



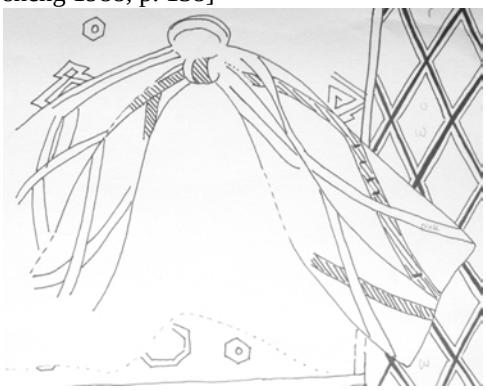
T20G10:97, right shoulder [from: Shaanxi sheng 1988, p. 138]



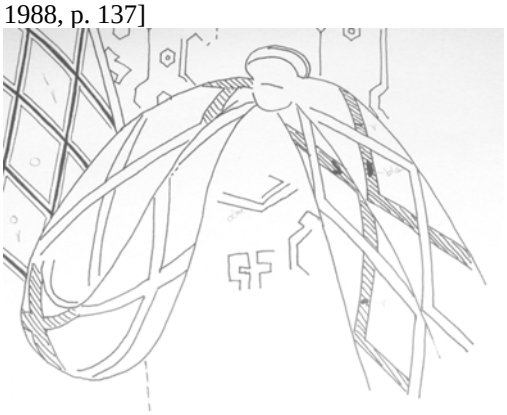
T20G10:97. left shoulder [from: Shaanxi sheng 1988, p. 137]



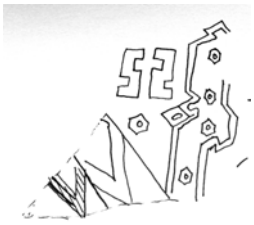
T22G9:1, left shoulder



T22G9:1, front, right tie



T22G9:1, front, left tie



T22G9:1, front, center

Fig. 75. Ties from the generals' armours (all as 'negatives' in the soil)

The system of decoration is the same on all preserved ties: Fine lines cross forming rhomb grids. The colours of the ties are not the same:
- T20G10:97 (type 1): light green ground with white and pink lines (excavation report)
- T2G2:97 (type 1): white and green: white (?) ground with green and black (?) lines
- T22G9:1 (type 2): black ground with yellowish white/light ochre and pink lines

There is almost no information about the polychromy of the tie on the armour fastener: For T20G10:97 'the fastener' is described as bright red, while the ties are light green. It is not clear if the strings of the armour fastener are made of the same pieces as the tie hanging down form it or if the tie is just knotted to the string. It is also not clear which part was 'bright red'. As the 'button' itself might have been white as on many warriors, this could mean that ties and armour fastener were of different colour.

[59] The ties are the right one of the chest and right one on the back.


Fig. 76. T22G9:1, Tie on the right part of the chest

On T22G9:1 all ties are of the same colour. This allow the assumption that the colours of chest, back and shoulder were the same on each sculpture, but different sculptures or different types of generals have different coloured ties.
The lines on T22G9:1 possess two colours: a yellowish white and pink. Two colours are also recorded for T20G10:97. On T22G9:1, the distribution of the colours can be observed:

First the pink lines were painted, afterwards the white ones. The white lines are further decorated by some kind of decoration: fine red and some blue lines and spots are visible[60], but the decoration cannot be reconstructed.
Where the lines cross, white-pink crosses are visible (with both possible directions), but also white-white next to pink-pink crosses (see fig. 75, T22G9:1). This seemed unreasonable in the beginning, but a reconstruction proofed that the distribution of the colour was not chosen by accident. There is a system which allows these different kinds of crosses.

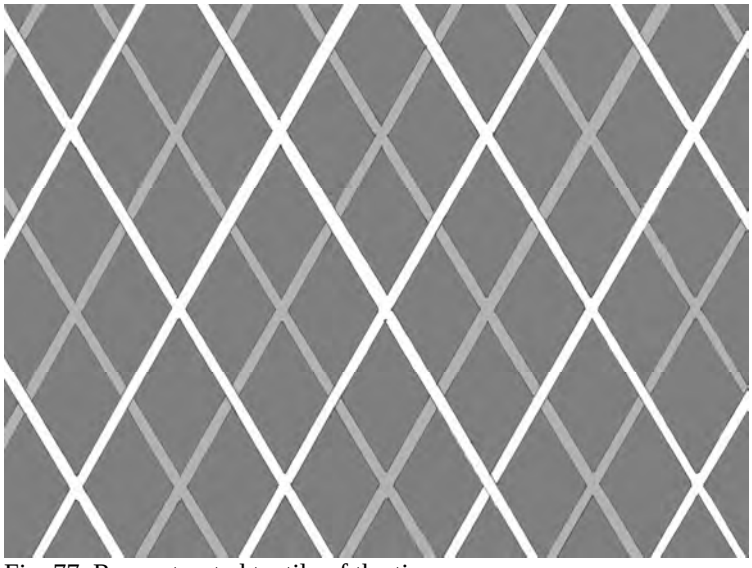


Fig. 77. Reconstructed textile of the ties


a: two-coloured crosses


b: one-coloured crosses

The reconstruction in fig. 77 shows two superimposed grids of lines, grey symbolising pink and white the white lines. When a fabric like this is folded, depending on the visible section two-coloured crosses appear (Fig. 77: a) or single-coloured (Fig. 77: b). This is another example for the exact observation of the properties of patterned textiles on which the polychromy of the terracotta army is based.

[60] Mostly the decoration is covered by the preserved colour of the lines.

Reconstructions by the Chinese archaeologists show the ties with multicoloured stripes. The stripes are not crossing, but would, if painted on the sculpture, follow the modelled folds. If unfolded, this kind of textile would show stripes in the length of the cloth. So far, there is no hint that this type of design was used on one of the sculptures.

Fig. 78. Tie on the generals' back (detail of fig. 21)

3.4 Connecting stitches on the armour

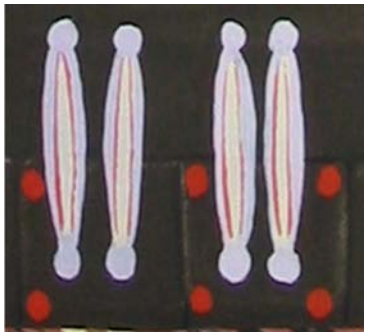
The colour of the connecting stitches of the armour is not described in detail in the excavation reports. For T2G2:97 light red or pink 'long-stitches' are mentioned[61], for T20G10:97 green V-shaped stitches.[62] The descriptions are incomplete as the round button-shaped stitches are not mentioned (and a general has no 'long stitches', but V-shaped stitches on the armour plates). Colour fragments on T9:1 show that the button-shaped stitches were red.

On T22G9:1 larger parts of the armour plates are preserved. This is the only preserved example of these details, and there is no hint if the other generals had been painted similar.

The button-shaped stitches are bright red (fig. 79 ①). The V-shaped stitches on the armour and the straight ones on the belt part are not so easy to reconstruct. The ground seems to be light violet, greenish white or light ochre. There are fine red lines painted (fig. 79 ②) following the length of the stitches. they are completed by short ones running cross-ways between them. Between the red lines sometimes a colour different from the ground is visible which appears to be whitish. In the middle of the V there is a red dot (③) which – at least partly – seems also to be modelled in the terra-cotta.

Fig. 79. Detail of T22G9:1 in pit no. 1.

[61] Table in appendix of Shaanxi sheng 1983, p. 396.
[62] Table in appendix of Shaanxi sheng 1983, p. 427.



Although the result is not completely clear, a reconstruction was attempted. It seems obvious that the V-shaped stitch is a string which starts at one a top ends on one side, then is pulled through a loop at the lower point in the centre of the armour plate and goes back to the other top end. The central loop is an independent part. As it is almost round, it seems consequent that it is painted like the small round stitches in the corners of the plates. The decoration on the V-shaped stitch was finally interpreted as a second thin string. The red lines indicate outlines and drill, the colour is slightly different from the main string. In a reconstruction this looks quite convincing.
The stitches in the belt-like part in the back are painted in similar way. The little red lines indicated a drill structure of the decorative string could not be found, but the area is not well preserved.

Fig. 80. Reconstruction of the stitches on the armour plate:
top: V-shaped stitches
below: straight stitches on belt-part of the back

3.5. Parts without any information - shoulder protections

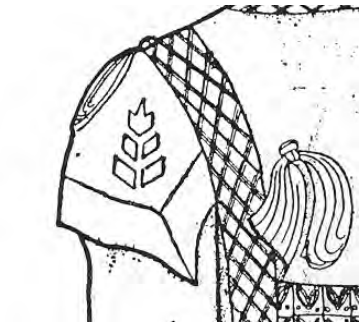


Fig. 81. Drawing of T4:1 (detail of fig. 13)

Fig. 82. Colour reconstruction of the shoulder protection (detail of fig. 21)

There are some parts where there is almost no information. The armour fasteners were already mentioned. The largest areas without information about the colour are the shoulder protection parts of the generals of type 1. They are made like the armour: A smooth central part is edged by a ca. 5 cm wide border and fastened below the suit of armour.
The sculptures give almost no evidence, as there are hardly any traces of colour remaining in these parts. On T2G2:97 black and yellowish white traces could be identified on the smooth parts, but no patterns. The other sculptures do not have colour traces anymore and descriptions and drawings are missing.
In the archaeological report Yuan 1990 there is a drawing of the general T4:1 from pit no. 2 (see fig. 13). On the shoulder pieces s rather large pattern is indicated, consisting of four rhombi and a three-forked ornament which together resemble a stylised flower with four leaves (fig. 81). In the colour drawing of the same general, this was interpreted as a blue pattern on ochre-yellow ground. The border shows a rhomb pattern in white and red, but different to the one on the border of the armour.
As no other information was available, the excavation report is not published yet, no one remembers details of the 1977 excavation campaign anymore and photographs or drawings are not accessible in the archive of the museum, the polychromy of these areas remains unclear.

4 Summary and conclusion

Nine generals have been excavated so far. Seven of them could be examined on colour fragments. There are some descriptions and drawings in the excavation reports with valuable information, but they are not detailed enough to understand the complicated polychromy. Fragments of colour in soil are preserved from two sculptures. They are the base of the investigation presented here.
All information was collected and interpreted. Colour drawings were made to visualise the situation. Patterns were documented and variations recorded to find the basic schemes for ornaments and colours. In the end, larger parts of five generals could be reconstructed in colour drawings.
Three types of generals were defined. Type 3 (without armour) could not be reconstructed sufficiently as there is too little information. Five generals of type 1 (3 sculptures) and type 2 (2 sculptures) serve as base of the investigation.

The clothes show the same vivid colour contrasts which were already observed on the kneeling archers. Outer jacket, inner jacket, sleeve cuffs/collar and shin protections all have different colours or at least adjacent parts are painted differently. The jackets of the generals show an interesting colour distribution: Three generals of type 1 have purple long jacket, two of type 2 a green one. Although there were no uniforms in Qin dynasty and on the infantrymen there seems to be no ‘preferred’ colours, this result looks like colours were attributed to special ranks or positions: Purple for type 1, green for type 2. As the long jackets are the largest colour area on the sculptures, these colours are very dominant.
Three different patterns could be identified on the armours. They are arranged on the border of the armour, the smooth chest part and the ties. All patterns were documented and interpreted as far as possible. Ornaments and colours could be reconstructed correctly for the first time. Pattern units, colour distribution and construction schemes were investigated. Some questions could not be answered and sometimes there is more than one possible explanation, but mainly the patterns are understood now. The following pages shows the reconstruction of the back of a general, based on B-0101 (general T9:1) and completed with details from T22G9:1. It can give an idea of the visual impression the generals originally had.
All generals have the same patterns on the respective part, but colours and small filling ornaments could be varied. The patterns seem to imitate woven textiles in an astonishing accuracy and they show a striking similarity to textiles from the Warring States to Han Dynasty which should be investigated further.
The patterns are much finer and more elaborate than thought before. Connection stitches of the armour plates and painted lines on the ties were decorated with extremely fine lines. The quality, the accuracy and detailedness of the polychromy are amazing. The realism already present in the terracotta modelling was completed by a refined polychrome including the imitations of textiles.

Two generals could not be included into the investigation as they were not in the museum in the time of 2003 to 2005. Reports, photographs or drawings except for the published ones, were almost not accessible yet. There might be a chance to get more information and to enlarge or correct the present results. This chance should be taken.
The investigation results were the base for painting a replica of a general in January to March 2006. The work on the replica put up a lot of questions - and solved some. A lot more information will be necessary until one general can be reconstructed without any doubt, but the results achieved so far made it possible to reconstruct the major parts.
The technical investigation on the polychromy was carried out parallel to the examination described here. The results are not complete yet and will be presented in a following report.

Fig. 83. Back of general T9:1 (photograph from the Museum of the Terracotta Army Lintong)

Fig. 84. Reconstructed back of the general (with additional information from T22G9:1)

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Carolin Roth, conservator-restorer (Dipl. Rest.); Wasserburg am Inn, realised the reconstruction of the polychromy on the two replicas. The work and the exchange of experiences resulted in the solution of the practical questions like the applications of patterns on a rounded body.

For background information on textiles and patterns I got support and valuable ideas from Prof. Lin Chunmei, Taiwan, Dr. Shing Soong-Müller, Munich; Dr. Margarethe Prüch,; and Mrs. Regula Schorta, Abegg Foundation Riggisberg.

Illustration credits

The source of pictures taken form literature or prepared by others is given in brackets in the figures' caption. References are not repeated if they figure is a detail of a preceding one. All photographs and figures without any reference were made by the author.

Year 2005

Identification of pigments of the wall paintings of a Han Dynasty tomb in Xi'an

Xia Yin, Catharina Blaensdorf

Introduction

On 21 Oct. 2004, Xia Yin was allowed to take some pigment samples from the painted walls of a Han tomb. The tomb is located at the east of Xi'an in a construction area of a university campus. The Xi'an Archaeology Institute is in charge of the ongoing conservation work. This tomb with a sloping entrance and a brick vault over a single chamber is about 10m below the present surface. Nothing is known about the deceased, the artist or the exact dating. The tomb had already been robbed, but the exquisite wall paintings are retained: the right side shows hunting figuration with sun and crane, the left side is entertainment dinner figuration.

Fig. 1. Conservator Feng Jian from the Xi'an Archaeology Institute working in the tomb chamber

The bright colours attracted the attention of the conservators who wished to identify the pigments. The green and red parts were extremely fresh and colourful. The bright yellow of the sun on the right wall and the orange of the painted folding screen in the banquette scene on the left wall were unusual colours of special interest.
Thirteen samples were prepared for PLM, two samples for cross-section detection,

three samples for Raman Microscopy Spectroscopy (RMS) and one sample for XRF.

PLM

All the samples were prepared in BLFD by Xia Yin, analysed by C. Blaensdorf and Xia Yin. Results are listed in table 1.

Sample description	*Stereo-microscope description*	*PLM analysis*
sample 1：east wall south part, sun, left side, lower part（E5）	3 layers. Lower layer: clay with fibre additives; thick white layer (background); very thin not complete gold-yellow layer on top	very fine particles cluster, n>1.662, IF dull yellow --$CaCO_3$, SiO_2, clay, gypsum --some yellow ochre ?
sample 2：west wall north part, middle part cloud, very bright red（E4）	3 layers. Lower layer is mixed with grass pieces and clay, the thick white background in middle, very fresh and bright red, very thin.	**cinnabar**: very fine, very round particles (artificially produced ?)
sample 3：west wall north part, middle part cloud, white（E3）	The back surface is some traces of grey bricks, on top is white layer	**white clay**（K, Al, silicate） or kaolin!
sample 4：west wall middle part, green（E2）	3 layers, the back surface is some traces of grey bricks, thick white layer in middle, very thin green layer on top	**malachite** -- white clay, lead white, cinnabar, red ochre --one large column red particle --very round red particles
sample 5：north wall, below dragon pattern, violet!!（E1）	Thick white layer below, violet pigment particles on top, from colourless to dark blue-violet	Lower index, anisotropic, no smooth surface, like clay under crossed polars; not CaF_2; no typical Han purple particle
sample 6：north wall middle part, middle of dragon pattern, white drop（D12）	White	**White clay**
sample 7：east wall middle part upper bright blue（D11）	White background, blue layer on top, coarse	**Azurite**
sample 8：west wall south part folding screen, yellow（D10）	White background, orange yellow layer on top	clusters of very fine particles, n> 1.662, IF: dull yellow --1 particle: orange yellow, n>1.662 --1 light yellow particle (orpiment??) --only very few white particles
sample 9：west wall middle part upper, dark red (D9)	Clay plaster, thick white layer, red like corrosion iron layer on top	**cinnabar** and little amount of **red ochre**
sample 11：east wall north part grey deer, grey (D8)	White ground layer (grey layer can not be seen）	**white clay** and coarse **cinnabar** and several **black** particles
sample 12：ground layer (D7)	Clay ground layer, white layer on top	**white clay** -- red ochre, red lead, cinnabar
sample 13：mould? (D6)	White layer on top，black and white coarse particles	Nothing looking like mould; could be detected by UV-light if it is active mould

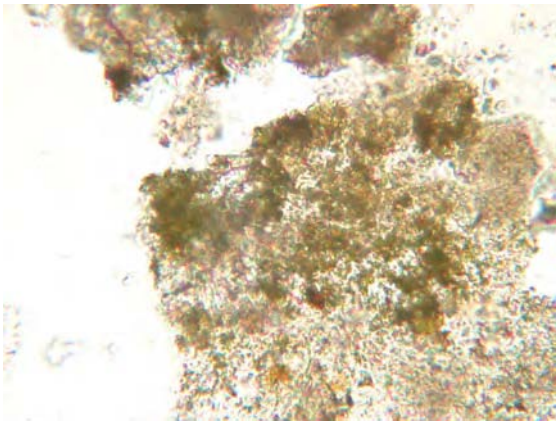
Table 1. PLM results of pigments samples form Han tomb

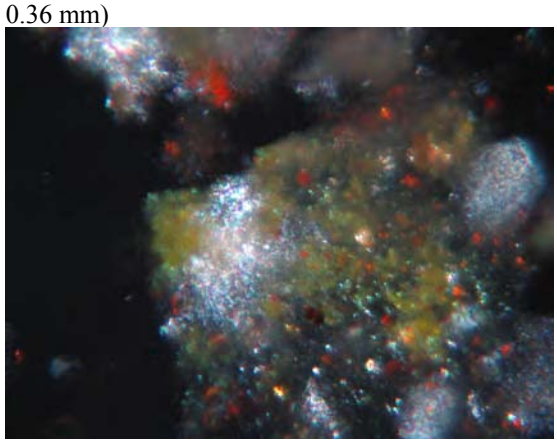
One of the pigments which could not be identified with PLM was the yellow or orange pigment. Ochre, orpiment and massicot could be excluded, but a positive

analysis was not possible. A microscopically similar pigment was found on the only yellow paint layer of the Terracotta Army of Qin Shihuang in fragment B-0107, where the main component was identified to be lead (Pb) with an amount of vanadium which is too high to be regarded as an impurity[1].

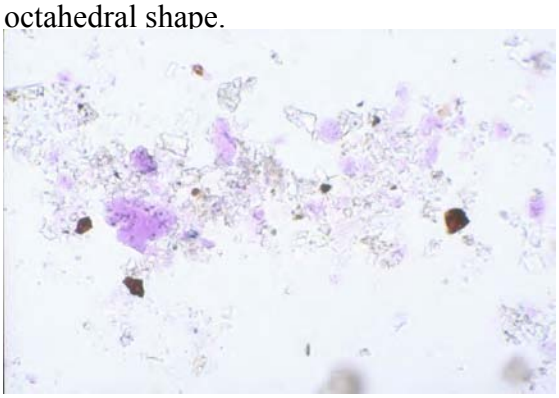
◄ Fig. 2. B-0107: Remnants of paint layer in soil, mounted in plaster, situation 2000-

▼ Fig. 3a and b: PLM analysis: Polarised transmitted light (left) and crossed polars (right): mixture of bone white and cinnabar from he pink layer and clusters of fine yellow particles (magnification 400x, i.e. horizontal edge of fig. = 0.36 mm)





The other pigment was a pale purple which did not show the optical properties typical for Chinese Purple which normally consists of crystalline plates with a characteristic octahedral shape.



B-0081, Purple in soil from the Terracotta Army, Magn. 400x (horizontal edge = 0.36 mm)

Han tomb, Sample E 1, light purple

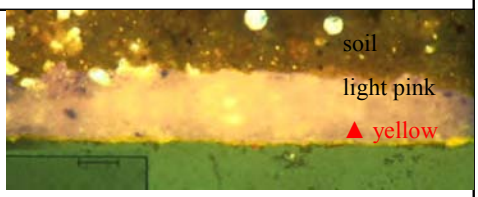
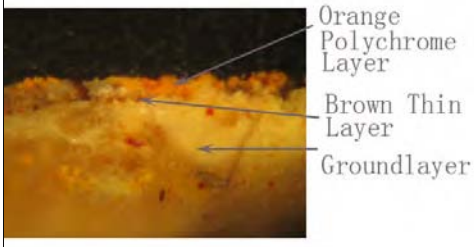
Magn. 630x (horizontal edge = 0.22 mm)

Cross-section

We prepared two cross-sections of Han tomb yellow (E5 and D10), and one cross-

[1] Investigations carried out in 2000, 2003 and 2005 with SEM-EDX by Klaus Rapp, Munich.

section of B-0107.

Sample No.	Cross-section No.	Description	structure/ sketch
B-0107	S-2b/04	2 layers: --top layer light pink: bone white and very fine cinnabar --below partially bright yellow layer Remark: between soil and pink layer is white resin during polishing procedure	 Fig. 4
Sample 1, E5	S-6/04	Can not identify layer structure, only 2 parts of a yellow zone in a white background (slightly yellow, containing red particles), where we may find 2 blue particles	
Sample 2, D10	S-7/04	3 layers: orange-yellow layer on top, very thin brown layer (seems like organic product) below, thick white with bright red particle layer next, then thick brown clay background can be seen	 Fig. 5

RMS

Because sample E-5,D-10 and E-1 are very hard to be identified by PLM, so we prepared cross-section samples, PLM samples and powder samples for RMS. Unfortunately PLM preparations (because of glass fluorescence) and cross-section samples (because of bad polish and no Nicolas) yielded bad results, we mainly used powder samples.

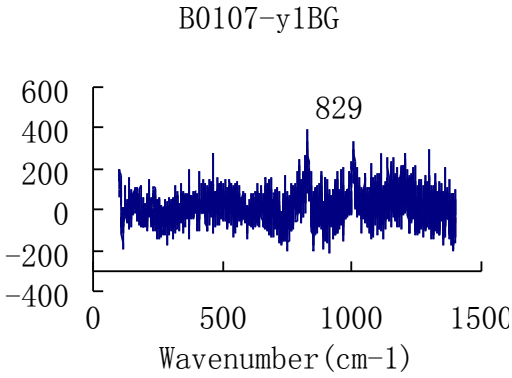
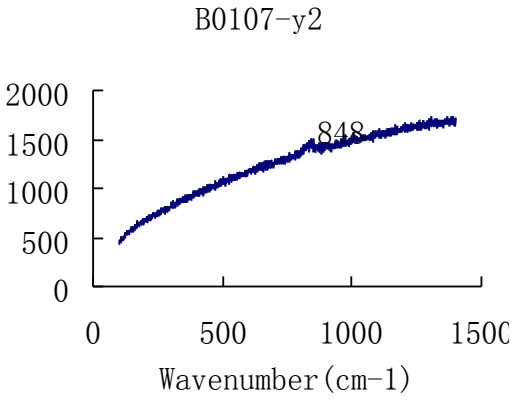
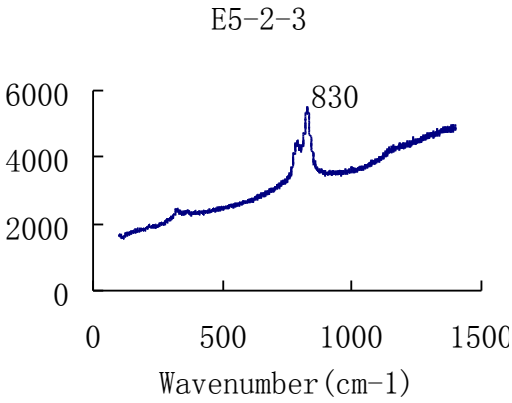
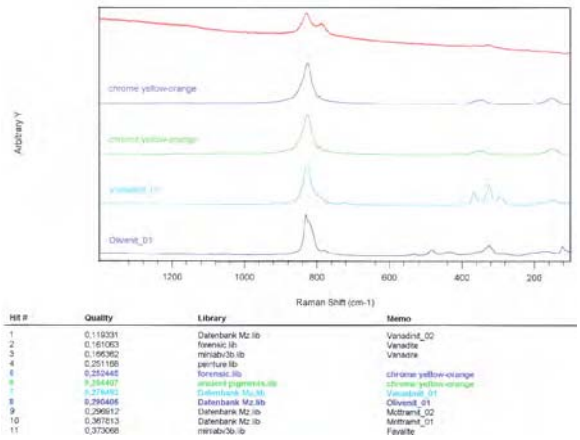
The measurements where performed by Dr. S. Greiff from the Roman Germanic Central Museum Mainz (RGZM) at the Department of Mineralogy of the University of Mainz

Instrument: Jobin Yvon LabRam HR, Microscope Olympus BX41

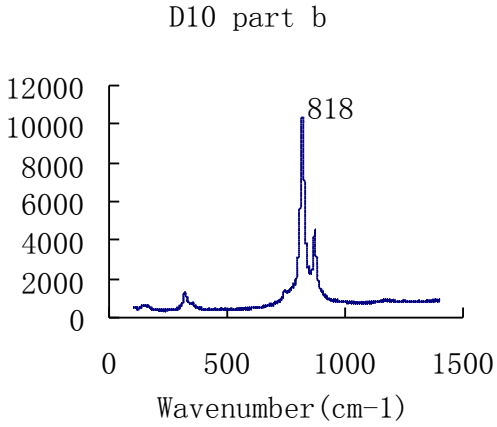
3 lasers: 514, 633 and 854nm

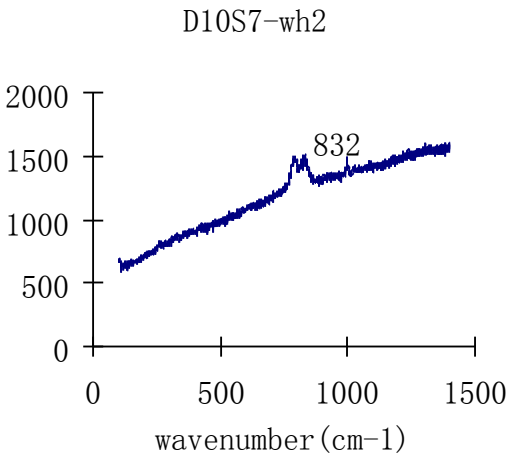
measurements done with Argon-Ion-laser at 514,532nm,50× objective

slit 100, hole 250, grating 1800, 2×25seconds

Raman spectra	Remarks
B-0107 	All measurements impaired due to signals from glass and resin Maybe vanadinite
	Probably apatite (bone white)
Sample 1, E5 	 Measurement (red) and standards from data base

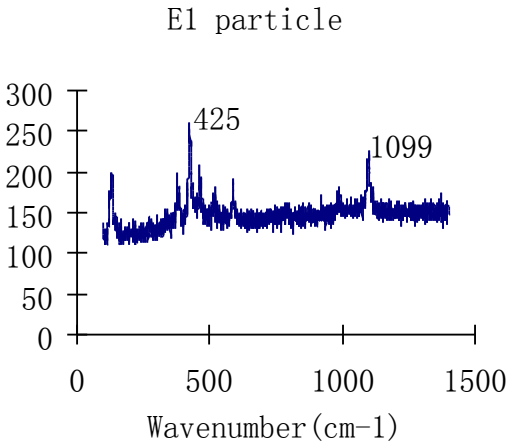
Sample 2,
D10

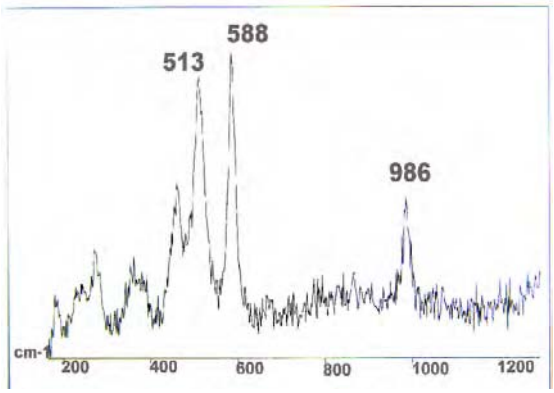




Maybe vanadinite with remains of white priming layer (i.e. rutil as part of clay sediment)

Sample 5,
E1

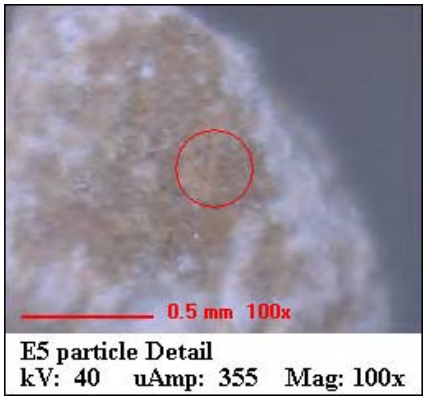


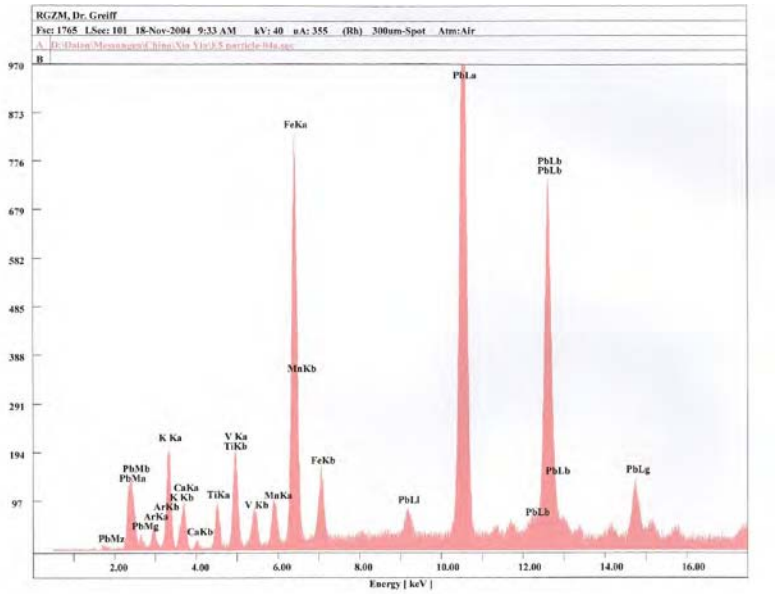


Purple particle E1 (left) and standard for Chinese purple (above)

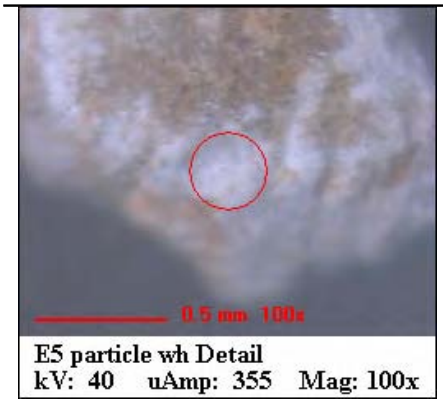
XRF

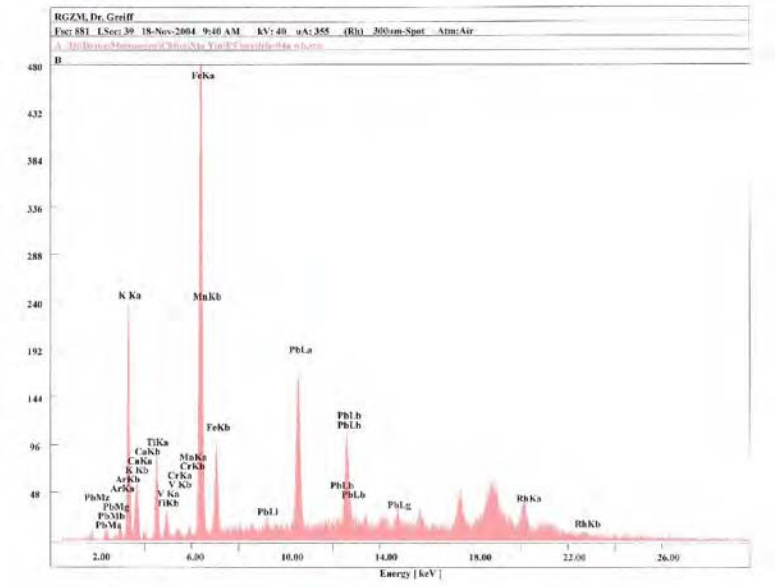
To confirm the result of Raman spectra, we have done XRF analysis on E5 (E1 and D10 are too small to analyze). The most interesting thing is, that the element component has Pb and V, it is similar compared with B-0107.





Orange area, showing Pb and V peaks





White priming layer

Fig. 6. Measurement with Micro-XRF on particle E5 from the paint layer of an orange folding screen: orange paint layer (top) and white priming layer (below)

SEM-EDX

Already in the year 2003 attempts were made to identify the yellow pigment of B-0107. The investigations with SEM-EDX, performed by Klaus Rapp, proved the presence of vanadium next to the lead.

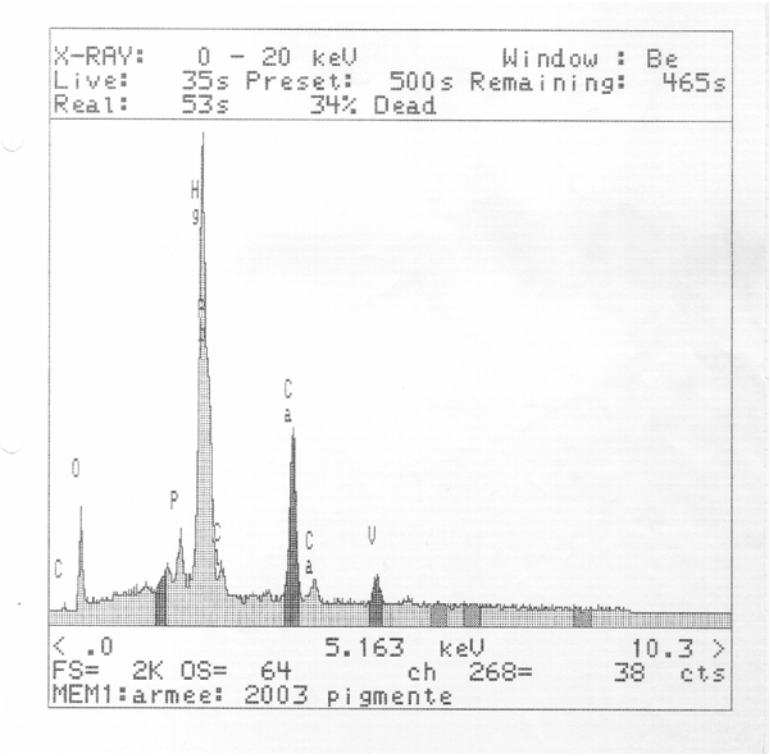


Fig. 7. EDX measurement on a cross section of B-0107

Additional investigations were made in February/March 2005 on a cross section of showing one single larger yellow cluster:

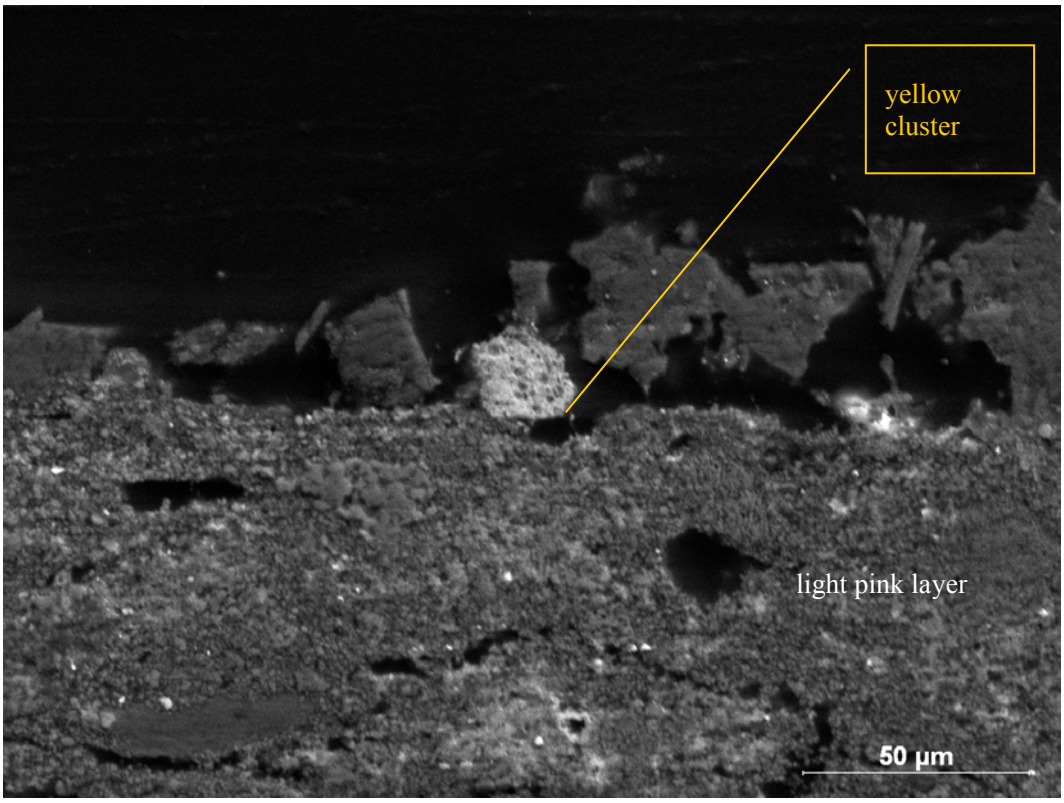
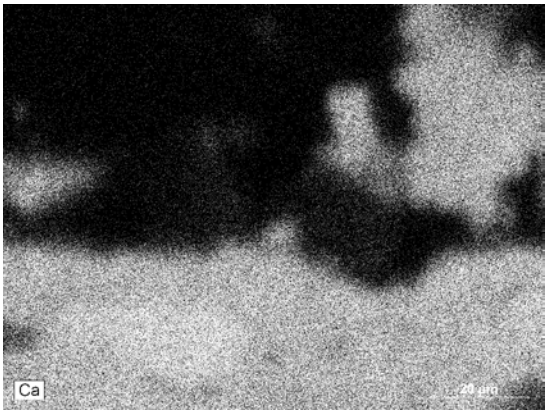
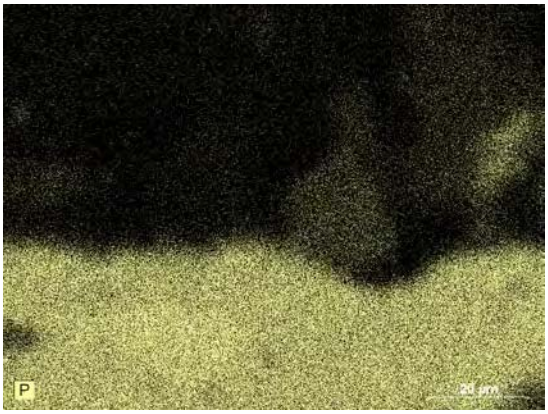


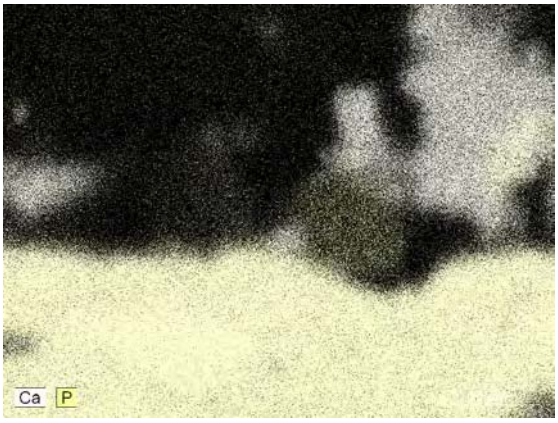
Fig. 8. SEM: Particle on top of light pink layer



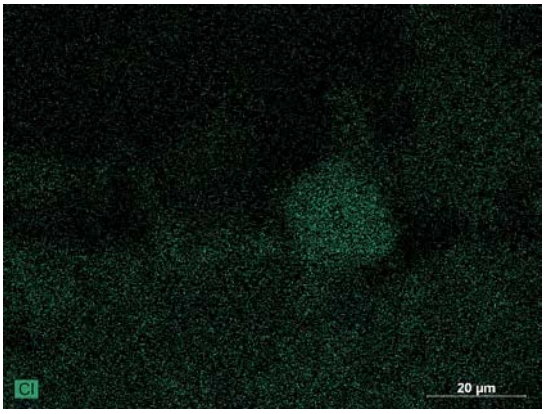
Ca



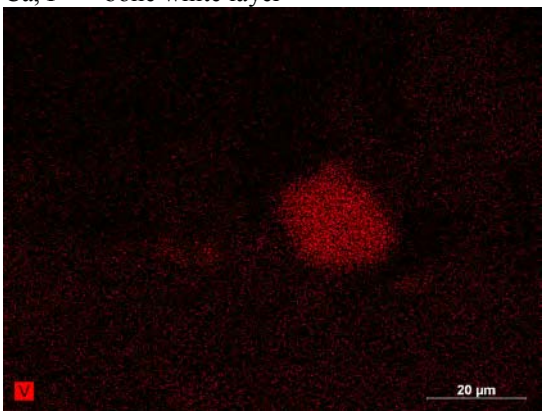
P



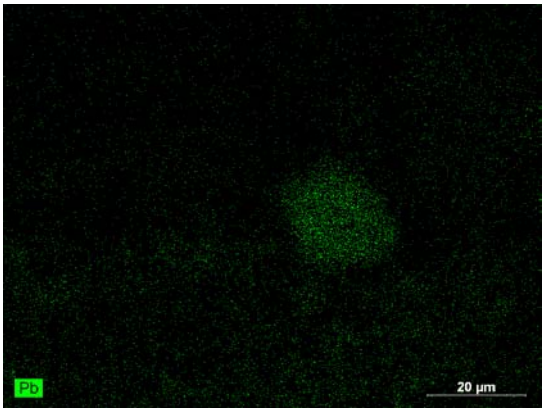
Ca, P >> bone white layer



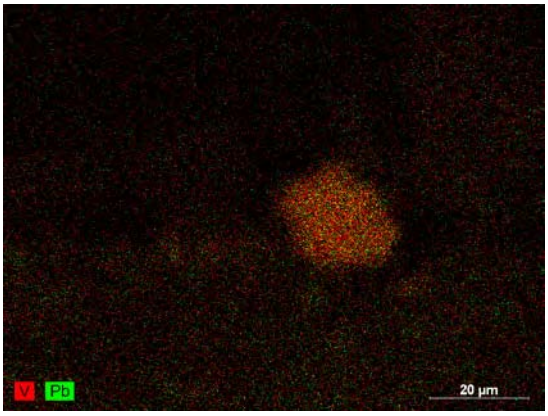
Cl



V



Pb



V, Pb

Fig. 9. Mapping for elements:
Ca, P >> bone white layer;
Pb, V, Cl main components of vanadinite ($Pb_5(VO_4)_3Cl$)

The mapping for elements showed that calcium and phosphate can be allocated to the

light pink layer, consisting of bone white (hydroxyl apatite, calcium phosphate), while vanadium and lead are only found in the yellow cluster and thin remnants of the yellow layer. The distribution of chlorite is not so easy to understand, though the resonance from the yellow cluster seems higher than from the pink layer. There is also some phosphor in the yellow cluster. The EDX analysis confirms the result of the element mapping (fig. 10).

Conclusions

The aim of the investigation was to analyse the pigments used in the tomb and to compare them to the ones used on the Terracotta Army of Qin Shihuang. Cross sections and PLM analysis were made by the authors. The Han Dynasty tomb shows a range of pigments that is typical for the ancient palette. On a clay plaster, a thin white layer was applied, consisting of white clay. White clay, earth pigments, cinnabar, malachite, azurite and a very fine black were used.

Two pigments could not be identified with PLM. Further investigations were performed using Raman spectroscopy and micro-XRF. The optical properties of the fine purple particles do not correlate to typical Chinese Purple: Compared to the Purple used on the Qin Terracotta figures and Han Yangling, the absence of the typical octahedral plates and the strong interference colours are irritating. Nevertheless the pigment could be identified as Chinese Purple (Han Purple) with Raman spectroscopy.

The yellow and orange pigments from the Han tomb contain lead as main element and probably consist of vanadinite. The yellow pigment from the Terracotta Army could not be identified clearly due to problems of sample size and preparation. But the presence of lead and vanadium also indicates the use of vanadinite here.
Directly after excavation the yellow and orange areas were very bright. Meanwhile both have faded or discoloured considerably: While the yellow sun is hardly visible against the yellowish white background, the orange railings of the banquet scene have turned brownish. The very high humidity, in summertime combined with high temperature, combined with biocide and consolidation treatment might have accelerated this process as the yellow found in the terracotta army still appears bright yellow.
The investigations on the yellow pigments are still going on. One problem for the investigation is that the obtainable amount of sample material is extremely small, but further analyses are planned for 2006.

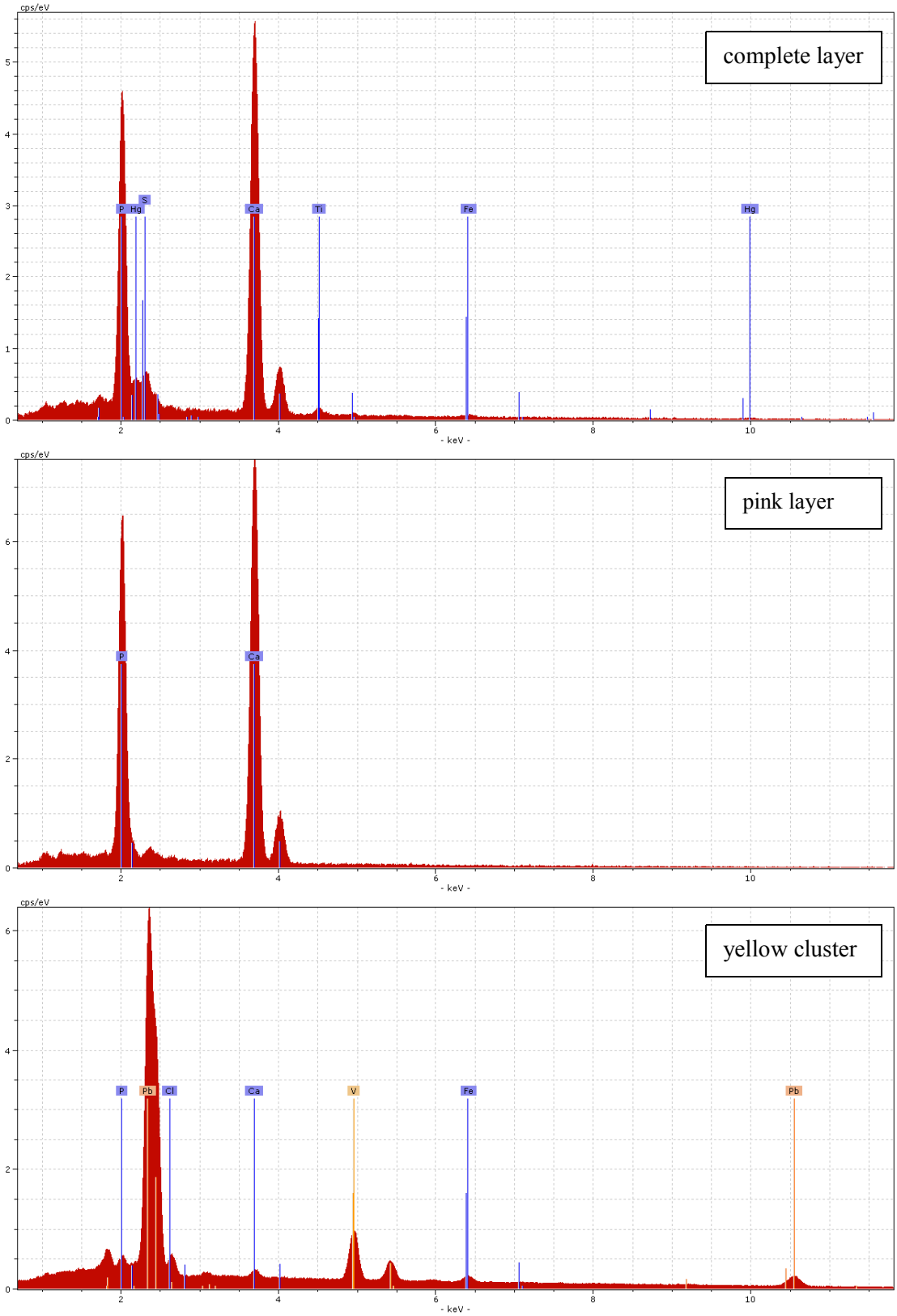


Fig. 10. EDX analysis of the cross section

Credits for photographs and figures

Fig. 1. Archaeological Institute Xi'an

Fig. 2. Museum of the Terracotta Army, Lintong

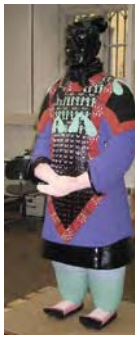
Fig. 3ab, 4. C. Blaensdorf, Bayerisches Landesamt für Denkmalpflege

Fig. 5. Xia Yin, Museum of the Terracotta Army, Lintong

all Raman spectra: Dr. Susanne Greiff, Roman Germanic Central Museum Mainz and University of Mainz

Fig. 6. Dr. Susanne Greiff, Roman Germanic Central Museum Mainz

Fig. 7-10: Klaus Rapp, Munich



Year 2005

Reconstruction of the polychromy on replicas of terracotta warriors – preparing the replicas

Catharina Blänsdorf, Wang Dongfeng, Wang Liang

Introduction

The investigations on the polychromy of terracotta warriors started in 2003 after kneeling warriors with preserved polychromy provided so much information on the original paint layers that it seemed reasonable to investigate colours and colour schemes more closely than before. In 2004, when the first results were visualised as colour drawings, the decision was made to paint 1:1 some replicas in the original technique, using the analysed materials and reconstructing the complete colour scheme.
Originally three types of warriors were scheduled: A general of type 2, a 'chariot officer' with 'apron-style' armour and a kneeling archer. As replicas terracotta sculptures in the original size, modelled by artists and produced according to the historical technique were planned. After tests made by the members of the laboratory of the museum in Lintong, it occurred that modelled terracotta sculptures could not be produced. The options of choice thus were terracotta sculptures commercially produced by a factory for souvenir purposes and gypsum casts of original sculptures.
In October 2005 gypsum replicas were prepared and lacquered with *qi* lacquer in the museum of the terracotta army. The replicas with reconstructed polychromy were presented in the exhibition 'Xi'an – Kaiserliche Macht im Jenseits' in the Art and Exhibition Hall of the Federal Republic of Germany in Bonn from April, 21 to June 23, 2006.

1. Production of the replicas

The choice if commercial terracotta sculptures or gypsum replicas had to be made in February 2005. At that moment the time for preparing and painting the replicas already had become rather short (the original planning had been to finish to production of the replicas in October 2004). Thus, the decision if gypsum or terracotta was not only a question of material but also of time.

1.1 Choice of material – terracotta or gypsum

The ***terracotta replicas*** are produced in a manufacture enterprise in the museum area. They are sold to tourists in the official museum shops and are of guaranteed quality and rather fine modelling. A sculpture from this factory was used for gluing tests ass part of the project work in 1999.
The sculptures are produced in moulds which are taken from fee modelled copies of warriors. They are not representing an individual sculpture, but a type of sculpture. All relevant types are available. The sculptures are made in parts which are then connected. Afterwards the surfaces are made smooth by hand and details are incised. Before firing the large (1:1 in scale) standing sculptures are cut in 'levels' again (legs and three parts of the body) to avoid cracks during firing. Kneeling archers are fired in one piece. The small kilns are similar to

antique ones and reduction firing is possible. They are heated with coal. The fired sculptures are reddish to greyish brown. That means the surfaces are too dark, but some rather light grey firings are rather close to the originals.
After firing the sculptures are connected again using gypsum applied in a thick layer on the inside. Head and hands are inserted and glued in with gypsum. Gypsum is also used to fill possible damages of the surface. Afterwards the surfaces are painted black with some kind of partly water-soluble paint and on top a layer of loess dust dissolved in water is applied to let them appear like just excavated.
The sculptures have the correct size. Surfaces are smooth and the edges are precise and clearly visible. Mainly details as armour plates and connections stitches, shoe laces and hair style are mainly realised correctly. Disadvantage is that the replicas do not reach the artistic quality of the originals: The posture seems stiff. Hands, ears and other details are too coarsely modelled and the facial expression does not correspond to the originals. The faces look fierce, sometimes mean, not concentrated, and sometimes features are exaggerated like caricatures.
On the technical view, the cutting in parts for firing is difficult, because it results in differences of the surface level and a lot of gypsum which is generously spread on the terracotta surfaces. The coatings with black paint and loess dust conceal the gypsum and uneven surfaces, but reduce the preciseness of the details. Furthermore, loess dust is powdery and sandy and not suited as a surface to paint on. For applying lacquer, they either would have to be removed or omitted – what would have resulted in a very inhomogeneous surface of terracotta and grey or white gypsum.

The ***gypsum casts*** are produced in the museum. The gypsum moulds are made from the originals, so principally they are conform in size and design with the original sculptures. For the cast a mixture of 80 % of gypsum and 20 % cement are used which is coloured light grey. Soap is taken as form release agent.
The disadvantage of these gypsum replicas was mainly the material aspect: Colour, surface, structure, absorption properties do not correspond to the terracotta. It was difficult to decide it applying *qi* lacquer would be possible and how it would look like. Another problem was that for the ‘chariot officer’ there is no mould anymore, because the old one was broken. According to a new law, making new casts of the originals is forbidden. Also the cast for the general of type 2 does not exist anymore. That meant: Two of the planned sculptures could not be made, and the offer was only a general of type 1 and a kneeling archer.

Facing these options in February 2005 decision was made to use gypsum casts and not terracotta replicas. The main argument was that the gypsum casts are closer to the originals and can be reworked if necessary while the terracotta cannot be treated anymore after firing. A way out would have been to rework the terracotta before firing, but this had not solved and hope that the joint could be filled invisible. But this alternative would have been so time consuming it had to be abolished.

1.2 Reworking the gypsum surfaces

In the beginning of May 2005 the casts could be examined in the basement of the laboratory of the museum in Lintong. It became obvious that the surfaces were rather bumpy and the all small details were unrecognisable or missing. Joints were filled up rather roughly. Most surprising was that some details are so completely different from the originals that the question came up if the casts were really taken from the originals. Maybe they are taken from the first casts which had been remodelled in some parts. The workers responsible for this

work said it would take 15 days to rework the details and smooth out and polish the surfaces. Critical parts were marked with pencil lines to outline what had to be done.
In the middle of October 2005 the two replicas were partly reworked, but not systematically and not sufficient. A campaign of reworking and recutting of shapes and details, extensive fillings and modelling happened in 16 days in October/November. Work was taking place under an enormous time pressure: the painters who should lacquer the sculptures were already hired and wanted to start. Besides the fact that they had to wait, also the weather got cooler and cooler, what meant that the conditions for lacquering were already more than disadvantageous. The scheduled and preferred time for the lacquering would have been September when it is warm also in the night and rainfalls result in enough humidity. In October the temperature already decreased dramatically and the humidity was very low as it was not raining much.
During the reworking process the deficiencies of the replicas became fully visible: the surfaces were bumpy, but polishing opened countless bubbles in the gypsum which had to be refilled. The cement used to fill the gaps of the joints from the cast segments was extremely hard. Some details were so wrong - as a tie with the loop pointing in the wrong direction or one with tow open ends or the transformation of the lowest row of armour plates in the back in something looking like a bandoleer – that the only possibility was to erase everything and recreate it by cutting or applying filling material. In the feet of the general iron rods for stabilisation became visible after the tips of the shoes had been cut into their original shape. They had to be sawn off and isolated. The heads were of much better quality and only showed holes in the surfaces and minor inaccuracies.
For the work chisels, seal cutting instruments, abraded spatulas and sand paper were used. For fillings 'Moltofill'[1] was used which hardens slower than pure gypsum. Disadvantage of the 'Moltofill' was that it is purely white what meant that the fillings stood out white on the light grey gypsum.
Sixteen days were just enough to finish the work. A lot of filling and modelling was necessary. For example, about 250 button-shaped stitches were modelled and applied on the armour plates just of the general. The complete apron of the general had to be remodelled, as well as both hands, the collar and all connecting stitches on the armour plate. Luckily the gypsum cast were 'bulkier' than the originals so that the new surfaces could mostly be created by incising into the existing material. After polishing all surfaces with fine sand paper the sculptures were dusted off and cleaned with a wet linen cloth to remove the fine dust.

1.3 Characterisation of the figures

The original of the kneeling archer was excavated decades ago from pit no. 2. The original sculpture could not be seen in the museum. Later on, a comparison with photographs in an illustrated book[2] showed that the original sculpture has not traces of polychromy anymore. It also showed that the head originally is from a different, but similar modelled kneeling archer.
The general is the sculpture T20G10:97 from pit no. 1. It is exhibited in a showcase in the hall of pit no. 2 – what was a big advantage as it could be visited many times to check the details of the modelling. In the back larger areas of the armour are reconstructed and many of the connection wires are completions. In total all relevant details are preserved and could be studied. The base slab for the general as separately produced and is made of a gypsum slab painted grey.

[1] 'Moltofill' is a commercially available filling material for renovating consisting mainly of gypsum and methyl cellulose.

[2] 秦始皇兵马俑博物馆 Qin Shihuang bingmayongbowuguan (ed.), *秦始皇兵马俑博物馆 Qin Shihuang bingmayongbowuguan ['The museum of the terracotta warriors and horses of Qin Shihuang']*, Beijing 1999.

2. Lacquering of the sculptures

The lacquering was supposed to correspond to the original in material and application: two thin layers of *qi* lacquer should be applied. After some discussions, it was decided to execute the lacquering in China. Mr. Wang Dongfeng contacted two painters, Mr. Liu Renrang and Mr. Yuan Songban. They are employed at the Center for the Preservation and Restoration of Cultural Property of Shaanxi Province in Xi'an. Their job is the reconstruction of paintings on historical architecture. A first meeting took place on June 21, 2005. Both painters have learned historical painting techniques and lacquering form 'old men in the countryside'. They regularly work with *qi* lacquer which for example is used for painting columns. They proposed to use a mixture of 95 % qi lacquer and 5 % tung oil, but later on used raw lacquer with an amount of xylene (dimethylbenzene). After applying the first layer, the layer should dry until it was not sticky anymore. Afterwards a second layer was applied. After several tests on gypsum slabs a suited method was found. The painters brought their self-made brushes, with are extremely short-haired and hard. They gave much better results than long-haired, soft and newly acquired ones.
Unfortunately the surface of the gypsum could neither be coloured grey nor isolated. This resulted in a slightly streaky application and the first tests also turned matt. On the sculptures the result looks okay, but some white or too light brown parts were visible on the kneeling archer which had to be retouched before painting the sculptures. The general which was the second one to paint turned out perfect.
Due to the colder weather the drying periods were longer. It was necessary to wait three days before the second application. The lacquering was performed in the show room of the terracotta replica workshop. The concrete floor was flooded to raise the humidity.
After three weeks the sculptures were dried and could be packed and sent to Germany. They arrived via air cargo in Munich on January 16th, 2006.

3. Photographical documentation

3.1 Kneeling archer


Fig. 1Filling and remodelling


Fig. 2. After finishing the polishing

Fig. 3. Transport to the work shop room fro lacquering

Fig. 4. Start of applying qi lacquer: Yuan Songban (right) and Liu Renrang (left)

Fig. 5. Lacuqering the body

Fig. 6. Applying the second layer of lacquer

Fig. 7. Body just after finishing the second layer

Fig. 8. Finishing sculpture alfter drying of lacquer

3.2. General


Fig. 9. Modelling the hands


Fig. 10. Fine polishing


Fig. 11. Part of back after polishing


Fig. 12. Start of lacquering, carried out by Liu Songban


Fig. 13. During lacquering


Fig. 14. Finishing the second application of lacquer


Fig. 15. After polishing

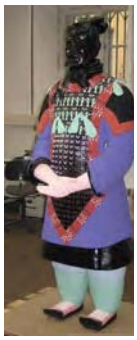

Fig. 16. Finished sculpture after drying of lacquer

Photo credits

Wang Liang, Museum of the Terracotta Army: 1, 2, 10, 11, 15
Wang Dongfeng and Wang Liang, Museum of the Terracotta Army: 4, 5, 6, 7, 8, 12, 13, 14
Xia Yin, Museum of the Terracotta Army: 9
Catharina Blänsdorf, Bavarian State Department of Historical Monuments: 3, 8, 16

Year 2006

Reconstruction of the polychromy on replicas of terracotta warriors – painting the replicas



Catharina Blänsdorf, Carolin Roth

Aims and preconditions

The gypsum replicas of two terracotta warriors, a general and a kneeling archer, were cast, reworked and lacquered in the Museum of the Terracotta Warriors and Horses of Qin Shihuang in Lintong in 2005. In January 16th, 2006, they arrived in Munich where they were painted in order to be presented in Bonn in the exhibition 'Xi'an – Kaiserliche Macht im Jenseits' (April to June 2006).
The aims of painting the replicas were to give a visual impression of what the polychromy might have looked like originally and to gain knowledge about the painting technique. The project was not only planned for the exhibition where the replicas could give an impression of the original intention of the sculptures: For the researchers within the project, especially with growing knowledge about the polychromy, it became clear that it is not possible to imagine the impression of a painted life-size warrior. Sketches, even in 1:1 scale, appear very different. Colours and patterns can be depicted, but the third dimension is missing and also the effect of different materials and surfaces structures cannot be properly imitated.
Besides the visual effect, also the technical questions were of importance. On a sculpture it is possible to study the workability of different kinds of painting media, the pigment consumption or the difficulties in the execution of paint and decorations on curved surfaces.

There were some preconditions which were decided before the work was started. They were deciding for the choice of the materials and the choice of colour tones:

1. The painted replicas should depict the warriors in a "fresh", i.e. unchanged or aged situation.
2. Materials and technique should be as close to the originals as possible.
3. The arrangement of colours should orientate on specific sculptures, but not be a reconstruction of two individual warriors. In any case, the reconstruction should be as complete as possible, including the option of more or less free decisions on areas without any information.

The base of the painting was the information gathered from observations on the originals. They comprised colour descriptions, colour sketches of details and warriors in small scale as well as self-made colour-charts made in Lintong to record frequently used colours. As discolorations caused by damages of the surface, adhering soil and impregnation with consolidants should be excluded, also analysis results and cross sections were used as base for the selection of pigments and mixtures.
The use of pigments accordant to the original paint layers and the use of raw lacquer as support meant the visual impression was different from the sculptures with preserved polychromy: The lacquer appears black and glossy instead of dark brown and dull, some colours are much more intensive than the colour documentation of paint fragments.
For the choice of the binding medium, the properties of the original paint layers were decisive. Thickness and surfaces structure should be reached. As analytical results were still missing, the choice of the binding medium required a series of practical tests which took four weeks.

1. Pigments

1.1. Sources of supply

The range of pigments used for the reconstruction was orientated on the results of the pigment analysis: Bone white, lead white, ochre, red iron oxide, cinnabar of different tones, light blue azurite, malachite, Chinese violet and bone black.

Materials bought in China

The larger amount of the pigments was purchased in China from a factory of mineral pigments in Beijing[1]. The pigments could be selected from the bags of the storage room. The following materials were bought there:

material	*product number /name*
White	bone white[2]
	'lead white' *qian bai* 铅白
malachite	*shi lü* 石绿 no. 2
	shi lü 石绿 no. 4
	shi lü 石绿 no. 5
azurite	*shi qing* 石青 no. 3
	shi qing 石青 no. 4
cinnabar	*zhusha* 朱砂
	chensha 辰砂

Table 1. Pigments bought in Beijing

For malachite and azurite the numbers indicate the fineness and/or quality of the material.[3] The words *zhusha* and *chensha* both have the meaning of cinnabar[4]. In this case *zhusha* is lighter and more orange red and *chensha* is darker.

The quality and brightness of the mineral pigments in China, when bought from a renowned factory, is very high and often better than comparable products in Germany. Though the quality of the mineral pigments from the factory in Beijing is good and reliable, the materials bought as 'bone white' and 'lead white' turned out to be something else: The 'bone white' was powdered bone, a material unsuited to be used as pigment and in aqueous media, as it turns greenish and smells of decay. It became clear that 'bone white' can only be bone ash and not ground bones. An investigation of with PLM proofed this: Ground bones appear as rounded transparent particles without inner structures besides cracks. Bone ash particles have distinct structures of microspores and layers of different density visible under crossed polars. Pores are sometimes black and therefore also visible in transmitted light. The bone white from the terracotta army has the same optical properties as bone ash.

The 'lead white' was analysed as a kind of asbestos, so there clearly was some kind of confusion.

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1 Brand 中国矿物颜料(*zhongguo kuangwu yanliao*; China Mineral pigments); producer: 北京金碧斋美术颜料厂 (*Beijing Jin Bi Zhai mei shu yan liao chang*; Beijing Art Pigment Plant); address: Building No.22, No.6 South Street of Hua Jia Di, Chaoyang District, 100102 Beijing. The sells room is located in a basement of a building of the Academy of Fine Arts which mainly serves as storage room and packing station for the factory.

2 As the powdered bone had a bad smell, the bag was not kept. The Chinese name was not written down.

3 No. 1 is the best and coarsest quality and therefore also the darkest one. No. 5 is the finest and lightest material. Azurite no. 5 is a mixture of azurite and malachite and rather greenish.

4 According to the description of the employees of the sells room, *zhusha* and *chensha* are different qualities of cinnabar and come from different regions, whereas *chensha* is the more valuable and "better" material. PLM analyses indicate that *chensha* is ground mineral cinnabar, while *zhusha* is artificial vermilion.

Materials bought in Germany

All material purchased in Germany were bought at the 'Kremer pigments' store[5] in Munich. They comprised different kind of ochre and iron oxide reds, bone blacks, replacements for the white pigments bought in China and additional qualities of cinnabar:

material	*product number /name*
Iron oxide red	48150 Eisenoxidrot 130 mittel PR 42 48200 Eisenoxidrot 130 M mittel 48120 Eisenoxidrot 120 PR 42 48320 Eisenoxidbraun 640 mittel PBr 6
Hematite	48600 Eisenoxidrot natur, Hämatit, nicht ganz feine Mahlung, für Wand PR 102
Ochre	40080 Französischer Ocker HAVANE PY 43, orange 40241 Rehbraun, Umbra natur
Yellowish earth	58250 Kaolin gelblich PW 19, weißer Bolus 58191 Kreide von Sarti, gelbstichtig, Steinkreide, Schneiderkreide
Bone black Ivory black	47100 Beinschwarz PBk 9 47150 Elfenbeinschwarz Mischung
Bone ash (Bone white)	58920 Knochenasche
Cinnabar	10624 Zinnober chient'ou, feiner 20µ 42000 Zinnober PR 106.77766 Quecksilbersulfit aus China (man-made) Zinnober bought from Kremer in 1988
'azurite'	10184 Blue Bice, Cupfer-Calcium-Carbonat

Table 2. Pigments bought at 'Kremer pigments' store

The range of different kinds of earth pigments, including also man-made products as artificial iron oxide reds show the difficulty to find the fitting pigment here. There is a wide range of colour shades in earth pigments. The exact composition and the colour of those used in the terracotta army are hard to identify as the samples always also contain particles from the surrounding soil, the earth pigments were selected according to their colour.

Chinese Purple

Chinese Purple, barium copper silicate $BaCuSi_2O_6$, is not a common pigment today anymore and cannot be purchased in pigment stores in Germany or in China. Prof. Heinz Berke from the University of Zurich is investigating Chinese Violet and the related Chinese Blue since many years and is working on the reconstruction of the ancient production technique. For the purpose of painting the replicas, he and his team provided 1 kg of Chinese Violet produced especially for this purpose.

Other sources

A number of pigments could also be taken from the collection of the workshops of the Bavarian State Department of Monuments and Sites, especially some charges of cinnabar, lead white and more earth pigments. Most of them are bought in the 1980's and 1990's and come several different sources which cannot be named anymore.

[5] Kremer Pigmente GmbH & Co. KG; address: Hauptstraße 41-47, D-88317 Aichstetten.

1.2 Used pigments

Firstly, tests were made on panels[6]. The mixture for every colour was determined before it was used on the replicas. A list of all mixtures is given in appendix 1.

White
There were different qualities labelled as 'Knochenasche' ('bone ash', 58920) and 'Knochenasche weiß' ('bone ash white', 58020). Both materials were slightly grey. Microscopically, they contain black particles next to the white ones. The 'white bone ash' was slightly more yellowish, but darker than the 'bone ash'. In the end, the problem was solved by the means of availability: 'White bone ash' could not be supplied anymore, only one type sold as 'bone ash' is still on the market. Heating bones first transforms them to black charred bones (bone black) at ca. 350 °C; at to temperatures of more than 850 °C with oxygen turns the charred (black) bones to white ash. Heating of the 'bone ash' again up to 900 °C reduced the greyish tinge slightly, but the process was so time-consuming and the result not so clearly better, that this method was not used for larger quantities. Although bone white is also the main material in the flesh tones, the slightly greyish tinge in the end did not have a negative effect.
For white and pink areas mixtures of bone white and lead white, but also pure bone white have been used. The choice was depending on the pigment analysis for the respective areas.

Ochre
There a few pigment analyses of ochre areas. The colour was chosen according to the colours documented in China and the bright ochre of F-014/98, a fragment of colour in soil.

Cinnabar
Depending on the particle size and maybe also on the processing, cinnabar can have different shades. Basically fine types are more light and yellowish red, while coarser types are darker and sometimes brownish. There are also brownish types which might be a lower quality. On the deliberate terracotta army, the use of different types of cinnabar can be seen clearly: Different nuances of red are used next to each other on different parts of the clothes. While mostly rather coarse types are used in the clothes, in the flesh tones always extremely fine cinnabar is used, often with a particles size if less than on 1µm.
For the reconstruction, it proved to be difficult to find cinnabar types as bright red as used on the terracotta army. In the end, eight different cinnabars were tested in different mixtures to find the perfect tone. Probably the extremely fine material is even lighter and brighter than the very fine synthetic vermilion (particle size about 2µm) which is available nowadays. As there was no time to try to grind the cinnabar down to such a fine particle size, this question remains unsolved.
Especially for the red decorations on the reddish brown border of the general's armour, the problem with the quality of cinnabars became evident. Substantial test series were required to find the matching tones. Especially the very bright and light red often found on the terracotta army was difficult to reconstruct as most cinnabars appeared to be too brownish and too dull.

Green
A medium dark green is one of the most frequent colours of the terracotta army. With PLM a broad range of particles sizes is visible. According to these observations, a green of the same brightness was mixed using the different types of malachite. For lighter green parts, other mixtures were used.
Most green areas on the terracotta warriors appear more yellowish compared to pure malachite. However, cross sections of green paint layers proof that there is no ochre inside the

[6] Pieces of wood with smooth black coating.

paint layers. Therefore pure malachite was used for the green areas on the replicas although they appear much ‘cooler’ (i.e. more bluish) now than on the originals. Tests also showed that only a minimal addition of ochre to the malachite is necessary to reach the more yellowish tone. Therefore it can e assumed that the yellowish tone on the originals is caused by remnants of soil penetrated into the surface of the green layer.

Blue

The azurite from the terracotta army has an unusual light and bright tone. The fragment F-014/98 of colour in soil was used for comparison of the blue. Tests showed that this blue tone could not be obtained with any of the azurite types from China or Kremer. Binding media have a strong influence on the colour of azurite, but even when the azurite was only mixed with water it did not have the light blue tone: All strong coloured types are much too dark; light coloured, fine grained azurite was too greyish or too greenish.

In this situation, the decision was made to use another material instead. The choice fell on a pigment sold as ‘Blue Bice’ at the ‘Kremer’ store which has exactly the right colour. The material is labelled as copper calcium carbonate. The analysis with XRD resulted in calcium carbonate and azurite. With PLM blue and green particles are visible with rounded shapes, indicating a synthetic production. The rather coarse material had to be grinded carefully before use (marble grinding slab and glass muller).

Purple

The Chinese Purple had to be prepared carefully before application by grinding on the marble grinding slab with a large glass muller. Although the material became much finer and more homogenous that way, the paint layers still give a grainy, velvety impression.

Black

First analyses on black areas ore patterns on the terracotta warriors resulted in carbon black, but later analysis showed that this probably was a mistake: If the sample is taken from the surface only (to avoid visible damages), the black can also come from soot and wood particles adhering to the surface of all fragments. Two samples taken from the depth of paint layer clearly proved that bone black was used.

Tests with bone black and ivory black as well as carbon black (Rebschwarz) showed that bone black gave the best results:

material	*effect in egg/glue*
Ivory black (47150 Elfenbeinschwarz Mischung)	deep black, velvety surface, some areas glittering
Bone black (47100 Beinschwarz PBk 9)	slightly greyish, high opacity, has to be ground on grinding slab
Carbon black (Rebschwarz, from workshop collection)	different, rather coarse structure, glittering surface, velvety surface, low opacity

Table 3. Types of black pigments tested for the black areas (‘sun and bird’ pattern; black lines and ornaments)

After these tests ivory black was used as black pigment, because it was the only deep black and therefore the most similar to the original paint layers.

2. Binding medium

The type of binding medium is as important as the choice of pigments. Degree of gloss and saturation of layers are depending on the binding medium. The appearance of the pigments, especially azurite, depends evidently on the type of binding medium: Bright blue in glue or gums, it appears dark and dull in oily or fatty media.

Nothing was known about the binding medium of the polychromy of the terracotta army when the work of the reconstruction was started. The choice of the binding medium therefore oriented on three main aspects:

1. Preferably materials should be used which were available and imaginable in Ancient China.
2. The material should be suited to achieve layers of the same properties as the original ones.
3. The layers had to achieve a considerable mechanical stability: As the replicas had to be transported to the exhibition in Bonn, the surface had to be hard-wearing enough to survive packing and transport without major damages.

If no material would reach a satisfying result concerning visual impression and/or stability, also other and modern materials should be tested.

2.1 Binding media for polychromy in Ancient China

There is no literature or description on traditional technique for painting sculptures in China. The few description mentioning binding media are instructions for "paintings" – a term that probably refers to water colour-style paintings on paper or silk.

Animal glue and ***plant gums*** are mentioned for this purpose. Both can be mixed or applied in change with ***alum*** to reduce the water solubility. This method is mentioned in descriptions of Chinese traditional painting techniques.[7] Skin glue, peach gum and alum are also the binding media which are still sold today as binding media for traditional Chinese paintings. Shops for painting materials sell skin glue, peach gum and alum in small bags - though often offering animal glue when being asked for peach gum. This probably means that there is no clear difference for the practical use. Skin glue is definitely wider spread and easier to find than peach gum nowadays.

Starch pastes are known as glues for paper. Water of cooking sticky rice or gruel was added to clay mortars. So far, there is no evidence that they might have been used as binding medium.

Egg has been used as painting medium since the antiquity. Investigations on Greek sculptures showed egg was used on marble surfaces which were planned to be exposed outside. There are no evidences for egg as binding medium in China, but two analyses carried out for the Roman Germanic Central Museum on a bronze bird from the Qin Shihuangling and a Han Dynasty wall painting gave the indication on egg.[8]

Oils and ***resins*** traditionally seem only scarcely be used as binding media. ***Tung oil*** is a typical addition for priming pastes for paint layers on architecture. Resins have never been found. *Qi* lacquer seems to have replaced the use of oils and resins in China.

It is not known if Chinese ever used ***casein*** as diary products were traditionally not consumed in China. Butter and milk were common food for the nomadic tribes in the north, the Mongols or also the Tibetans, but these peoples also did not produce cheese. Even nowadays, casein is not known in China.

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[7] Yü Feian (Silbergeld 1988, p. 17) describes several qualities of skin glue and the interfacing layers of alum.

[8] Black swan of pit K007; wall painting from the tomb of Binwang in Chunyi near Binxian, form the Eastern Han Dynasty (25-220 AD).

2.2 Information from the polychomy of the terracotta army

The polychrome on the terracotta sculptures shows properties which allow drawing conclusions on the type of paint: thickness, surface structure, solubility can still be observed.
All paint layers are rather thick (0.1-0.8 mm, multilayer structures up to 1.0 mm). The brush strokes are well visible, clear ridges and marks from single hairs are preserved. An application in more than one layer can be assumed. Some of the thick layers (as flesh tones) show a tendency to separate at certain levels. Nevertheless of work economy, an application in more than three layers does not seem reasonable.
The paint was suited to be applied in thick layers, as raised applications, but also in very fine lines. It is possible that different mixtures of binding media might be used according to the purpose, but it can be assumed that principally the same system has been used.
All paint layers appear matt and powdery today, but flakes of better preserved paint layers still show a good stability against water (i.e. they can be immersed into water without dissolving). This indicates that the binding medium was not completely water soluble after drying anymore. Also from the practical aspect it seems reasonable that the binding media was not completely water-soluble, because this would have been highly risky already during the production. Additionally, there are no water-marks or typical water damages visible although mud and rain water has penetrated into the pits. Multi-layered structures in different colours shows that often the later applications did not dissolve the earlier ones anymore, but in some cases the two obviously are mixed: In cross sections no borderline is visible and the colours are mixed into each other instead of overlying in horizontally oriented layers (‘Marble cake’ effect). This can mean that the layers got insoluble after some time, but could be dissolved again when fresh or treated mechanically.
An evaluation of the original degree of gloss is not possible. It can only be assumed that the paint layer was less glossy than the lacquer. The fact that all painted terracotta objects from Chinese tombs have matt surfaces might be an additional hint.

2.4 Tests with different binding media

These considerations and observations lead to decision to focus on water-based materials as animal glues, gums or starch, but with an addition of a less water sensitive material.[9] Egg and casein are water-based, but turn insoluble after drying. Casein therefore was also included though it was likely than all the others.
Oily media were only considered as additives as pure oil or oil/resin layers would azurite into a dark, unattractive colour and need a considerable time to dry. This prolongs the painting process. Addition of oily media also resulted in more smooth surfaces with ‘rounded’ brush marks as the paint still has the time to flow after application.
Modern materials were only tested in a very small range.

For the visual impression the following criteria were relevant. The paint had to be suited to produce
a. thick layers,
b. visible brush strokes and suited to produce thin, plastically applied lines,
c. suited to paint large areas as well as extremely fine patterns with lines of less than 0.3 mm
d. matt or semi gloss surface as a contrast between paint layer and glossy lacquer had been intended by the artists.

[9] A large number of tests were performed by Carolin Roth in preparation of the painting of the replicas. Preliminary tests had been made by C. Blänsdorf before.

The materials were purchased in Germany: Hasenhautleim (skin glue for rabbits), gum Arabic, rice starch and wheat starch were bought at the 'Kremer pigments' store. Casein binding medium from the company 'Schmincke' (no. 50 088) was used for tests. Small amounts of peach gum (桃胶), skin glue (明胶) and alum were bought for test purposes. Sturgeon glue used for tests was bought by Zhou Tie in Xi'an several years ago. The supply of eggs was bought on the farmer's market always the same morning.
Pigments with different properties were used for the test applications: Bone ash, malachite, ochre, cinnabar and azurite. All tests are listed in appendix 2. The main results can be summarised as follows:

Animal glues
Glues remain water soluble and swellable. When a second layer is applied, the first one easily solves, so it is difficult to spread them homogenously over larger areas. If alum is used to reduce the water solubility, it cannot be added to the glue, as the glue solution also becomes high viscose and difficult to use after several hours. Alum solutions (10%) can be used as interfaces between single applications. It is suitable to reduce the water solubility.
Paint layers bound with skin glue can be applied in thick layers without problems of tensions or cracking. They can also be used for plastic applications. They were used for *lifen* decorations, the Chinese equivalent of European *pastiglia* technique.
Skin glues gave good results, but sturgeon glue did not. Applications of alum solutions are inevitable here, nevertheless the layers became streaky.
Animal glue can be mixed with starch paste. A mixture of wheat starch and skin glue (5-8%) in a ratio of 1:2 gave a rather good result; a higher proportion of wheat starch did not produce satisfying results. Further tests with rice starch or other mixtures are necessary to evaluate this type of medium. An addition of linseed oil (1 part on 4 parts of glue) reduces the water solubility, but alum layers are nevertheless necessary for the application of a second layer. The layers tend to get blotchy. Animal glue can also be used in mixtures with egg. These types of media are described in the paragraph *egg*. Mixtures between skin glue and gum Arabic: see *gums*.
Evaluation: Paint layers with skin glue gave good visual results concerning thickness of layers, brush marks and impasto structures as well as fineness of lines. Applying several layers on larger areas is difficult as the second application dissolves the first one. The layers remain water-sensitive. Water drops leave marks, swelling reduces surface structures.

Gums
Like animal glue bought in China, also the peach gum contained quite a lot of impurities. For the tests, pulverised gum Arabic has been used instead.
Gums are suited to produce thin, semitransparent layers without structure. Thin layers normally have a low opacity. They are the traditional binding medium for water colours. If applied thickly, the brittle layers tend to flake off. If applied in many overlying thin layers, the danger of dissolving the previous layers again is high, even if alum is added. The borders tend to stay visible as "water marks". Also mixtures of two parts of skin glue and one part gum Arabic (by volume) produce these problems of water marks and remain very water sensitive.
Besides these problems it seems unlikely that for the terracotta army a binding medium might have been used that requires at least four or five applications, because this is much to time-consuming and therefore uneconomic.
Additions of alum to the gum solution reduce the water solubility slightly, but create problems with acid sensitive pigments as azurite. Tests with applications of alum layers in between the paint layers was not be tested in this series as gums seemed not give any satisfying results.
Evaluation: Gums, especially gum Arabic are not suited as binding medium due to the water-sensitivity and brittleness. Gums as additives to other media could be tested in further tests.

Starch pastes

Rice starch gave good results when prepared as a 7% solution in water. The surface is matt, the brush marks remain visible, but there are no disturbing marks or blotches. It was not easy to apply in thin lines, a it is rather viscose.

Rice does not grow in the northern parts of China. In ancient times the wide-spread type of cereal seems to have been millet or sorghum. Wheat is now the most frequent grain in the Xi'an area (next to maize which was imported much later), but it is not clear since when. Wheat starch was not suited as binding medium, because the paint became cloddy and had no opacity. Also different proportions and preparations did not help to achieve a better result.

Mixtures with animal glues are possible. The result is better than pure starch pastes, but maybe poorer than poor animal glue. The mixture of skin glue and wheat starch paste (2:1 by volume) gave good results.

Evaluation: For evaluation of the properties of starch pastes as binding medium and additive, more tests are necessary. The executed series did not seem promising using wheat starch, but rice starch gave interesting results.

Casein

Casein can be used as strong glue, but also as paint medium. In the tests casein (solubilised with borax) gave rather smooth layers. After two days they are water insoluble. In the end, casein was given up more for principal considerations than for the practical experiences.

Some of the layers applied on test panels developed a distinct crack system or flaked off due to high tensions some days or weeks after drying.

After 12 months most of the casein layers on test panels have developed a crack system, some even with detaching and cupping flakes due to high tensions.

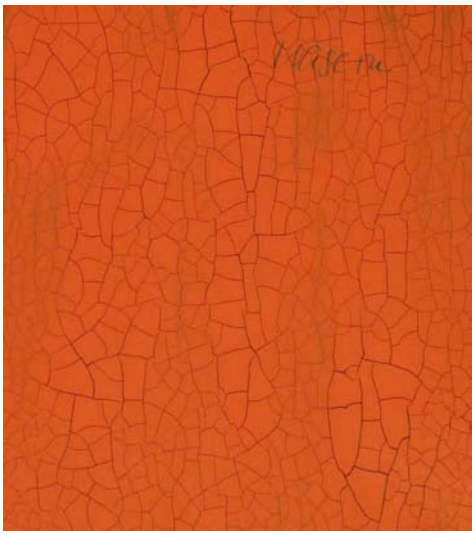


Fig. 1. Cinnabar bound in casein (January 2007), lower edge of pictures = 6 cm.

Egg

Egg is a natural suspension of fatty and aqueous components and can be mixed with almost every type of binding medium: animal glue, starch paste, oils and resins. Egg can either be used as egg yolk or egg white or a mixture of both. Egg yolk is fattier, egg white more brittle. Paint layers with egg turn water-insoluble after drying and get very stable over the time.

As painting material nowadays only eggs of free-running, if possible ecological bread chicken can be used as the 'normal' eggs contain too little sticky compounds and are not suited as binding medium anymore. The eggs should be as fresh as possible.

Egg white produces translucent paint layers. Opacity can only reached with at least three applications. If not diluted, the layer is very brittle and tends to flake off after drying. The addition of alum can reduce the water-solubility. Layers with egg white and alum were matt and had very well visible impasto from the brush marks.

Egg yolk gave glossy, very stable layers, but the higher amount of oil had a negative effect on azurite which appeared dark and dull. Furthermore, azurite in egg yolk or egg white + yolk has to be used immediately as the prepared mixture thickens to a high viscous 'cream' which cannot be used anymore after 24 hours.

Egg white + yolk gave satisfying results when binding medium and pigments were mixed and prepared on a grinding slab. The water insolubility is reached only after some days, so

application of a second layer has to be performed with care. Very fine lines can be drawn without problems, but a thicker application with visible brush marks cannot be reached.
Mixtures of egg with *oily media* were rather dark and dried slowly.
A mixture of egg and *casein* gave good results because different from only egg the layers had an impasto. Also fine lines can be drawn which were slightly raised, a property visible on the originals.
The properties of mixtures of egg and *skin glue* depend very much on the rations. It is also important if egg yolk or yolk and white are used. Mixtures with more than 50 % off egg yolk were too transparent, too slow-drying and rather dark, because the fatty compounds were too high. Mixtures with egg yolk and white were suited better.
In the end, a mixture of egg (yolk and white) and skin glue was used.

3. Choice of warriors and colour scheme

For the replicas only the type of warrior could be chosen, but not the individual sculpture. There is only one mould for a kneeling archer and one for a general in Lintong, so there was no choice about the sculptures at all. What could be chosen was the colour scheme used for painting. The first idea was that the replicas should be reconstructions of the individual sculptures used for the cast. For the general this was possible, but not for the kneeling archer.

3.1 Kneeling archer

The gypsum cast of the kneeling archer (fig. 2) was prepared by the museum of the terracotta army. The mould is taken from a sculpture excavated in the 1970's. Neither position nor number could be found, but the sculpture is depicted in illustrated books[10] on the terracotta army (fig. 3). In 2005, the sculpture could not be seen in the museum, maybe it is on display elsewhere. Comparisons with other pictures of the same book proofed that the head actually belongs to another sculpture which was also not accessible in the museum (fig. 4).
There was no information about the polychromy of this warrior(s) at all. Therefore the colour scheme of one of the 11 documented kneeling archers should be executed instead. Finally, kneeling archer no. 002812 was selected (fig. 5 and 6). The choice depended on several reasons:
1. Almost all areas could be reconstructed without doubt. Only the colour of the lower part of the shin protection was not clear and the details of the face had to be reconstructed.
2. The colour combinations were vivid and bright and therefore a representative example of well-balanced colour concept.
3. The main colours, especially the ones of the jacket, were different from the ones of the general. This was important for the exhibition to avoid the impression that there might have been some kind of uniform.
4. The original sculpture was not planned for the exhibition in Bonn. This was important because the polychromy belonging to a sculpture in the exhibition, but painted on another figure would have been confusing.
On the lower part of the shin protection yellowish white and light greenish paint fragments were found next to blue ones. Maybe the different colours can be explained by a change of concept, but a structure cannot be recognised. On the replica a greenish light ochre tone was used which can be found on other sculptures as well, but white and blue could also have been imaginable solutions.

[10] Photographs taken from 秦始皇兵马俑博物馆 Qin Shihuang bingmayong bowuguan (ed.), *秦始皇兵马俑博物馆 Qin Shihuang bingmayong bowuguan [The museum of the terracotta army of Qin Shihuang]*, Beijing 1999, p. 103 and 107.

Fig. 3. Sculpture of a kneeling archer (without no.), model of the body of the replica [秦始皇兵马俑博物馆 (ed.), *秦始皇兵马俑博物馆*, Beijing 1999, p. 107]

Fig. 4. Kneeling archer (without number), model for the head of the replica [秦始皇兵马俑博物馆 (ed.), *秦始皇兵马俑博物馆*, Beijing 1999, p. 103]

Fig. 2. Gypsum replica for reconstructing the polychromy (after reworking the surfaces), Lintong, Oct. 2005

Fig. 5. Sculpture 002812

Fig. 6. Colour drawing of reconstructed polychromy of sculpture 002812

Fig. 2-6. Kneeling archer. From sculpture to colour scheme for reconstruction

3.2 General

The model of the replica is general T20G10:97 from pit no.1 (fig. 7). He was standing on the second chariot in corridor 10 and he is the first general in this corridor as the chariot in front is commanded by an officer. The sculpture is on exhibition in a showcase in pit no. 2. For the reworking of the gypsum cast as well as for colour documentation the sculpture could be examined. There are only tiny remnants of paint layers retained on the sculpture. Some more information can be found in the excavation report[11]. All available information is compiled in table 4. This information was combined and transferred in a colour drawing (fig. 8).

part of sculpture	*observation on the sculpture*	*table of colours, excavation report*	*drawings, excavation report*
face	light, pale pink		
jacket	purple	light purple	
sleeve cuffs		bright red	
'closing' or 'connecting' device (armour fastener ?)		bright red	
v-shaped stitches on armour		light green	
ties on armour	tiny remnants of white		light green with pink and white stripe
'border' (of armour ? or jacket ?)		light purple	
border of armour			rhomb grid pattern: ground colour: light purple
ornaments on border			rhomb grid and dark elements: dark violet/black four rhomb filling: black, yellow, red and white broken lozenge and 'frog' fillings: red dark violet, white, pink
chest part of armour			'sun and bird' pattern: sun: light green, 'pincers': chest nut brown
separation line between patterns			existing
inner jacket, lining	white		
upper part of shin protection	light, maybe blue (?)		
trimmings of shoes	had been painted		

Table 4. Information on the colours of general T20G10:97

Completion of missing parts

The drawing shows that for larger parts there is no information. Because on a sculpture, different than in a drawing, it is impossible to leave parts blank, a model for the completion was developed. This means that the final version is only *one* possibility how the general might have looked like. As far as possible, solutions were developed using information from other generals, especially T22G9:1 from pit no. 1, where a lot of polychromy is preserved in the soil and T2G2:97 which is a general in equivalent position. For larger areas, the completion

[11] 陕西省考古研究所，始皇陵秦俑坑考古发掘队 Shaanxi sheng kaogu yanjiusuo/Shihuangling Qin yong keng kaogu fajuedui (ed.), *秦始皇陵兵马俑坑。 一号坑发掘报告 1974-1984. Qin shihuangling bingmayong keng. Yihao fajuedui 1974-1984.* Beijing 1988, Tables: vol. 1, p. 427. Drawings: vol. 1, p. 137 left upper part and below, p. 138.

Fig. 7

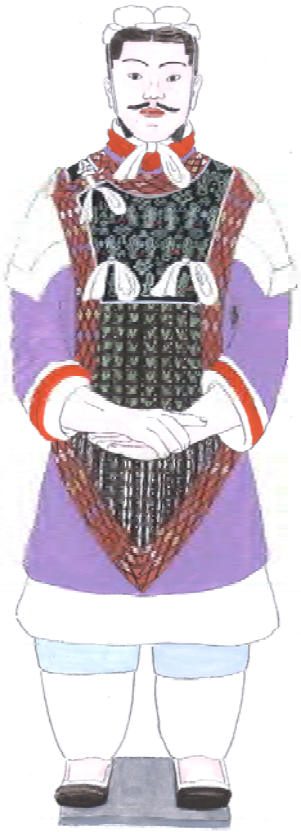


Fig. 8

Fig. 9

Fig. 7. Sculpture of general T20G10:97 [秦始皇兵马俑博物馆 (ed.), *秦始皇兵马俑博物馆*, Beijing 1999, p. 74, fig. 83]

Fig. 8. Colour documentation based on preserved fragments of polychromy on the sculpture and descriptions

Fig. 9. Replica after reworking and fillings, Oct. 2005 [Wang Liang, Museum of the Terracotta Army]

Fig. 10

Fig. 11

Fig. 10. Completion of polychromy, step 1

Fig. 11. Completion of polychromy, final version (without trimming of shoes and tie of cap)

Fig. 7-11. General. Colour scheme of general T20G10:97 and steps of completion

was developed step by step during the painting process. For jacket, shin protections and tie different solutions were tested with paper models before the decision was made.

Shoulder protections

Fig. 13. Colour reconstruction of the shoulder protection [Annual report 2005, p. 50, fig. 82]

There is very little information on the decoration of the shoulder protections. It is not clear if they are part of the armour or separated parts. The reconstruction by the Chinese archaeologists based on a drawing of general T4:1 from pit no. 2 shows a blue flower-like pattern on yellow ground on the smooth parts and rhomb design in red on white on the border (fig. 13). As it is not clear what this reconstruction is really based on and there are definitely misinterpretations in other areas, this solution was not transferred to the replica. There are traces of black on the shoulder parts of T2G2:97, the equivalent of T20G10:97, maybe with traces of a light coloured pattern which cannot be reconstructed.
On the replica the possibility is realised that the shoulder protections are part of the armour and therefore have the same ground colours. A pattern was not reconstructed as the design was too unclear.

Collar and sleeve cuffs

The tables in the excavation report only names ‘bright red’ for the sleeve cuffs. As the sleeve cuffs normally have at least two colours, one for the outside and one for the lining, it was assumed that red meant the colour of the outside. The same colour normally appears on the collar. As colour of the lining the same colour as on T22G9:1 was chosen although the colour combinations are different there (green jacket, blue sleeve cuff).

Border on hem of outer jacket

T22G9:1 shows that the jacket has a decorated border while sleeve cuffs and collar belong to an undergarment. This border on T22G9:1 is black with a red design. The neckline is not preserved here, but there is no pattern not on the lower part of the jacket. The pattern was taken from the chariot general of bronze chariot no. 1 who wears the same type of jacket (fig. 14). Also the type of jacket was copied what means that the border is running around sleeves and neckline, but stops at the waist. The height of the border was taken from T22G9:1. The pattern was sketched out on paper (fig. 15).

Fig. 14. General from bronze chariot no. 1 [Sketch after 秦始皇陵兵马俑博物馆，陕西省考古研究所(ed.), *秦始皇陵铜车马。发掘报告 QinShihuangling tongchema. Fajuebaogao*, Beijing 1998, vol. 1, p. 58]

Fig. 15. Sketch for the border of the jacket (original 2.2 cm in height)

Lining of outer jacket
For the lining of the outer jacket, visible on the underside at the lower end of the jacket, red was chosen. Red can be found on T22G9:1, but T2G2:97 the lining is pink, T9:1 the jacket is green on the outside and inside. Every colour is imaginable on this position.

Inner jacket
On the inner jacket there is no colour preserved except for white or link pink for the lining. Based on the present knowledge, every colour was possible here. The decision for green is based on the observation that purple parts are often combined with green or blue. Blue was abolished because the introduction of another strong colour in this place gave a very gaud, somehow unbalanced impression. Green appears as repetition of the green in the ties.

Border on hem of inner jacket
The idea to decorate the hem of the inner jacket with a border was transferred from T2G2:97. This general outer has a violet outer jacket. The inner jacket is of unknown colour, but a 2.2 cm wide, light pink border is preserved as well as the white lining. In the reconstruction white was chosen for the border and light pink for the lining. A pattern was applied to the border as equivalent to the border on the outer jacket. The pattern was designed in resemblance to textiles from Mawangdui and patterns found on the bronze chariots (fig. 16). The pattern was sketched on paper (fig. 17). Its execution was one of the very last steps of the painting process.

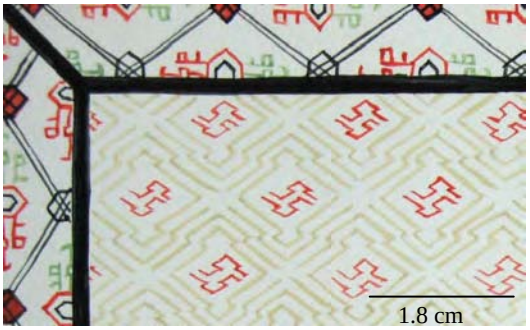


Fig. 16. Quiver box, outside, pattern in ochre and red on white ground. Colour sketch of pattern

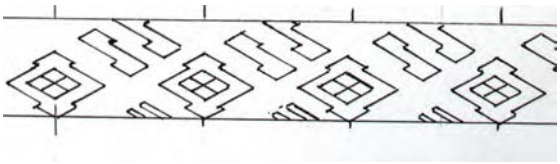


Fig. 17. Drawing for pattern of border

Shin protections
There was no evidence for the colour of the lower part of the shin protections. Green is a colour used very frequently on clothes and on shin protections. After painting the lower part green, the upper part was repainted in a darker blue than originally planned to balance colours again.

Border of shoes
There is hardly any information on the colours for the borders of shoes. On T2G2:97 and T9:1 a rather light colour, maybe pink or white, have been used. On the replica a darker pink was used to achieve a contrast to the skin colour of the feet right next to the border. It is also not known if these borders might have been decorated as well. As the borders probably were applied strips of textile it seems imaginable that they had pattern, but no information exists on this. Therefore the border remained unichrome without decoration.


Fig. 18. Inner jacket with decorated border, back of general

Details of the decorations of the armour

Fig. 19. Details of armour: rhomb grid on border; connection stitches; ties and ‘bird and sun’ pattern

The decoration of the armour was mainly clear from the given information. The interpretation of the bird and sun patterns as green ornaments with light ochre outlines follows the design on T22G9:1. The reddish brown ‘pincer’ ornaments (fig. 19: 1) are oriented on the ‘chest nut red’ of the drawing.

The addition of small red lines on the light ochre stripes of the green ties is also in accordance with T22G9:1. A complete pattern cannot be reconstructed there, but fine red and some blue lines can be distinguished. The scattered red lines (fig. 19: 2) in the reconstruction are supposed to indicate a pattern without being too definite.

The insertion of purple broken lozenges (fig. 19:3) in the rhomb grid pattern was oriented on the colour annotations of ‘dark violet’ in the drawings of the excavation report, and on fragment B-0101 of T9:1 which clearly has purple bro ken lozenges. ‘Dark violet’ is a mis-interpretation of black, but the colours were not changed anymore when this became clear.

The colours of separation line between the patterns (fig. 19: 4), blue on white, were also copied from B-0101.

The colours and design of connection stitches (fig. 19: 5), light purple with ochre and red for the long ones and bright red for the small ones, was copied from T22G9:1. The table in the excavation report mentions green for the v-shaped stitches. This information was not used, because there was no information on the other colours. Therefore on the replica the v-shaped stitches might have the ‘wrong’ colour (purple instead of green), but the system of colours on the armour plate is one that is really existing.

Armour fastener

The tables in the excavation report mention a red part which might be the armour fastener, but the word is not clear. Red armour fasteners can be found on many infantrymen. On the generals, no f paint layers have survived from these parts. From the modelling it is not clear if the armour fastener with the tie hanging down from it is made of two parts or of one string that ends in a tie. On the replica the second possibility was chosen and the information in the excavation report was ignored. Colours and design are copied from the ties on the armour.

Tie of cap

The tie of the cap was the last area to be painted on the replica. The only information on this part is that is had been painted, but nothing is known about possible colours, relations to the ties on the armour and decorations with patterns. As the tie for the cap consist of two parts (one running around the forehead and ending in the tie; the second one connected to that and

is running around the back of the head), it even can have been painted in two colours. A decoration with patterns seems possible as the other ties are decorated as well. On the other hand, no patterns could be detected on the cap ties of the generals of the bronze chariots. The choice of purple is deliberate and was taken because it gave a rather well-balanced impression, but any other solution is as possible as the chosen one (fig. 20).

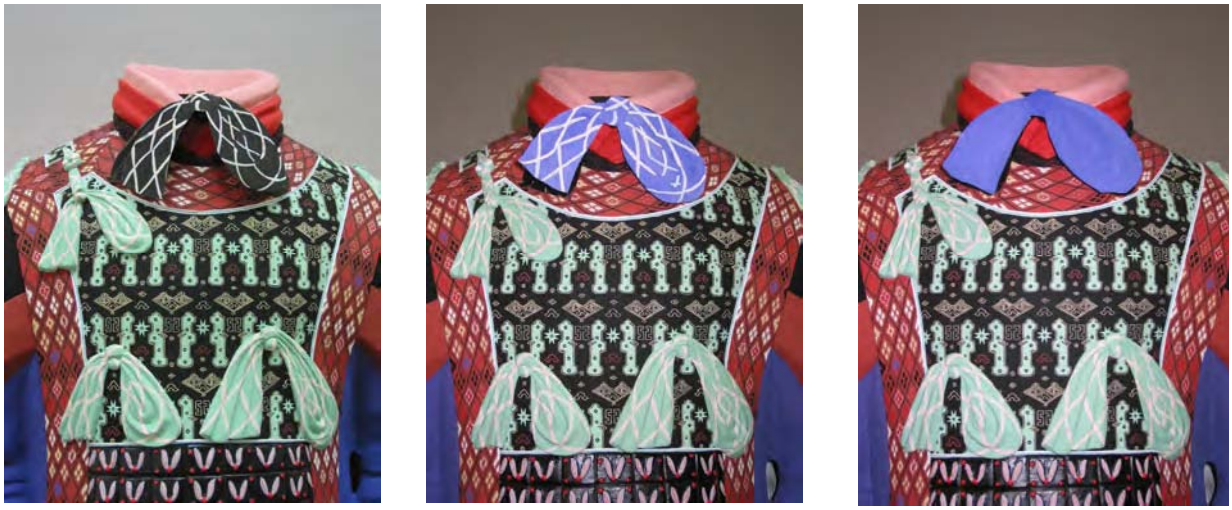


Fig. 20. Painting the cap tie: Tests with different designs painted on paper. The influence on the balance of the polychromy becomes visible. Purple without pattern (to the right) was chosen as definite solution

Carnations

Small light pink areas in the face of the general are the only retained remnants of the flesh tones. Hands and feet do not show any traces of paint layers anymore. The structure and the execution of details as eyes, lips, brows, moustache and fingernails were reconstructed using the information gathered from the examination of a number of different sculptures.

4. Realisation of the polychromy

In a test series pigment mixtures and binding media were tried out and evaluated. Finally, a mixture of egg yolk and white (a whole egg) with skin glue was selected as binding medium. The rabbit skin glue was prepared as 10 % solution and diluted to approximately 7 %. The fresh egg was prepared by removing the yolk bag and filtration through a fine gauze. Egg and skin glue were mixed in the ratio 1:1. The glue has to cool down before mixing and the prepared mixture has to be warmed very carefully to prevent the denaturation and coagulation of the egg.

With this binding medium thick, opaque layers with visible brush marks could be obtained. They are rather matt, but polishing is possible after drying. After 24 hours a second layer could be applied. For the clothes two layers were sufficient, only the purple was applied three times. The flesh tones were painted four times (both tones twice). As on the originals they are thicker than other layers.

4.1. Kneeling archer

The kneeling archer was the first sculpture to be painted. The painting process was started with the armour. The selection of the colours followed the tones given in the gouache colour sketch. The tables in appendix 1 list the pigment mixtures used for each area. For all colours different mixtures were tested. Especially red tones required series of tests (fig. 21).

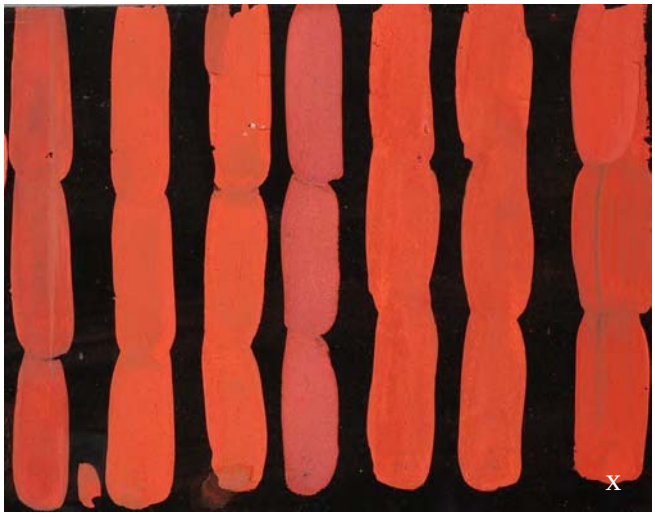


Fig. 21. Tests with different types of cinnabar in several mixtures for the connection straps of the armour of the kneeling archer, here mixtures of *chensha* and *zhusha*.
From left to right (*chensha* : *zhusha*) 2:1, 1:1, 3:1, *chensha*, 8:1, 9:1, 13:1.
13:1 (first on the right, marked with x) was the final mixture.

For the hair pin and the bone 'button' on the armour fastener pure bone ash was used instead of the 'standard' white mixture (bone ash-lead white 1:1).

For the collar and the sleeve cuffs, the light blue 'Blue Bice' was used in combination with ochre. The thin whitish layer on top, maybe a glaze, visible on the originals was not executed. Test showed that the blue has to be applied after the ochre to reach a smooth transition from ochre to blue. The other was round this was not possible due to the coarse particles of the Blue Bice, although the pigments was prepared on the grinding slab (fig. 22).

Fig. 22. Collar of kneeling archer: Ochre on blue (left) with hard, streaky transition and blue on ochre (right) with smooth transition of colours.

Completions

The red line at the hem of the jacket is a completion. Because of the tiny fragments preserved, details like this could not be defined. The hem of a jacket can have a colour accent as visible on T21G18:07. On most kneeling archers there no coloured border line could be found, if it was not there or if it is lost, is not clear.
The lining of the jacket is almost not visible on the model warrior 002812 und probably was not painted at all. Because it is visible on the replica, a colour was chosen for this area. Pink was chosen in resemblance to the warrior T21G18:SH001 which has a similar colour distribution: a brownish pink jacket (lighter than on 002812) and pink trousers. For the lining on the replica a darker pink than the trousers was chosen.

4.2 General

The general was painted after the polychromy of the kneeling archer was finished except for the flesh tones. The painting process was started with the chest part and the borders of the armour. The clothes were painted afterwards.

Chest part of armour – 'bird and sun' pattern
The black was painted with vertical brush strokes to reduce the amount of beginnings or short strokes. The pattern was transferred with a grid. This grid was drawn on a paper which was adjusted to the curvature of the body, like a pattern for sewing (fig. 23). The lines were perforated with a fine needle and green earth was dusted through the holes. With a smaller perforated pattern the ornaments could be transferred into the grid. The dots of green earth could be dusted off after painting.
Fig. 24 shows the steps from transfer to the finished pattern.

Fig. 23. General with paper pattern to transfer the construction grid on the chest part of armour

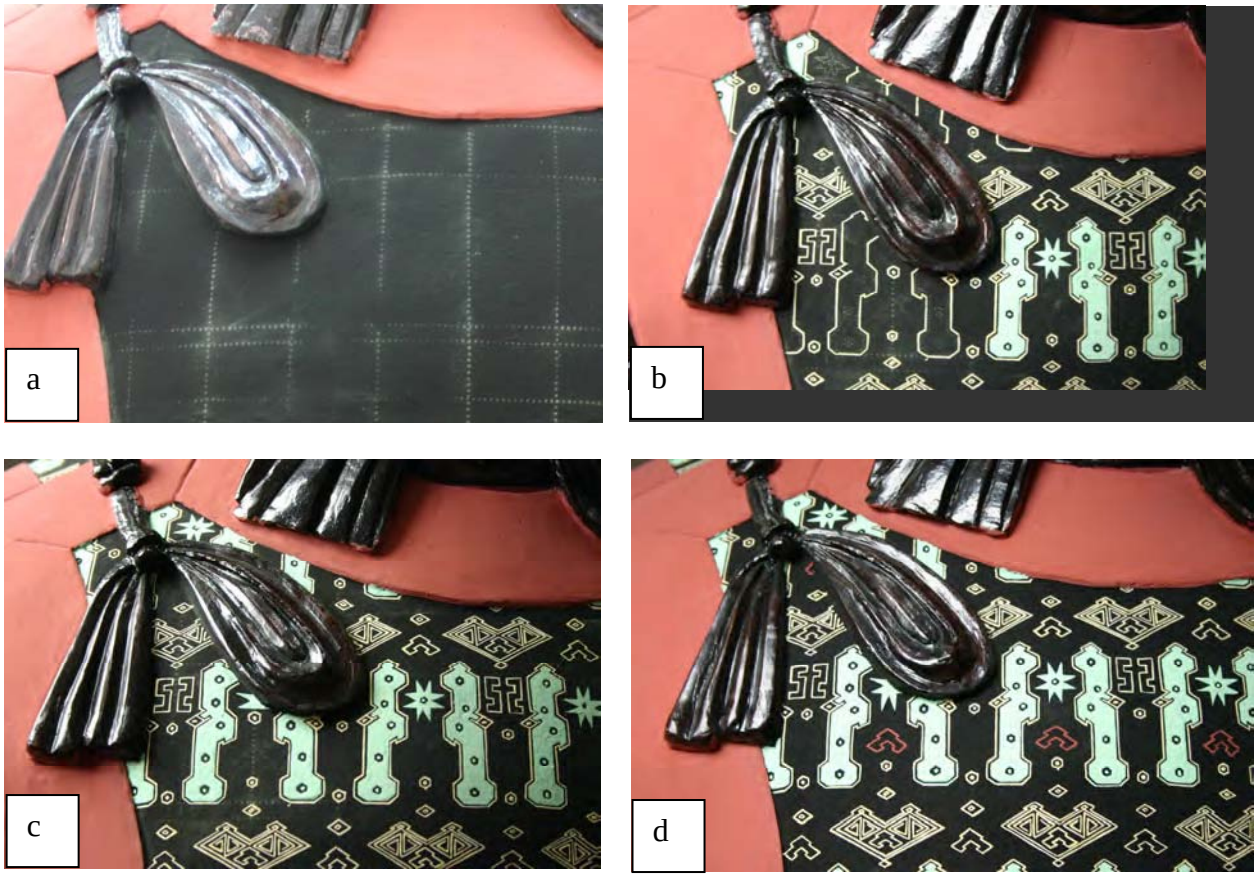


Fig. 24. Painting the 'bird and sun' pattern on the chest part of the armour.
a Transfer of subsidiary grid; b. Painting the outlines (ochre) and filling the ornaments (green)
c. Ochre and green finished; d. Finished pattern after insertion of reddish brown ornaments and removal of grid

Border of armour with rhomb grid

The colour tone of the reddish brown ground oriented on the colours documented for the fragment B-0101. There are no pigment analyses from this border part, but analyses of similar colours identified a mixture of cinnabar and red iron oxide. As mixtures of cinnabar and hematite turned out to be too brownish, mixtures of synthetic vermilion (*zhusha*) and an artificially produced iron oxide red, Eisenoxidrot 48150, were tested in 16 different ratios (fig. 25). Six mixtures were chosen as suited (marked grey in table of fig. 25).

In the final mixture, a ratio of 4:9 to 4:10 was used. Remnants of colour pf the reddish brown border (on T9:1) as well as areas with a similar colour (zigzag band in ornament of border of chariot officer, fragment B-0114) appear purplish in parts. This seemed to indicate that Chinese purple might have been added to the reddish brown.[12] Test showed that an addition of Chinese purple (about 20 %) gave exactly the right nuance of purplish and whitish that also can be observed on the originals.

Another problem occurred with the choice of the pigment for the red ornaments in the rhomb grid pattern. All types of cinnabar seemed more brownish and less bright than the one on the original. Furthermore, the contrast to the reddish brown tended to be so low that the red was almost invisible on the brownish red. Test with different mixtures of cinnabar in the egg/glue medium did not give satisfying results. Therefore also other media were tested (fig. 26). Casein gave brighter tones, but tended to develop cracks. Cadmium orange is more bright than cinnabar, but too lurid. In the end, the best result was obtained using the cinnabar bought at ‘Kremer’ in 1988, bound in rabbit skin glue (approximately 7 %). Paint bound in glue tended produce slight water marks around the margins if applied on the reddish brown ground. This drawback was accepted because the overall impression was fitting.

	no.	iron oxide red (Eisenoxidrot Kremer Nr. 48150)	vermilion (*zhusha* from Beijing)
red / light colour	1	1	4
	2	4	15
	3	2	7
	4	4	13
	5	1	3
	6	4	11
	7	2	5
	8	4	9
	9	1	2
	10	4	7
	11	2	3
	12	4	5
	13	1	1
	14	4	3
	15	2	1
brownish / dark	16	4	1

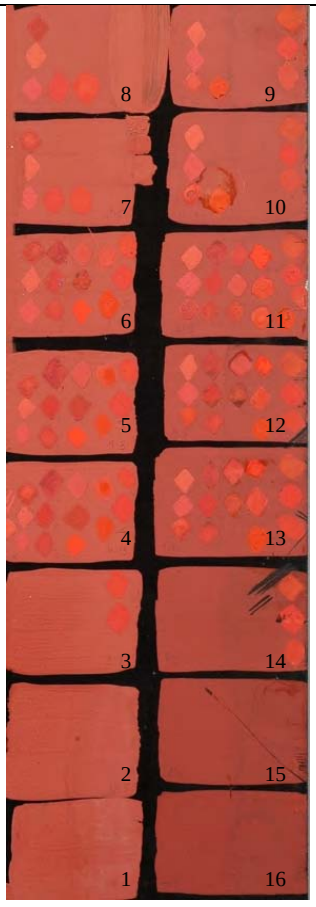
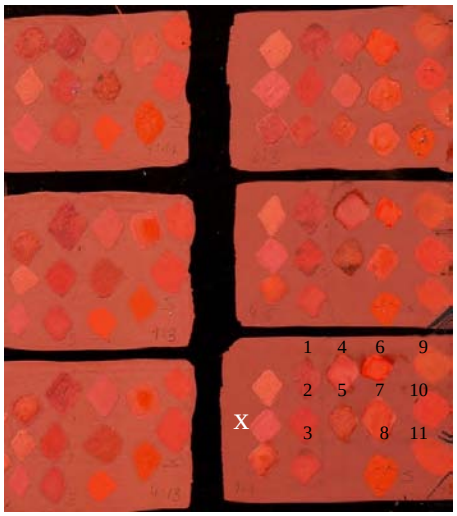


Fig. 25. Tests mixtures for ground of rhomb grid. Suited mixtures are marked grey.

[12] The rather dark brown tone observed on fragment B-0101 might also result of discoloration caused by consolidants which made the lighter, more purplish tone appear rather dark and brownish.

Fig. 26.
Tests for red rhombi on reddish brown. Tests on reddish brown test areas no. 4-6 and 11 to 13.
Tested mixtures:

1 *chensha* in egg/glue: too dark and too coarse
2 egg/glue: still too dark and too coarse
3 egg/glue: fine, but too 'cool' (bluish) in colour
4 egg/glue: very fine, light
5 round box from China: too dark and too coarse[13]
6 cadmium orange in egg/glue: too bright
7 *zhusha* + vermilion Kremer no. 42000in egg/glue
8 *zhusha* in casein
9 *zusha* in casein
10 cinnabar Kremer in casein: bright, light and 'cool' colour
11 *zhusha* + vermilion Kremer no. 42000 in casein
x Kremer cinnabar from 1988 in skin glue



Execution of the rhomb grid pattern

The rhomb grid was constructed following the one on B-0101 (General T9:1) from pit no. 2 and general T22G9:1 from pit no. 1: On the width of the border of 5 cm three rhombi are arranged on top of each other. Slight displacements are caused by the curving of the border, so that the length of rhombi varies between 30 and 35 mm. The construction on the replica is based the on the 'ideal' measures of 16 mm in height, 34 mm in width and angles of 50 or 130°. The construction of the rhomb grid was performed according to the system described in the Annual report t 2005.[14] A paper strip of 17 mm width served as positioning device for marking the starting point along the edges. Additionally the centre was marked (fig. 27). As the width of the border varies slightly, the heights of the rhombi had to be adjusted.

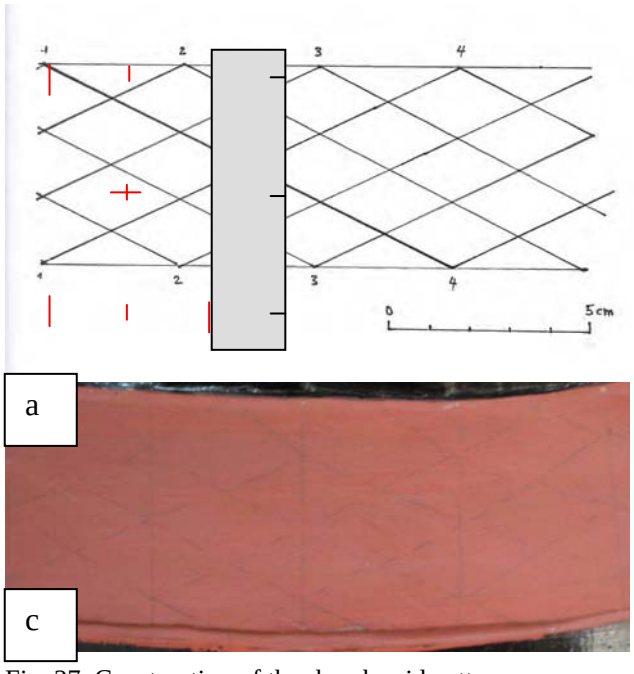


Fig. 27. Construction of the rhomb grid pattern:
a. Construction system using paper strip (grey) with marks to define starting and crosspoints of lines.
b. Application on the sculpture
c. Border with subsidiary partition grid and rhomb grid lines in pencil.

[13] Cinnabar bought in China, purchased in Shanghai (上海蓝珀文化用品有限公司)
[14] The polychromy of clothing and armours of the generals from the terracotta army, p. 30/31.

The rhomb grid then was executed in black colour (fig. 28a), followed by tracing the black outlines (fig. 28b), inserting the four lozenges and the other ornaments (28c). The pencil lines could be removed with an eraser after the black lines had been applied.

Fig. 28. Painting the rhomb grid pattern
a. Black rhomb grid; b. Black contour lines; c. Four lozenge fillings complete and geometrical fillings started; d. Pattern finished
[C.Roth]

Clothes
The colours of the clothes were mixed and tested before application. Pigment analyses of purple paint layers seems to indicate that, although there are different nuances of purple, differing from bluish to pinkish purple in all mixtures cinnabar seems to be present. The comparison with documented colours also made clear that an addition of cinnabar was needed. The mixture of 70:1 also showed how little cinnabar is necessary to obtain a reddish tinge of the purple colour.

4.3 Flesh tones

There is very little of the flesh tones on the two original sculptures left. The general appears to have a pale, only slightly pink face. The face of the kneeling archer shows two layers of light pink. All the details and the surface structure are lost.[15]
The reconstruction is showing the principle of the flesh tones not the individual solutions of these two sculptures. The reconstructions are based on observations on 60 samples of flesh tones from faces, hands and feet. There are one-layered, double-layered and also three-layered structures. One-layered flesh tones are mostly very light tone, sometimes appearing white. Two-layered tones are mostly built up light on dark, more seldom also the other way round or of two layers of identical colour. Three-layered structures are still not really

[15] On the original archer, the face has a double layer, the colours seem identical. The eyes are not retained, nor are the eyebrows, moustache or fingernails. The white of the eye does not show a difference from the colour of the face, as it can be observed sometimes if the skin tone is very light, but the tiny remnants of paint are not sufficient for a complete reconstruction. The hands seem to have the same colour as the face, on the fingernails there is no paint anymore; the colour of the feet is not retained.

understood yet, but are interpreted as a double layer on an abolished one layer system so far. The second application (i.e. the overpainting) in all cases appears to be built up light on dark.

Hands, feet and faces often do not have the same colour and there seem to be all kinds of combinations of lighter or darker hands and feet combined different coloured faces. Also the number of layers does not have to be the same on the parts of flesh tone. It looks as if hands, feet and faces are painted separately from each other. An explanation for this practise is still missing.

One the replicas one possibility of flesh tones was realised, trying to use a 'logic' appearing structure. All parts have a double layer with a lighter tone on top of darker one. Each tone was applied twice, so altogether there are four layers. Compared to the originals, the flesh tones are still rather thin, but the layers are thicker than the one of the clothes.

Fig. 29. Painting the heads of the replica; application of first layer

The layers were applied following the features of the faces and the longitudinal alignment of hands and feet. This procedure can be observed on sculptures or fragments with preserved polychromy as well. A surprising effect became visible during the painting process: the second, lighter tone tends to cover the first one incompletely in the deeper recessions of the modelled surface. The darker pink remaining visible there serves as natural appearing modelling of the skin.

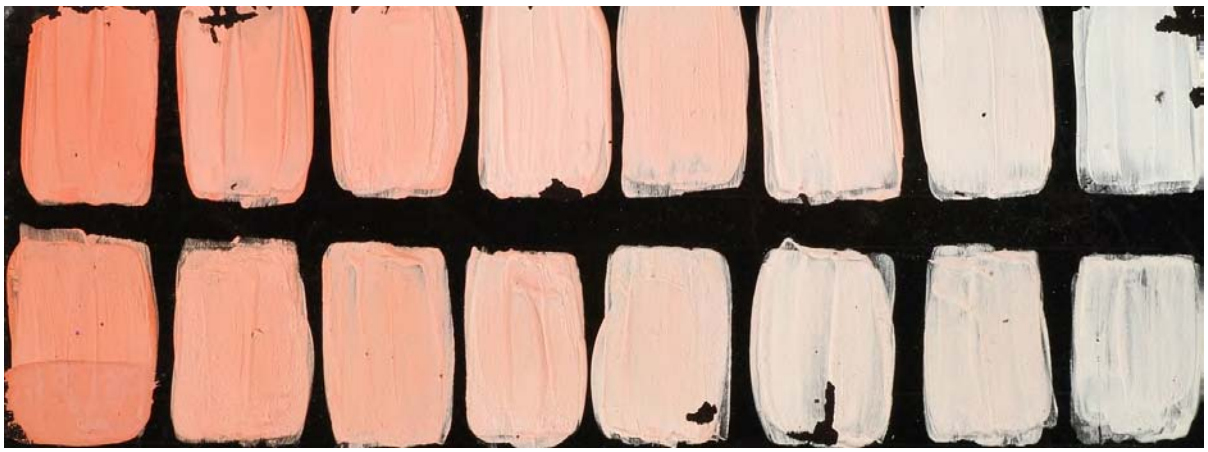


Fig. 30. Sequence of mixtures for flesh tones with *zhusha* and two different mixtures of white: top row: lead white /bone ash 1:1; lower row: bone ash

Eight mixtures of pink, containing *zhusha* and white in different ratios were tested (fig. 30). *Zhusha* was chosen because the pigment analyses revealed the extreme fineness of the cinnabar used in flesh tone (often below 1µm), the Chinese *zhusha* with an average particle size of 2µm was the material closest to the original. As white bone ash/lead white 1:1 (fig. 30, upper row) and bone white only (fig. 30, lower row) were tested. The mixtures containing lead white appear more opaque and whiter. It was finally used for the flesh tones.

Fig. 31. Painting the head of the kneeling archer:
Double layer of darker pink (left), followed by a double layer of lighter pink (right; with eyes already painted and moustache begun)
[C.Roth]

Faces

Both head were painted with a double layer of the darker pink, followed by a double layer of lighter pink (fig. 31). The kneeling archer is slightly paler than the general, a deliberate decision to demonstrate the different nuances of flesh tones found on original sculptures.

In the eyes the second layer of pink omitted. The white of the eyes, painted in white, is applied directly on the darker pink. The dark pink visible on the inner side of the eye lid around the borders of the white appears as natural shades of the eye. A black contour line indicating the eye lashes was not painted because no evidence for such a line as ever been found so far. The shadow below the sculpted eye lid together with the darker pink appears as dark line.

The iris was painted dark brown; the eyes of the kneeling archer are darker as the ones of the general. The pupil was omitted so the glossy black lacquer is visible. This version is supported by findings of some of the original sculptures and results in a surprisingly vivid expression (fig. 32). Other sculptures clearly show another version with the pupil applied with black. This possibility was not realised on the replicas.

Hair line, moustache and eyebrows were applied with single, fine lines in black (fig. 32, 37, 38). The hair line is painted on the temples and the back of the neck (fig. 37). This system was observed on sculptures with preserved polychromy. While the structure of the moustache could clearly be reconstructed from pictures of the originals, the - mostly heavily damaged - eyebrows could not be reconstructed completely from preserved originals. Size and shape of the brow as well as the direction and length of the hairs were designed using photographs of the Chinese colleagues.

Fig. 32. Right eye of the general [C.Roth]

The lips are painted in a pink with a higher amount of red than the colour of the faces. The layer is very thin. An application of a glaze like thin layer seems to have been used also on the originally sculptures and might explain why the lips' colour is missing on some of the preserved faces today. Also the greyish 'shadow' remaining of moustaches might be due to the very thin application: With the loss of the topmost surface layer, moustache and red of the lips must have got lost.

Hands and feet

Hands and feet have the same colour. The colour of the top layer is slightly lighter than faces, a combination often found on original warriors and also fitting to the real situation. Like on the faces the darker layer remained slightly visible in recessions of the modelling. Fingernails are applied in white on top of the second pink layer (fig. 34).

Fig. 33. Left foot of kneeling archer [C.Roth]

Fig. 34. Hands of kneeling archer [C.Roth]

4.4 Tools

Pigments and binding medium were mixed on the grinding slab into a homogenous paint. The coarse Chinese Purple had to be prepared by grinding the pigment on the marble grinding slab first. Deep scratches in the glass slab and the plane of the glass muller give evidence of the hardness of the pigment. The prepared paint was kept warm by placing the glass with the paint into warm water.

Fig. 35. Paint brushes used for painting the replica. The large ones on the left were used for the jackets.

As paint brushes those with rather long hair from China turned out to be the most suited ones (fig. 35, 36). For the application of the coarser pigments as the Chinese Purple and the Blue Bice only these Chinese paint brushes were suited to obtain a smooth, homogenously spread application.


Fig. 36. Painting with Chinese paint brushes

Fig. 38. Head of kneeling archer

Fig. 37. Head of general

4.5 Consumption of pigments

The reconstruction also gave the possibility to estimate the amount of pigments used for painting the sculptures. Especially for the heavy and expensive pigments this was of interest. Synthetically produced vermilion costs about 200 Euro per kg in Germany[16], mineral cinnabar of good quality between 1780 and 2436 Euro. Good qualities of azurite are about the same prize range, malachite is about 870 Euro per kg. Prices in China were about one tenth of the German prices, but considering the difference of the monetary value this is very expensive in China as well (almost the same in Germany).
Cinnabar and also azurite and malachite have always been expensive painting materials, also in the Chinese antiquity. The consumption for painting all burial goods of Qin Shihuang therefore were also a matter of money.

Painting tested gave the possibility to estimate the consumption of material. The base of the estimation was a paint layer of considerable thickness, obtained by two applications using the mixture of egg and skin glue as binding medium. These tests showed the following results:

material	*average consumption*
chensha	1 g per 20 cm^2or 500 g per m^2
zhusha	ca. 1 g for 25 cm^2 or 400 g per m^2 flesh tones of each warrior: 25-50 g
malachite, *shilü* no. 2 and no. 4 (1:1)	1g for 26 cm^2 or 385g per m^2

For the calculation is larger scale, only rough estimations are possible so far with a large spread, but they might point in the right direction. The calculation is based on the knowledge that a whole warrior has a surface of 4-6 m^2. The jacket and the shin protection of the replica of the kneeling archer were measured and calculated to have a surface of about 1.02 m^2 (shin protections about 0.30 m^2, jacket about 0.72 m^2). For the general the surfaces of the larger parts were only roughly estimated: lower part of shin protections 0.25 m^2, upper part of shin protection 0.10 m^2, inner jacket 0.18 m^2, outer jacket 0.70-0.80 m^2, sleeves and collar outside 0.48 m^2 each.
A green jacket thus would consume about 300g of malachite, a red jacket 300 to 375 g cinnabar. Additionally 25-50 g cinnabar are needed for the flesh tones and probably the same amount for smaller parts as armour straps (20 cm^2 on the kneeling archer) or hair ribbons etc. Though colour distributions are not clear yet, a preliminary rough calculation could be the following:
With 7000 soldiers and every third having would have as much green as a jacket, 700 kg of malachite would be necessary.
With 7300 sculptures and every sculpture requiring 50-100 g of cinnabar for flesh tones and details, 365-700g of cinnabar are needed.
As almost every sculpture has pink, reddish brown or red parts and if it is estimated that these require the same amounts of cinnabar, another 365-700 g of cinnabar are needed.
Completely red parts as sleeve cuffs or jackets are not included in this calculation yet. If every 10^{th} sculpture has as much red as a jacket, another 220 to 270 kg of cinnabar would be necessary.
This at altogether adds up to 920 to 1670 kg of cinnabar. Additionally also the shafts of weapons and other equipment is partly painted red. It seems realistic to calculate that between 1000 and 2000 kg of cinnabar were necessary to paint the terracotta army and the sculptures from other burial pits.

[16] Prices for pigments, including VAT (value added taxes of 16 %): catalogue of 'Kremer pigments' 2006.

Painting process

Fig. 38 a-d. Carolin Roth painting the replicas, February/March 2006

30. 01. 2006

16. 02. 2006, morning

16. 02. 2006, evening

02. 03. 2006

15. 03. 2006

06. 04. 2006

Fig. 39. Painting the kneeling archer

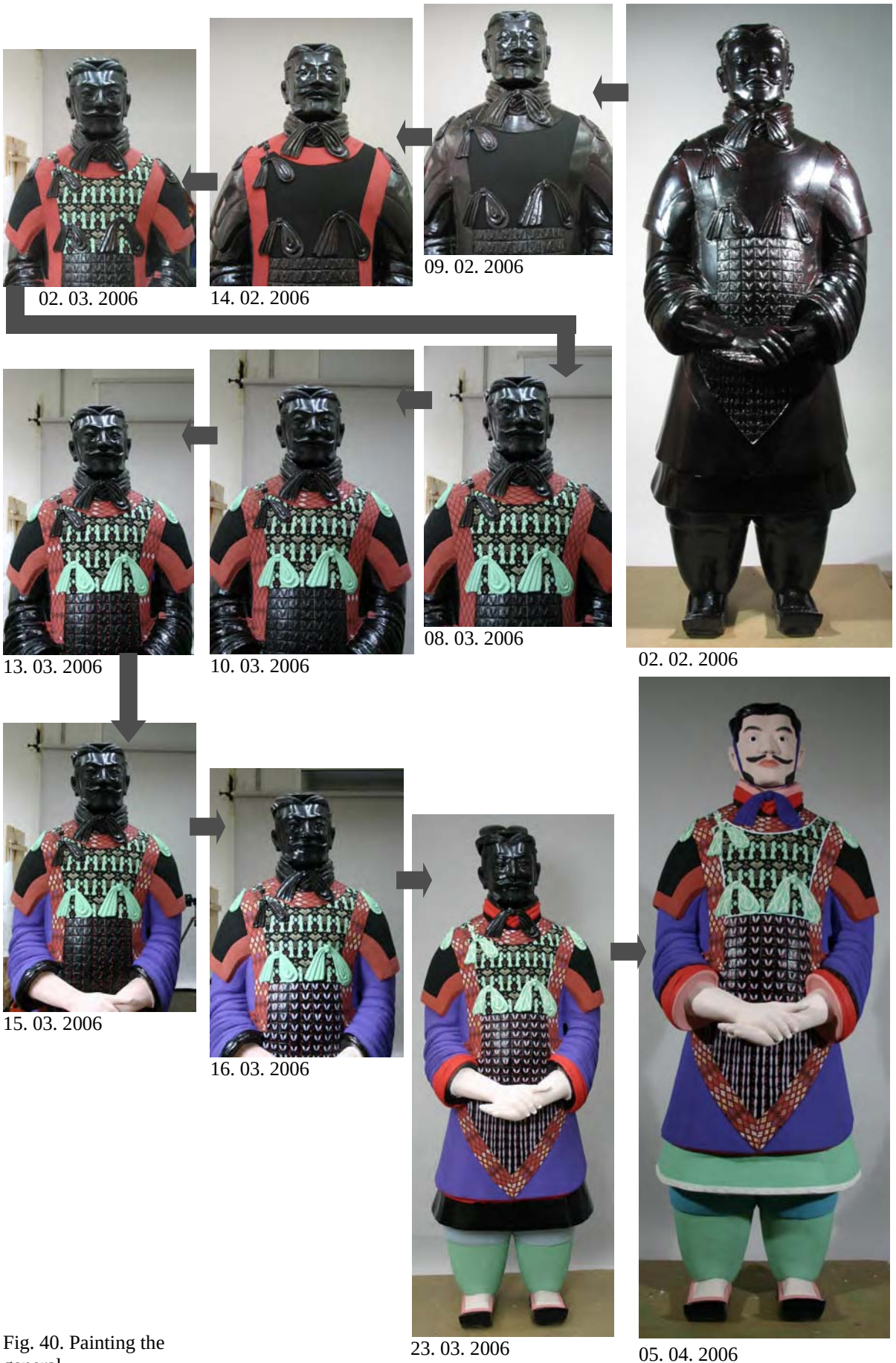


Fig. 40. Painting the general

5. Replicas on exhibition

Art and Exhibition Hall Bonn: 'Xi'an – Kaiserliche Macht im Jenseits',
21. 4. – 23. 7. 2006

The replicas were planned to the presented in the exhibition 'Xi'an – Kaiserliche Macht im Jenseits', Art and Exhibition Hall of the Federal Republic of Germany (KAH) in Bonn. There they belonged to the part showing the research work of the project and the results of technological investigations and conservation.
On April 4th painting was finished. On April 6th, the replicas were packed and transported to Bonn (fig. 41). The replicas were transported in the transport boxes made and used by the Museum of the Terracotta Army in Lintong for sending the replicas to Germany. An additional protection of the surface was necessary now.

Fig. 41. Packing the replicas for transport to Bonn, April 6th, 2006

The Opening ceremony was held on April 20th, followed by a symposium on scientific questions concerning the exhibited objects and the research work ('Under the yellow earth', April 21st to 22nd). The replicas were standing in the lobby in front of the entrance to the exhibition (fig. 42).
The exhibition attracted about 110000 visitors.

Fig. 42. Replicas in the lobby of the Art and Exhibition Hall in Bonn [Kunst- und Ausstellungshalle der Bundesrepublik Deutschland]

Munich: Studio exhibition of 'Wissensspeicher' to the 'Long Night of Museums'
31. 8. – 21. 10. 2006

In August 2006 the congress 'The Object in context: Crossing Conservation Boundaries' organised by the IIC (International Institute for Conservation) took place in Munich. On the occasion of the congress (August 28th to September 1st) a large number of museums in Munich had organised small exhibitions focussing on conservation subjects. As C. Blänsdorf and S. Bucher were accepted as speakers on the congress and Bavarian State Department of Monuments and Sites was offered to present their work in exhibitions in the own house, an exhibition on the 'China Project' was conceived.

Fig. 43. entrance to the exhibition with introduction posters from Bonn exhibition

Fig. 44. Main room with information on conservation and technique, model of pit and replicas

Fig. 45. View into the main room of the exhibition [M. Hundemer, Bavarian State Department of Monuments and Sites]

The exhibition was set up in the room of the department of wall painting restoration, next to the 'Säulenhalle' which is the main exhibition and meeting hall of the department. All aspects of the project were presented with posters. Display cases showed original objects like terracotta fragments, imprints in soil and fragments of stone armour pieces as well as materials, tools and examples of reconstruction of the terracotta sculptures and the stone armour as well as a virtual reconstruction and panorama videos. Additional information was given by introduction panels and the animation film by the TU Darmstadt both prepared for the exhibition in Bonn.
Designed for a short period of only nine days (until the 'Day of the open Door' of historic monuments on September 9th), the exhibition was prolonged due to high interest of the public. Finally, the exhibition could be visited until the 'Lange Nacht der Museen' (Long Night of the Museums) on October 21. During the final event, about 200 people visited the exhibition between 7pm and 2am.

Fig. 46. Replicas in the exhibition in Munich

The exhibition would not have been possible without the support of many people who contributed to the success in many ways:
Bavarian State Department of Historical Monuments, especially Bernhard Symank and Reinhard Zehentner who offered their office as room for the exhibition; Johannes Hallinger, Nina Wiesner for help with moving furniture in and out and announcing the exhibition; Holger Pitzig for organising infrastructure of all kind; Markus Hundemer for posters and photographs; Susanne Scherff for flyers; the team of the Central Laboratory for help setting up and dismantling the exhibition.
Kathrin Adelfinger and Stefan Demeter who helped enormously during the setting up of the exhibition.
The ‘wardens’ during the seven weeks, especially the members of the laboratory and the China project as well the trainees of the restoration workshop, Heidi Weinbeck and Mariya Martsynkovska.
The Art and Exhibition Hall in Bonn, especially Henriette Pleiger, who provided poster panels, labels and supports from the Bonn exhibition.
Prof. Manfred Koob, Technical University Darmstadt who allowed the animation film on the Qin Shihuangling to be shown in the exhibition.

6 Summary

The reconstruction of the polychromy on two replicas of warriors from the terracotta army was performed in three months in the beginning of the year 2006. The replicas were planned to be presented in the exhibition in Bonn as visual impression of how warriors might have looked like originally. They were also a part of detecting and analysing the original painting technique. This text gives a detailed description and documentation of the painting process.

The polychromies are based on the knowledge about the originals. As far as possible the polychromy two individual sculptures was reconstructed. Completions of all parts were made, even if no information was available, at least so far that all areas were covered with paint layer which had been painted on the originals. The contrast and the distribution between lacquered and painted areas therefore are correct.
For the completions other sculptures of the same type were used as models. Some parts nevertheless remained completely without information. Here the decision depended from the esthetical feeling of the authors and can be discussed. With several colour for choice, the least gaudy or lurid version preferred.

As materials pigments and binding media were used which were also available in the Chinese Antiquity. The pigments were known form pigment analyses, but the binding medium could only be chosen after a series of tests trying to match the properties of the original layers. An egg/skin glue mixture was the medium of choice. Egg as binding medium was confirmed by the analyses carried out in Pisa shortly afterwards.[17]

The process of decisions from the choice of a colour scheme, the completion of missing parts to the selection of materials, mixtures and the procedure of painting is described for both sculptures, a general and a kneeling archer. The painting of the sculptures was realised by Carolin Roth.

The painting replicas were presented in the exhibition in Bonn and in a small studio exhibition on the research project in Munich. Momentarily they are packed in the transport boxes again waiting for a new presentation. As the gypsum is rather soft and suffers from every set-up, especially the feet are already quite damaged. Also the paint layers are sensitive and already show traces of touching them and fastening them with straps on wooden constructions as security measurement for transport. The five months of exposition to a normal room situation also showed the problems of dust which is difficult to remove from the rather coarse surfaces as the Chinese Purple, but also from fine-grained ones as the black which tends to get more and glossier with every dusting.
Nevertheless, of course the sculptures are planned to be exhibited again. The decision about place and conditions will be made in spring 2007.

Illustration credits in brackets below the figures; all unmarked pictures by C. Blänsdorf.

[17] See: Ilaria Bonaduce, Maria Perla Colombini, The binding medium of the Terracotta army polychromies, in this volume.

Appendix 1: Pigment mixtures

Kneeling archer

part / area	*mixture of pigments*	*oriented on*
red straps on **armour**	13 parts cinnabar *chensha* (coarse) 1 part cinnabar *zhusha* (fine)	drawing of warrior 002812 cinnabar in soil from F-003/96 red straps on F-004/2000, F-007/99
white stitches on armour	1 part bone ash 1 part lead white	drawing of warrior 002812
white armour fastener with hair pin	bone ash	
pink hair ribbon	*chensha* bone ash	drawing of warrior 002812
reddish brown **jacket** (outside)	2 parts cinnabar *zhusha* 6 parts hematite	drawing of warrior 002812 reddish brown robe on F-003/99, F-005/99, F-007/99
pink jacket lining (inside)	3 parts syn. vermilion (Kremer 42000) 20 parts bone ash	drawing of warrior S001
red border of jacket	synth. vermilion Kremer no. 42000 *zhusha* (fine) as shoe laces	completion following kneeling archer no. T21G18:07
collar and sleeve cuffs: ochre / blue	*ochre* 3 parts French Ochre (HAVANE ORANGE) 1 part greenish yellow iron oxide (No. 48020) *blue* Blue Bice	drawing of warrior 002812 blue and ochre on F-014/98
light pink **trousers**	1 part synth. vermilion (Kremer 42000) 70 parts bone ash	drawing of warrior 002812
shin protection, upper part: green	4 parts malachite *shilü* no. 5 (light) 1 part malachite *shilü* no. 4 (medium) 1 part malachite *shilü* no. 2 (dark)	drawing of warrior 002812 self-made colour-chart (g 1)
shin protection, lower part: light green	12 parts bone ash 10 parts lead white 2 parts malachite *shilü* no. 4 (medium) 6 parts Kreide von Sarti gelbstichig 1 part Rehbraun	drawing of warrior 002812 (colour not definitely clear)
red shoe laces	synth. vermilion Kremer no. 42000 *zhusha* (fine)	drawing of warrior 002812
flesh tone	white with red in varying proportion: *white*: 1 part bone ash 1 part lead white *red*: cinnabar *zhusha*	drawing of warrior 002812, frequent structure on faces and hands feet: completion according to hands
pupil	ivory black cinnabar	completion: one of the frequent colours of pupils
white of eyes finger nails	1 part bone ash 1 part lead white	completion: frequent in terracotta army
moustache eyebrows	ivory black	completion: frequent in terracotta army
lips	as flesh tone, but more cinnabar	drawing of warrior 002812

Appendix 1: Pigment mixtures

General

part / area	*mixture of pigments*	*oriented on*
border of armour, reddish brown ground	4 parts cinnabar (*zhusha*) 9-10 parts iron oxide red (No. 48150) 3 parts Chinese Purple	drawing of B-0101 addition of Chinese Purple according to observation on T9:1
black rhomb grid and black ornaments	ivory black	analyses from black belt pattern of F-004/2003
red ornaments	cinnabar from workshop (Kremer, 1988) in skin glue	drawing of B-0101
ochre ornaments	Rehbraun greenish yellow iron oxide (No. 48020)	drawing of B-0101
white ornaments	1 part bone ash 1 part lead white	drawing of B-0101
purple ornaments	Chinese purple	drawing of B-0101
chest part of armour, black ground	ivory black	drawing of B-0101 photographs of colour in soil from T22G9:1
chest part of armour, 'bird and sun'	malachite shilü no. 5	drawing of B-0101 photographs of colour in soil from T22G9:1
'bird and sun' pattern contour lines, geometrical patterns	9 parts bone ash 1 part Rehbraun	drawing of B-0101 photographs of colour in soil from T22G9:1
'bird and sun' pattern reddish ornaments	as reddish brown ground of border	drawing of T20G10:97 in Yuan 1990, p. 293
white line around 'bird and sun' pattern	1 part bone ash 1 part lead white	
blue line on white line	Blue Bice	
ties on armour, green ground	4 parts malachite *shilü* no. 5 (light) 1 part malachite *shilü* no. 4 (medium) 1 part malachite *shilü* no. 2 (dark)	drawing of T20G10:97 in Yuan 1990, p. 293
ties on armour, light ochre stripes with red ornaments	*light ochre*: *red*: cinnabar Kremer 42000	drawing of T20G10:97 in Yuan 1990, p. 292, 293 (labelled 'white') colour in soil of T22G9:1: light ochre with red lines
ties on armour, pink stripes	*white* 1 part bone ash 1 part lead white *brown* some Rehbraun	drawing of T20G10:97 in Yuan 1990, p. 292
red **stitches on armour** lines on Purple stitches	cinnabar Kremer 42000	colour in soil of T22G9:1
light purple stitches on armour	1 part bone ash 1 part lead white 2 parts of Chinese violet	colour in soil of T22G9:1
greenish ochre on purple stitches	12 parts bone ash 10 parts lead white 2 parts malachite *shilü* no. 4 (medium) 6 parts Kreide von Sarti gelbstichig 1 part Rehbraun	colour in soil of T22G9:1 mixture as shin protection lower part of kneeling archer
white armour fastener	bone ash	

General (part 2)

part / area	*mixture of pigments*	*oriented on*
purple outer **jacket** (outside)	Chinese Purple	traces of colour on T20G10:97
outer jacket, border	ivory black	colour in soil from T22G9:1; border only on arms and neck down to waist
outer jacket, border, red ornaments	cinnabar *zhusha* (fine)	red lines from colour in soil from T22G9:1; pattern from charioteer of bronze chariot no. 1: red ornament on black ground
outer jacket, red lining (inside)	*zhusha*	oriented on T9:1 and colour in soil of T22G9:1
inner jacket, green (outside)	4 parts malachite *shilü* no. 5 (light) 1 part malachite *shilü* no. 4 (medium) 1 part malachite *shilü* no. 2 (dark)	free completion
inner jacket, light pink lining (inside)	*white*: 1 part bone ash 1 part lead white *red*: cinnabar *chensha*	free completion
inner jacket, white border	1 part bone ash 1 part lead white	presence of border on all edges oriented on T2G2:97
inner jacket, border, ornaments	ochre: as ochre ornaments on border red: cinnabar no. 42000 (Kremer) in skin glue, 7 %	pattern oriented on archaeological textiles from Mawangdui
collar and sleeve cuffs (from undergarment) red and pink	*red* cinnabar Kremer no. 42000 *pink* 3 parts synth. vermilion (Kremer 42000) 20 parts bone ash	description of T20G10:97 in excavation report 1988, vol. 1, p. 427 colour according to B-0051, fragment of jacket in soil
shin protection, upper part: light blue	Blue Bice	white and blue paint particles in T20G10:97 >> interpreted as blue
shin protection, lower part: green	4 parts malachite *shilü* no. 5 (light) 1 part malachite *shilü* no. 4 (medium) 1 part malachite *shilü* no. 2 (dark)	free completion
tie of cap, purple	Chinese Purple	free completion
shoulder pieces	black: ivory black border: as reddish brown border of armour	black: from T2G2:97 border: free completion
trimming of shoes, pink	synth. vermilion Kremer no. 42000 bone ash	completion; pink from T9:1
flesh tone	white with red in varying proportion: *white*: 1 part bone ash 1 part lead white *red*: cinnabar *zhusha*	frequent structure on faces and hands feet: completion according to hands
pupil, brown	ivory black cinnabar	completion: one of the frequent colours of pupils
white of eyes finger nails	1 part bone ash 1 part lead white	completion: frequent in terracotta army
moustache eyebrows	ivory black	completion: frequent in terracotta army
lips	as flesh tone, but more cinnabar	drawing of warrior 002812

Appendix 2: Tests with different types of binding media (Carolin Roth, January 2006)

Suited mixtures are marked grey. Dark grey: best result

Bindemittel	Rezept	Bemerkungen
Hautleim (chinesisch)	10%ig in Wasser+ eingesumpfte Pigmente	Der Leim quillt im Vergleich zum deutschen Produkt sehr ungleichmäßig und löst sich nicht vollständig auf; diese Unregelmäßigkeit zeigt sich in der Farbschicht während des Auftrages als kreisrunde, transparentere Bereiche, die dann aber vollständig wegtrocken. Eventuell fein sieben. Auftrag zweischichtig zeigt sich aufgrund der guten Löslichkeit in warmem Wasser etwas schwierig. Kaum Pinselduktus.
Hautleim (chinesisch) + Alaun	10gr Hautleim + 1g Alaun auf 100ml Wasser + eingesumpfte Pigmente	Der Alaun bewirkt innerhalb weniger Stunden, dass die komplette Leimlösung wasserunlöslich und sehr zäh wird. Zum Kleben sicher geeignet, nicht aber als Bindemittel für Pigmente.
Hautleim (chinesisch) + Alaun	10%ig in Wasser+ eingesumpfte Pigmente + Alaun (10%ig in Wasser) als Schicht zwischen zwei Aufträgen	Mit diesem Verfahren ist es gut möglich, einen zweischichtigen Farbaufbau mit Hautleim auszuführen. Die Oberfläche ist samtig matt, besitzt kaum Tiefenlicht und zeigt einen leichten Pinselduktus.
Hautleim (chinesisch) + Leinöl	4 Teile Hautleim, 1 Teil Leinöl Geschüttelt	Deckt relativ schnell, ohne Alaun-Zwischenschicht keine zweimaliger Auftrag möglich. Auch dann farblich ungleichmäßiges Auftrocknen. Farben trocknen etwas dunkler auf, Knochenweiß wird eher transparent, gelblich. Perlt leicht auf dem Lackuntergrund.
Hautleim + Eigelb	Mischungsverhältnis 0,5: 1	Insgesamt eher wie beim Leinölzusatz: durch das gesteigerte Tiefenlicht schlechtere Deckkraft, gute Bindekraft, bei zweimaligem Auftrag innerhalb kürzerer Zeit wird die erste Schicht angelöst. Malachit tendiert zum verklumpen, Weiß deckt schlecht. Insgesamt inhomogen und leicht klumpend (v.a. Malachit) Allerdings sehr gute Fließeigenschaften für feinere Malerei.
10 % Hautleim + Vollei	Mischungsverhältnis 1: 1	Sehr gute Deck- und Bindeeigenschaften, auch feinste Malerei möglich, satter Pinselduktus. Insgesamt sehr zufrieden stellend. Zweischichtiger Auftrag nur nach gutem Zwischentrocknen möglich.
Hautleim + Gummi arabicum	10% Hautleim + Gummi arabicum (2 RT Wasser + 1 RT Gummi), Mischungsverhältnis 1: 1	Sehr gute Deck- und Bindeeigenschaften, allerdings problematisch bei zweischichtigem Aufbau, (Bildung von starken Wasserrändern). Bleib nach dem Trockenen sehr feuchteempfindlich. Die Oberfläche ist matt und glatt, es gibt kaum Pinselduktus.
Vollei + Leinölfirnis + Dammarfirnis	1 Vollei (=1 RT) + ½ RT Leinölfirnis + ½ RT Dammarfirnis (Dammar 1:2 in Balsamterpentinöl)	Cremige Farbe, gute Deckeigenschaften, allerdings bei Ocker Unregelmäßigkeiten beim Auftrocknen, leider nicht sofort übermalbar. Darum auf der Probeplatte nur einschichtig, trocknet sehr langsam.
Vollei + Leinölfirnis	1 Vollei (2 RT) + 1 RT Leinölfirnis	Gute Deckkraft, kräftiger Duktus, insgesamt trocknet die Farbe aber zu dunkel auf. Zweischichtiger Aufbau erst nach dem vollständigen Durchtrocknen und Abbinden möglich.
Eiklar	Eiklar + Alaun, Mischung 4: 1 Alaun 10%ing in Wasser	Sehr lasierendes Bindemittel, deckende Farbschicht erst nach mindestens dreimaligem Auftrag, dafür sehr kräftiger Pinselduktus und matte Oberfläche.
Fischleim Fa. Kremer	1:1, 1:3, 1:5 mit Wasser	Der Fischleim kann nicht rein verwendet werden. In der Verdünnung 1:3 ist er einigermaßen gut verarbeitbar, die Oberfläche trocknet etwas fleckig auf. Erst in der Verdünnung 1:5 erhält man eine fast fleckenlose, allerdings leicht Wasserflecken bildende Farbschicht – allerdings wird es dann mit dem Übermalen unmöglich. Eventuell wäre 1:4 ideal.
Hausenblase + Alaun	Ca. 5-8 %ig in Wasser, mit Zwischenschicht mit Alaunlösung (1:10 in Wasser)	Ohne eine Zwischenschicht mit Alaun ist eine Übermalung unmöglich. Schlechte Deckeigenschaften, wohl durch Wiederanlösen, Farben in sich streifig.

Bindemittel	Rezept	Bemerkungen
Hausenblase + Reisstärke + Alaun	Hausenblase 5-8% + Reisstärke 7%, Mischung 1:1 mit Zwischenschicht Alaunlösung (1:10 in Wasser)	Optische Verbesserung dank der Reisstärke, aber ohne Alaun ein wäre eine zweite Farbschicht nicht befriedigend auszuführen. Ohne Alaun auch fleckig.
Reisstärke	7% in Wasser aufgeschlossen	Sehr gute Deckkraft, beliebig zu überarbeiten, ohne Ansätze. Matte Oberfläche, mittlerer Pinselduktus. Dünne Linien etwas schwieriger, da das Bindemittel etwas zu pastos ist.
Weizenstärke	7% in Wasser aufgeschlossen	Unmögliches Bindemittel für Farben. Pigmente klumpen, Farbe deckt nicht, auch mit viel Netzmittel unbefriedigende Haftung auf dem Lack. Völlig ungeeignet. Auch nach folgendem Rezept nicht als Bindemittel geeignet: 3:1 oder 4:2 Wasser: Stärke, in normalem kalten Wasser mischen, in einer Teflonpfanne auf 80°C erhitzen, kochend ständig rühren, mindestens 30 Minuten, je länger umso spannungsärmer. In kaltem Wasser aufgießen, abkühlen und 2x durch ein feines Haarsieb streichen.
Weizenstärke + Hautleim	Mischungsverhältnis 5:1, (Hautleim 5-8 %ig)	Deutliche Verbesserung zu Weizenstärke alleine, aber insgesamt Verschlechterung für den Hautleim.
Weizenstärke + Hautleim	Mischungsverhältnis 1:2, (Hautleim 5-8 %ig)	Sehr gutes Ergebnis, möglicherweise ist wenig Weizenstärke als Zugabe förderlich für die Übermalbarkeit. Ergebnis eine gleichmäßige Oberfläche, mittlerer Duktus. Gleicher Versuch mit Reisstärke wäre interessant.
Kasein (Borax)	Schminke - Bindemittel + eingesumpfte Pigmente	Leicht zu verarbeiten, allerdings stark saugend beim zweiten Anstrich. Die Eigenschaft des Kaseins, wasserunlöslich aufzutrocknen, tritt erst nach wenigen Stunden ein, bzw. ist erst nach zwei Tagen erreicht. Die Farbschichten sind sehr glatt, besitzen kaum Duktus. Auf der Oberfläche der Skulptur allerdings, aufgrund der noch leicht saugenden Terrakotta, schwacher Duktus.
Vollei	Ganzes Ei zusammen geschüttelt, dann Eihaut heraus gesiebt.	Gute Binde- und Deckeigenschaften, allerdings muss das Pigment vorher angeteigt sein, um eine Unter- oder Überbindung zu vermeiden. Leider tritt die Wasserunlöslichkeit erst nach mehreren Tagen ein, überarbeiten ist also nur vorsichtig möglich. Dickerer Auftrag mit sichtbarem Duktus nicht möglich. Trocknet nicht ganz fleckenlos. Feinste Linierungen möglich.
Vollei + Kasein	Mischungsverhältnis 1:1	Gute Fließeigenschaften, mittleres Deckvermögen. Trocknet etwas schneller wasserunlöslich auf als das Vollei alleine. Feine Linierung möglich – auch pastos!!

Year 2006

Small archers and model of T21G18

Catharina Blänsdorf, Wang Liang

Introduction

The group of eight kneeling archers from pit no. 2, T21G18, was the base to investigate the polychromy of the terracotta army. Their polychromy was consolidated and is preserved well enough to reconstruct it completely. Besides the documentation of the single sculptures, the eight warriors can be also seen as a group. Attempts to show them as a part of a formation were firstly carried out and presented in 2004.[1] The compilation of drawings shows the different colour schemes, but does not give the impression of looking into the pit. The front views are arranged according to the (assumed) position inside the pit, but there is no pit visible and no arrangement of the sculptures in space.

Eighteen small scale replicas were bought in Lintong while the large ones were cast. The replicas were thought to serve different purposes: To test the painting process and see the effect, but also to reconstruct different colour schemes of kneeling archers. The set of sculptures in the state of terracotta – lacquered – painted, not only shows the three important steps in the work process, but also visualises the enormous change the sculptures underwent by being painted (fig. 1). Seeing the set the other way round (painted - lacquered – terracotta), it gives an idea what has been lost when the paint layer flaked off and the grey terracotta was exposed again. For someone knowing the warriors nowadays, the terracotta 'version' looks more familiar and closer to the originals, but it is exactly the same sculpture each time.

Fig. 1. Small replicas, three steps of production process: terracotta – lacquered – painted

The small replicas also served as models for the large (1:1) replicas. Fig. 41b in the report 'Reconstruction of the polychromy on replicas of terracotta warriors – painting the replicas shows the small replica of the kneeling archer being painted next to the large – always being one step ahead and giving the possibility to check and correct the effect of the chosen colours.

[1] New investigations on the polychromy of the terracotta army - Kneeling archers and officers with decorated borders, in this volume, p. 27: Colour drawing of nine kneeling archers.

After the large replicas had been painted (as well as one of the small ones), eleven more small sculptures were painted, representing all sculptures of which the polychromy has been documented so far.

1 Painting the replicas

The small scale replicas come from the replica factory inside the museum of the terracotta army in Lintong. They were bought only fired, without the coating of black colour and loess dust which is applied for selling them. The small replicas are not modelled very finely and some details are missing or wrong, but the overall impression is acceptable. As they are made by moulds, they are almost identical, what is a disadvantage as they are too similar by that way, but there is only one mould for each size of replicas, what meant that there was not any choice. They are 20 cm high. Compared to the originals the proportions are not fitting perfectly. The replicas are too tall or too slim and compact for their height. If enlarged to the width and depth an original warrior has (80x 90 cm), the replicas would be 2m tall instead of 1,20m (table 1).

	original sculptures [cm]	*replicas [cm]*
height	120-125	20 (without base slab)
width (max.)	ca. 80	8
depth (max.)	ca. 90	9

Table 1. Dimensions of the terracotta sculptures and the replicas of the kneeling archers

Fig. 2. Painting the small replicas

The sculptures were not lacquered with *qi* lacquer in China. Shellac dyed black with soot was used to imitate the lacquer coating. The pigment layers were carried out like on the large replicas[2], using egg/skin glue (1:1) as binding medium and mineral pigments. The painting was realised by Carolin Roth and Catharina Blänsdorf (fig. 2).

For the decision about the colours, the colour drawings made in Lintong on site in front of the sculptures as well as self-made colour charts to record the colours and the descriptions in the documentations were used. Each colour was mixed individually. The structure was carried out like on the originals, only the multi-layered structure of the faces was not imitate to avoid that the features of the small replicas would disappear underneath a thick layer of paint.

[2] See: Reconstruction of the polychromy on replicas of terracotta warriors – painting the replicas, in this volume.

2 Arrangement of small replicas to a formation of warriors

The small replicas can be arranged as a group of warriors. As in the pit they were set up in two rows (fig. 3).
The digital photograph can be easily manipulated creating a background which resembles a (simplified) view into a corridor of the pit.
However, preliminary arrangement of the sculptures also revealed problems of these attempts:

1. Depending on the question if the height or the depth of the sculptures are regarded as starting point of calculations, the distances between the sculptures and connected to this the visual impression changes. Fig. 4 and 5 show the results of this effect.

Fig. 3. Preliminary arrangement of painted replicas

Fig. 4. Distance between warriors calculated from the height of the warriors.

Fig. 5. Distance between warriors calculated from the width/depth of the replicas.

2. As at least nine of the reconstructed warriors come from the corridor G18, this corridor was regarded as model for a reconstruction. The dimensions were measured using different plan of pit no. 2 made by the Chinese archaeologists (fig. 6). Due to inaccuracies unavoidable in drawn plans squeezing a pit of ca. 100 to 120 m in a DIN A4 scale, measurements differ slightly, but basic measurements could be taken. According to the plans[3] the length of G18 is 20.64 to 22.50 m, the width 2.13 to 2.40 m. The plans show 40 kneeling archers in G18, arranged in two rows, what means there are 20 archers in a row (from east to west, fig. 7). Calculated with an average depth of 90 cm per sculpture, this would mean that there is 13 to 25 cm of space between the sculptures (table 2).
This calculation finally showed that there must be a mistake in the plans: If this was correct, the arrangement would correspond to fig. 4, but the sculptures are definitely not that packed and close to each other inside the pit.

calculated length of corridor	*average space for each sculpture*
20.64 m	1.03 m
21.6 m	1.08 m
22.5 m	1.125 m

Table. 2. Interspaces between sculptures in G18 calculated from archaeological plans with 20 sculptures per row

[3] Three plans of the pit were used, the measures were calculated including and excluding the outlines.

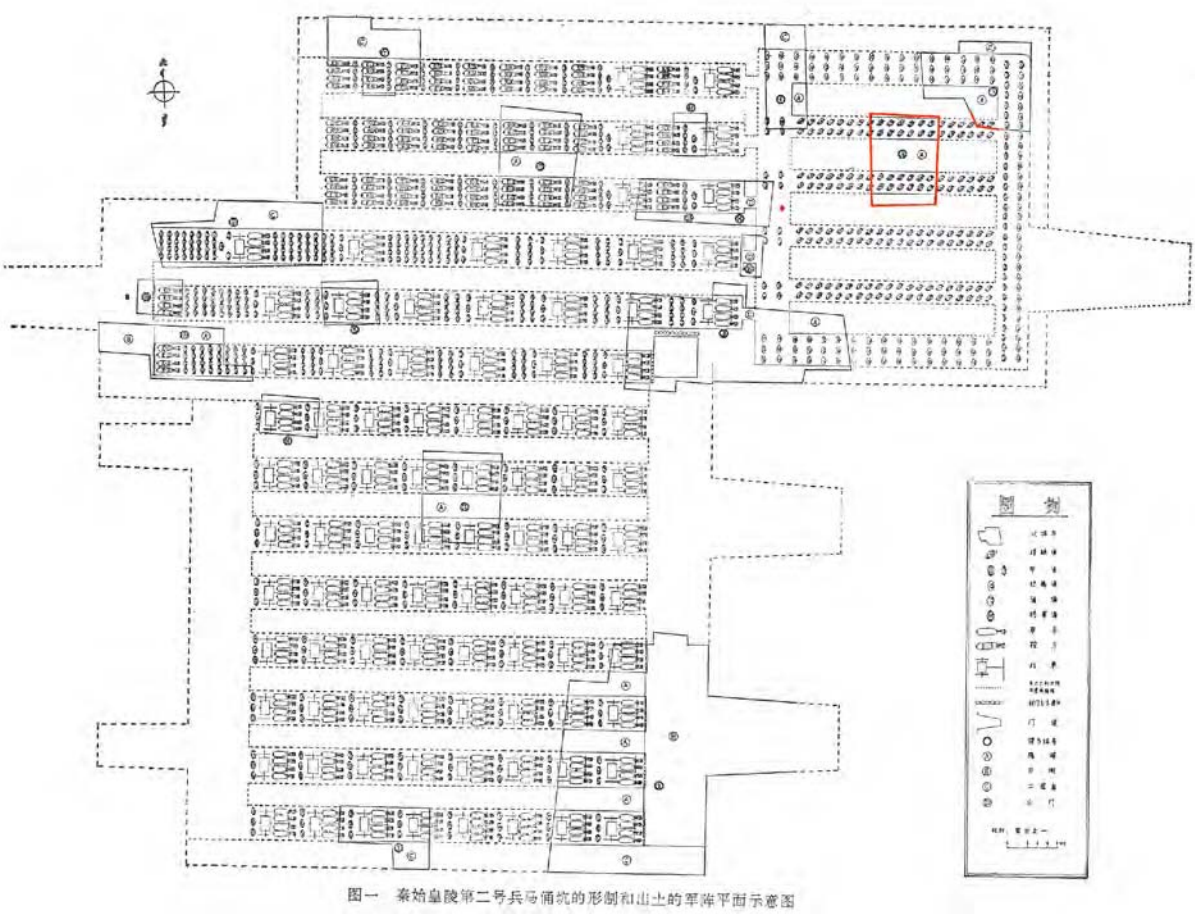


Fig. 6. Plan of pit no. 2, published in the excavation report in *Wenwu* 1978, vol. 5, p. 2
Red lines: outlines of excavation sections in 1977

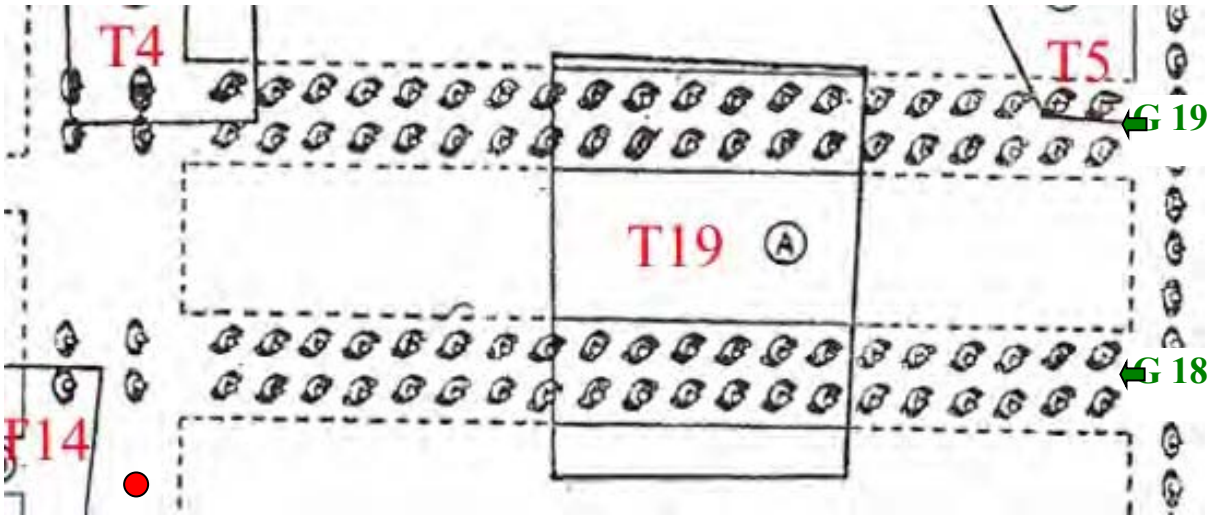


Fig. 7. Detail from fig. 6, showing the corridors G18 and G19 as well as the excavation sections from 1977 touching these two corridors
Red dot: a kneeling area outside of the formation in the eastern part of the pit

3 Reconstructing the arrangement in corridor G 18

A meticulous check including the measuring of the corridor, interviewing the archaeologist Mr. Liu Zhancheng and counting the sculptures in the pit and in the laboratory new results, was undertaken by Wang Liang to recover the original positions of the kneeling archers in pit no. 2. It became obvious that the situation is not perfectly recorded or the respective documents are not accessible. The results of this investigation are described below.
The determination of the dimensions also became necessary because a box for the small warriors was supposed to be built, representing the situation inside the corridor to scale. Therefore the exact measures of the corridor, the dimensions of the pillars and the position of the sculptures had to be known.

3.1 Dimensions of the corridor and position of excavation section T19

Measurements on site brought the following results: The pit is 250 cm wide, the excavated part is 1440 cm long. The wooden pillars measure 25-30 cm in diameter and mostly are square, but four are round (fig. 8, marked grey). The walls nowadays are 160 cm high, but according to the archaeologists they originally had a height of 320 cm.

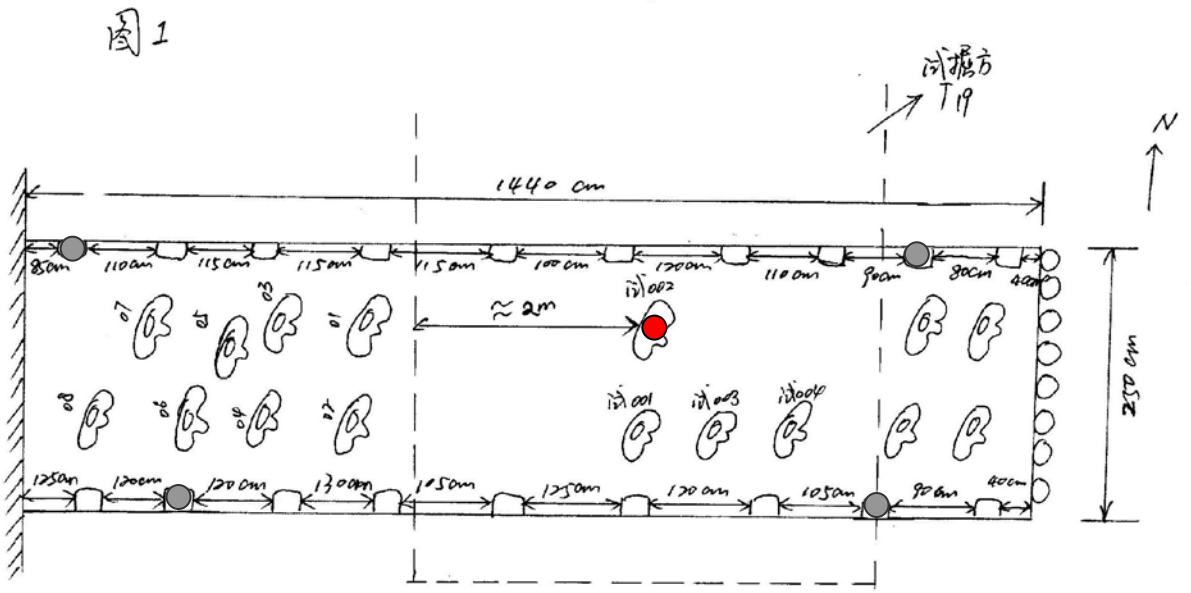


Fig. 8. Sketch showing the measurements of corridor G 18 taken insite the pit [Wang Liang]

According to Wang Liang's investigation, the total length of the corridor is about 21 m, leaving 7 m unexcavated. As the unopened part in the western end measures about 5 m, the partly excavated one in the eastern end should be about 2 m.
The distances between the pillars were also measured, showing that the pillars were set up fairly regularly. When the measures were transferred to a drawing to scale, it became obvious that on the southern part of the corridor (lower edge of the drawing) the given measures do add up to the total length of the corridor.[4] Because of this problem, the exact outlines of excavation section T19 are not clear either. The variation is a shift about 50 cm to east or west.

[4] The interspaces add up to 1080 cm, plus 9 pillars with a diameter of 30 cm to 270 cm = 1350 cm. total length of corridor 1440 cm. The difference might be caused by slightly inaccurate measuring or the eastern end of the corridor is not straight, making the southern edge shorter than the northern one.

3.2 Number of sculptures inside G18 and attribution of sculptures to ascertained positions

Section T19 was completely excavated in 1977, refilled for the building of the hall over the pit in 1994 and uncovered again. The excavation sections of 1977 are marked in the plan from 1978 (fig. 6).[5] The part west of section T19 was excavated in 1999 to 2003. Nowadays, this excavated area of G18 is empty except for one sculpture (SH002, indicated with a red dot in fig. 8). The positions of the sculptures in the western part are recorded as shown in fig. 8.
According to the excavation report in 1978, 24 kneeling archers have been found in section T19, arranged in four rows of six warriors, two rows in G19, another two rows in G18. According to the archaeologists three sculptures have been taken out between SH 002 and T21G18:01. As these two sculptures are only about 2 m apart from each other, squeezing in three sculptures seems almost impossible. Thus it was also discussed that there might have been five archers and not six per row in T19.
West of T19 two rows of four warriors were excavated between 1999 and 2003. In the unopened part east of T19 two times two warriors are assumed by the archaeologists. This means that 1440 cm of G18 contained two rows of eleven or twelve archers.
The unexcavated western end of 5 to 7 m could contain three to maximum six archers in each row. This would mean that corridor G18 contains 14 to 18 archers pre row and not 20 as indicated in the excavation report of 1978, thus allowing much more space between the single archers: With 1.16 m to 1.5 m per archer, the distance would be 26 to 60 cm in average.

There are 17 kneeling archers registered in the museum (i.e. they have been taken out of the pit). Nine of them clearly come from G18 and can be positioned exactly (T21G18:01-08 and SH001, the ones with paint layer excavated since 1999). Two more (002813 und 002814) were excavated in G18 in earlier time. For five more the position is not recorded (002812, 002815, 02532, 02534, 02744), the latter three of them being excavated in 1977.
A total number of 27 kneeling archers have been unearthed from G18 and G 19 in 1977, but it is not clear which sculptures have been taken out of the pit. There seem to be two empty spaces of about $1m^2$ in G19, but according to Liu Zhancheng no sculpture has been removed from there after 1994. Displacement of sculptures due to the pillage in antiquity is a possible explanation for the irregular positioning of some warriors. As some are clearly tipped over, they might also have been pushed around by the intruders to get easier access to the pit.
It seems reasonable that all kneeling archers were found in G18 and G19 as these areas are the centre of the formation of archers. Confusingly, two kneeling archers are reproduced in the excavation report of 1978, referring their position to T10. The same drawing of one of them was reprinted in Yuan 1990, p. 144, numbering it T13:1, what would mean that it comes from section T13. Both locations are highly unlikely as chariots are found in these areas and might be a mistake of reading (19 might look similar to 10 and 13 when handwritten). Nevertheless, at least one kneeling archer has been found outside of his formation. It is still inside the pit in corridor K2 (red dot in fig. 6 and 7). This leaves the question open if kneeling archers might be found in other areas of the pit as well.
In the end, the total number of kneeling archers in G 18 and the positions of the existing archers could not be cleared yet. 11 archers can be attributed to the corridor, two of them (002813 and 002814) without cleared position. On the four to six archers which additionally must have been removed from section T19 it is not clear which sculptures they are.

3.3 Position of archers in G18

[5] In 1994, section T19 was renumbered as T18. A confusing aspect is that later on (probably after 1994) a grid of excavation areas of 20 x 20 m was set up which is also identified by the letter ‘T’. Thus, nowadays corridor G18 is located in (excavation area) T21, but the (excavation section) T19 crosses the corridors G18 and 19 as well as the partition wall between them.

For the positioning in the box, the exact position of the archers should be determined. The important questions were:
1. How much distance was there towards the walls and between the rows (distances in north-south direction)?
2. Is the distance between the sculptures always the same or does it vary (distances in east-west direction)?
3. Are the positions of the sculptures next to each other parallel (i.e. vertical to the wall) or slightly diagonally arranged (fig. 9)?

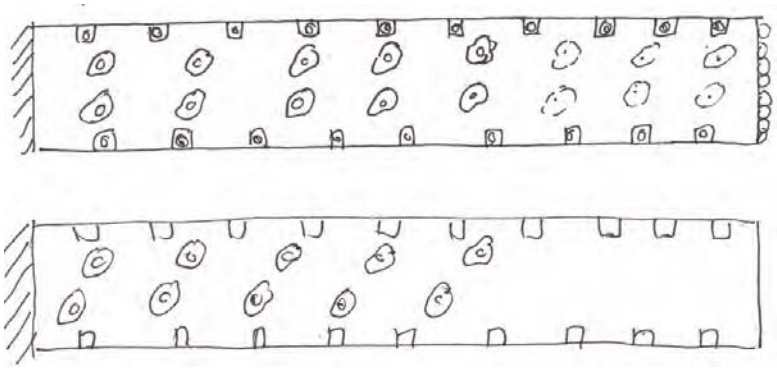


Fig. 9. Possible alignment of the rows of archers

A parallel or symmetrical

B diagonal

1. The question concerning distances in north-south direction could not be answered very accurately. It seems that the distance to the wall is rather small, but the sculptures are not placed in the interspaces between projecting pillars. It seems reasonable that the distance between the rows was a large as possible, so it was possible to walk between the rows if necessary. The clearance between the pillars is 190 cm (250- 2x 30). The width of a sculpture is about 80 cm, resulting in only 30 cm to distribute between sculptures and pillars. Though that it not that little as the walls are receding between the pillars and the sculptures are no square blocks, it nevertheless means that there was just enough space between the sculptures to squeeze through.

2. Concerning the distances within each row (east-west direction) the situation is also not completely clear, but there are tendencies: However the positioning of the now missing sculptures is made, the distances between the sculptures are smaller in the eastern part than in the western part of the corridor. There might be several explanations. A dislocation by the pillagers is possible, but also an uneven distribution from the beginning: As the sculptures were probably carried in through the doorways (ramps) in the eastern end, the corridor was filled up starting from it western end. Maybe the workers realised that there were too many sculptures left after being halfway through filling the corridor, and instead of moving all sculptures again, they just put them closer to each other in the end to reach the given total number. The difference is quite high: While the distances between the sculptures in the western part, southern row are about 100 cm, the ones in the eastern end are about 20 to 30 cm.

3. The question of the alignment of the rows could also not be finally answered. White the sculptures in the western part seem to be arranged more diagonally (the northern row protruding), the ones in the eastern part look more symmetrically arranged. Excavation reports and archaeologists prefer the symmetrical arrangement, but the diagonal looks more elegant and lively and seems as reasonable for G 18 on the base of the excavation situation.

One confusing aspect concerning the eight kneeling archers with preserved polychromy from the western part of the pit was that obviously the numbers of the sculptures has been changed. Finally the correct position or attribution could be found using photographs of the excavation situation. To avoid further confusion, the numbers written on the sculptures themselves are used in the following (marked red in fig. 10). Fig. 10 shows the two number systems.

Number according to excavation records	*number on the sculptures*	*storage room number*
01	T21G18:01	005504
02	T21G18:04	005505
03	T21G18:02	005506
04	T21G18:03	005507
05	T21G18:06	005508
06	T21G18:05	005509
07	T21G18:07	005510
08	T21G18:08	005511
SH001		005743

Fig. 10. Numbering system of kneeling archers in western part of G18
[Museum of the Terracotta Army]

With all information combined a paper model was made to define the positions of the kneeling archers (fig. 11). The model is a compromise and a suggestion. It served as base for the realisation of the model/transport box.

In fig. 11 the marks on the archers mean:
Red outline = taken out of the pit and identified
Black outlines and numbers = inside the pit and identified (SH 002 to 004 meanwhile taken out of the pit as well)
Black outlines, no number = still inside the pit, not excavated
Brown paper squares = suggestion position of additional archers which cannot be identified
The colour schemes and photographs of the warriors should help to identify the sculptures.

4 Realisation of model box

The box is designed to serve from transport and storage as well as model of a part of G 18.[6] It possesses wooden walls and looks rather technical from the outside (fig. 14a). A wooden top covers the box. All the walls can be taken off. The ‘southern’ wall is divided into two sections (fig. 13). Inside nine archers are arranged in a row, from T21G18:08 to SH004. As the dimensions had to orientate on the replicas, the box is rather larger (157 cm long, 59 cm high). The height of the replicas was the base of the calculations, what means that there is more space between them than in the original situation.

[6] Dimensions and design by Catharina Blänsdorf and Rolf Snethlage. The construction was realised by Stefan Demeter, cabinetmaker and furniture restorer (Dipl. TU).

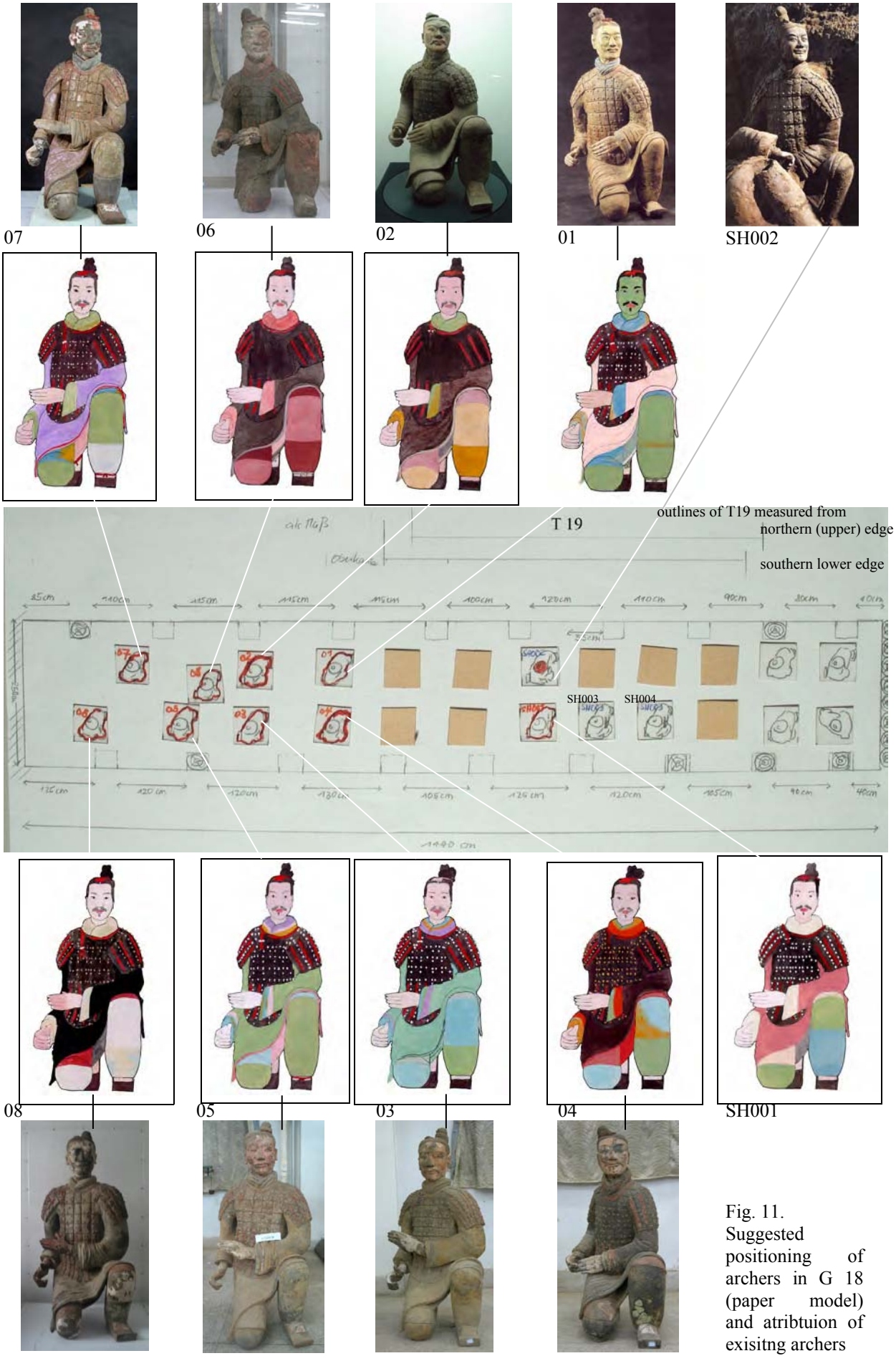


Fig. 11. Suggested positioning of archers in G 18 (paper model) and atribtuion of exisitng archers

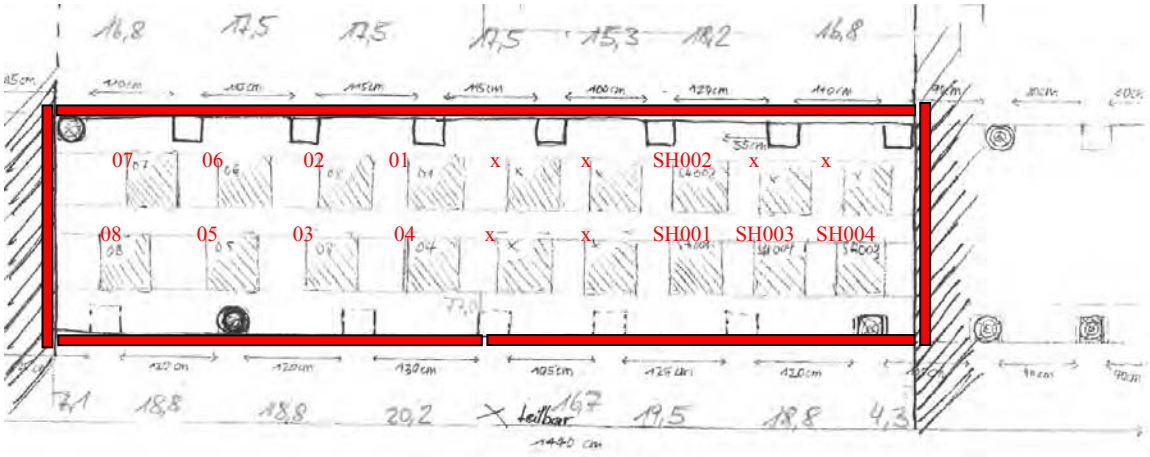


Fig. 12. Plan for construction of the box. The walls are marked red.
Dimensions, inside: 152.2 cm x 35.4 cm, height of walls: 45.3 cm

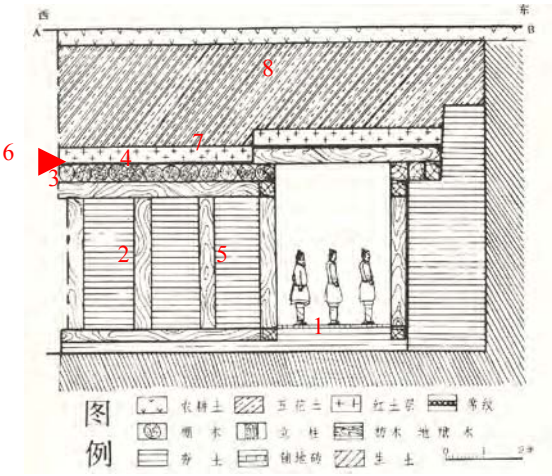


Fig. 12. Section through pit no. 1.

1 brick tile floor
2 wooden pillars
3 support beam
4 roof beams
5 rammed earth wall
6 mats
7 clay layer *qing gaoni*
8 filling with earth

Inside the box, the appearance of the corridor is imitated as it looked like originally. The wooden pillars are imitated with pine branches, the square and round shapes and the position is exactly like in the paper model. A vertical support beam on top of the pillars was reconstructed from drawings of pit no. 1 (fig. 12). The roof is made of pine branches as well and connected, so that the roof can be taken off in two parts.

The brick tile floor is imitated in a plywood board. As the small replicas, unlike the originals, possess a base slab, holes are cut into the plywood floor to put the terracotta slab in. The slabs therefore were cut to an accurate shape so the sculptures can also be exchanged. The fitting of the base slabs into the holes also means that the replicas cannot slide away. The box can be carried without the replicas tipping over or dislocating.

The plywood floor is loose and can be removed easily. This means, if new ideas about the arrangement of the archers occur, the floor can be exchanged easily.

Floor and walls were painted with egg/glue tempera (1:1, skin glue prepared 7%) and pigments on top of gesso ground made with chalk (Steinkreide). The tile structure was incised into the priming layer. The colours of walls and floor were orientated on fragments of a floor tile and a piece of rammed earth from the walls around the burial ground.

Mats will be placed on top of the roof beam and the layers of clay *qing gaoni* and some earth from the filling will be applied. As the warriors SH002 to SH004 are on restoration momentarily, their polychromy can be documented in 2007 and their replicas painted one by one. The other six sculptures might be also identified in the next year and could be painted then. If not they will remain grey.

Fig. 13. Transport and model box for replicas of archers
a. Box closed
b. Box without cover; front part of roof taken off
c. View into the box without roof and front wall
d. View into the corridor, comparable to view from east into the G18 in pit no. 2

Literature

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Yuan 1990 袁仲一 Yuan Zhongyi，*秦始皇陵兵马俑研究 Qin Shihuangling bingmayong yanjiu*. Beijing 1990

Year 2006

Plastically applied decorations – technique and reconstruction tests

Catharina Blänsdorf

Introduction

An important part of the investigation of the polychromy of the sculptures from Qin Shihuang's burial complex (*Qin Shihuangling*) is the understanding of the painting technique and its intended appearance. The fact that the surface structures, mainly visible as brush marks, are not only an accidental side effect of the application technique, but an effect the painters were well aware of was realised for the first time in 2001 when a head of kneeling archer T21G18:08 was examined: The brush marks follow the natural line of the facial features and thus increase the lively impression of the faces.
Observations made on sculptures from other pits than the terracotta army showed that the painters not only knew how to include a maybe unavoidable effect into their conception, but also deliberately used plastically applied surface structures as medium of design.
These plastically applied structures have been found on different types of sculptures as the acrobats, the bronze chariots and the bronze birds. The visual impression is similar to the technique known in Europe as *pastiglia* and in China as *lifen*, an application made in the gesso preparation of a sculpture, normally followed by gilding of the raised ornamental structures. In China, this technique can be observed very often on Buddhist sculptures. On the sculptures from the *Qin Shihuangling* however, the application is not made in the ground layer, but in the paint layer itself. Lines and dots of paint are applied on top of the paint layer forming ornamental structures.
Another type of design was produced by using brush marks as distinct surface structures. Although it is not unusual to include brush marks as part of the painting process, the way it has been used on the bronze birds can be considered exceptional.
The paint used on the terracotta sculptures was of a considerable viscosity and formed thick layers. All painted patterns, like on the generals or 'chariot officers' are also 'three-dimensional' in the way that the applied lines are raised. This effect supports the impression that the patterns imitate textiles with woven-in ornaments like damask or brocade which typically are also not completely flat. The same technique was also used in monochrome layers. This means that the applied pattern has the same colour as the ground and is only visible because of its relief structure. All examples of this technique observed so far are made on white or light pink paint layers.

1 Acrobats skirts

The acrobats with the numbers T1G3:05 and T1G3:06 (fig. 1 and 2) from pit K9901 could be examined in the museum of the terracotta army. They have a very light pink skin and wear skirts of almost the same colour. The skirts cover waist and thighs and are made of a straight piece of fabric which wrapped around the body. The edges overlap either in the front (acrobat no. T1G3:06) or in the back (acrobat no. T1G3:05). The skirts are decorated with a border which either only runs around the lower edge (acrobat no. T1G3:06) or around the three edges of the skirt (acrobat no. T1G3:06). This border is not modelled or indicated in the terracotta,

but only painted. On the mighty acrobat no. 06 it is 14 cm wide, on the smaller, asthenic acrobat no. 06 it is 8.5 cm. Acrobat no. T1G3:04 which is fragmentarily preserved and could not be observed in detail resembles acrobat no. T1G3:05 in his heavy set built and also seems to wear a similar designed skirt.

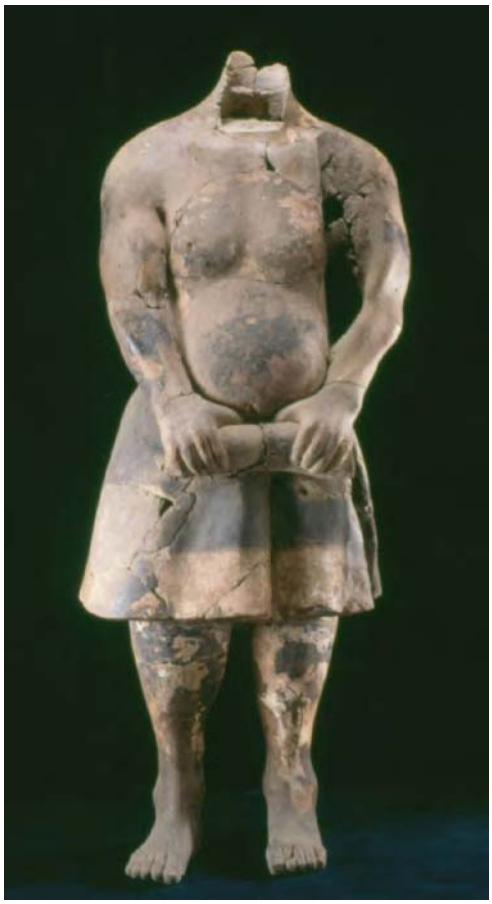


Fig. 1. Acrobat no. T1G3:05
[Museum of the Terracotta Army]

Fig. 2. Acrobat no. T1G3:06
[Museum of the Terracotta Army]

1.2 Acrobat no. T1G3:05

The skirt of acrobat no. T1G3:05 originally has been light pink. Skirt and border contain bone ash and some cinnabar as pigments. The part of the skirt is mainly black today, revealing some brownish white areas only on right left thigh and on the small fragments of paint layer preserved on the back. The blackening is a discoloration probably caused by the fire in the pit. Why the border did not turn black is not clear yet. As the pigments are the same in both areas, the use of different binding media might be the reason. On acrobat no. 04 the same type of blackening can be observed, only the other way around: the skirt is white and the border turned black. Additionally also the flesh tones show patchy areas of blackening, clearly showing that the black tone is a secondary effect.
On the skirt of acrobat no. T1G3:05 a fine pattern is painted in black (fig. 3). The interpretation of the ornaments is not solved yet, but it seems to be a composition of geometrical elements and stylised animals which in another design were also observed on the ‘apron-style’ armour of the ‘chariot officers’.
The border of the skirt however shows a plastically applied pattern. It consists of vertical rows of lozenges filled with a pattern of four small lozenges. Every second row is shifted in level about the half height of a lozenge, so that in every third row the vertical peaks of the lozenges

point directly at each other. The rows of the lozenges starting with a half lozenge on the upper edge appear slighter bigger than the ones on the rows in between, so there might be a change of size between the rows. Very small lozenges are interspersed between the rows of lozenges. They are positioned between the sides of the lozenges.
The lozenges measure from peak to peak 1.0 to 1.3 cm in height and 2.5-3.5 cm in length. The distance from the centre of one lozenge to the next is 1.7 to 2.0 cm in height and in width to the next but one 5.7 to 6.0 cm (often 5.8 cm). In the skirt the distance of between the centres of the 'sun' ornaments which might the fixed points for the construction of the ornament, is also 5.7 to 5.8 cm in width, in height it is 3.9 to 4.2 cm (often 4.0 cm). This seems to indicate that the basic grid for both ornaments is the same (5.8 x 2.0 cm). 5.8 cm is also the height of the birds on the chest of the generals. This could mean that there are some basic dimensions which were used for several patterns.
Though the pattern is constructed strictly, it is applied free-hand, resulting in small irregularities, but also giving the possibility to show a certain distortion caused by the stretching of the fabric. The lines of the lozenges are about 1mm wide and very even, hardly varying in thickness.
Acrobat no. T1G3:04 has the same pattern on the border of the skirt. The decoration on the skirt itself cannot be reconstructed anymore from the colour fragments remaining on the sculpture, because the original surface is completely lost.

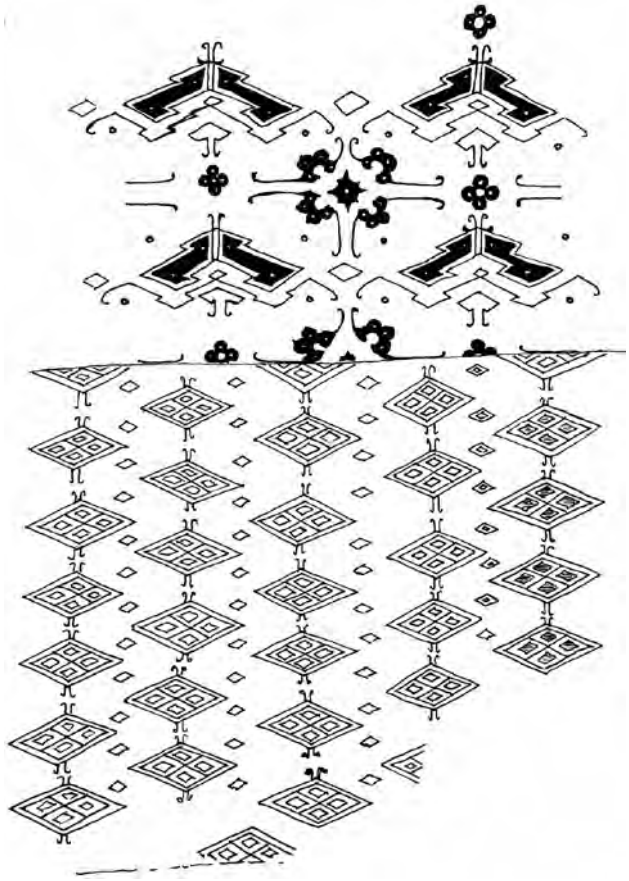


Fig. 3. Acrobat no. T1G3:05, line drawing of skirt decoration. Front part above his right knee

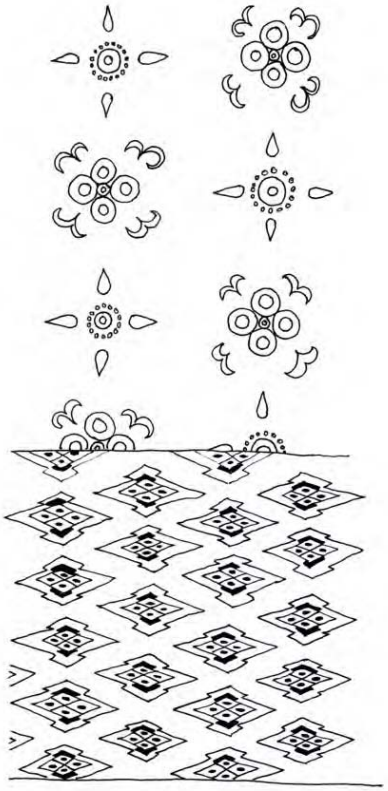


Fig. 4. Acrobat no. T1G3:06, line drawing of skirt decoration with completions of damaged areas. Front part above his left knee

1.2 Acrobat no. T1G3:06

Acrobat no. T1G3:06 has an extremely pale skin. The skirt which is mainly blackened by the fire, but probably had the same colour. Both paint layers contain bone ash and very little cinnabar. Skirt and border have the same colour and both have a decoration of plastically applied ornaments. The skirt shows a more large-scale pattern of two types of 'rosettes'. From the construction point of view, these 'rosettes' are alternately arranged on the cross points of a grid, the distances between the cross points measuring 3.4 cm in height and 4.2 cm in width.

The border shows the same type of lozenge pattern as on the border of acrobat no. T1G3:05. The lozenges are arranged in vertical rows, with every second shifted in horizontal level about a half lozenge, but in detail the lozenges are different: They all seem to have the same size, measuring about 1.2 x 2.5 cm, and are arranged more close to each other with distances of 1.6 cm in height and 4.2 cm in width between the centres. They are broken lozenges. The tiny interspersed lozenges are missing. Like on acrobat no. 05, the width of the pattern unit of the skirt is the same as on the border. The lines of the lozenges are very fine, measuring less than 1 mm and very even in thickness (fig. 5).

Fig. 5. Front of the acrobat no. T1G3:06 above the left knee, with the best preserved fragment of the border design with rows of broken lozenges is visible; on the upper edge, some dots of the 'rosettes' can be seen.

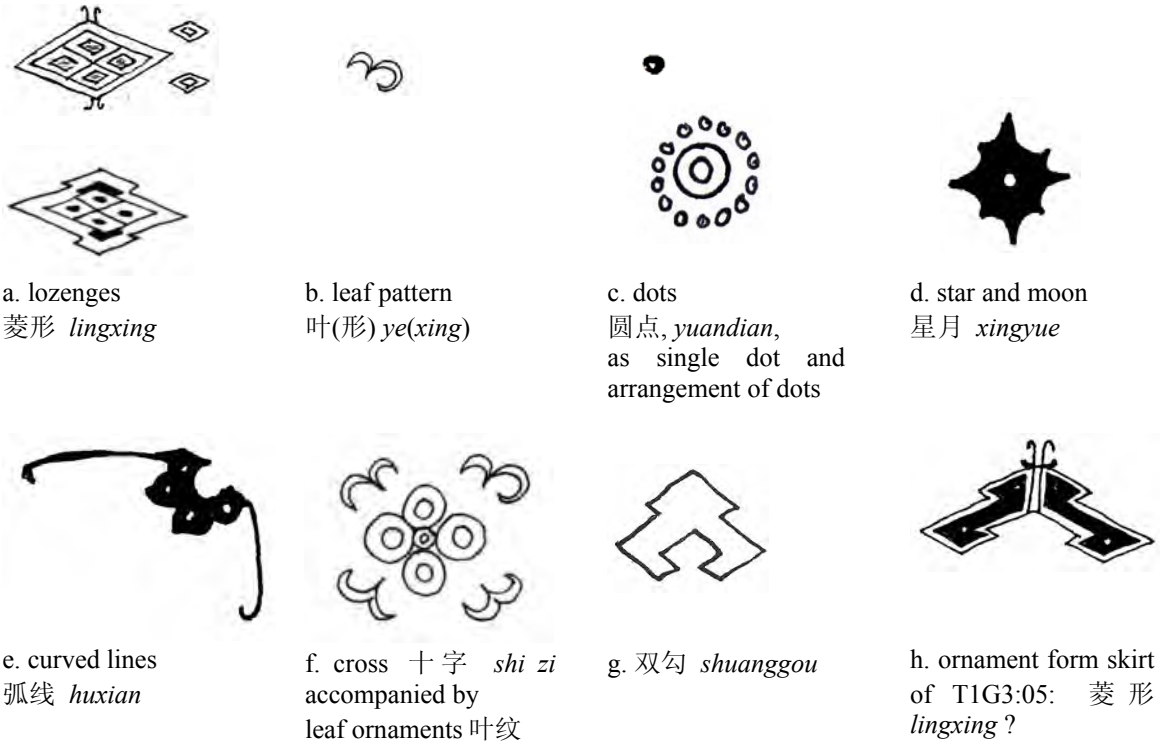
1.3 Imitation of textiles

On both acrobats, skirt and border do not or only slightly differ in colour, but are differentiated by the direction of brush strokes: Running vertically on the skirts, they are oriented horizontally on the border. On acrobat no. T1G3:05 the border is also applied on the short length of the skirt. The brush marks follow the orientation of the border, running vertical to the border on the lower edge now. The lozenges are tilted about 90 ° here.
The brush strokes are applied very evenly, resulting in very straight homogenous brush marks. These brush marks produce a slightly wavy surface structure with a clear direction. The applied ornaments are run across these directions. The impression is the one of a textile with a visible thread direction and ornaments manifesting themselves in a raised structure – an effect typical for damasks.

These observations raise the question if the polychromies are imitations of real textiles and if there are possible prototypes. Zhang Weixing 2002 describes the decorations of eight acrobats. He differentiates six types of patterns (fig. 6): 1. lozenges (菱形 *lingxing*), 2. leaf patterns (叶(形), *ye*(*xing*)), 3. dots (圆点, *yuandian*), 4. star and moon (星月 *xingyue*), 5. mountain pattern (山形 *shanxing*), 6. curved lines (弧线 *huxian*) which occur in different variations[1]; additional he names a 'cross' ornament (十字, *shizi*) and the 'pincer' type ornament (双勾 *shuanggou*). These ornaments are combined in different ways on the skirts of

[1] Zhang Weixing 2002, p. 69.

the eight acrobats. The explanations are useful tools to explain the ornaments, although they are not convincing in every detail and Zhang Weixing also says there are difficulties and doubts. An example is his identification of a (unknown) bent ornament in the skirt of acrobat T1G3:05 (fig. 6h) as *lingxing* (lozenge) which in fact resembles a *shuanggou* ornament (fig. 6g). Obviously the interpretation of the antique patterns is difficult nowadays as the original understanding is lost.



a. lozenges
菱形 *lingxing*

b. leaf pattern
叶(形) *ye*(*xing*)

c. dots
圆点, *yuandian*,
as single dot and arrangement of dots

d. star and moon
星月 *xingyue*

e. curved lines
弧线 *huxian*

f. cross 十字 *shi zi*
accompanied by
leaf ornaments 叶纹

g. 双勾 *shuanggou*

h. ornament form skirt of T1G3:05: 菱形 *lingxing* ?

Fig. 6. Ornaments as identified by Zhang Weixing 2002 on the acrobats' skirts.

According to Zhang Weixing 2002 the colours are black and white, except for the purple skirt of fig. T1G3:03. Although he did not realise the problem of black discoloration by the fire and the differentiation between white and light pink, in principle this observation is right.
Zhang Weixing 2002 also gives some considerations concerning textile prototypes[2], looking for the types of fabrics and literal sources. He distinguishes between textiles with woven ornaments (织花) and painted (画绘 *hua hui*) or printed patterns (印花 *yinhua*). The uni-coloured patterns as the lozenge patterns on the borders, he identifies as woven patterns, also because of the relief structure, the two-coloured as printed or painted patterns. He refers to the large number or excavated textiles from *zhanguo* (Warring States Period, 480-221 BC)) to the Han Dynasty (without naming any). Already as early as the Shang Dynasty many of the textiles show lozenges. Concerning the two-layered patterns he quotes the Kaogongji (考工记), a *zhanguo* literal source, and to the fact that printing with woodcut blocks was already known in *chunqiu* (Spring and Autumn Period, 771-480 BC) and *zhanguo*. The pattern on the skirt of acrobat no. T1G3:05 looks like painted to him, but might be printed as well.

For the knowledge about textiles from the period of *zhanguo* to the Han Dynasty, especially the tombs of the former stat of *Chu* in southern China are interesting. Very different types of textiles were found the north-western autonomous region of Xinjiang, mostly from the Han

[2] Zhang Weixing 2002, p. 70/71.

and later Dynasty, partly coming from Chinese productions, but also showing clearly non-Chinese, Central Asian influences.
In fact most textiles from *zhanguo* to Han dynasty with patterns in two or more colours are not printed, but woven or embroidered. There are different techniques for textiles with woven patterns as *luo* (gauze), *sha* (tabby), *qi* (patterned tabby), *ling* (twill leave), *duan* (satin and damask), *jin* (warp- or weft-faced compound tabby or twill silk weaves), *rong* (velvet) or *kesi* (silk slit tapestry).[3] Some are monochrome, but most have two or more colours. The more expensive textiles, also plain ones, were made of silk, but peasants wore (plain) hemp clothes.

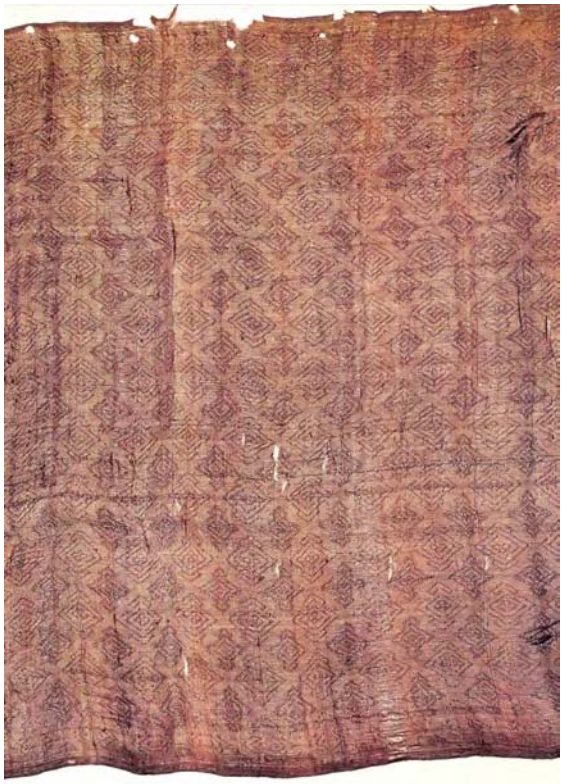
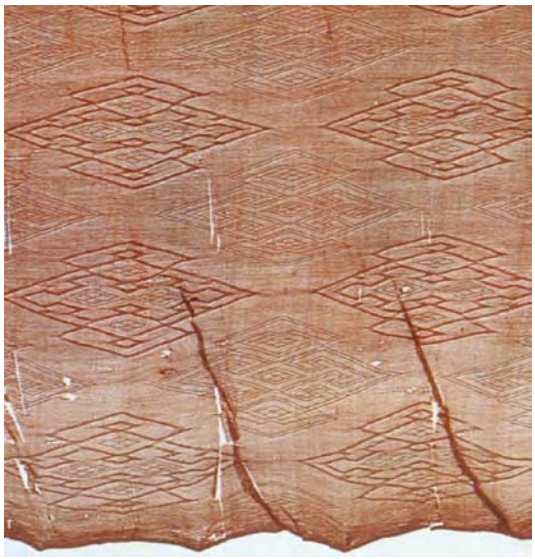


Fig. 7ab. Brown damask from Mawangdui, tomb no. 1, lozenges measure 32, cm in length and 2.8 cm in height; working width of textile: 49.5 cm
[Arts and Crafts 6, 1991, object no. 50, colour plates, p. 62, details]

Fig. 8ab. Bright red silk gauze from Mawangdui, tomb no. 1, lozenges are about 5 x 2 cm; working width of textile: 48 cm
[Arts and Crafts 6, 1991, object no. 45, colour plates, p. 54/55, details]

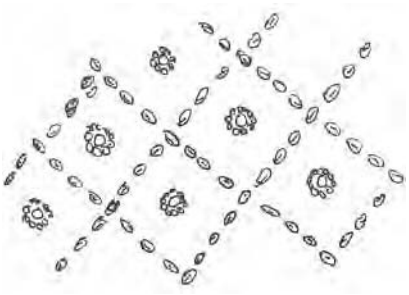
[3] Gao Hanyu 1992, p. 259-267.



The elaborate up to five coloured silk *jin*, often translated as 'brocades' as well were the most expensive and most valuable textiles of the time. Decorations with embroidery were also wide-spread and allowed to produce large-scale intricate patterns which could not be obtained by weaving techniques. Gauze embroideries following the structures of the plain silk tabby fabric produce a similar impression as woven patterns.
The findings from Xinjiang are partly imported Chinese silk textiles. The textiles from the region itself are made of wool as it is not possible to grow mulberry trees in larger scale in a desert area. Patterns are woven-in or embroidered.

For the comparison with the acrobats textiles from the Western Han Dynasty tombs in Mawangdui near Changsha are very interesting. Being produced later than the Terracotta Army (tomb no. 1 can be dated 168 BC) the textiles cannot be regarded as direct prototypes of the paint layers, but they give an idea what kind of textiles could be represented here.
Two types of monochrome patterned textiles with lozenges have been found in tomb no. 1, one being a damask (fig. 7), the other a crossing warp silk gauze (fig. 8).[4] In both textiles the ornaments appear with a relief structure. The damask is brown, the silk gauzes red to brownish red. The ornaments are broken lozenges arranged in the same way as on the acrobats' skirts, showing different types of fillings.

[4] Descriptions and photographs of textiles in Arts and Crafts 6, 1991. Damask: textile no. 50: description: catalogue p. 19, photograph: colour plates p. 62. Silk gauzes: textiles no. 45-47, description: catalogue p. 18, photographs: colour plates p. 54-57.



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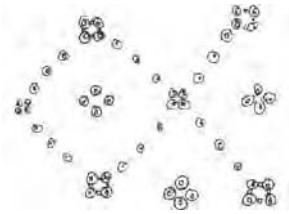

b

Fig. 9. Silk with embroidery from Mawangdui, tomb no. 1,
a. Grid 3 x3 cm, reddish brown and green ornaments on reddish brown silk)
[Arts and Crafts 6, 1991, object no. 62, catalogue p. 23, colour pl. p. 71]
b. Grid 3 x3 cm, ochre yellow ornaments on brown
[Arts and Crafts 6, 1991, object no. 62, catalogue p. 23, colour pl. p. 72]

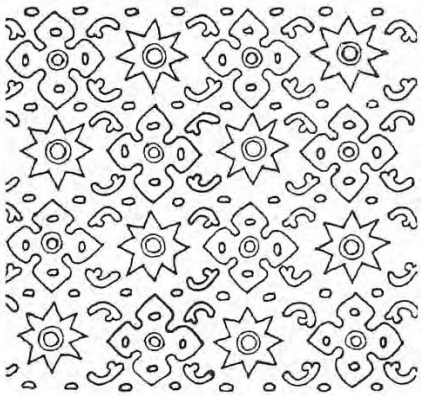

Fig. 10. Drawing of a jin textile from Mawangdui, tomb no. 1, probably two-coloured
[China, 7000 years Silk 2002, p. 48]

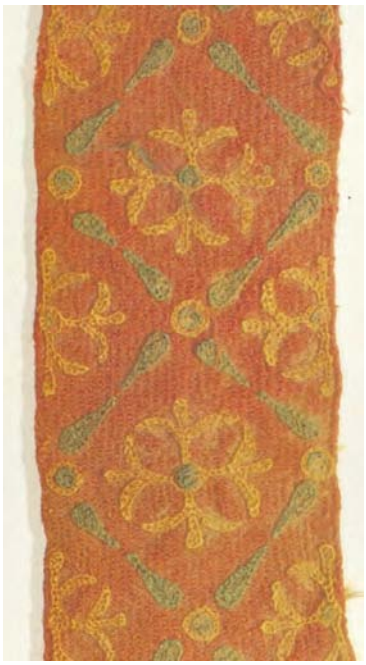

Fig. 11. Woolen embroildery, Han dynasty; tomb no. 1, from Saiyiwake, Luopo county, Xinjiang
working width of textile: 7 cm
[Arts and Crafts 6, 1991, object no. 63, catalogue p. 93, colour plates p. 73]

Examples of textiles similar to the 'rosette' decoration of acrobat no. T1G3:06 ('dots' and 'crosses' with 'leaves' according to Zhang Weixing) cannot be found so easily. Two textiles with embroidered decoration from tomb no. 1 in Mawangdui show small round elements arranged in a diagonally arranged square rhomb grid. One textile is embroidered with circles of loops around a dot as centres of the rhomb grid. The other shows the same grid, but with 'four pointed petal flowers' as centres or cross points.[5]. These textiles resemble the acrobat's skirt as they have both types of round elements ('four petal flowers' and dots arranged around a centre) which can also be found there. Different is that they are multicoloured.
For another example from the same tomb only a drawing could be found (fig. 10).[6] According to the context it is a *jin* weave and therefore probably two-coloured. It shows 'four petal flower' elements alternating with 'stars', both elements linked with 'leaves'. A third example a woollen textile from Xinjiang can serve, showing 'cross' shaped elements in a grid of rhombi embroidered in green and yellow on a red background.[7]
These four antique textiles have in common that their pattern is based on a grid of quadratic rhombi which is well visible. This element is missing on the acrobats' skirt. For the production technique damask or embroidery seem possible, maybe also a *jin* 'brocade' with coils which stick out like the nap of a velvet. The rounded shapes of the ornaments might be an indication for embroidery, although monochrome embroideries have not been found so far.

1.4 Reconstruction of the skirt of acrobat no. T1G3:06

The original impression of the skirt of acrobat no. T1G3:06 was reconstructed on a black panel, omitting the lacquer layer. The pigment layer consists of bone ash with some cinnabar (*zhusha*), resulting in a light pink. The binding medium was egg/skin glue 1:1. The paint layer was applied several times. In the top layer the brush was drawn vertically for the skirt and horizontally for the border. The effect of fabric structure can be seen in fig. 12. The pattern was transferred using a paper with holes and dusting through. For the ornaments the same mixture was use as for the ground. They were applied with paint brushes. Although the lines are partly less than a millimetre high, the patterns are well visible.

Fig. 12. Detail of panel in slight raking light.

Fig. 13. Reconstruction of skirt of the acrobat T1G3:06.
Realisation by Carolin Roth.

[5] Arts and Crafts 6, 1991, catalogue, p. 23.
[6] China, 7000 years Silk, 2002, p. 48.
[7] Arts and Crafts 6, 1991, object no. 63, description: catalogue p. 93, photograph: colour plates, p. 73.

2 Belt pendent of general from bronze chariot no. 1

The bronze chariots have not been included into a detailed investigation about the painting technique (yet). Today observations on the chariots themselves are not possible because the exhibition situation. The knowledge about the polychromy is based on photographs and descriptions only.
A comparison of patterns, colours and techniques with the terracotta sculptures is interesting and important because the polychromy is very well preserved as there is no lacquer underneath and there are various kinds of decorations. Among them there are two parts which show raised applications of colour. Both are white.

The charioteer of the bronze chariot no. 1, an officer in a general's rank and clothing, but without any protective armour, is wearing a valuable pendent hanging now from the belt, probably indicating his high rank (fig. 14). It consists of a ring hanging on a textile loop. On the ring, a string of threads or a folded textile is tied which is tucked into the jacket to be out of the way during the ride. The ring is painted white and small white dots are applied on top of the paint layer. The diameter of the ring is about 4 cm.

Fig. 14. Detail of charioteer of bronze chariot no. 1. Pendent on belt [Awakened 2001, p. 35]

Discs like this one are well known in China as *bi* discs. They are made of jade (or nephrite) can be decorated with ornaments. The most common type has a pattern of small raised dots called 'grain pattern' (fig. 15). Early examples of bi discs without decoration have been found in Sanxingdui near Chengdu/Sichuan in a capital of the Shang Dynasty (16th to 11th cent. BC). *Bi* discs can vary is dimension (there are examples of 10 to more than 25 cm in diameter) and also in the ratio of diameter to width of the ring. The example on fig. 15 has a rather broad ring.[8] On the charioteer of the bronze chariot no. 1 especially the 'grain pattern' allows to identify the pendent as jade bi disc.

Fig. 15. Jade bi disc with 'grain pattern', Han Dynasty tomb at Tianwang city, Baoji, diameter 14 cm.
[Selected treasures 2001, p. 106]

[8] This specimen also has remnants of a dragon-like animal which might have been an eye for hanging it. Normally the discs are just round.

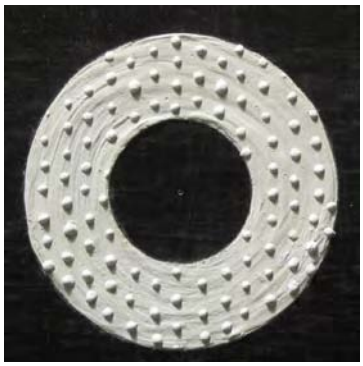

Fig. 16. Reconstructed *bi* disc on test panel, raking light. Realisation by Carolin Roth.

The bi disc was reconstructed on a black panel as well. Size and distribution of dots were calculated before from the observation that the original has always four dots in a 'row'. The diameter is 3.8 cm, the one of the inner how 1.8 cm. The dots form isosceles triangles (with three 60° angles). Compared to the original the dots might be slightly too far apart from each other, but in principle the effect is fitting. Painting materials and painting techniques were the same as for the acrobat's skirt. The pigment is pure bone ash. Every dot was applied twice.

A very similar structure of decoration with applied dots can be observed on the shield of the same charioteer. The intricate cloud (?) pattern is painted in several colours. The white can be found as smaller part of the inner structure on the outside (centre of the shield) and, in larger areas, in the border ornaments on both sides (fig. 17). Especially in the border the ornaments resemble inlay works on bronze objects, for example the shaft of the umbrella of the same chariot, where ornaments are inlaid in silver and gold into the bronze surface or the bronze shaft end of a weapon from the state of Qin (probably Qin Dynasty, fig. 18).

Fig. 17. Inside of shield of from bronze chariot no. 1. Weight areas can be recognised by the dot pattern (see arrows). Height of shield 37 cm
[Photographs: Awakened 2001, p. 36; Sketches: 秦始皇陵铜车马 1998, p. 126/127]

Fig. 18. Bronze shaft end *dun* with silver inlay [Museum of the Terracotta Army]

3 Plumage of the bronze birds

The bronze water fowl from pit K0007 originally have been painted. The paint layer is much poorer preserved than on the bronze chariots, due to damages by the virulent fire in Antiquity and to the heavy corrosion of the bronze. Nevertheless, smaller areas have remained giving some indication about the former polychromy.
The polychromy can be classified basically into black and white ones. From all birds restored so far, cranes and swans are white, while geese are white or black (fig. 19). The respective colour covers the birds completely and serves as priming layer as well. It can be assumed that the birds had been painted realistically on top of this layer with accents of other colours like reddish beaks or the grey and red areas typical for cranes. There are only few hints for this realistic conception as tiny remnants of red on the head of crane no. 25.[9] This is not astonishing as most of these accents probably had been painted as thin glazes on top of the main colour. The same can be observed on some warriors of the terracotta army where the colouring of lips and moustache is lost today.

3.1 Materials

On some of the birds pigment determinations were made. White layers contain bone ash[10], black layers soot.[11]. The only example of a colouring in the first layer is and an addition of Chinese Purple and charcoal black in the white of crane no. 25.
The black layers are much thinner than the white ones and have a glossy surface. The appearance resembles *qi* lacquer, but the analyses proved that no lacquer had been used. The white layers mainly are very thick (up to 1mm) and mainly matt. On several birds a transition of white to brownish to almost black areas can be observed (fig. 22). These can be interpreted as discolorations caused by the fire resulting in a deposit of soot, but also in a change inside the paint layer. Maybe the binding medium got charred.

Fig. 19. Bronze goose with black plumage after conservation
[Roman Germanic Central Museum]

Like on the acrobats the blackened areas often are more compact, better preserved and slightly glossy. Analyses of the binding medium, carried out independently on samples of a white and a black bird, resulted in egg.[12] Different from the warriors, the black and the discoloured white areas have an appearance of oil-containing layers with a smoother structure and a surface gloss.

[9] Information by Duan Qingbo to Christian Eckmann from the Roman Germanic Central Museum Mainz.
[10] Polychromy of crane no. 25, swan no. 38. Pigment determination with PLM by C. Blänsdorf.
[11] Information from Susanne Greiff, Roman Germanic Central Museum Mainz.
[12] Analyses of the black bird: Dr. Ursula Baumer and the Doener Institute for the Roman Germanic Central Museum Mainz. Analysis of the white bird: Prof. Maria Perla Colombini and Ilaria Boneduce, Università di Pisa, for the Bavarian State Department of Monuments and Sites.

3.2 Feather structure

Fig. 20. Neck of swan no. 27. The black line indicates one of the bows. [Catalogue Bonn 2006, p. 193]

Fig. 21. Feathers of body between the wings, swan no. 38 [Roman Germanic Central Museum]

Fig. 22. Discoloured feathers of white swan in the museum of the Terracotta Army: body feathers (upper part) and wavy down feathers of abdomen (lower part)

The most interesting about the polychromy is that the surface structure imitates the plumage of the birds. The structures are very fine and realistically arranged. The effect is so striking that preliminary considerations were made if these structures could be imprints of real feathers.
There are four different types of structures:

1. Short feathers at the neck, forming slightly curved round bows of regular size which are arranged in circles around the neck (fig. 20).

2. Fine down feathers on chest and abdomen showing a stippled structure or fine wavy structures which vary in thickness and partly also in horizontal level (fig. 22, lower part).

3. Feathers on the body. They overlap in a fish-scale way, a new feather appearing always in the gap between two feathers of the upper row. The feathers broaden slightly to the tip which is rounded (fig. 25).

4. Long pinions of the wings, running parallel with a slightly pointed asymmetrical tip.

The feathers of the body and the pinions show the typical feather structure of fine parallel lines with slightly separate endings (fig. 21). They are about 2 cm wide. The quill is raised and 1 to 2 mm wide.
It is not possible to reconstruct a whole bird, because too much of the paint layer or its surface is missing on all birds, but it is obvious that the fine feather structure are suited to create a highly realistic impression. The distribution and design of the feather types also indicates that the artisans made observations on real birds, even distinguishing between the softer rounded feathers on the body from the harder and more pointed pinions.

3.2 Reconstruction of the application technique

In the context of the reconstructions on warriors and the panels with the decorations of the acrobats' skirts, tests were also made to reproduce the structure of the feathers. Preliminary tests already showed that it is possible to obtain a feather-like impression by structuring freshly applied and soft layers of bone ash in skin glue. After some tests a model of a black and a white plumage was made on a black panel. It was attempted to reproduce the different types of feathers and give an impression of plumage.

In general, the application of the feathers has to be started with the feather in the 'lowest' level, i.e. the one which is overlapped from all other. Practically this means, one has to work from tail to head – a slightly strange procedure as in normal drawing process one would start with the head or the front of the bird and not the last feather on the tail and the downs of the abdomen. Thus, the application of the feathers follows the system with which the feathers on a real bird would overlap.
For the application a rather soft, round bristle brush was used. The choice of the paint brush is essential for the effect. The quills are applied in a second step with a fine hair brush. They are 1 to 2 mm wide with a narrower tip.
Tests also showed that reconstructions of short feather and down feather structures are more convincing on a rounded support than on a flat one. The slight bows visible on the neck automatically develop when a broad flat brush is used on an object with a rather small diameter (like a small glass bottle or wooden pole of ca. 4 cm).

White plumage
The white layer was applied several times. In a cross section from crane no. 25 a stratification with of least five applications is discernible. As pigment bone ash was used. The binding medium was skin glue without egg to save time, because it can be applied without drying phases. If a drying time of 24 hours is allowed, the same effect can be reached with egg/glue mixture. It became obvious that the surface has to be polished until no brush marks are visible anymore. If not the brush marks interfere with the feather structure and result in a rather 'unclear' image.

Fig. 23. Reconstruction of the white plumage. Realisation by Carolin Roth.
a. Short feathers on neck, b. wavy down feathers, c. stippled structure, d. body feathers, e. pinions

For the feathers a mixture of egg/skin glue (1:1) was used. The outlines of the feathers were sketched on the ground. Every feather was executed individually. For the feathers of the body and the pinions, a thicker layer of paint was applied with a bristle brush in the shape of the feather. The structure was drawn into the wet paint, slightly overlapping the feather of the previous row. For the neck features a broader paint brush was applied with changing pressure resulting in waves of different thickness (fig. 23: a). The abdomen downs were either stippled (fig. 23:b) or applied in wavy 'lines' (fig. 23:c).

Black plumage

The black plumage was executed similar to the white one. The feathers were modelled without ground layer, because in this case the black ground layer had a bad adhesion to the extremely smooth test panel. The layers of black are much thinner than the white ones because soot is an extremely fine pigment while bone ash is rather coarse and a good filling material. For the black, egg/glue was used as binding medium and lamp soot as pigment.
After drying, the structure of the black plumage was almost invisible while the one of the white stood out clearly. Even in raking light the feathers were hard to detect. The situation changed when the surface was polished slightly with cotton wool: The surface became semi-matt and the structure became visible due to the light reflection (fig. 24).

Fig. 24. Detail of the reconstructed black plumage after polishing. Height of cut-out detail 4 cm.

Fig. 25. Detail of a well-preserved part of a black bronze bird [Roman Germanic Central Museum]

The comparison between original and reconstructed plumage (fig. 24 to 26) shows that the original has an even finer and more subtle structure. Outlines of the feathers forming a kind of 'wall' in the reconstruction are not visible in the originals. The quill is slightly too dominant in the reconstruction.
Nevertheless, the tests showed that it is possible to produce very similar feather structures with bristle brushes. It also explains why the black paint layers are thinner than the white ones and why they have to be glossy, i.e. polished.

Fig. 26. Feathers on beginning of neck on bird no. 27 [Roman Germanic Central Museum]

4 Conclusion

The tests to reproduce different kinds of plastically applied structures used on sculptures from Qin Shihuang's tomb showed that the visual impressions can be obtained very well using an egg/glue mixture. This can be applied plastically like *pastiglia* on a gesso or chalk ground. The colour has to be rather thick for this purpose and has to solidify quickly, properties which also could be reached with this mixture, but not with pure egg as binding medium.

Plastically applied structures were used very skilful: Visible brush marks can imitate different types of structures as lines in the skin structure, thread structures in textiles or feathers. Applied dots, lines and ornaments stand out clearly from the background. All plastically applied designs are monochrome, mostly white or light pink. Only on the birds, they also are executed in black.

Besides the technical aspect of realising the different structures, the question of the imitated materials is of interest.
On the acrobats' skirts textiles of different production technique are reproduced which seem to go back to existing prototypes. Some of the patterns and ornaments can be found in very similar arrangements on textiles from the Western Han Dynasty, excavated in Mawangdui. The interpretation of the ornaments and the production technique imitated here is not finished yet.
On the belt pendent, a jade disc is imitated in the same technique. The white areas on the shield of the bronze charioteer might imitate a similar structured paint layer on a real leather shield, but also resembles inlays as they were used in bronze objects in that time. White can stand for silver, as on the belt hooks of the horsemen of the terracotta army, but could also depict jade or bone.
The plumage of the bronze birds is technical the most challenging of these applied decorations although it is only produced by bristle brushes. The principle method for the execution could be found in the reconstruction tests, but the originals are even finer and more realistic than the reconstructed ones. Also for the reconstruction it became clear that it was necessary to observe living waterfowl to study their plumage, the shape, size and overlapping of the feathers. According to our observations on the geese and swans in parks of Munich, the realism on the bronze birds is striking.

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The binding medium of the Terracotta army polychromies

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Introduction[1]

The binding medium of the pigment layers of the terracotta army was unknown since 2006. Attempts to identify the material(s) were made in the early 1990's, but failed completely. The only organic residues detected were components of the *qi* lacquer which obviously had migrated through the paint layer and into the adhering soil.

Another attempt by Patrick Dietemann in 2005[2] on a sample of the terracotta army also did not provide any results. The chance to have samples analysed at the University of Pisa was also made possible by Patrick Dietemann who established the contact to Maria Perla Colombini and Ilaria Bonaduce. The motivation to try analyses again also arose from the observation that paint layer flakes from a face (F-013/2003) which was had been consolidated in Munich did not dissolve after being immersed in water for days. The samples were sent to Pisa in autumn 2005 and preliminary results could be obtained just when the reconstruction of the polychromy on replicas was on the way in spring 2006.

The samples for analysis had to be selected carefully. Different colours, different parts of the body and different sculptures should be represented. Furthermore, a treatment with biocides or consolidants should be excluded as far as possible. As there is hardly any documentation of conservation treatment in China, samples either taken from freshly excavated fragments or from fragments stored and treated in Munich were preferred. In the end, a number of fragments from several kneeling archers from pit no. 2 and the face mentioned above could be provided in this way. Additionally, a quite large sample from a smashed white bronze swan from the Qin Shihuangling was provided by Katja Eckmann who was working on the conservation of this swan in the workshop of the Archaeological Institute in Xi'an at that time.[3] Altogether seven samples from different paint layers and two samples of *qi* lacquer for comparison were used for the analyses.

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1 Text of introduction by Catharina Blänsdorf.

2 Dr. Patrick Dietemann, at that time in the Central Laboratory of the Bavarian State Department of Monuments and Sites and responsible for organic chemistry.

3 Katja Eckmann, conservator-restorer from the Roman Germanic Central Museum, working in the Archaeological Institute of Shaanxi Province (陕西省考古研究所) in 2005, did the conservation of the swan with the number 38 (according to the plan of the Archaeological Institute) from pit no. K0007.

Materials and Methods

Reagents

All the solvents were Baker HPLC grade and used without any further purification. N,O-bis(trimethylsilyl)trifluoroacetamide (BSTFA) containing 1% trimethylchlorosilane, N-tert-butyldimethylsilyl-N-methyltrifluoroacetamide (MTBSTFA) with 1% trimethylchlorosilane were purchased from Sigma-Aldrich (USA). The following solutions, apart those for the amino acids, were prepared by weighting pure substances, and were used as standards:

- amino acids solution in HCl 0.1N, purchased from Sigma-Aldrich (USA) and containing 12.5 μmol/ml of proline (Pro) and hydroxyproline (Hyp), and 2.5μmol/ml of aspartic acid (Asp), glutamic acid (Glu), alanine (Ala), arginine, cysteine, phenylalanine (Phe), glycine (Gly), hydroxylysine, isoleucine (Ile), histidine, leucine (Leu), lysine (Lys), methionine (Met), serine (Ser), tyrosine (Tyr), threonine, valine (Val);
- norleucine solution in bidistilled water (Sigma-Aldrich (USA), purity 99%), 138.66 μg/g, was used as derivatisation internal standard for amino acids;
- hexadecane solution in isooctane (Sigma-Aldrich (USA), purity 99%), 80.34μg/g, was used as injection internal standard.
- derivatisating solution for amino acids prepared daily mixing 300μl of N-tert-butyldimethylsilyl-N-methyltrifluoroacetamide (MTBSTFA) with 1% trimethylchlorosilane, 700μl of pyridine and 28mg of pyridine hydrochloride (PyHCl)

All standard solutions were used to derive calibration curves

Apparatus

- OMIX pipette tips C18, 100μl (Varian, Palo Alto, CA, USA)
- Microwave oven model MLS-1200 MEGA Milestone (FKV, Sorisole (BG,) Italy).
- 6890N GC Network Gas Chromatograph System (Agilent Technologies, Palo Alto, CA, USA), coupled with a 5975 Inert Mass Selective Detector (Agilent Technologies) single quadrupole mass spectrometer equipped with PTV injector. The mass spectrometer was operated in the EI positive mode (70 eV). The MS transfer line temperature was 280°C; the MS ion source temperature was kept at 230°C and the MS quadrupole temperature at 150°C. For the gas chromatographic separation an HP-5MS fused silica capillary column (5%diphenyl-95%dimethyl-polysiloxane, 30m x 0.25mm i.d., 0.25 μm film thickness, J&W Scientific,

Agilent Technologies) with a deactivated silica pre-column (2m X 0.32mm i.d., J&W Scientific Agilent Technologies) was used.

- *for amino acid analysis.* The PTV injector was used in splitless mode at 220°C, with a splittless time of 0.7 min. The carrier gas was helium (99.995% purity) at a constant flow of 1.2 ml/min. The chromatographic conditions for the separation of silylated amino acids were as follows: initial temperature 100°C, isothermal for 2 min, then 4°C/min up to 280 °C, and isothermal for 15 min. The MS transfer line was kept at 280°C. Mass spectra were recorded both in TIC (Total Ion Current) and SIM (Single Ion Monitoring) mode.

Analytical procedure

The sample is subjected to ammonia extraction. In order to solubilize proteins and to separate the proteinaceous matter from insoluble inorganic salts, such as calcium carbonate, that can interfere in amino acid analysis, 300-400 µl of NH_3 2,5N are added twice to the sample in an ultrasonic bath at 60°C for 120 minutes.

The extracted ammonia solution (containing proteinaceous matter) is evaporated to dryness under a stream of nitrogen and redissolved in 100 µl of 1% trifluoroacetic acid solution.

The peptides and proteins contained in the acidic solution are then loaded into the preconditioned (100µl acetonitrile/water (1/1), twice; 100µl of 1% trifluoroacetic acid solution, twice) C18 tip by means of 10 cycles of dispensing-aspirating. The C18 tip is rinsed two times with 100µl of 1% trifluoroacetic acid solution to remove salts and other non- or poorly-retained materials. Peptides and proteins are thus eluted with 100µl acetonitrile/water (3/1) containing 0.1% of trifluoracetic acid, two times.

The purified peptides and proteins acidic solution is then evaporated to dryness under a stream of nitrogen and is subjected to acidic hydrolysis assisted by microwaves (Power=250 W) in vapour phase with 35 ml of HCl 6N at 160°C for 50 min. Under these experimental conditions it is possible to find a good compromise between the effectiveness of the hydrolysis of the more stable peptide bonds (ile-ile, val-val, ala-ala, ile-ala) and the need to reduce the loss of the more chemically labile amino acids.

After the hydrolysis, bidistilled water (100 µl) is added to the acid hydrolysate giving rise to the amino acids solution. An aliquot of the amino acidic solution, added with 5µl of the

norleucine solution, is evaporated to dryness under a stream of nitrogen and is subjected to derivatisation with 40µl of the derivatising solution for amino acids, at 60°C for 30min and, after the addition of 5µl of the hexadecane standard solution, 2 µl are analysed by GC-MS.

Principal Component Analysis (PCA)

The identification of the proteinaceous material (egg, casein or animal glue) in unknown samples may be performed by principal component analysis (PCA) of the relative percentage content of eleven amino acids (ala, gly, val, leu, ile, ser, pro, phe, asp, glu, hyp) using a reference data set of 79 reference samples containing egg, casein and animal glue. In particular, the PCA is performed, using XLSTAT 6.0 (Addoinsoft, France), on the correlation matrix of the data and the first two components account for 95,3% of the variance of data.

Samples

In Table 1 a description of the samples analysed is reported. The seven paint samples were collected by means of a scalpel in order to select only the pigmented layer, In addition three qi lacquer samples together to a reference sample of urushi lacquer were analysed in order to determine their proteinaceous content. A sample of earth (earth-blank) was also analysed to evaluate the contamination level introduced by the soil.

Table 1. Description and weight of the samples analysed

sample	origin	description	weight (mg)
1	pit no. 2, test area 21 corridor 20 (T21G20); face of a warrior, fragment no. F-013/03, excavated in 2003	pigment layer in soil; with reddish pink from upper lip	12.7
1.2	pit no. 2, test area 21 corridor 20 (T21G20); face of a warrior, fragment no. F-013/03, excavated in 2003	pigment layer in soil; almost white: another part of the face	6.4
2	pit no. 2, T21G18, kneeling archer no. SH 001, face (fragments from area C5/C6) excavated in March 2005	several parts from the pink face in soil, one containing an imprint of a corroded bronze arrow shaft (green)	11.3
3	pit no. 2, T21G18, kneeling archer no. 8 greyish white shin protection	the shin protection was first painted green (malachite), then overpainted in greyish white, the sample contains the greyish white layer in soil	10.9
4	pit no. 0007, bronze bird no. 38, sitting swan, between the overlapping wings on the back	several fragments of thick white found inside the bird's body; surfaces show traces of soil; blue and green spots form corrosion products that penetrated the paint layer	4.5
5	pit no. 2, T21G18, warrior no. 7, sleeve, violet; sample 7/2002	violet flakes in soil	14.4
6	pit no. 2, excavation area T21G18, warrior no. SH001, shin protection, lower part	blue	11.6
7	pit no. 2, excavation area T21G18, warrior no. SH001, shin protection upper part	green	10.2
L1	008/98 button: part of an arm protection of a standing warrior, from pit no. 2, excavation area T4, test area 9 (probably infantryman): lacquered armour plates, red connection straps, button-like stitches back or not painted-sample comes from one of the "buttons"	qi laquer	1.1
L2	004/00 lacquer: part of the armour o f a charioteer from pit no. 2, T5G1, level of the waist, back; armour plates lacquered , connection straps red, "button"-like stitches pink, robe pink	qi lacquer	0.3
L3	pit no. 2; T17: collected in pit. 2, origin unknown, collected before 1998	qi lacquer	1.1
URU 1		reference urushi lacquer	0.1

Three blanks were also analysed in order to determine the ambient contamination and to determine the detection limit of the analytical procedure

Results and discussion

In Table 2 the relative amino acid composition of the investigated samples is reported together with the amount (in μg) of the sum of the quantified amino acids contained in the sample

Table 2. Relative amino acid percentage content of the investigated samples.

sample	Ala	Gly	Val	Leu	Ile	Met	Ser	Pro	Phe	Asp	Glu	Lys	Hyp	Tyr	μg
b1	13.9	33.2	10.8	18.6	9.8	0.3	6.2	4.6	2.5	0.0	0.0	0.0	0.0	0.0	0.05
b2	8.0	22.1	9.6	20.9	10.7	0.2	7.1	5.5	6.6	6.1	3.1	0.0	0.0	0.0	0.06
b3	13.9	21.1	16.4	27.5	10.2	0.2	6.0	4.0	0.6	0.0	0.0	0.0	0.0	0.0	0.11
earth	6.9	13.5	9.7	13.1	8.2	0.9	5.4	5.3	6.1	10.3	8.6	0.0	11.8	0.3	0.24
1	10.9	14.7	12.8	22.1	11.5	0.2	13.1	6.9	7.8	0.0	0.0	0.0	0.0	0.0	0.38
1.2	5.5	9.5	7.9	13.5	6.5	0.0	9.6	7.2	7.1	13.5	17.9	0.0	0.0	1.7	0.62
2	7.1	13.3	9.5	16.9	8.8	0.2	10.0	5.1	6.8	12.5	9.6	0.0	0.0	0.0	0.54
3	7.9	13.0	9.7	15.1	8.5	0.1	12.0	5.3	5.7	13.4	9.3	0.0	0.0	0.0	0.42
4	8.0	11.9	10.8	20.3	10.3	0.1	8.8	4.6	7.2	10.4	7.5	0.1	0.0	0.0	0.32
5	10.2	12.3	12.0	14.8	9.4	0.0	7.8	2.9	7.6	14.4	8.5	0.0	0.0	0.0	0.35
6	10.2	12.2	11.9	14.8	9.3	0.0	7.8	2.9	7.6	14.4	8.5	0.0	0.3	0.0	0.62
7	10.2	13.2	9.6	13.7	7.7	0.0	9.0	14.5	5.1	12.4	4.7	0.0	0.0	0.0	0.70
L1	8.9	15.5	10.1	16.8	9.2	0.1	13.3	5.4	4.0	11.0	5.7	0.0	0.0	0.0	0.22
L2	10.6	15.7	14.8	25.1	9.5	0.2	7.1	5.2	5.1	4.6	2.2	0.0	0.0	0.0	0.12
L3	25.0	28.1	6.6	9.9	5.8	0.0	14.3	2.2	2.7	2.8	2.4	0.0	0.0	0.0	0.35
URU 1	23.8	26.8	6.4	9.6	5.6	0.0	13.7	2.1	2.6	7.1	2.2	0.0	0.0	0.0	0.34

The average amount of proteins contained in the blanks, calculated as the sum of the quantified amino acids, is 0.07μg. On the basis of the calibration curves, the detection limit of the whole analytical procedure to reliably assess the presence of a protein is 0.2μg. The earth-blank contains proteins at the threshold level of the procedure: it can be considered environmental contamination.

Qi lacquer sample L1 contains proteins at the earth-blank level and sample L2 has a protein content lower than the limit. All the other samples showed a protein content higher than the earth-blank level. In Figure 1 A and B the SIM chromatograms of the URU 1 sample and sample 2 respectively are reported.

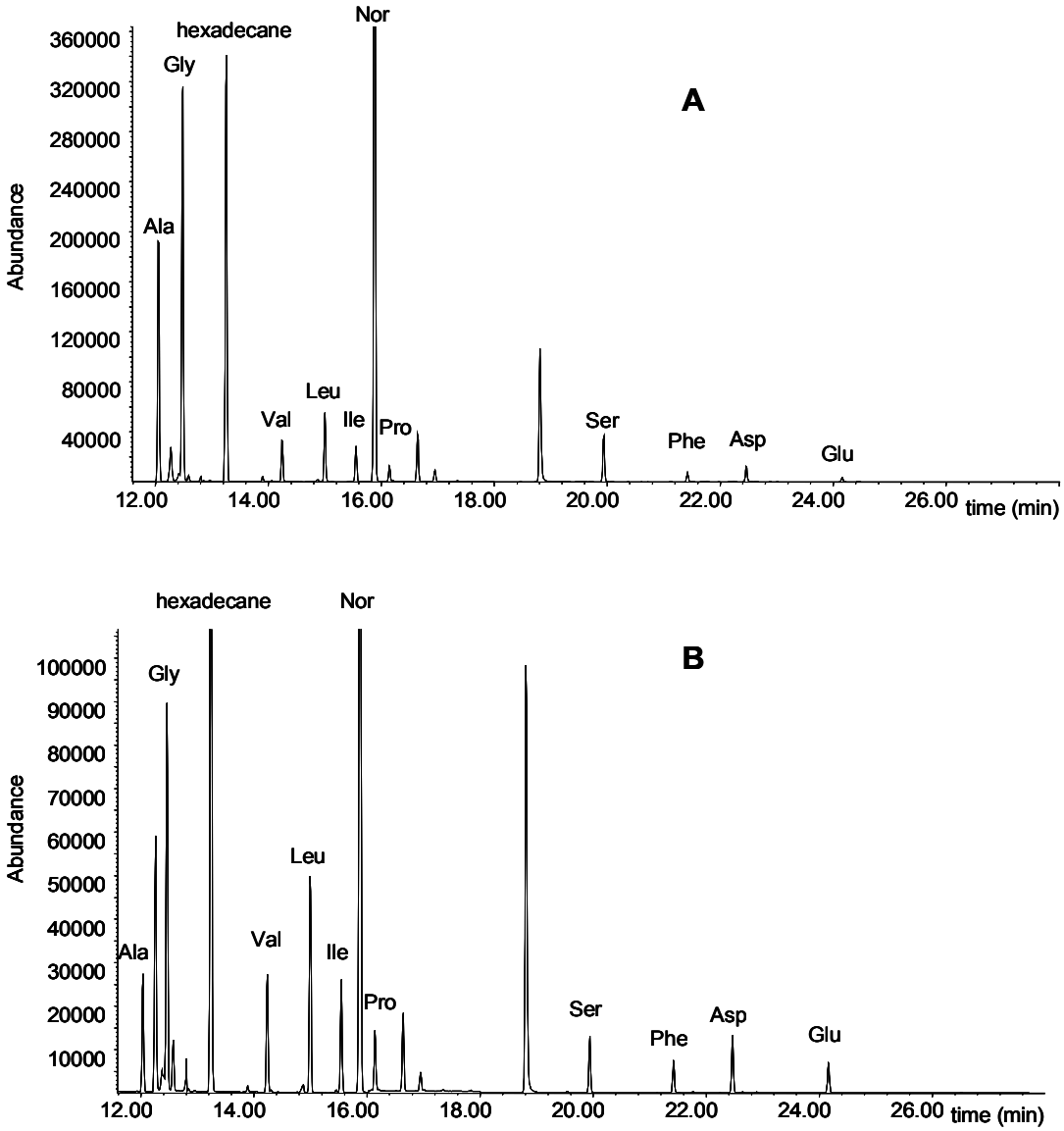

Figure 1. A SIM chromatogram of the URU sample. B-SIM chromatogram of the sample 2

A close look to the amino acid composition reveals the absence of methionine, lysine and tyrosine in almost all samples. These amino acids are considered the most labile amino acids, indicating that the proteinaceous media is partly degraded. The absence of hydroxyproline assures that animal glue is not present. The amino acid relative percentage content was thus submitted to the principal component analysis. The resulting score plot is reported in Figure 2.

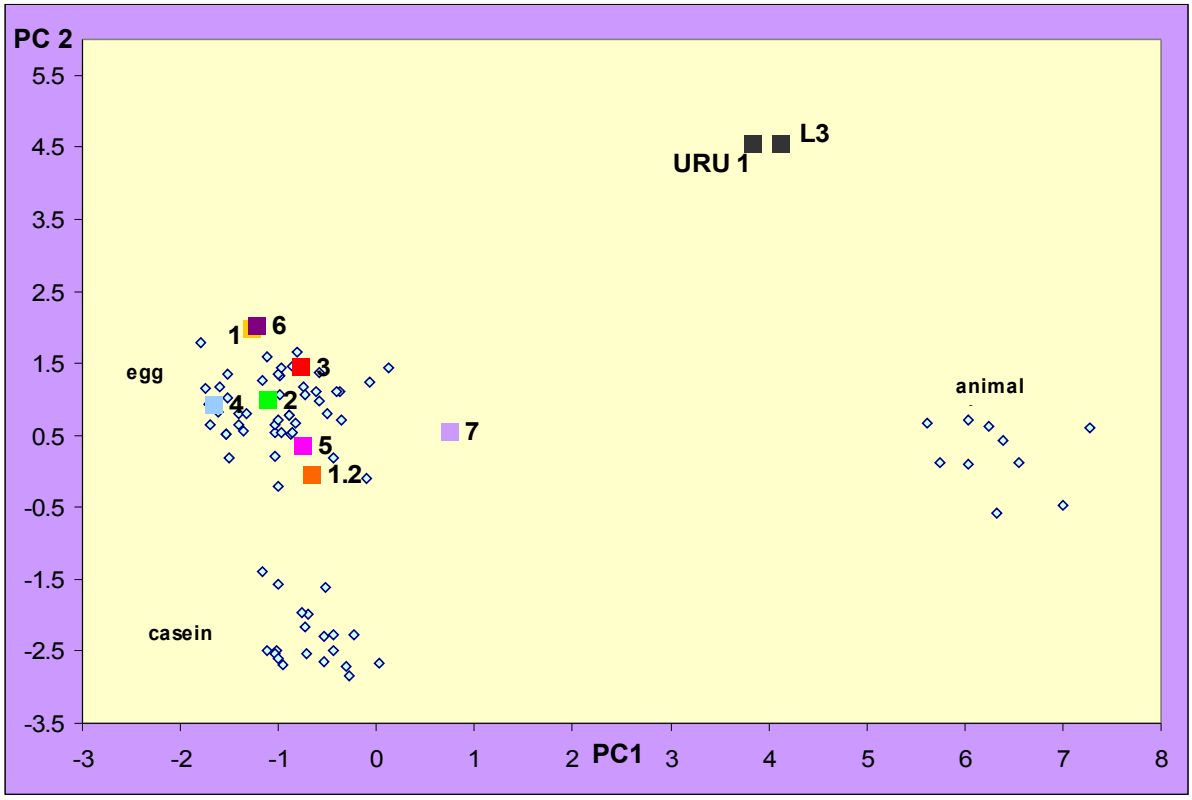

Figure 2. Principal component analysis score plot of the paint samples 1-7 and the qi lacquer sample URU 1 and L3.

All the paint samples are clearly located in the egg cluster, thus indicating that this was the binding media used. The urushi sample and the qi lacquer sample L3 (the only qi lacquer sample containing proteins in an amount higher than the ambient contamination of the earth-blank) constitute a self standing cluster well separated from the others. This result indicates that qi lacquer was not the binding medium used and that the proteinaceous content of the qi lacquer didn't penetrate the paint layer.

Conclusions

The binding media used in the polychromes of the Terracotta army is egg.

ZWISCHENBERICHT FÜR DEN ZEITRAUM: 01.01.06 BIS 31.12.06

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Vorhaben:
Erprobung und Optimierung von Konservierungstechnologien für Kunst- und Kulturgüter der Provinz Shaanxi / VR China

Darstellung der wichtigsten wissenschaftlich-technischen Ereignisse und anderer für das Vorhaben wesentlicher Ereignisse (z.B. personelle Veränderungen)

1. Personelle Veränderungen

Frau Sandra Bucher hat am 15.11.06 ihren Mutterschaftsurlaub angetreten.

2. Arbeitsaufenthalte, Delegationen

2.1. Nov./Dez. 2006 – Arbeitsaufenthalt chinesischer Kollegen vom Museum der Terrakottaarmee in München

Die Schwerpunkte des Arbeitsaufenthalts vom 3. bis 29. November der chinesischen Kollegen Herrn Rong Bo und Herrn Zhang Zhijun im Jahr 2006 waren die folgenden Themen: Klimamessungen in der Krypta St. Seebald in Nürnberg sowie Messung und Auswertung der Salzgehalte im Mauerwerk eines Bauernhauses in Schupf bezüglich der Höhen- und Tiefenverteilung.
Bei einer Exkursion nach Bamberg besuchten die chinesischen Kollegen zusammen mit Hr. Prof. Snethlage und Hr. Horn am 20. 11. 2006 Prof. Dr. Rainer Drewello. Am Lehrstuhl für Konservierungswissenschaft und Denkmalpflege der Otto-Friederich-Universität Bamberg wurde der Einsatz von modernsten 3D-Technologien wie 3D-Scannern, 3D-Software und Texturierungsprogrammen in der Denkmalpflege und die virtuelle Rekonstruktion von Kulturgütern vorgestellt.
Herr Wang Dongfeng, der bereits in den vergangenen Jahren mit Frau Bucher zusammen an der Bergung und Konservierung der Steinpanzer gearbeitet hat, setzte in der Zeit vom 3. November bis 15. Dezember die Arbeiten zur Entfernung der Korrosionsschicht von den Drähten fort und bereitete die bereits konservierten Fragmente vor, in dem einen neue Transportsicherung aufgebracht wurde.
Fast alle in München gelagerten Fragmente, insgesamt 29 Terrakottafragmente sowie ein großes und ein kleines Steinpanzerfragment wurden von den chinesischen Kollegen nach China zurücktransportiert. In München verblieben sind einige bereits beprobte Fragmente für die Untersuchung der Terrakottaeigenschaften sowie bemalte Terrakottafragmente mit noch ungesicherter Farbfassung. Weiterhin sind Einzelplatten, Steinbruchstücke und Einzeldrähte der Steinpanzer für weiterführende Versuche in München verblieben.

Von deutscher Seite fanden 2006 keine Arbeitsaufenthalte in China statt.

2.2. Lenkungsausschusstreffen

Das Lenkungsausschusstreffen fand am 20/21. Februar 2006 in Xi'an im Tanghua Hotel statt. Die Arbeiten in den einzelnen Teilprojekten wurden vorgetragen, diskutiert und das weitere Vorgehen geplant. Es wurde im Besonderen auf die Planung der Ausstellung in der Bundeskunsthalle in Bonn eingegangen. Für die Übersetzung wurde von der Münchner Seite Herr Chen beauftragt.

2.3. Aufenthalt in China zum Zweck der Besichtigung und Planung

Vom 23. – 30.7. hielten sich Herr Emmerling, Frau Blänsdorf und Herr Kocher in China auf. Die Reise diente der Besichtigung des Museum der Terrakottaarmeee in Lintong und der Steingrotten in Anyue sowie der Planung weiterer Arbeiten in den Teilprojekten. Besucht wurden das Museum der Terrakottaarmee, das Zentrum für die Konservierung und Restaurierung von Kulturgütern der Provinz Shaanxi und das Archäologische Institut der Provinz Shaanxi in Xi'an. Während des Besuchs in Anyue, Sichuan, konnten die für die Zusammenarbeit geplanten Grotten, Huayan-Grotte bei Shiyangshi und Yuanjue-grotte bei Anyue, eingehend besichtigt werden. Bei dem anschließenden Treffen im National Institute for Cultural Property (NICP) wurden neben den Arbeiten in Anyue auch weitere mögliche Projekte einer Zusammenarbeit vorgestellt und abgestimmt.

2.4. Besuch einer chinesischen Delegation

Die Delegationsmitglieder Prof. Dr. Zhao Rong, Fan Yanping, Wu Yongqi, Yin Shenping, Han Jinke und Han

Wei waren vom 24. – 28. April in München. Die Herren Wang Dongfeng und Wang Liang kamen bereits am 18. April in München an und flogen ebenfalls am 28.4. zurück. Im Rahmen des Besuchs wurden Besichtigungen des Schlosses Neuschwanstein, der Wieskirche, der Porzellanmanufaktur und des Schlosses Nymphenburg, des Schlosses Herrenchiemsee, der Fraueninsel sowie der Münchner Innenstadt unternommen. Da die Herren Zhao Rong und Wu Yongqi auf Einladung der KAH Bonn den 24. und 25.4. in Salzburg verbrachten, nahmen sie an den ersten drei Ausflügen (Neuschwanstein, Wieskirche, Nymphenburg) nicht teil. Als Übersetzer wurden Herr Chen Ganglin bzw. Frau Ma Yimin beauftragt.

3. Kongresse, Tagungen

3.1. Symposium „Unter der Gelben Erde“ in Bonn

Zum Auftakt der Ausstellung „Xi'an – Kaiserliche Macht im Jenseits“ in Bonn fand vom 21. bis 23. 4. 2006 ein Fachkongress mit internationalen Teilnehmern statt. Unter dem Titel ‚Unter der gelben Erde' wurden die wissenschaftlichen Ergebnisse vorgestellt wurden, auf denen die Ausstellung beruht. Die Beiträge werden in einem Kongressband veröffentlicht, im Januar 2007 erschienen ist.

3.2. IIC – Kongress in München

Vom 28.8 bis 1.9. 2006 fand der Kongress „Objects in context: Crossing concervation boundaries', organisiert vom International Institute for Conservation (IIC) in London und dem Doerner-Institut, in München statt. Frau Bucher und Frau Blänsdorf präsentierten in Vorträgen ihre Arbeiten innerhalb des Projektes: „Stone armor 2200 years ago: early mass production methods in China“ bzw. „A colourful world for the Emperor's soul: the polychromy of the terracotta sculptures at Qin Shihuang´s burial complex". Herr Horn stellte anhand eines Posters mit dem Thema "3D Models of Terracotta Warriors – Virtual colour reconstruction of the polychromy" seine Arbeiten zu virtuellen Farbrekonstruktionen an Figuren der Tonkriegerarmee vor.

4. Ausstellungen

4.1. Ausstellung in Bonn

Vom 21.4 – 23.7. fand in der Kunst- und Ausstellungshalle in Bonn die Ausstellung „Xian – Kaiserliche Macht im Jenseits“ statt. Die Ausstellung zeigte chronologisch geordnet, Stücke der Qin- bis Tang-Dynastie. Die Auswahl der Einzelstücke basierte auf dem chinesisch-deutschen Forschungsprojekt. Insbesondere konnten Stücke gezeigt werden, die normalerweise China nicht verlassen dürfen, jedoch ausnahmsweise gezeigt werden konnten, weil sie im Rahmen des Projektes konserviert worden sind. Die Forschungen zur Technik und die Konservierungsmethoden und –erfolge wurden in gesonderten Vitrinen, Wandtafeln und Computeranimationen vorgestellt. Zwei Animationsfilme der TU Darmstadt gaben einen profunden Einblick in das historische und geographische Umfeld der beiden großen Grabanlagen Qin Shihuangling und Zhaoling. In drei Monaten besuchten 110 000 Besucher die Ausstellung.
Während der Ausstellung fanden Themenführungen zu bestimmten Aspekten statt, die auch von Mitarbeitern des Forschungsprojektes gehalten wurden. Frau Blänsdorf stellte die Farbfassung der Terrakottafiguren vor (21. 6.), Frau Zorn aus dem Römisch-Germanischen Zentralmuseum die daoistische und buddhistische Symbolik ausgewählter Ausstellungsstücke (14. 6.).

4.2. Ausstellung im Rahmen des Wissensspeichers

Als Rahmenprogramm des IIC-Kongresses in München fand eine Reihe von Studio-Ausstellungen stand, bei denen die einzelnen Institutionen besondere Projekte der Forschung und Konservierung vorstellten. Das Bayerische Landesamt erstellte zwei Ausstellungen, von denen eine das Forschungsprojekt mit China präsentierte. Dieses war mit zwei Vorträgen auch auf dem Kongress vertreten. Die Ausstellung zeigte die verschiedenen Aspekte des Projektes mit Postertafeln, welche die Konservierung der Erdarchitektur, die Forschung zu Technologie und Konservierung der Farbfassung, Untersuchungen zur Terrakotta und deren Klebung sowie die Bergung und Erhaltung der Steinpanzer vorstellte. Fünf Vitrinen enthielten originale Bruchstücke sowie die Materialien und Werkszeuge, die zur Herstellung der Steinpanzer und zur Bemalung der Terrakottafiguren dienten. Die zwei in Bonn gezeigten großen Kopien von Kriegern mit rekonstruierter Bemalung bildeten den Mittelpunkt der Ausstellung.
Auf zwei Monitoren wurden Arbeiten zum Einsatz der Virtuellen Realität am Beispiel des Grabkomplexes des Ersten Kaisers vorgestellt: Am Computer bearbeiteten 3D-Modellen gezeigten werden, welche farbenprächtige Erscheinung die Tonkrieger ursprünglich besessen haben. Ein Video visualisierte die Farbrekonstruktion eines Generals der Terrakottaarmee. Durch eine virtuelle „Szene“, die aus mehreren Panorama-Filmen zusammengesetzt war, konnte man sich durch die Gruben der Tonkrieger bewegen.
Weiterhin wurde ein Modell eines Ganges aus Grube 2 ausgestellt, das zu diesem Anlass gebaut worden war. Einführende Texttafeln und der erste Teil des Animationsfilmes aus Darmstadt konnten aus der Bonner Ausstellung nach München übernommen werden.

Ausstellungseröffnung war 31. 8. Wegen großen Interesses wurde die zunächst für 10 Tage konzipierte Ausstellung verlängert. Sie war auch am Tag des offenen Denkmals (9. 9.) und bis zur ‚Langen Nacht der Museen' (21. 10.) zu sehen. In dieser letzten Nacht benutzten 200 Besucher die Möglichkeit, die Ausstellung zu besuchen.

5. Arbeiten zu kunsthistorischen und kunsttechnologischen Fragestellungen

5.1. Farbfassungen der Terrakottafiguren: Kleidung, Muster und Materialillusionen

Die Rekonstruktion der Farbfassung ganzer Figuren muss sich mit der Farbverteilung und der Schließung fehlender Bereiche beschäftigen, da keine Figur und kein Muster ohne Fehlstellen erhalten sind. Um korrekte Rekonstruktionen anfertigen zu können, ist es erforderlich zu verstehen, was diese Farbfassungen darstellen sollten, besonders den Schnitt der Kleidung und die Art ihrer Verzierungen. In derselben Weise können auch Skulpturen von Tieren wie Wasservögel oder Pferde und Gegenstände wie die Bronzekutschen untersucht werden.
Beispiele erhaltener Textilien aus der Zeit der Streitenden Reiche (*zhanguo*) bis Han Dynastie sowie gemalte oder modellierte Darstellungen von Bekleidungen und Mustern wurden mit den Terrakottafiguren verglichen. Diese Arbeit wird dadurch erschwert, dass es fast keine Publikationen in westlichen Sprachen gibt und auch in Chinesisch wenig grundlegende Arbeiten. Die Untersuchungen sind deshalb erst begonnen, konnten jedoch bereits einige Fragen klären. Die Terrakottakrieger tragen Jacken und haben dicke bauschige Ärmelaufschläge und Kragen. Die Untersuchungen der Farbigkeit und die Vergleiche konnten zeigen, dass die Jacken selbst mit glatten Kanten enden, Ärmelaufschläge und Kragen also zu einem Untergewand gehören. Die Generäle tragen doppelte Jacken, wobei die Kanten der Außenjacke mit schmalen Borten eingefasst sind. Zumindest in zwei Fällen ließ sich darauf eine feine Musterung nachweisen. An der Außenjacke enden die Borten in der Taille, während sie an der Innenjacke, wenn vorhanden, um alle Kanten herumlaufen. Dieselbe Art der Jacken konnte auch an den knienden Tierpflegern nachgewiesen werden. Dort sind allerdings nur die Halsausschnitte, nicht die Ärmelkanten mit Borten besetzt. Ärmelaufschläge und Kragen zeigen dieselbe Farbabfolge und sind ein- bis zweifarbig. Als dritte Farbe ist manchmal noch das Futter zu sehen, das meist hell gestaltet ist. Das Vorkommen von rosa Futterstoffen ist insofern erstaunlich, als an historischen Textilien der Zeit nur ungefärbte Futterstoffe nachgewiesen wurden.

Die an Gipskopien im Maßstab 1:1 realisierten Rekonstruktionen von Fassungen zeigten nicht nur, wie erstaunlich kräftig die Farbtöne sind, wenn sie ohne Fehlstellen und Verschmutzungen zur Wirkung kommen, und wie viele Farben zum Einsatz kamen. Die extrem farbenfrohe, aber harmonische Farbwirkung war ein überraschender Effekt dieser Rekonstruktionen, da trotz Beschreibungen dieser „Farbigkeit" in grafischen Rekonstruktionen immer sehr viel gedecktere Farben dargestellt wurden. Die Farbigkeit der Kopien ist jedoch durch zahlreiche Pigmentanalysen zuverlässig nachgewiesen. Die Bemalung der Inkarnate klärte nicht nur technische Fragen, sondern zeigte auch, dass die Maler bis in die Details der Augenbrauen realistische Darstellungen schufen.

Die Muster auf den Panzerborten herausgehobener Offiziere wurden bereits 2004 und 2005 untersucht. 2006 wurden die Muster auf den Röcken der Akrobaten untersucht, die sich technisch insofern von den Soldaten unterscheiden, als sie einfarbig und plastisch gestaltet sind. Die verwendeten geometrischen Formen sind teilweise ähnlich, z.B. die gebrochenen Rauten, gewinkelte Ornamente und achtzackige Himmelskörper (meist als „Sonne" interpretiert), teilweise aber auch ganz anders, mit geschwungenen Formen oder rosettenartigen Applikationen. Ähnlichkeiten lassen sich vor allem zu Textilien aus Mawangdui bei Changsha nachweisen. Dort wurden Stoffe gefunden, die fast identische Muster aus gebrochenen Rauten in versetzt angeordneten Reihen zeigen. Es handelt sich um Seidengazen und einen Damast. Stoffe mit rosettenartigen Dekorationen könnten Stickereien, Damaste oder auch samtartige Textilien darstellen. Die Interpretation der Muster ist auch in diesem Fall nicht einfach. Vor allem die rosettenartigen Dekorationen, die an Streublüten erinnern, sind ungeklärt, da es noch keine floralen Ornamente in dieser Zeit in China gibt. Die Erklärung als „Kreuz"- oder „Punkt"- und „Kreis"- Ornamente erscheint jedoch auch unbefriedigend. Die Herkunft dieser Formen ist auch noch unklar.

Neben Textilien sind auch andere Materialien fasstechnisch nachgeahmt worden: Am Wagenlenker der Bronzekutsche Nr. 1 stellt eine weiße, mit Pünktchen besetzte Scheibe eine *bi* Scheibe aus Jade mit dem typischen Kornmuster dar. Der Wagenlenker zeigt somit auch, dass die rituellen *bi* Scheiben als Gürtelanhänger getragen wurden. Ähnlich strukturierte weiße Flächen am Schild dieses Wagenlenkers erinnern an Einlegearbeiten, z.B. die Silber- und Goldtauschierungen an qinzeitlichen Bronzeobjekten. Dass Silber- und Beinobjekte mit weißer Farbe dargestellt wurden, zeigen die Gürtelschnallen (im Original Bronze oder Silber) und die Haarspangen und Knebelknöpfe (im Original aus Knochen) an den Terrakottakriegern.
Technisch faszinierend und einzigartig sind die Gestaltungen der Bronzevögel mit einem lebensechten Gefieder. Verschieden gestaltete Federarten, wie Flaum, Dauen und Schwungfedern und ihre Anordnung auf dem Körper können als Nachweis gelten, dass die Handwerker-Künstler der Zeit lebende Vögel genau studierten.

5.2. Aufnahme und Auswertung der Inschriften in der Jinchuanwan-Grotte

Unter der finanziellen Unterstützung der BLFD habe ich in der zweiten Hälfte des Jahres 2006 die folgenden wissenschaftlichen Arbeiten erfolgreich durchgeführt:
1. Englische Übersetzung der Texte. Die vier Texte von dem Mönch Xinxing (540-593), dem Begründer der Drei Stufen Lehre, wurde zusammen mit anderen orthodoxen buddhistischen Texten in einer Grotte in Jinchuanwan in der Provinz Shaanxi, eingemeißelt und dadurch überliefert. Drei von den Texte Xinxings sind besonders wertvoll, weil sie anderwärtig nicht überliefert sind und neue historische Materialen für die Forschung der einst populären buddhistischen Lehre bringen. Die übersetzten Texte sind:

1) Clarifying the Methods in the Scriptures about Arousing the Mind to Enlightenment in Accord with One's Depth of Capacity 明諸經中對根淺深發菩提心法
2) Clarifying the Methods in the Scriptures of the Great Vehicle about the Difference of the Mundane and Transmundane two Stages Persons Arousing the Mind to Enlightenment 明诸大乘修多罗中世间出世间两阶人发菩提心同异法
3) The Abridged Excerpts from the "Chapter of Moon Store" of the *Great Collection Sutra* 《大集月藏分经》略抄出
4) Sutra of Buddha Names of Seven Rosters 七階佛名經

2. Fotodokumentation der Grotte. Die eingemeißelten Texte und die Grotte mit ihrer Umgebung sind systematischen digital mit der Auflösung 3456x2304 Pixels dokumentiert. Von den zahlreichen Dokumentationsfotos sind 83 Bilder exemplarisch wie vereinbart mit dem A4 (210x297mm) Format entwickelt. Diese sollen der Restaurierung sowie der weiteren Forschung der Grotte dienen.

6. Untersuchung zur Maltechnik und Rekonstruktionen von Farbfassungen

Der Schwerpunkt der Arbeiten im Jahr 2006 war die Umsetzung der gewonnenen Erkenntnisse über die Farbfassung in Form von Rekonstruktionen, die auf Abgüssen, kleinen Kopien oder Musterplatten ausgeführt wurden. Zwei Abgüsse im Maßstab 1:1, eine General und ein kniender Bogenschütze, waren Ende 2005 in China vorbereitet und lackiert worden. Die Bemalung erfolgte in München und wurde Anfang April fertig gestellt. Die beiden Figuren waren in der Ausstellung in Bonn zu sehen. Die Bemalung der Kopien erbrachte über die bereits erfolgte Dokumentation der Farbfassungen weitere wichtige Erkenntnisse, welche die Wirkung der Figuren und die technische Realisierung solcher Farbfassungen betreffen.
Die Pigmente wurden den nachgewiesenen Farbmitteln entsprechend ausgewählt und zum größeren Teil in einer Beijinger Fabrik für mineralische Pigmente gekauft. Das heute nicht mehr erhältliche Chinesisch Violett wurde extra zu dem Zweck der Bemalung von Prof. H. Berke an der Universität Zürich hergestellt (insgesamt 1 kg), so dass auch hier mit dem nachgewiesenen Material gearbeitet werden konnte. Als Bindemittel wurde experimentell eine Mischung aus Hühnerei und Hasenhautleim als das Material ermittelt, das den Originalen am ähnlichste Schichten ermöglichte. Durch die Analysen an der Universität Pisa durch Prof. Maria Perla Colombini und Ilaria Bonaduce wurde Ei als Bindemittel in der Fassung der Terrakottaarmee und den Bronzevögeln zur gleichen Zeit nachgewiesen. Die Bemalung wurde durch die Dipl. Restauratorin Carolin Roth ausgeführt. Für Fragestellungen, die sich während der Arbeit ergaben, wurden von Frau Blänsdorf weitere Untersuchungen durchgeführt, wie z.B. zur Partikelgröße von Zinnober in rosafarbenen Farbschichten, sowie Farbmuster erarbeitet. Alle Flächen wurden farbig geschlossen, auch wenn für einzelne Flächen das Wissen über die Farbigkeit fehlte. Für die Schließung dieser Flächen wurden andere Figuren als Vergleich herangezogen und auch Muster der Generäle der Bronzekutschen einbezogen. Somit ergab sich ein Gesamteindruck, der zwar in Details diskutiert und korrigiert werden kann, aber eine realistische Möglichkeit für die Bemalung darstellt. Anhand der Bemalung konnten auch Fragen nach dem Pigmentverbrauch, der Art der zu verwendenden Pinsel und Werkzeuge, Auftragsstärken und Empfindlichkeit der Farbschichten geklärt werden.

Anschließend an die zeitlich auf den Ausstellungsbeginn in Bonn ausgerichteten Arbeiten wurden weitere Rekonstruktionsversuche unternommen. Elf farbig gefasste kleine Kopien von knienden Bogenschützen wurden in einer Kiste aufgestellt, die im Inneren als Modell des Ganges G18 aus Grube 2 gestaltet ist, aus dem zumindest neun der Bogenschützen stammen. Die Farbfassung zweier Tierpfleger in halber Lebensgröße wurden an kleinen Kopien ausgeführt, welche die sehr unterschiedlichen Farbigkeiten und die Art der Kleidung mit aufgesetzten Borten deutlich zeigen.

Die plastisch gestalteten Muster auf den Röcken der Akrobaten, einem Gürtelanhänger des Generals der Bronzekutsche Nr. 1 und der Bronzevögel wurde auf Musterplatten nachgestellt. Es zeigte sich, dass die gewählte Bindemittelmischung auch hier zu sehr guten Resultaten führte. Für die aufwendige Gestaltung des Federkleides der Bronzevögel konnte ein Arbeitsablauf und eine Auftragstechnik gefunden werden, die möglicherweise der ursprünglichen Technik entspricht.

Die Analysen an der Universität Pisa waren die erste erfolgreiche Bindemittelbestimmung an Proben der Terrakottaarmee. Dies wurde durch ein spezielles Verfahren erzielt, bei dem das Probenmaterial gereinigt, durch

mikrowellenunterstützte saure Hydrolyse aufbereitet und mit GC-MS analysiert wurde. Die Kombination von molekularbiologischen Verfahren und analytischer Chemie ermöglichte, auch aus den sehr geringen Probenmengen trotz Verunreinigungen und Abbau des Bindemittels noch eindeutige Ergebnisse zu erzielen. Da ein solches Verfahren bislang nicht zur Verfügung stand, waren alle bisherigen Versuche ohne positives Ergebnis geblieben.

7. Untersuchungsschwerpunkt Farbfassungskonservierung

Die Versuche im Jahr 2006 konzentrierten sich auf die Optimierung der Festigerzusammensetzung für die Elektronenstrahlmethode (EB-Methode). Die bisher verwendete Formulierung erfordert eine hohe Energiedosis zum Aushärten und der resultierende Film ist nicht flexibel genug. Polymerisationsversuche mit einem neuen, in hohem Maße hydrophilen Monomer (Glycerolmethacrylat, GMA) ergaben viel versprechende Ergebnisse. Die Zugabe dieses neuartigen Monomers zur Festigermischung hat drei große Vorteile gegenüber dem herkömmlichen HEMA (Hydroxyethylmethacrylat): Zum einen ist die zur Aushärtung erforderliche Energie deutlich herabgesetzt, der resultierende Film weist eine stärkere Haftung zur Terrakotta auf und ist zudem hydrophiler, kann also besser Wasser speichern. Im Laufe des Jahres wurde zunächst die Eignung von GMA für Elektronenstrahlhärtung untersucht, danach der optimale Anteil der Substanz in der Festigerformulierung ermittelt. Alle Tests wurden auf Objektträgern sowie auf standardisierten Terrakottaproben mit aufgelegten originalen Lackschollen durchgeführt.
Parallel wurde eine effektive Synthesemethode für das Monomer GMA im Labormaßstab entwickelt. Da GMA relativ neu auf dem Markt ist und zur Zeit noch teuer, ist eine günstige Synthesemöglichkeit von Vorteil.
Ein weiterer Punkt 2006 war die Suche nach einer geeigneten Analysemethode zur Charakterisierung der Polymere, aus denen die gefestigten Filme in der EB-Methode bestehen (v. a. PolyHEMA, PolyGMA,). Ein großes Problem ist, dass es sich um unlösliche Polymere handelt, was die meisten gängigen Analysemethoden zur Bestimmung von Molmasse und Vernetzungsgrad ausschließt. Eine spezielle Anwendung der Feststoff-NMR-Spektroskopie könnte hilfreich sein, dies muss jedoch noch weiter erprobt werden.

8. Virtuellen Farbrekonstruktionen von Figuren der Terrakottaarmee. Entwicklung und Ausführung von virtuellen Objekt- und Panoramavideos.

Farbrekonstruktion an 3D-Modellen von Kriegern der Terrakottaarmee

Der Schwerpunkt der Arbeiten für das Jahr 2006 lag auf der Vorbereitung und Ausführung der Präsentation der 3D-Modelle für die Ausstellung „Xian – Kaiserliche Macht im Jenseits“ in der Kunst- und Ausstellungshalle der Bundesrepublik Deutschland (KAH) in Bonn. Ziel der virtuellen Bearbeitung war es zu zeigen, welche Farbigkeit die Figuren der Tonkriegerarmee ursprünglich besessen haben. Mit Hilfe von am Computer bearbeiteten 3D-Modellen sollte das ungefähre ursprüngliche Erscheinungsbild der Tonkrieger visualisiert werden. Das heutige Erscheinungsbild diente dabei als Ausgangspunkt für die Ergänzung der gealterten Farbigkeit sowie für die Rekonstruktion der ursprünglichen Farbigkeit.
Für die Bearbeitung am Computer wurde die Oberfläche mehrerer Tonkrieger mit 3D-Scannern digitalisiert. Die dabei entstandenen Gitter-Modelle bilden die Grundlage für die Gestaltung der Oberfläche mit Texturen. Als Texturen wurden Digitalfotos verwendet, die den heute sichtbaren Zustand der Krieger zeigen. Auf diesen Texturen aufbauend, erfolgte die virtuelle Bearbeitung der 3D-Modelle mit einer 3D-Paintsoftware.
Anhand von zwei unterschiedlichen Ansätzen sollten die Möglichkeiten der virtuellen Realität aufgezeigt werden. Beim der ersten Variante wurde am Beispiel des knienden Armbrustschützen T21G18-01 mit dem „grünem Gesicht“ eine virtuelle Ergänzung der Farbigkeit durch Retuschen anhand gealterter Farbwerte ausgeführt. Die zweite Variante erfolgte am Beispiel des hochrangigern Generals T9:1 mit einer virtuellen Rekonstruktion der annähernd ursprünglichen Farbigkeit.
Zur Veranschaulichung der Vorgehensweise für beide Varianten wurden 3D-Animation erstellt, welche in chronologischer Abfolge die einzelnen Arbeitsschritte zeigen. Abgespeichert auf zwei DVD’s konnten beide Animationen in Form einer Endlosschleife mit DVD-Abspielgeräten kontinuierlich auf Monitoren in der Ausstellung vorgeführt werden.

Entwicklung und Ausführung von virtuellen Objekt- und Panoramavideos

Da dem Besucher der Terrakottaarmee in China der Zutritt zu den Gruben der Krieger und Pferde verwehrt ist, verbleibt ihm nur der Blick vom Grubenrand. Durch eine in der Grube angefertigte virtuelle Rundumsicht können die Tonkrieger aus unmittelbarer Nähe studiert werden. Mit Hilfe der Panorama-Videos ist es möglich, sich virtuell in die Gruben zu begeben.
Für die Ausstellung in Bonn im Jahr 2006 wurde ein Entwurf für die Präsentation von Panoramavideos erstellt; im Anschluss daran erfolgte die Ausführung und Umsetzung dieses Konzepts. Für die Präsentation auf einem Monitor in der Ausstellung wurden mehrere Panorama-Movies aus dem Grabkomplex des Ersten Kaisers zu einer „virtuellen „Szene“ zusammengefasst. Ausgehend von einer Startseite konnte hier zu drei unterschiedlichen

Panoramen navigiert werden, welche den „Blick in die Grube“ von besonders eindrucksvollen Plätzen aus den Gruben 1 und 3 ermöglichte.

9. Konservierung der Steinpanzer

Die Arbeit im Jahr 2006 konzentrierte sich auf die praktische Umsetzung des Restaurierungskonzepts. Dafür wurden verschienen Partien von Steinpanzern für die museale Präsentation fertig gestellt. Mit Hilfe der Lasertechnologie konnte die bisherige Präparation des Objekts optimiert werden: Man entschloss man sich, das Objekt auf einer durchsichten Plexiglasplatte zu präsentieren. Sie sollte es für den Betrachter ermöglichen, auch die Objektunterseite und somit das komplizierte Verknüpfungssystem der Drähte, sichtbar zu machen. Um eine sichere Auflage zu ermöglichen, musste eine passgenaue Auflage hergestellt werden. Dafür wurde die Auflagefläche mit einem Laserscanner vermessen. Mit Hilfe dieser Daten konnte eine Vakuumtiefziehform gefräst werden. Diese ermöglichte das Tiefziehen einer Acrylglasplatte mit einer Stärke von nur 2 mm. Die Platte mit eingebettetem Fragment wurde auf 4 Tragesäulen über einem Spiegel positioniert und konnte so beidseitig betrachtet werden.
Die Restaurierung erfolgte in München in Zusammenarbeit mit chinesischen Kollegen. Zunächst wurde eine exemplarische Dokumentation des Fragments erstellt. Erfasst wurden Bestand, Zustand und Restaurierungsmaßnahmen. Steinplättchen und Bronzedrähte wurden mechanisch mit Blaseballen und Pinseln gereinigt. Die Reinigung der Erdkrusten erfolgte mittels Ultraschallmeißel und Mikroschleifgerät, wobei sich besonders das Schleifgerät bewährte. Aufgrund der kleinen Schleifscheiben war ein sehr detailliertes Abarbeiten der Auflagen möglich. Da bei dem Schleifvorgang kaum oberflächlicher Druck ausgeübt wurde, bleiben auch extrem fragile Steinpartien unbeschadet. Die Festigung der stark pulverisierten Steinpartien erfolgte mit einem elastifizierten Steinfestiger auf der Basis von Kieselsäureester (Remmers 300E) behandelt. Das Festigungsmittel wurde mit einer Pipette so lange aufgetröpfelt, bis das mürbe Material keine Flüssigkeit mehr aufnahm Zum Kleben formschlüssiger Bruchkanten wurde Mowital H15-B30 in Ethanol (30%) benutzt. Bei abgeriebenen Bruchkanten wurde der Lösung 60% Glasplättchen (Größe 15 µm) als Füllstoff zugegeben und mit Pigmenten grau eingefärbt. Zur Vorisolierung wurde die Klebefläche drei Mal mit einer 1% Lösung, nass in nass bestrichen.
Ein weiterer Schwerpunkt lag auf der Literaturrecherche zum Thema Steinbearbeitung am Beispiel von Jade. Nachdem die Herstellungstechnologie der Steinpanzer weitgehend untersucht wurde, blieben Fragen offen. Die Oberfläche der einzelnen Plättchen zeigen keinerlei Bearbeitungsspuren von Sägeblättern oder Rotationsscheiben, die dazu dienten, den Stein aufzuspalten. Auch die Entdeckung der antiken Werkstätten für Steinpanzer, in welchen verschiedenste Werkzeuge und unfertigen Plättchen gefunden wurden, konnte diesbezüglich keinen Aufschluss geben. Zudem blieb die Literaturrecherche zur Bearbeitung von Kalkstein im Alten China erfolglos. Aus diesem Grund wurden Literaturangaben zur Bearbeitung von Jade konsultiert und ausgewertet. Jadebearbeitung hat in China eine jahrtausendlange Tradition. Es konnte davon ausgegangen werden, dass die Bearbeitungstechnik des äußert zähen Gesteins durchaus auch auf den um ein vielfaches weicheren Kalkstein übertragen wurde.

Stand der Arbeiten im Vergleich zum geltenden Arbeits-, Zeit- und Finanzierungsplan, Gründe für eventuelle Änderungen

Arbeits- und Zeitplan: Der Stand der Arbeiten entspricht den Vorgaben der Vorhabensbeschreibung.

Finanzierungsplan: Die Finanzierung der Forschungsarbeiten im Jahr 2006 erfolgte nach den Vorgaben des Finanzierungsplans. Einzelheiten sind der Jahresabrechnung aufgelistet.

Haben sich die Aussichten für das Erreichen der Vorhabensziele geändert? Wenn ja, welche Probleme sind entstanden?

Die Vorhabensziele konnten erreicht werden.

Haben sich die Vorhabensziele geändert? Wenn ja, warum?

Die Ziele des Vorhabens haben sich nicht geändert. Die Forschungen in den Bereichen Terrakottarestaurierung, Polychromie der Tonkrieger, Steinpanzer und virtuelle Rekonstruktion wurden planmäßig fortgesetzt. Die Vorhabensbeschreibung ist im Antrag für die Projektphase 2004 bis 2006 enthalten.

Sind inzwischen Ergebnisse anderer Arbeitsgruppen bekannt geworden, die für das Vorhaben von Bedeutung sind? Wenn ja, welche?

Trifft nicht zu

Sind für Vorhabensergebnisse
- Patente angemeldet worden?
- Erfindungen in Anspruch genommen worden?
- Neuerungen und / oder Verbesserungen bereits gemachter Erfindungen angefallen?

Wenn ja, bitte spezifizieren.

Trifft nicht zu

Liste eigener Publikationen von Vorhabensergebnissen
(bitte Sonderdruck gemäß Zuwendungsbescheid beifügen)

Publikationen

Die Publikationen befinden sich im Ausstellungskatalog und in der Publikation des BMBF „Der Vergangenheit eine Zukunft geben“. Die Publikation des IIC Kongresses kann auf Wunsch in Kopie angefordert werden.

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Catharina Blänsdorf, Xia Yin, Die Terrakottaarmee – Befunde und Analysen für eine originalgetreue Rekonstruktion der Farbigkeit, p. 169-173

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Sandra Bucher Fiuza, Duan Qingbo, Wang Dongfeng, Stone armor 2200 years ago: early mass production methods in China

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Poster: Felix Horn, '3D Models of Terracotta Warriors – Virtual colour reconstruction of the polychromy'

21. 6. Themenführung „Restaurierung und farbliche Rekonstruktion der Terrakottafiguren" in der Ausstellung in Bonn durch Frau Blänsdorf, sowie drei weitere Führungen auf Anfrage am 21. und 22. 6.

1. 9. – 21. 10. Verschiedene Führungen durch Mitarbeiter des China-Projektes in der Ausstellung „Chinas Terrakottaarmee" im Bayerisches Landesamt für Denkmalpflege München