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Paint Layers and Pigments on the Terracotta Army: A Comparison with Other Cultures of Antiquity

Today it is the terracotta itself – mostly gray, in parts reddish – that determines the chromatic impression made by the excavated clay warriors, but originally the terracotta figures were colourfully painted in rich contrasts. This polychromy was essential to the perception and appearance of the army. Research indicates that the extravagant polychromy of the clay figures is to be viewed as an imitation of the real appearance of the military uniforms of Qin Shi Huangdi's army: *"The colours of the clothes reflect the appearance of the Qin army and prove that in the Qin Dynasty the colours of the army uniforms did not mark differences of rank."*[1] It is assumed that the Qin soldiers provided their own uniforms, having their clothes sewn from available materials. One soldier, for instance, wrote to his mother "[You should] *look for low-priced silks or cottons which can be used to sew shirts and jackets.*"[2] The investigations undertaken so far give a fairly precise concept of the many colours and of the painting techniques used for the polychromy.

Fragments with flesh-coloured pigments and/or remnants thereof make it clear that there is a great variation among flesh colours. Skin tones range from light to dark and from warm to cool pink; perhaps this was to more clearly characterize the imperial army, which was recruited from various peoples of different kingdoms. *"In the 26th year of his reign (221 BC) Ch'in Shih-huang-ti annexed all the feudal lands under the heavens, brought peace to the people and declared himself the sole sovereign."*[3] As a broken piece documents, the fingernails are done in white on top of the flesh colour. The pupils were left blank within an otherwise white eyeball, so that the dark brown lacquer of the ground remains visible. The hair likewise is the brown colour of the lacquer ground, being untreated with further colour.

Individual pieces of clothing are set in contrasting colours, for example a red top with blue pants. According to findings so far, the dominant colours for the costumes are red, green, blue and purple, more seldom yellow and white[4]. So far no black has been found. Details such as collars or the hems of sleeves are set off in other colours. The uniform belts and the borders of the armor are mostly decorated with finely drawn and painted geometrical patterns. Chinese archaeologists have drawn up a detailed reconstruction of these patterns (colour plate IV, fig. 5-7).

The armament that the clay warriors wear over their clothes depicts leather armour made up of many plates, which frequently are held together by small green or red ties[5]. At stomach and shoulder level additional red fabric ribbons join the plates together, allowing the armoured body to move more easily. The armour plates are coated with brown lacquer to represent leather.[6] Grave findings from the Zhan-Guo Dynasty[7] (Age of the Warring States, 481-222 BC) substantiate that the kingdom's soldiers used shields and armor of leather that had been impregnated with lacquer. Impregnation was necessary to harden and stabilize the leather. The plates of the armour on the Qin terracotta soldiers are also coated with lacquer for the sake of realistic depiction. The fact that lacquer, rather than a paint layer of brown pigment, was used to colour the armour plates supports the theory that the terracotta army is to be regarded as an imitation of the real Qin soldiers.

A certain tension between the three-dimensional forms and the polychromy of the clay figures can be detected on the following details: Where there is only a layer of lacquer (as the ground) – i. e., where no thick-layered application of pigment was planned – the terracotta was always very carefully and individually worked. For instance, the hair on the figures is precisely incised, the soles of the shoes and the plates of the armour are differentiated. The light reflexes of the extremely thin lacquer layer make it easy to discern the finely incised decoration in the clay. In contrast, the sculptural elements that are covered with polychromy lack this finely detailed treatment. The pigment layers are conspicuously thick. This indicates that there was a foresighted overall plan for the appearance of the clay army already at the time that the figures were modelled, and that this plan took the differentiations in the polychromy into consideration.

The army of the First Emperor is characterized by such details as the differentiated flesh tones, the hair and pupils glowing with lacquer in contrast to the matte skin, the colour contrasts on individual garments, the fineness of the incisings and of the handling of the terracotta surfaces, and the geometric border ornamentations. The different optical effects from surfaces treated with lacquer or with pigment suggest the materiality of the substance – leather or textile – that was being imitated. All of these techniques made it possible to produce a colourful, 'alive' and realistic army, created for the eternal soul of the emperor in an underground world without light, never intended for the eyes of strangers.

Even if the terracotta army is an imitation of the real army, there is still the possibility that the pigments and polychrome materials could have further significance and meaning. It is particularly conspicuous that very expensive, precious, artificially-made pigments (cinnabar, malachite, azurite, orpiment, bone white, Han purple and Han blue) are documented for the polychromy of the clay warriors. Thousands of figures are painted with high quality pigments, of which an enormous quantity was needed. Yellow or green earth colours, i. e., cheaper and less colour intensive natural products, have so far not been identified. Whether these costly pigments document the luxury of the emperor or emphasize the status of his army, which had a pre-eminent importance during his reign, is an open question. Material value and aesthetic standards supplement one another in the case of an imperial patron.[8] Valuable and costly painting materials were also enjoyed by the Roman emperors, but were denounced by Pliny the Elder as a waste: The pigments *"that belong to the floridi*[9]*, or 'blooming', luminous colours, preferred by the ostentatious patrons because of their splendid appearance and their extravagance, were therefore not included in the supply contracts but had to be paid for separately or acquired by the patron."*[10] Vitruvius documents the emperor's love of 'luxury' pigments *"with expressly sharp rebuke of the degenerate* *taste that places value only on the cost of the pigment and not on artistic execution."*[11]

In contrast to the Chinese and Roman desire for expensive pigments – on the part of emperors separated by worlds – in ancient Greece the effects of different ochre tones, the *colori austeri*[12] of the so-called four-colour painting, were crucial. *"To bring the art of the brush (i. e., of painting in its narrower sense) to fruition it was necessary to employ the pigments in richer nuances ... In this period four-colour painting was a consciously practiced colouring that apparently was intended to represent traditional values."*[13] Even if four-colour painting is a technique for wall paintings and not for sculpture, a painted polychrome design is also documented on Greek sculptures, for example on small terracotta figures from the 5th century BC with their surviving paint: *"In the depths of the folds of their garments the large robed female figures on the gable of the Parthenon exhibit abundant remnants of a black pigment that apparently was intended to strengthen the natural shadow in the depths of the folds as well as the overall play of light and shadow on the figures. The same technique is found on the clay figures. The clay figure of a woman shown in a dance step wears a coat whose folds are in part flatly modelled. Only very strong brush strokes in a brown-red ochre strengthen the relief of the robes."*[14] For a correct interpretation of the iconological meaning of the pigments one must moreover take into consideration that, in contrast to the mighty temples of the Greeks, the terracotta soldiers were not created for a 'magnificentia publica'. The army was intended as a 'luxuria privata' of the emperor, for his underground, eternal life.

Painting Technique, Polychrome Build Up and Painting Materials

The fragments show differences in the build up of the paint layers. The build up consists of a dark brown lacquer ground, either one or two layers deep, followed by pigmented layers. It is not known if the terracotta surface was impregnated with a material that can no longer be identified today, before the ground was applied. The possibility of an impregnation is suggested by the lack of adhesion and by the absence of any discoloration of the terracotta because of penetration by lacquer. The sap of the East Asian lacquer tree Toxicodendron vernicifluum (Chinese: qi; Japanese: urushi) is in any case a component of the brown to dark-brown ground, the lowest identifiable layer on the terracotta surface[15]. Investigative methods included infrared spectroscopy, micro-hydropyrolysis, microchemistry and the scanning electron microscope. The two-layered ground, about 0.1 mm thick, is very sensitive to changes in moisture and reacts to loss of moisture with extreme shrinkage in volume, visible in drastic shrinkage-induced craquelure and severe arching of the existing scales. It is this extreme reaction of the ground to the loss of moisture that makes such complex conservation work necessary to preserve the polychromy. Apparently additional organic elements were mixed with the lacquer used to cover the clay figures; these additives could eventually explain the peculiar, extreme tension of the ground layer. It is still not known if the clay figures were painted according to techniques typical of the time, or if these techniques were used only for this grave complex. Polychromy work with comparable characteristics and conservation problems is unknown in the literature. Nonetheless it cannot be ruled out that similar polychromy has been lost in excavations. Cheng Te K'un describes bronze and clay findings from the Western Chou era that were coated with lacquer: *"...the decorative lacquer surfaces had flaked off... sometimes traces of the original lacquer surface may be seen."*[16] Mänchen-Helfen mentions a white drawing on a frieze with a lacquer ground in a grave chamber in Lo-yang from the pre-Han era; it could be rubbed off easily.[17] The build up of the paint layers on small figures dating from the Han era, found at the grave site in Yang Ling, is similar to that on the terracotta soldiers.[18] The pigment layer on top of the highly tension-ridden lacquer ground is matte and water soluble, as on the terracotta figures.

Through studies in Munich the following pigments could be identified on the polychromy of the terracotta warriors: natural cinnabar, malachite and azurite as natural pigments; bone white[19] and so-called Han purple as artificial pigments[20]. This is the earliest documented use of Han purple in China. It is unknown in European painting.

The pigments are variously used: there are layers of pure pigments as well as layers of pigments with small amounts of additives and layers of 'true' mixtures. Cinnabar was used without mixing for the reds. Small additions of cinnabar were found in the malachite on the green ties on the armor. Some white layers on the garments contain Han purple. The flesh tones and the purples, for example, were mixed together. Typical for all the flesh tones is the peculiar thickness of the layer (up to 0.20 mm), probably necessary to cover up the dark coloured ground. The number, colour and strength of the layers vary on the flesh tones (colour plate IV, fig. 1-7).

The following layers were identified on fragments with flesh tones:

- The flesh tones on a hand[21] are applied in two layers over the ground; the lower layer is white and very thin, the upper one pink and thick.
- The finger[22] of a different figure has a thin orange layer below and a thick layer of pink pigment above.
- Over a thick orange-coloured layer[23] (bone white and cinnabar) there is a thin, light pink layer.
- On one fragment the pink-coloured flesh shows a homogeneous pink-colored matrix consisting of a few grains of red pigment and white "clump"; Bone white and cinnabar are documented. The rose-coloured matrix is achieved using extremely finely ground cinnabar. Colourants materials in the flesh layers have not yet been identified.

Observations on the Use of Pigments in Ancient China

The following overview on the use of pigments is based on an analysis of the rather limited literature that is available and draws parallels to western painting techniques.

Cinnabar

As a pigment cinnabar (Chinese: tansha) is already documented in the Shang Dynasty (ca. 1650-1050 BC) on incised inscriptions on oracle bones,[24] there is evidence of the use of cinnabar on lacquerware from the Zhanguo Dynasty (480-221 BC).[25] The largest deposits of cinnabar are to be found in China and Japan.[26] The highest quality, chensha, was found in Chenzhou (Hunan Province).[27] The 'magic elixir' (Chinese: pu su chih ts'ao)[28], cinnabar was an extremely important material in ancient Chinese culture and alchemy.[29] Liu An (179-122 BC/Western Han Dynasty) already knows that *"red cinnabar is in truth mercury"*.[30] The extraction of mercury from natural cinnabar was also known to the Romans in the first century BC. Vitruvius reports *"When the veins of ore are excavated many drops of mercury separate out as a result of blows from the iron tools; they are immediately collected by the miners ... When the ore has been taken out of the oven the little drops of mercury that are precipitated cannot be collected individually because of their small size but rather are swept togther into a vessel with water, where they combine, flowing together into a mass."*[31]

According to Wang Kuike, the artificial production of cinnabar from mercury and sulfur – synthethic cinnabar (Chinese: yinzhu) – is *"probably one of the earliest chemical compounds created by man. It can be counted among the most remarkable achievements of early chemistry."*[32] In the book of Master Baopu (284-364) Ge Hong reports that *"cinnabar, if it is heated, results in mercury, which after many transformations regresses to cinnabar again."*[33] More detailed information on the relationship of mercury and sulfur and their synthesis into cinnabar is found in the Tang period (618-907) in the *"Metamorphosis of Mercury"*.[34] Around this time the Chinese discovery became known in Europe, via Arabian[35] culture.

It is not possible to establish exactly when man-made cinnabar first began to be used in place of natural cinnabar in painting; the use of artificially manufactured cinnabar is documented on red lacquerware in the Ming Dynasty (1368-1644).[36]

Cinnabar is unknown in ancient Egyptian painting[37] and in the early Mesopotamian cultures.[38] There iron oxides such as hematite and burnt yellow earth served as red pigments.[39] Egypt did not have any cinnabar deposits. In Persia, on the other hand, natural mercury sulfide and hematite have been found on painted architecture, for instance in Persepolis (c. 520-330 BC).[40]

In contrast to China, where natural cinnabar is already known as a painting material in the Shang Dynasty (1650-1050 BC), in the West the mineral was discovered around 400 BC, according to historic sources. In his Naturalis Historia Pliny the Elder quotes Theophrastus[41], according to whom cinnabar was *"discovered by the Athenian Kallias (405 BC), who originally hoped to be able to melt a red stone from the silver mines into gold. But cinnabar was already found in Spain at that time, although in a harder and sandier state ... The Greeks call cinnabar dragon's blood (kinn...baris) ... That is also what they* [the Greeks] *call the manure-like liquid of a dragon squashed by the weight of a dying elephant, when the blood of the two animals mixes ... There is however no other pigment in painting that renders blood so characteristically."*[42]

According to Rhousopoulus[43], cinnabar (also called 'minium' in classical sources) was already used before the time of Theophrastus; the pigment has been documented on polychromed limestone figures from the 6th century BC in the Acropolis Museum in Athens. Cinnabar was very popular with the Romans and was not only one of the *"inter pigmenta magnae auctoritatis"*[44], but rather also had ritual significance.[45] The pigment is documented in Pompeii.[46] Deposits were located in Spain and Ephesus.[47] According to Pliny the Elder cinnabar was mainly imported by the Romans from Sisapo in Spain, but it had to be processed in Rome. *"It is not permissible to finish and render the cinnabar in Spain; the crude ore is brought sealed to Rome, about 2000 pounds a year."*[48] According to Pliny the highest quality cinnabar was found in Ephesus.

Malachite and Green Copper Pigments

In the Qin Dynasty (221-206 BC) the pigment malachite (Chinese: kongqing, shih lu) is documented not only on the polychromy of the terracotta army but also for instance on the wall paintings in Xianyang (Shaanxi Province).[49] The malachite used to paint the terracotta figures is pure; the copper carbonate does not contain chloride. In the Mogao grottos in Dunhuang (Gansu Province) the use of malachite as well as of atacamite as a green pigment is proven.[50]

According to Yang Wenheng, copper ores were mined on a large scale in China already before the 11th century BC.[51] In 1974 a copper mine from the Spring and Autumn era (770-476 BC) was found on Tonglü Mountain in Daye, in Hubel Province southeast of Wuhan Province: a rich deposit that contained large amounts of malachite in addition to chalcocite.[52] According to archaeological discoveries from other pits in this mine, it is certain that the mine was worked from the Age of the Warring States up until the Han era, i.e., from the 5th century BC until the 3rd century AD.[53] During the Song Dynasty (960-1127) malachite was recovered on the You River (Jangxi Province).[54] Further deposits are found in Huize, Dongchuan and Gongshan in Yunnan Province.[55]

In the West the copper deposits on Cyprus[56], in the Sinai[57] and in Armenia[58] were famous; this is also the source of the term '*armenium*'[59] used by classical authors for the green pigment. An early use of malachite in Egypt is documented on the wall paintings of the 4th Dynasty (2600-2423 BC) into the period of the New Empire (1580-1085 BC).[60] In Europe the pigment is found in Pompeii[61]; in Persia in Persepolis (520-330 BC)[62]. In Pliny malachite is described under the term chrysocolla.[63]

Today there are doubts concerning the documentation worked out c. 30 to 40 years ago regarding the historical distribution and use of malachite.[64] Recent investigations more and more frequently document copper carbonate with a chloride content. The presence of atacamite has been variously interpreted: on the one hand it is assumed that the chloride-containing copper mineral is a reactive product from malachite[65] or also from Egyptian blue and Egyptian green[66]; on the other hand, that natural or synthetically manufactured[67] copper compounds with a chloride content were used as green pigment.

Blue Pigments

In early China probably only azurite (Chinese: hence) was used as a natural blue pigment.[68] Azurite was employed in painting by at least 250 BC, as evidenced by the polychromy on the terracotta army and by wall paintings from the Qin period. Azurite is also found on wall paintings from the Yuan Dynasty (1279-1368)[69] in Henan Province and on Buddhist wall paintings from the Ming era (1368-1644) in Shaanxi Province[70].

Like the Egyptians, the Chinese also produced an artificial blue pigment, so-called Han blue, a barium copper silicate (BaCuSi4O10). The chemical compound of barium copper silicate is very similar to that of Egyptian blue, a calcium copper silicate compound ($CaCuSi_4O_{10}$).[71] Vitruvius passed on the production method for Egyptian blue, which does not differ essentially from that for Han blue.[72] According to Wiedemann and Bayer[73] *"copper sulfides were used together with barite and silica sand or quarzite to make the pigments."* Barite deposits (BaSO4) can be found all over China.[74] Han blue was first discovered in 1983 by

West FitzHugh and Zychermann on painted terra-cotta from the Han era (206-220).[75] It is not known if artificial barium copper pigments were produced before the Qin Dynasty.

According to Noll, azurite and lapis lazuli[76] *"have not been found in a single case"*[77] on ancient Egyptian wall paintings. Only Spurell finds azurite on the painted eyebrows of a mummy from the Fifth Dynasty (2563-2350)[78] and on paintings from the 18th Dynasty (1580-1314 BC)[79]. In general the dominant opinion says that there was no interest in azurite in ancient Egypt because it was unstable; it was replaced by man-made Egyptian blue. The latter can be traced back to the Fourth Dynasty (c. 2600 BC), on painted stone sculptures and wall paintings.[80] The precious recipe for the production of Egyptian blue was adopted by the Romans.[81] Known in Latin as caeruleum aegypticum, Pompeii blue or *vestorianum*[82], this blue pigment has been documented in Pompeii.[83] Azurite and lapis lazuli, on the other hand, are not found in Pompeii.

In Persia architectural fragments at Persepolis (520-330 BC) exhibit mainly Egyptian blue; only very few of the investigated fragments show azurite.[84] In contrast late archaic Greek terracotta figures are painted with azurite as well as with Egyptian blue.[85]

Purple Pigments

Only ancient China invented a purple pigment, an artificially produced barium copper silicate ($BaCuSi_2O_6$) known as Han purple (compare the section on blue pigments). Han purple could be documented several times on fragments from the terracotta army.[86]

A purple clay was obtained in Greece and Egypt by mixing red ochre with chalk[87] or gypsum[88]. The Pompeian *'purpurissum'* of the wall paintings is an organic pigment (murex brandaris), *'creta argentaria'* ($CaCO_3$)[89] served as the substrate.

Investigation into pigments and techniques used in painting the Terracotta Army continues. Future findings will no doubt reveal even more clearly the precise significance of the army and its polychromy for antique sculpture as a whole. A beginning has been made with this conference.

(translated by Margaret Will)

Notes

1 SHAANXI SHENG KAOGU YANJIUSUO/SHIHUANGLING QIN YONG GENG KAOGU FAJUEDUI (eds.), [Archaeological Institute of the Shaanxi Province, Archaeological Team for the Excavation of the Terrcotta Army at the Mausoleum of the First Chinese Emperor], *Qin Shihuang ling bingmayong keng. Yihao keng fajue baogao 1974-1984* (The Pits of the Terracotta Warriors and Horses from the Mausoleum of the First Emperor of Qin. Report on the Excavation of Pit. No. 1, 1974-1984), 2 vols., Beijing 1988. (Translation into German in Extracts to LIN CHUNMEI, *Forschungsbericht Bayerisches Landesamt für Denkmalpflege, Zentrallabor* (7), Munich 1992, p. 24.

2 Written on a wooden writing tablet out of grave no. 4 (M 54:11) from the Qin era in the district of Yunmeng Suihudi (Hubei Province); in: LIN CHUNMEI, 1992, p. 24.

3 CHAN-KUO T'SE: *Ranks of the Warring States*, in: COTTERELL, ARTHUR, *Der Erste Kaiser von China*. Frankfurt am Main/London 1981, p. 70.

4 LIN CHUNMEI 1992, p. 23.

5 So far traces of red and green pigments representing the small button-like connecting ties on the armour have been found on the analyzed fragments. BRINKER, HELMUT/GOEPPER, ROGER (eds.): *Kunstschätze aus China*. Exhibition Catalogue, Zürich/Berlin/Hildesheim/Cologne 1980/81, p. 113, describe *"golden buttons ... One group of armoured warriors wore a green tunic with lavender-blue patterns on the collars and cuffs, dark blue pants, black armour with white rivets, golden buttons and purple cords, and black shoes with red ties. "* It is not specified if this is a yellow pigment or if gold leaf was really used. The Chinese say, that there is no gilding.

6 SCHLOMBS, ADELE in: LEDDERROSE, LOTHAR/SCHLOMBS, ADELE (eds.): *Jenseits der Grossen Mauer. Der Erste Kaiser von China und seine Terrakottaarmee*, Exhibition Catalogue, Dortmund 1990, pp. 292 f. refers to the depiction of small metal plates, connected in a similar manner, on figures of officers in pit no. 2.

7 Jiang Ling excavation site (Hubei Province). The royal city of Jiang Ling was the center of lacquer production during the Zhang Guo Dynasty. Lacquered leather armour in Japan is also mentioned by KÜMMEL, OTTO: *Die Kunst Chinas, Japans und Koreas*, Potsdam 1929, p. 761.

8 To correctly interpret the iconology of the pigments one must take into consideration the fact that, in contrast to the mighty temples of the Greeks, the terracotta soldiers were not created for a *magnificentia publica*. The army is the emperor's *luxuria privata* for his underground, eternal life, and is not intended for his people or for future generations.

9 The *colori floridi* are: minium (cinnabar), cinnabaris (dragon's blood), chrysokolla (green acidic copper carbonate), armenium (malachite and azurite), indicum purpurissum (indigo) and purpurissum (a white extender tinted with a red pigment).

10 PLINIUS SECUNDUS. D. Ä,: *Naturalis historiae Libri XXXVII*, First Century BC, Edition and Translation into German: KÖNIG, RODERICH/WINKLER, GERHARD: *Naturkunde*. Liber 33, Munich 1984; Liber 34, Darmstadt 1989; Liber 35, Düsseldorf/Zürich 1997; Liber 36, Darmstadt 1992; Liber 37, Kempten 1978.

11 BERGER, ERNST: *Die Maltechnik des Altertums nach den Quellen, Funden, chemischen Analysen und eigenen Versuchen*, Munich 1904 (Reprint 1992), p. 79; *VITRUV (MARCUS VITRUVIUS POLLIO): Decem Libri de architectura*, First Century BC; Latin Text and Translation into German: FENSTERBUSCH, CURT: *Vitruv, Zehn Bücher über Architektur*, Darmstadt 1964, Liber septimus, Kap. 5 & 8. *"Who among the ancients did not appear to have used cinnabar sparingly like a medicament? But nowadays whole walls are being coated with it everywhere. In addition there is copper green, purple and Armenian blue... And because they are expensive a special clause is put in the building contracts that the pigments must be provided by the patron and not by the worker. "*

12 KÖNIG/WINKLER (PLINIUS): The *colores austeri* pigments include sinopsis, rubrica (red chalk), paraetonium (chalk) or ochre and atramentum (black pigments).

13 SCHEIBLER, INGEBORG: *Griechische Malerei der Antike*, Munich 1994, p. 102.

14 BRINKMANN, VINZENZ: *Farbigkeit der Terrakotten*, in: HAMDORF, FRIEDRICH WILHELM (ed.): *Hauch des Prometheus. Meisterwerke in Ton*. Staatliche Antikensammlungen und Glyptothek, Munich 1996, p. 25.

15 For the scientific analyses see the article by HERM in this publication.

16 CHÊNG TÊ-K'UN, *Lacquer Work*, in: CHENG TÊ-K'UN: *Chou China*, Vol. III, Archaeology in China, Toronto 1965, p. 278. No scientific analyses of the coating are specified.
17 MÄNCHEN-HELFEN, OTTO VON: *Zur Geschichte der Lackkunst in China*, in: Wiener Beiträge zur Kunst- und Kulturgeschichte Asiens (XI), 1937, pp. 2-64.
18 During the work in Munich several painted fragments of grave furnishings from the Han era could be examined visually.
19 This pigment, hydroxyl apatite, is produced by burning bone material at 1000 °C.
20 Investigative methods included x-ray diffraction, energy dispersive x-ray fluorescence, electron scanning microscopy and polarization light microscopy.
21 Fragment 006-1991.
22 Fragment 005-1992.
23 Fragment 005-1998.
24 ROY, ASHOK (ed.): *Artists' Pigments. A Handbook of their History and Characteristics*, vol. 2, Washington/New York/Oxford 1993, p. 160.
25 BURMESTER, ANDREAS: *Technical Studies of Chinese Lacquer*, in: BROMELLE, N. S./SMITH, P. (eds.): *Urushi.* Proceedings of the Urushi Study Group, Tokyo, June 10-27, The Getty Conservation Institute, Los Angeles 1988, p. 163.
26 YU FEIAN: *Chinese Lacquer Painting Colors, Studies of their Preparation and Application in Traditional and Modern Times*, Hong Kong/Seattle/London 1988, p. 5: *"China's important production sites include: Yuping, Bijie, Guizhu and Anshun in Guizhou Province; Xiyang, Xiushan and Pengshui in Sichuan Province; and Baoshhan and Dali in Yunnan Province; as well as other site".*
27 WANG KUIKE: *Alchemie im alten China*, in: Wissenschaft und Technik im alten China, Basel/Boston/Berlin 1989, p. 203.
28 In accordance with his pronounced interest in the immortality the First Emperor had sorcerers working on production of a wonder drug to ensure his immortality. During the Han Dynasty alchemistic experiments involving the treatment of cinnabar with fire were begun (WANG KUIKE 1989, p. 201).
29 Ancient Chinese alchemy was composed of three parts: *"First protochemical experiments with metals and other minerals for the discovery of an elixir of life; second investigations for metallic production of artificial gold or silver as 'therapeutic' metals; third pharmaceutical and botanical research into macrobiotic plants"* (WANG KUIKE 1989, p. 201).
30 LIU AN, *Huai Nan Bi Shu* (The ten thousand infallible arts of the prince of Huai Nan), in: WANK KUIKE 1989, pp. 202-203.
31 FENSTERBUSCH (VITRUV), 1964, Liber septimus, Kap. 8, § 1-2.
32 WANG KUIKE 1989, p. 203.
33 GE HONG: *Buch von Meister Baopu*, in: WANG KUIKE 1989, p. 203.
34 WANG KUIKE 1989, p. 203.
35 A red pigment consisting of quick silver and sulfur was described by the Arabic alchemist Jabir at the end of the 8th century (KOPP, H.: *Geschichte der Chemie*, vol. 4, Braunschweig 1843-47, p. 184). According to STILLMANN, J. M.: *The Story of Alchemy and Early Chemistry*, New York 1960, p. 185, the process for making artificial cinnabar is described for the first time in Western literature in the Lucca manuscript (*Compositiones ad Tingenda*).
36 BURMESTER 1988, p. 176: *"The absence of accompanying elements prove the appliction of vermilion, a synthetic cinnabar produced by repeated sublimation."*
37 LUCAS, A: *Ancient Egyptian Materials and Industries*, ed.: HARRIS, J. R., London 1962, pp. 347-348.
38 GETTENS, RUTHERFORD J./FELLER, R. L./CHASE, W. T.: *Vermilion and cinnabar*, in: Studies in Conservation (17), 1972, p. 46.
39 LUCAS 1962, pp. 346-347.
40 STODULSKI, LEON/FARELL, EUGENE/NEWMANN, RICHARD: *Identification of ancient Persian pigments from Persepolis and Pasargadae*, in: Studies in Conservation (29), 1984, p. 148. Cinnaber was underlaid with hematite.
41 CALEY, EARLE, R./RICHARDS, JOHN, F. C.: *THEOPHRASTUS on Stones, Introduction, Greek Text, English Translation and Commentary*, Columbus, Ohio, 1956, § 59, 58: *"They say that Kallias, an Athenian, from the silver mines, discovered and demostrated the method of preparation; for thinking that the sand contained gold because it shone brightly, he collected it and worked on it. But when he saw that it did not contain any gold, he admired the beauty of the sand because of ist colour and so discovered this method of preparation. This did not happen long ago, but about ninety years before Praxiboulus was archon at Athens."*
42 KÖNIG/WINKLER (PLINIUS), Liber XXXIII, § 114, 83; According to RÖMPP: *Chemie-Lexikon*, NEUMÜLLER, OTTO-ALBRECHT (ed.), 9[th] Edition, Stuttgart 1983 (under the heading cinnabar): *"the term cinnabar is derived from the Arabic and originally meant red dust. In Greek this became kinnabari and in Latin cinnabari."* For more details see ROOSEN-RUNGE, HEINZ: *Buchmalerei*, in: Reclams Handbuch der künstlerischen Techniken, Stuttgart 1988, p. 78, also on the identification of cinnabar as the colored resin dragon's blood in antiquity. GETTENS/FELLER/CHASE 1972, p. 45: *"The name cinnaber is supposed to be of Indian origin, and was used sometimes to designate dragon's blood, a red resin."*
43 Quoted in the notes in: CALEY/RICHARDS (THEOPHRASTUS) 1956, p. 194.
44 KÖNIG/WINKLER (PLINIUS), Liber XXXIII, § 111, 80.
45 *"Cinnabar is found in the silver mines; it is now of high repute among the pigments and at one time was not only highly revered but considered sacred by the Romans. Verrius names the authorities, whom one must of necessity believe, (who say) that on feast days the faces of statues, even of Jupiter, and the bodies of the triumphant were coated with cinnabar; Camillus was adorned in this way in his triumph. ... However I am surprised at the reason for this custom, although it is known that (cinnabar) is coveted by the people of Ethiopia and that the fashionable there paint themselves completely with it and that the statues of the gods there have this colour."* KÖNIG/WINKLER (PLINIUS), Liber XXXIII, § 111 und 112, 81.
46 LUCAS 1962, p. 77.
47 The deposits of cinnabar are already mentioned in THEOPHRAST: CALEY/RICHARDS (THEOPHRAST) 1956, p. 57: *"There is also a natural and a prepared kind of cinnaber. The cinnaber in Iberia, wich is very hard and stony, is natural, and so is the kind found in Colchi ... The prepared kind comes from one place only, a little above Epheso. It is a sand that shines brightly and resembles scarlet dye ..."*
48 KÖNIG/WINKLER (PLINIUS), Liber XXXIII, § 118, 85.
49 *"The first traces of Qin wall painting were excavated from places no 1 and 3 at the old capital Xianyang, in 1974-75 and 1979, respectively. Archaeological reports ... indicate that among the approximately 440 small fragments ... were included black, red ochre, yellow, crimson, cinnabar, azurite and malachite pigments ..."*; YU FEIAN 1988, p. 23. The investigative methods are not mentioned.
50 *"The results of the analyzed samples show that malachite was used for about one third of the paintings, atacamite for two thirds."* (ZHOU GUOXIN: *Untersuchungen der Pigmente der alten chinesischen Wandmalerei*, in: Meishu yannjiu (3), 1984, pp. 61-68; German translation by HAN ZHONGGAO 1991, pp. 15/ not published.).
51 YANG WENHENG: *Gesteine, Mineralien und Bergbau*, in: Wissenschaft und Technik im Alten China, Basel/Boston/Berlin 1989, p. 247. VOGEL, HANS ULRICH: *Bergbau in China*, in: China, eine Wiege der Weltkultur, 5000 Jahre Erfindungen und Entdeckungen, Exhibition Catalogue, Hildesheim/Mainz 1994, p. 118, mentions that *"ancient mines were excavated next to Tonglü Mountain (Wuhan Province), also further to the south the copper mine Gangxia which is dated to the latter part of the Western Zhou period (11th century to 770 B.C.)."*
52 *"... the old mine has survived with all its shafts, tunneling, wooden posts and beams, and its primitive mechanisms for removal of water and extraction of the ore... It is in fact an ideal 'museum' of Chinese mining technology."* (YANG WENHENG 1989, p. 248). C14 analyses indicate that the mine was probably used between 1500 B.C. and 200 A.D. (VOGEL 1994, p. 118).
53 VOGEL 1994, p. 118.
54 YU FEIAN 1988, p. 8, cites FAN CHENGDA, *Gui hai yu heng zhi*: *"This sort of mineral is called malachite. There is also a type fragmented like clods of earth that is called paste green."*
55 YU FEIAN 1988, p. 9. It is not mentioned when these mines were active.
56 CALEY/RICHARDS 1956, § 183; KÖNIG/WINKLER (PLINIUS) Liber XXXIII.
57 COLOMBO, LUCIANO: *I colori degli antichi*, Firenze/Fiesole 1995, p. 49; ROOSEN-RUNGE 1984, p. 95.

58 KÖNIG/WINKLER (PLINIUS), Liber XXXV, § 6; in detail in AUGUSTI, SELIM: *I colori pompeiani,* in: Ministero della Pubblica Istruzione, Direzione Generale delle Antichità e Belle Arti (ed), Studi e Documentazioni, vol. I, Rome 1967, p. 61.

59 AUGUSTI 1967, p. 104.

60 LUCAS 1962, p. 345; NOLL, WALTER: *Alte Keramiken und ihre Pigmente. Studien zu Material und Technologie,* Stuttgart 1991, p. 201.

61 AUGUSTI 1967; GETTENS, RUTHERFORD J./WEST FITZHUGH, ELISABETH: *Azurite and Blue Verditer,* in: Studies in Conservation (17), 1972, p. 45-69, op. loc. cit., 19, 1974, p. 18.

62 The fragments excavated in Persepolis come from the painted architectural elements of the terrace. The sample was taken in the Hall of the Hundred Columns: *"The two relief pigments (29 and 33) and the sample from the Fogg relief (F3) were identified as malachite ($CuCO_3$ $Cu(OH)_2$), a widely occurring material in the upper oxidized zones of copper ore deposits. It has been found in numerous ore deposits in Iran."* (STODULSKI/FARELL/NEWMAN 1984, p. 145).

63 PLINIUS Liber XXXV § 6; Liber XXXIII § 86; RIEDERER, JOSEF: *Technik und Farbstoffe der frühmittelalterlichen Wandmalereien Ostturkestan,* in: Beiträge zur Indienforschung, Museum für Indische Kunst Berlin (4), 1977, p. 376; ROOSEN-RUNGE 1984, p. 89. The name chrysocolla comes from the Greek and means *"gold-glue"* because the mineral is used to solder gold: *"The goldsmiths also claimed chrysocolla for themselves to solder gold and maintained that all similar green substances have their name from it."*(PLINIUS Liber XXXIII, § 93). RÖMPP 1983 mentions a bluish green, gel-like copper mineral ($CuSiO_3$ xnH_2O) under the heading "chrysokoll".

64 RIEDERER 1977, p. 377; NOLL 1991, p. 201.

65 RIEDERER 1977, p. 377: *"This pigment (atacamite) could already be documented on painted Egyptian objects and on medieval wall paintings in southern Germany, suggesting that this is a widespread pigment employed in place of the less frequent malachite."*

66 SCHIEGL, S./WEINER, K. L./EL GORESY, A.: *Discovery of Copper Chloride Cancer in Ancient Egyptian Polychromic Wall Paintings and Faience: A Developing Archaeological Disaster.* Max-Plank-Institut für Kernphysik, Heidelberg 1989. According to investigations by SCHIEGL/WEINER/EL GORESY 1989, atacamite results from the decomposition of old Egyptian blue and green frits, with the so-called copper chloride cancer.

67 EL GORESY, AHMED/JAKSCH, H./RAZEK, M./WEINER, KARL LUDWIG: *Ancient Pigments in Wall Paintings of Egyptian tombs and temples: an archaeometric project,* Max-Plank-Institut für Kernphysik, Heidelberg 1986, p. 102.: that pigments with a copper chloride content *"were used in the Old / Middle Kingdom* (2850-1570) *as a green pigment and are recognized to be also synthetic and not natural minerals (atacamite) as indicated in the literature. No application of this pigment was found in the New Kingdom* (1570-715). *Techniques of production are discussed."*

68 RIEDERER 1977, p. 373: *"In China wurde stets Azurit verwendet."*

69 The wall paintings are now in the Museum of Art in Philadelphia. They were removed in 1924 from a temple close to Xinxiang (Henan Province). MALENKA, SALLY/PRICE, BETH. A.: *A Chinese Wall Painting and a palace Hall Ceiling: Materials, Technique and Conservation,* in: AGNEW, NEVILLE (ed.): *Conservation of Ancient Sites on the Silk Road.* Proceedings of an International Conference on the Conservation Grotto Sites, The Getty Conservation Institute, Los Angeles 1997, p. 127.

70 GETTENS, RUTHERFORD J.: *Pigments in a Wall Painting from Central China,* in: Technical Studies in the Field of the Fine Arts (VI), 1938-1939, p. 104: *"Tempel Hua Yen Ssu in I-ch'ang, Ping-Yang Fu in southwestern Shansi province."*

71 WEST FITZHUGH, ELISABETH/ZYCHERMANN, LYNDA A.: *An Early Man-made Blue Pigment from China – Barium Copper Silicate* 1983, pp. 15-23.

72 FENSTERBUSCH (VITRUV) 1964, Liber septimus, XI, reports on the synthetic production of this blue pigment: *"The discovery of the material that can be used to produce it artificially and of the method for its production earned great admiration. Sand is so finely ground with sodium carbonate that the mixture is like a flour; Cypriot copper is rasped into shavings with rough files and mixed with it, and then the mixture is sprayed with water so that it conglomerates. ... When they are dry they are put in a kiln. When the copper and the sand melt together from the force of the fire they lose ... their properties and take on ... a blue color."*

73 WIEDEMANN, HANS/BAYER, GERHARD: *Formation and Stability of Chines Barium Copper-Silicate Pigments,* in AGNEW 1997, p. 379.

74 WIEDEMANN/BAYER 1997, p. 379, with no information on the mines.

75 On Han-Blau: WEST FITZHUGH/ZYCHERMANN 1983, p. 15; on Han-Violett: WEST FITZHUGH, ELISABETH/ZYCHERMANN, LYNDA A.: *A Purple Barium Coppersilicate Pigment from Early China* 1992 (37), pp. 145-154.

76 Lapis lazuli is described as a precious stone in ancient Western sources, but its use as a pigment in antiquity has so far not been documented.

77 NOLL 1991, p. 204 and p. 209.

78 According to both PETRIE and SMITH (quoted from LUCAS 1962, p. 340) however, the painting on the eyebrows was green (a "green malachite paste") and not azurite.

79 LUCAS 1962, p. 340.

80 NOLL 1991, p. 209; LUCAS 1962, p. 342 und REAHLMANN, ERNST: *Über die Farbstoffe der Malerei in den verschiedenen Kunstperioden,* Leipzig 1914, p. 4. According to studies by EL GORESY/JACKSH/RAZEK/WEINER 1985, p. 101, the production of Egyptian blue, a blue glass frit, was known during the Old Kingdom (2850-2052 B.C.) in Egypt: *"Both are multicomponent synthetic pigments and consist of cuprorivaite ($CaCuSi_4O_{10}$) with variable amounts of wollastonite ($CaSiO_3$ with Cu); Cu-rich glass and tenorite (CuO). They were prepared by melting a Cu-rich ingredient with lime and desert sand, sometimes at temperature below 743°C – much lower than laboratory experiments showed."*

81 *"The artificial production of steel blue (Egyptian blue) was first discovered in Alexandria. Later Vestorius set up a factory in Puteoli (Pozzuoli)"*, FENSTERBUSCH (VITRUV), 1964, Liber septimus, XI.

82 The name *Vestorianum* is stamped in the Egyptian blue pigment ball that was found in Pompeii. It was Vestorianus who brought the recipe for the production of this pigment from Alexandria to Rome (COLOMBO 1995, p. 95).

83 *"In the Pompeiian blue wall colour the lighter blue is produced by mixing in more of the whitish gray medium in which the blue frits are then more seldom distributed. ... Otherwise the glass frit here is exactly the same as in Egypt, it is also in a grayish white medium of the same nature and has the same chemical and optical properties."* (RAEHLMANN 1914, p. 9). According to analyses by AUGUSTI 1967, p. 64, *"... tutti i campioni di colore azzurro, da me esaminati, presentano la medesima composizione, risultando costituiti prevalentemente da silicati di rame e di calcio ... L''azzurro pompeiano' è quindi un colore artificiale, corrispondente all'antico 'azzurro egiziano'."*

84 STODULSKI/FARELL/NEWMANN 1984, p. 149.

85 BRINKMANN 1996, p. 25.

86 HERM, in this publication.

87 NOLL 1991, p. 193.

88 LUCAS 1962, p. 346.

89 AUGUSTI 1967, p. 74.

蒂美

兵马俑的彩绘和颜料：兼与古代其它文明之比较

摘要

我们对出土兵马俑残片上的原始彩绘作了保护。项目进行期间，彩绘的工艺和材料得到了研究和分析。通过取得的成果，使我们今天对彩绘鲜明的色彩和和工艺有了较清楚的认识。不同的肤色、画得发亮的头发和瞳仁是士兵俑的典型特征。此外，其服装强烈的色彩对比以及衣服镶边的几何纹饰也颇具特色。守卫皇帝不朽之魂的大军施色艳丽，为此使用的都是优质名贵的颜料，如朱砂、孔雀石、石青、雌黄、磷灰石以及人造的无机汉紫(硅酸钡铜)。在彩绘中鉴别出汉紫硅酸钡铜，这是迄今所知这种颜料最早的使用。这么珍贵的颜料竟如此大量地使用，这一现象值得注意。

基于史料，以彩绘工艺为重点，将颜料在中国的使用与在古代其它文明中的使用作了比较。