古代雕塑彩绘和秦始皇兵马俑

The Polychromy of Antique Sculptures and the Terracotta Army of the First Chinese Emperor

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The Polychromy of Antique Sculptures

古代雕塑彩绘和秦始皇兵马俑

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Wu Yongqi · Zhang Tinghao
Michael Petzet · Erwin Emmerling · Catharina Blänsdorf (Eds.)

吴永琪 · 张廷皓 · 佩策特 · 艾默林 · 布楞斯多福 (主编)

The Polychromy of Antique Sculptures and the Terracotta Army of the First Chinese Emperor

古代雕塑彩绘和秦始皇兵马俑

Studies on Materials, Painting Techniques and Conservation

材料、绘画技术和保护之研究

International Conference in Xi'an,
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Museum of the
Terracotta Warriors and Horses, Lintong
ICOMOS Germany
Bavarian State Department
of Historical Monuments, Munich

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西安秦始皇兵马俑博物馆
德国国际古迹遗址协会
慕尼黑巴伐利亚州文物保护局

MONUMENTS AND SITES
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III

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Front Cover: Greek terracotta, about 260 BC, Staatliche Antikensammlungen München, NI727 (photographer: Christa Koppermann) – three warrior heads with polychromy (photo: Bayerisches Landesamt für Denkmalpflege)

Back Cover: Head of Terracotta Warrior with consolidated polychromy (photographer: Laboratory of the Museum ot the Terracotta Army and Bayerisches Landesamt für Denkmalpflege, Siegfried Scheder)

封面：古希腊陶俑，约公元前 260 年，慕尼黑国家古希腊罗马艺术收藏馆，NI727 (摄影：克里斯塔 · 克佩曼)
– 三个带彩绘的秦俑头像 (摄影：巴伐利亚州文物保护局)
封底：保护后的带彩绘的秦俑头像 (摄影：秦俑馆保管部实验室和巴伐利亚州文物保护局)

Editorial staff: Chen Ganglin, Irene Helmreich-Schoeller, John Ziesemer

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Preface

An international Symposium on "Polychromy of the Terracotta Army of the First Chinese Emperor Qin Shihuangdi, Studies on the Polychromy of Antique Sculptures; Materials, Painting Techniques and Conservation" was held at the Historical Museum of the Shaanxi Province in March, 1999. This was the first congress ever held on the polychromy of antique sculptures in the People's Republic of China. Polychromy of antique sculptures has, of course, been one of the central topics of discussion of archaeologists since the 19th century and has influenced comtemporary European art into the 20th Century. Intense original colouring cannot be found on a single antique Greek sculpture. Partially due to diverse influences over the centuries, partially due to the deliberate removal of existant colouring, the general public sees sculpture as monochromatic - either white or material-based in colour, even though current research proves it to have been otherwise. The state of information regarding Near Eastern cultures, Egyptian sculpture and Estruscan plastic art is similar to that which has been passed down to us on antique Greek sculpture: at an absolute minimum, fragments or shadowy traces of colour give us a vague idea of the artistic quality and original wealth of the polychromy on antique sculptures.

Thousands of terracotta figures, some life-size, some only a few centimetres high, have been excavated in China in the last twenty years. Almost all of these sculptures are elaborately painted; a large number of these figures have been preserved with their original colouring. Without a doubt the most spectacular discovery has been the tomb of the First Chinese Emperor, Qin Shihuangdi. Not only the internationally renowned Terracotta Army of the emperor, but also numerous other burial offerings are completely coloured. These realistically and intensely coloured figures give us the impression of a striking presence and power previously unknown in antique sculpture.

The papers presented at this Symposium cover not only Chinese excavations, but also examples from Egypt, the Near East and Europe. Questions concerning clothing and textiles as well as aspects of colour symbolism and the meaning of colour in different cultures were examined. And last but not least, painting techniques, materials and conservation problems in the different cultures, with concentration on the aspects of natural science and conservation, were presented.

Compiled in this publication are the revised papers presented at the Symposium; a general view, and a survey on the polychromy of ancient scupture. It is exciting to pursue the similarities and differences to be found in the finishing of sculptures in the early advanced civilisations. Parallel uses of the colour blue are particularly notable, thus supporting the presumption of an intense cultural exchange in antiquity.

The organisers of this Symposium - notably the Museum of the Terracotta Warriors and Horses, the Department of Historical Monuments, and ICOMOS - hope that the research on the polychromy of antique sculptures and the cultural exchange will continue.

We thank all Speakers for their papers and all participants in the Symposium for their interest and contributions. We would also like to thank Dr. Chen Ganglin, who edited the Chinese papers for the publication. Dr. Irene Helmreich-Schoeller proofed the English translations. Special thanks to Diplom-Restauratorin Catharina Blaensdorf who, together with the colleagues from the Museum of the Terracotta Army, Mr. Prof. Guo Baofa, Mr. Zhao Kun and Mr. Xia Yin prepared and organised the Symposium.

Dr. Egon Johannes Greipl
General Curator
Bavarian State Department
of Historical Monuments

DirectorWu Yongqi
Museum of the
Terracotta Army Lintong

Prof. Dr. Michael Petzet
President of ICOMOS

Minister Zhang Tinghao
Ministery for the Protection
of Cultural Assets,
Provinz Shaanxi

前言

1999 年 3 月，以“秦俑及彩绘文物研究保护”为主题的国际学术研讨会在中国古都西安举行，这是第一次在中华人民共和国进行的古代彩绘文物的专题讨论会。自 19 世纪以来，古代雕塑彩绘一直是考古学领域探讨的一个中心课题，它也对 19 和 20 世纪欧洲的艺术创作有很大影响。上千年由于受到各种因素的影响，特别是许多文物上尚存颜色被人为有意去除，结果今天已无一座保留当初色彩的古希腊大理石雕刻留传世间。虽然有各种新的研究成果不断证实色彩的存在，但还是有很多人认为这些雕塑本来就是单色、白色或材料原色的。论留传条件，近东文化、埃及雕像和伊特拉斯坎雕塑与古希腊的类似：正是它们留传至今的至多为微不足道的残片或模糊的色彩痕迹，使人依稀感受到古代雕像彩绘曾经的丰富和艺术质量。

在过去的 20 年里，中国出土了成千上万的陶俑，有些大如真人，有些身高不过寸许——几乎所有这些雕塑表面都敷彩，其中不少陶俑还保留着其原始的彩绘。毫无疑问，这几十年中最著名的考古发现当属秦始皇陵。不仅兵马俑，而且其它大批人偶、动物俑类的陪葬品也全部彩绘，通过这一写实的和强烈的色彩，让人领略到之前无人能够感受的活生生的古代雕塑和其感染力。

在这次研讨会中，来自世界各地的学者们有的针对中国的出土文物，有的涉及埃及、近东和欧洲的范畴。他们探讨了服饰色彩在不同文化中的象征和意义，还从自然科学和修复工艺的角度，对绘画工艺、颜色材料及保护问题进行了介绍和交流。

论文收集了研讨会上发言人所做的报告。它们勾勒出了古代雕塑彩绘的概貌，探讨了古代文明在雕塑表面表现方法上的异同。从中我们可以看到，不仅仅是在蓝色应用方面的相似性令人惊奇，而且在古代雕塑表现方法上也十分类似，可以推测，早在古代，多文明之间的文化交流便已相当密切。

这次研讨会的所有组织者——秦始皇兵马俑博物馆、巴伐利亚州文物保护局和德国国际古迹遗址协会——都怀着这样的愿望，那就是将古代雕塑彩绘的研究和文化交流继续进行下去。

我们对所有发言人所做的报告，对与会者对此专题持有的兴趣表示感谢。

我们还想向陈钢林博士先生表示谢意，他作了付梓前所有中文报告的准备和编辑。伊雷妮 · 黑尔姆赖希-舍勒博士女士作了英文校订。

最后要衷心感谢卡塔琳娜 · 布伦斯多福修复师女士，秦俑博物馆的郭宝发副研究员、赵昆、夏寅等先生，这次研讨会的准备和组织工作，正是他们一道完成的。

张廷皓局长
陕西省文物事业管理局

埃贡 · 约翰内斯 · 格莱佩尔博士
巴伐利亚州文物保护局局长

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秦始皇兵马俑博物馆

米夏埃尔 · 佩策特博士教授
国际古迹遗址协会主席

Michael Petzet

Introduction

Opening speech held in Xi'an, March 22, 1999

We have come together here in Xian, the old Chinese imperial city, on the occasion of the discovery of the First Chinese Emperor's world-famous terracotta army 25 years ago. Eleven years ago I travelled to the People's Republic of China for the first time together with Dr. Döll from the Federal Ministry of Research and Technology and with Dr. Weidemann, my colleague from the Roman-Germanic Museum in Mainz. On this journey first arrangements for the cooperation with representatives of the Province of Shaanxi were made. I had no idea then how and to what extent these agreements would have an effect on matters of conservation practice. Today, I am especially pleased to see that many of the representatives with whom these arrangements were made are present. I am sure they can remember as well as I do how we started this cooperation together. I am particularly grateful to name, as representatives of many others, Minister Zhang Tinghao and Director Wu.

Ten years ago the People's Republic of China was facing tremendous transformations. Most of all the economic changes of the past decade in China continue and affect the lives of millions of people with breathtaking speed. In Germany, as well, the reunification of both German states has caused many changes. Furthermore, the overall structure of Europe has been transformed. I am not here to talk about international politics. However, conservation practice and archaeology in particular are closely related to politics, to economy and the development of states in general – a relation which is much closer than normally assumed. The new building of the Xian Museum, for example, would not have been possible without the economic upturn in China, and the new airport of Xian is directly linked to the archaeological discoveries in Lintong. The majority of the sensational archaeological discoveries not only in the Province of Shaanxi but everywhere in China, cannot be separated from the terrific economic development. In our modern world conservationists here in the Province Shaanxi are faced with tasks and problems unheard of until then. These problems include the sheer amount of archaeological finds and their exceptional quality, the question of financing, logistic and administrative tasks. And here, apart from the daily tasks which those who work for conservation offices or museums in China have to cope with, the readiness of China to cooperate internationally was, from my point of view, an important prerequisite for managing the problems of preserving the monuments and archaeological sites. As President of ICOMOS Germany I am familiar with conservational challenges in many countries. Therefore, I may emphasise that the results of our joint efforts, some of which discussed in our conference, are extraordinary and deserve international attention.

Our cooperation resulted not only in contacts with the relevant German institutions, but also in contacts with colleagues in Switzerland, France, Italy, Japan and the United States. Conservation practice and archaeology and, in this context, science and research in the widest sense have a common responsibility to protect the historical heritage of mankind, in particular the monuments and sites on UNESCO's list of the world's cultural heritage. One of the most beautiful and impressive monuments of this category is undoubtedly the tomb of the First Chinese Emperor. The unique terracotta army is not merely a gigantic example of the antique burial culture, but, in fact, it is also the largest complex of antique sculptures discovered so far. With this spectacular discovery China has gained an outstanding position in the history of sculpture and is thus equal to the other antique civilisations in Greece, Rome or Egypt. The terracotta army has enabled China to fill people all over the world with enthusiasm about the Chinese civilisation and to redefine the status of Chinese culture. Well-known as the Chinese Wall may be, being the only building that can be seen from space, for the last 25 years Chinese civilisation worldwide has most of all been identified with the terracotta army. For millions of people the chance to see these sculptures in the original remains a life-long dream. The opportunity for me and my colleagues not just to visit these monuments but to actually take part in their preservation has been one of the most wonderful experiences of my career.

Antique sculptures were polychrome. Not only in China but also in other antique civilisations sculptures were painted in colours. Although this has been known among experts since the 19th century, scholary work, analysis of the technique and the interpretation of the meaning of polychromy are still at the beginning. Therefore, we are still far away from a comprehensive idea of what antique sculptures originally looked like. The lectures at this congress will focus on such questions as the materials. Considering the fact that these sculptures were in wet soil for over 2000 years the analysis is a challenge even to modern science. All over the world natural science in our days is confronted with unprecedented radical changes. Despite spectacular scientific achievements research on archaeometry has only just started. Advances in natural science need to be made use of for our aims. It gives me great satisfaction to know that for our joint research on the polychromy of the terracotta army we have been able to employ the latest methods and technologies and that on the occasion of this project, the restoration workshops of the Bavarian State Conservation Office have been equipped with these technologies. In the following lectures we will learn a great number of details of these modern methods.

Not only antique sculptures but also antique textiles were coloured. An understanding of the polychromy of antique sculpture is therefore only possible by understanding the types of antique clothing. Knowledge of antique clothing is a prerequisite for the understanding of the painted surfaces of the warriors. Some of the lectures on this topic will try to bring coloured sculpture and textiles together and thus bridge the gap between two isolated fields of research. Knowledge of real textile finds can be supplemented by the "documentation" as found in the colour scheme of antique sculptures – a method that has been used far too rarely. It is high time that classical archaeology pays more attention to the results of textile research. Due to its silk production the old Chinese Empire again had an outstanding position, whose influence on late antique and early Christian cultures cannot be overestimated. The history of the silk route has not yet been written comprehensively. Recent findings along this trade path offer new clues to the understanding of the cultural exchanges in the Antiquity. The idea that antique China was totally isolated from the other antique empires is completely outdated and is disproved by each new discovery.

As far as I know, it is for the first time that an international congress is held which focuses on the polychromy of antique sculpture in a global context. Usually, research concentrates on regional problems and developments, and only very rarely a scholar who, for instance, is working on aspects of the classical Greek period, can get an overall view of the latest results of contemporaneous civilisations. Xian, starting point of the antique silk route, is also for that reason predestined to hold a conference where relations, connections, interdependences, but also cultural differences in the antique world can be discussed.

The congress "Polychromy of the Terracotta Army of the First Chinese Emperor Qin Shihuangdi", organised by the Museum of Terracotta Warriors and Horses, the Bavarian State Conservation Office and ICOMOS Germany does not, of course, show all the results of a decade of German-Chinese collaboration in the field of conservation practice. This collaboration has been generously supported by the German Federal Ministry of Education, Science, Research and Technology and recently also by the Bavarian State Government. It is therefore my privilege to send you the regards of the Bavarian State Government and in particular of our Minister of Science and Art, Hans Zehetmair. An important result of our cooperation with the Office for the Protection of Cultural Goods in the Province of Shaanxi has been the realisation of a conservation concept to preserve the unique grotto temple of the Great Buddha of Dafosi near Binxian. The results have already been published by our Conservation Office. The results of our collaboration with the Museum in Lintong on questions of preserving the terracotta army will also be published soon.

The opening of our conference is another occasion to thank Minister Zhang Tinghao and all Chinese colleagues, especially Wu Yongqi, the director of the Museum in Lintong, as well as his predecessor, the famous archaeologist Professor Yuan Zhongyi. Moreover, I have to thank all those colleagues from the Bavarian State Conservation Office who have been involved in the China project, particularly Prof. Emmerling and Prof. Snethlage.

I am glad that this congress here in Xian has been made possible and I am convinced that it will be a great success. Perhaps it would even be interesting if the topic of our conference could be discussed again in Xian in ten years time, exchanging once again the latest results. Apart from that, a special concern also will be to further develop the friendship that arose in the course of the last years between the Chinese and German colleagues, using our combined efforts to seek ways to preserve our great cultural heritage.

佩策特

序言

1999 年 3 月 22 日在西安开幕式上的讲话

值世界闻名的秦始皇兵马俑发现 25 周年之际，我们汇聚到西安这座古老的中国皇城。 11 年前，我第一次来中华人民共和国旅行，同行的尚有联邦德国研技部的德尔博士和我的同事，古罗马-日尔曼中央博物馆的魏德曼博士。此行为与陕西省的单位合作拉开了序幕。我们签订的协议将会如何和在何种程度上，对文物保护方面的合作产生影响，对此我当时尚无明确的概念。今天，当我看见许多当年参加我们会谈的伙伴也在场，欣慰之情，油然而生。我敢肯定，他们同我一样，对我们合作的起步还记忆犹新。在这里，请允许我怀着由衷的谢意，提代表许多人的两位的名字，张廷皓局长和吴永琪馆长。

十年前，中华人民共和国面临巨大的改革。过去十年里，中国发生的经济变革最为显著，这一变革没有终止，而且正以惊人的速度改变着成千上万人的生活。在德国，两德统一也带来了某些变化，连欧洲的整体结构也变了。我在这里并不想谈论国际政治，但是，文物保护，尤其是考古与政治、经济和国家的整体发展不无联系，其联系比一般人想象的要紧密得多。没有中国的经济发展，譬如就不可能有西安的陕西历史博物馆的新馆，而西安新机场的建成，则与临潼的考古发现息息相关。不仅陕西省，而且在中国各地，大量令人惊异的考古发现均与飞速的经济发展有着不解之缘。当今世界，文物保护工作者在陕西省所面临的任务和问题都是

空前的。问题不仅在于这儿考古发现的数量之众，质量之精，而且涉及经费、后勤和管理。姑且不论中国文物保护工作者和博物馆专家所要对付的日常任务，在我看来，中国愿意进行国际合作，乃是有效解决古迹和考古遗址的保护问题的一个重要前提。作为德国国际古迹遗址协会的主席，我熟谙许多国家的文物保护工作。因此，我可强调指出，我们双方共同努力的成果是非同寻常的，应受到国际上的重视，在这次研讨会上，我们将有机会对部分成果进行讨论。

我们的合作单位不仅包括有关德国的专业机构，而且还有瑞士、法国、意大利、日本以及美国的同事。文物保护和考古，在这一点上，还有最广义的科学和研究，都要共同对保护人类的历史遗产、尤其是联合国科教文组织名单上的世界文化遗产负责。毋庸置疑，这一级别中最美、给人印象至深的文物之一，就是秦始皇陵。举世无双的兵马俑不仅是古代墓葬文化的巨制，而且事实上也是迄今为止所发现的古代雕塑中最大的群体。由于这一引人瞩目的发现，中国在世界雕塑史中也获得了显著地位，可与古希腊、罗马和埃及文明相媲美。通过兵马俑，中国能唤起世人对于中国文明的热情，中国文化的地位因此也要重新定义。尽管中国长城妇孺皆知，她是太空中可见的唯一建筑，但在过去 25 年里，世界上大多数人均把兵马俑与中国文明作等量齐观。亲眼目睹真实的兵马俑，对成千上万的人来说，乃是毕生的愿望。至于我和我的同事不仅有机会参观这些文物，而且竟然能亲身参与保护它们，这不能不说是我事业中最美好的经历之一。

古代雕塑是敷了彩的。不单在中国，而且在其它古文明中的雕塑均经过彩绘。即使这一事实自 19 世纪以来已为专家所了解，但科学研究、技术分析乃至对彩绘意义的阐释仍然处于起步阶段。因此，古代雕塑的外貌究竟如何，我们的认识还是非常不全面的。这次研讨会上，将有报告专门探讨诸如有关彩绘材料方面的问题。鉴于这些雕塑在湿土下埋藏了 2000 多年，即使对现代科学而言，分析工作也并非不是一种挑战。当今世界各地，自然科学都面临空前彻底的变革。尽管这些科学成就引起轰动，可是考古定年学的研究才刚开始。为了我们的目标，我们要充分利用自然科学的进步。我感到十分欣慰的是，在共同研究兵马俑的彩绘时，我们成功地使用了最新的方法和工艺，项目着手之际，巴伐利亚州文物保护局的修复车间已掌握了这一工艺。在下面的报告中，我们将会更多地了解这些先进方法的细节。

不仅古代雕塑，而且古代纺织品也都上过彩。因此，只有理解古代服装的形式，才能理解古代雕塑的彩绘。对古代服装的认识又是了解兵马俑表面彩绘的前提之一。这次会上的有些报告将围绕这个专题，在彩绘雕塑和彩绘纺织品的结合观察上进行尝试，从而消除两个孤立的研究领域之间的隔阂。对出土纺织品的认识可以作为补充文献，来说明古代雕塑的彩绘配色，然而难得有人使用这种方法。古典考古学应立即更加重视纺织品的研究成果才是。古代中华帝国因其丝绸生产也占优先地位，她对古代晚期和早期基督教文化的影响再怎样评价也不会过高。全面的丝绸之路史尚未有人撰写。这条贸易之路迄今仍在使用，沿路最近的考古发现会对我们了解古代文化交流提供新的线索。那种古代中国与其它古代帝国彻底隔绝的观点业已完全过时，这一点在每次考古新发现中都得到了证实。

据我所知，举办以世界范围的古代雕塑彩绘为题的国际研讨会，这还是第一次。通常情况下，研究集中在地区问题和发展上，象一个如从事研究希腊古典时期的学者，又能通观同时期其它文明的最新成果的，实在是凤毛麟角。西安是古代丝绸之路的起点，也是基于此因，注定要在这儿举行研讨会，来探讨古代世界不同文化的关系、交往、相互依赖以及彼此差别。

这次“秦始皇兵马俑彩绘”研讨会系由兵马俑博物馆、巴伐利亚州文物保护局和德国国际古迹遗址协会共同举办，她当然不能展示这十年德、中两国在文物保护领域合作的所有成果。这一合作得到了德国教育、科学、研究和技术部的经济援助，新近又得到巴伐利亚州政府的赞助。因此我很荣幸向你们转达巴伐利亚州政府、尤其是我们的科学和艺术部的汉斯·策厄特迈尔部长的问候。我们和陕西省文物事业管理局合作的一项重要成果，是实施保护独特的彬县大佛寺的维修方案。该成果已由我们保护局出版。我们与临潼秦俑馆合作保护兵马俑的成果，也将会不久出版。

置研讨会开幕之际，我想向张廷皓局长和所有的中方同事、特别是临潼秦俑馆的吴永琪馆长及他的前任、著名的考古学家袁仲一教授致以谢意。此外，我还想向参与中国项目的巴伐利亚州文物保护局的所有同事、尤其是艾默林教授和史奈特拉格教授表示感谢。

这次研讨会能在西安举行，我很高兴，我相信，她一定会取得圆满成功。倘若十年后，又在西安讨论我们研讨会的专题，重新交换最新成果，那也许是饶有趣味的。此外，我们特别关切的是，继续发展多年来在中、德双方同事间建立的友谊，经过我们共同的努力，去探索保护我们伟大的历史遗产之途径。

(英译中：陈钢林)

袁仲一

秦始皇陵兵马俑服装的颜色

秦兵马俑坑是中国历史上第一个封建皇帝秦始皇陵园中的一组陪葬坑，距今已有 2200 多年的历史。一、二、三号兵马俑坑内共有陶俑、陶马约 8000 件。其中有车兵、骑兵、步兵等不同的兵种。它是以秦王朝真实的军队作为原形塑造的，是秦军的缩影。陶俑身上原来通体彩绘，可惜出土时颜色大部分已脱落，仅存少量的残迹，个别的残存的颜色较多，色彩如新。通过陶俑身上残存的色彩，可以大体上了解两千多年前秦人对服色的爱好和审美情趣等许多社会问题。

一、陶俑彩绘颜色的出土情况

兵马俑坑出土的陶俑身上残存的彩绘颜色，主要有红、绿、蓝、紫、黄、黑、白等，各色在色调上因深浅浓淡的不同而有多种不同的色阶。

陶俑身上原来全部绘彩，但在俑坑建成初期因山洪爆发陶俑被水浸泡，公元前 207 年又因农民起义军项羽放火烧了俑坑，经过这两次大的劫难，陶俑身上的彩绘颜色已大部分脱落。陶俑出土时存留下来的颜色，一部分已和陶俑脱离粘附于泥土上，有些颜色虽仍存留在陶俑身上，因埋在地下两千多年受自然的破坏，颜色对俑体的附着力已很脆弱极易脱落。

彩绘的方法：是先平涂一层生漆作底，在底层上再涂绘彩色颜料。涂层的厚度不一，生漆层厚 0.03-0.06 毫米，颜色层厚者为 0.09-0.20，薄者为 0.01-0.04 毫米。以生漆作为底层的作用是使俑体的表面滑涩相宜，吸水适度，利于施色，并增强颜料的附着力。在陶质器物上彩绘以生漆作底的技艺创始于秦，流行于汉，汉代以后罕见，似乎已被施用胶矾水处理绘画材料的方法所取代。

颜料的物质成分经分析鉴定：大都是天然的矿物颜料，其中的紫色、铅白和铅丹被认为是用化学方法制造的。紫色为硅酸铜钡，这种物质是本世纪八十年代才被偶然发现而为人们所认识的，在自然界中未见发现。关于铅白($2PbCO_3 \cdot Pb(OH)_2$)和铅丹(Pb_3O_4)的制造，分别见于公元前 4 世纪的《计倪子》和公元前 2 世纪的《淮南子》两部书中。兵马俑彩绘颜料中的硅酸铜钡和铅白、铅丹的发现，进一步证实了中国远在两千多年前已能采用化学方法制造颜料，在科技史上具有重要的意义。

二、各类不同陶俑的服饰颜色

一、二、三号兵马俑坑出土的陶俑，以其身份地位的不同可分为军吏俑和一般士兵俑两大类。而军吏俑中又有高级军吏俑及中级、下级军吏俑的区别；一般士兵俑中又有车兵、骑兵、步兵等不同的类别。 这些不同的武士俑衣服颜色的情况，举例简要介绍如下：

高级军吏俑(俗称将军俑)：二号兵马俑坑 T4 试掘方出土的一件高级军吏俑，身穿双重长衣，外重长衣为深紫色(近似玄黑)，内重长衣为朱红色，下身穿粉绿色长裤，头戴褐色冠，脚上穿黑色履。上身并穿着彩色鱼鳞甲，甲片为褐色，甲片上缀有朱红色的联甲带，甲衣的周边及领部、胸部、肩部绘有精美的彩色图案花纹，花纹的颜色丰富、艳丽。另外，还有几件高级军吏俑，有的(1T2G2:97)身穿紫色长衣、下身穿粉红色裤，外披彩色鱼鳞甲；有的(II T9:1)身穿双重长衣，内重长衣为白色，外重长衣为绿色。

中级军吏俑：如二号俑坑 T4 试掘方出土的一件中级军吏俑，身穿绿色长衣，领和袖口镶着白色和红色的花边。下穿红色长裤，头戴的冠和脚上穿的履均为褐色。上身穿的铠甲为褐色，缀有红色的甲丁和联甲带。甲上镶着白色宽边，甲的领口和背带上有精美的彩色图案花纹。一号俑坑 T10 方七过洞出土的一件中级军吏俑，身穿粉红色长衣，押着粉紫色衣边，外穿带彩色花边的甲衣。

下级军吏俑出土的数量较多，有的身穿朱红色长衣，镶着绿色的袖缘，下穿粉绿色裤；有的身穿粉绿色长衣，朱红色袖缘，下穿白色裤。下级军吏俑的铠甲都是褐黑色，甲上没有彩色图案花纹。

战车上的御手和车士俑服饰的颜色：兵马俑坑出土的战车，每辆车上有武士俑三件。其中一件御手，立于车的中部负责驾御车马。另外两件为车士，位于御手的两侧，手持兵器负责与敌对军格斗。车兵服饰及服色的情况，现以二号兵马俑坑 T1 试掘方出土的三个武士俑为例予以说明。御手俑身穿绿色长衣，外套褐黑色铠甲，甲上有白色的甲丁、朱红色的联甲带。下体穿粉紫色裤、绿色的护腿。头戴白色软帽，脚穿黑色履。另外两件车士，都身穿褐黑色铠甲，甲上缀有白色的甲丁、朱红色的联甲带；头上戴着白色的软帽。两件车士上下衣的颜色不同。其中一俑穿红色长衣，绿领，绿袖口；下身穿蓝色裤，套着紫色的护腿。另一件俑上身穿绿色长衣，下身穿粉紫色裤，套着白色和深紫色的护腿。

骑兵俑：出土于二号兵马俑坑， T12 试掘方出土的一骑兵俑，身穿粉绿色上衣，外披褐黑色铠甲，甲上缀有朱红色的联甲带，下身穿粉紫色长裤。另外还有的骑兵俑穿红色长衣，下穿绿色裤。

跪式步兵俑：如二号俑坑 T10 试掘方出土的一跪式步兵俑，上身穿绿色长衣，衣领和袖口为朱红色，下身穿天蓝色裤，套着粉紫色护腿，头上扎着朱红色的发带，脚上穿褐黑色履。

立式步兵俑：此种俑的数量最多，有身穿铠甲的重装步兵俑，也有不穿铠甲的轻装步兵俑。其服装的颜色多种多样。上身穿的长衣有绿色、红色、天蓝色等；下身穿的裤子有天蓝、粉绿、粉绿等不同的色彩。

从上面列举的各种不同身份、不同兵种的陶俑身上的服装颜色，可以获得如下两点新认识：

第一，秦国的军队除铠甲外没有统一的服装颜色，上衣和下衣的颜色都是多种多样，而是各随所好，不拘一格。不但车兵、骑兵和步兵三大兵种服装的颜色不统一，而每个兵种内部也没有统一颜色的服装，就连同一辆战车上的三个乘员的服色也互相歧异。这说明秦国没有统一的军服。

秦国实行的是征兵制，主要成份是农民，达到服兵役年龄的农民都被编在国家的户籍之内，接受一定的军事训练，战时被征入伍，战争结束即回家种田。服役的年龄为17-60岁。服役期间除铠甲和兵器是统一由政府配给外，身上所穿的衣服都是自备的。湖北省云梦县睡虎地四号秦墓出土的两件写在木牍上的家信，是参加攻淮阳的秦军士兵黑夫和惊兄弟二人向家中写的要衣服和钱的家信。信的内容：木牍甲(M4:11)黑夫的家信："遺黑夫錢，毋操夏衣來。今書節(即)到，母視安陸絲布賤，可以爲襌裙襦者，母必爲之，令與錢偕來。其絲布貴，徒[以]錢來，黑夫自以布此。黑夫等直佐淮陽，攻反城久，傷未可智(知)也，願母遺黑夫用勿少……。"木牍乙(M4:6)惊的家信："……願母遺錢五、六百，　布謹善者毋下二丈五尺。……用垣柏錢矣，室(實)弗遺，即死矣。急急急。"这两封信清楚地说明秦军的服装是自备的，在军中的零花钱也要从家中索取。秦人从军纯是尽义务，没有薪俸。兵马俑各武士俑的服装和服色，实际上是当时秦国社会上流行的服色、服装，是秦人服饰文化的真实缩影。

第二，秦国军队中的服装颜色没有等级的区分，也就是说军官和一般士兵，以及军官中的高级军官和中、下级军官彼此之间所穿衣服的颜色，都没有明显的区别，而是各随所好。秦军反映等级高低的主要标志在冠与铠甲的不同。高级军吏俑，头戴　冠，穿彩色鱼鳞甲；中级军吏俑，头戴双版长冠，穿带彩色花边的铠甲；下级军吏俑，头戴单版长冠，穿不带彩色花纹的铠甲；一般士兵，头上一律不戴冠，穿的甲衣甲片比较大，甲上不带彩色花纹。上述情况为以往人们所不知，为考古史上首次发现。它不见于文献记载，可补史书之缺。

三、从陶俑上下衣的颜色看秦代服饰的流行色

根据兵马俑坑出土的各类武士俑身上残存的颜色，大体可以了解秦人对服装颜色的爱好与情趣。

上衣的颜色：已出土的武士俑的身上存有颜色残迹可明确其上衣的颜色者，计 277 件俑。其中穿红色上衣者 88 件，粉绿色 118 件，粉紫色 52 件，天蓝色 16 件，白色 2 件，褐色 1 件。可见绿、红、紫三色是上衣的主色，分别占总数的 42.6 %、 31.8 %、 18.8 %。天蓝、白、褐三色数量很少，分别占 6 %、 0.7 %、 0.4 %。

下衣的颜色：下衣即长裤和短裤，根据俑身上存留的颜色残迹，可知下衣的服色者计 425 件俑。其中穿绿色下衣者 223 件，红色 78 件，天蓝色 61 件，粉紫色 50 件，白色 13 件。这说明下衣的主色为粉绿色，占总数的 52.5 %，其次为红、天蓝、粉紫三色，分别占 18.4 %、 14.4 %、 11.8 %，白色为少数，占 3.1 %。

护腿的颜色：护腿分为两种，一是圆筒形的一节护腿，二是护腿分为上下连属的两节，两节的颜色不同。现以第一种护腿为例说明其服色。根据颜色残迹可明确其服色者计 177 件俑。其中穿粉绿色护腿者 102 件，白色 7 件。可见护腿是以绿色为主色，占总数的 57.6 %，其次为粉、紫、红、天蓝，分别占 16.4 %、 11.3 %、 10.7 %，白色最少，占 4 %。

围领的颜色：根据 182 件陶俑围领上残存的颜色遗迹，其中绿色围领 68 件，粉紫色 60 件，朱红色 26 件，白色 18 件，天蓝色 10 件。可见以绿色和粉紫色数量最多，分别占总数的 37.4 %、 33 %；其次为朱红色，占 14.3 %；白色和天蓝色数量较少，分别占 9.9 %、 5.5 %。

袖缘的颜色：袖口的颜色有单色和双色两种，这里仅以单色袖缘为例。单色袖缘目前发现 239 件，其中绿色 99 件、粉紫色 80 件、朱红色 47 件、天蓝色 8 件、白色 5 件。可见以绿色、粉紫色数量最多，分别占总数的 41.4 %、 33.5 %；其次是朱红色，占 19.7 %；天蓝色、白色分别占 3.3 %、 2.1 %。

从上面的统计数字，我们大体可以了解两千多年前秦人最喜爱的衣服颜色是什么。上衣，最喜爱的是绿、红、紫三种颜色，其次是天蓝色，个别的为白色、褐色。下衣，秦人最喜爱的是绿色，其次是红、天蓝、粉紫三种颜色，个别的为白色。护腿，秦人最喜欢的是绿色，其次是粉紫、红、天蓝三色。这说明当时秦人的服装以绿、红、紫、蓝四色为流行色，其中尤偏爱于绿色。另外，在上衣的领部和袖口都镶彩色的花边，使其绚丽美观。

对上衣和下衣以及衣服上镶的花边的颜色，秦人非常计究颜色的搭配，喜爱强烈的对比色。绿色的上衣，一般押着粉紫或朱红色的衣缘，下身穿天蓝或紫色、枣红色的裤。红色的上衣，其领和袖口一般是押着绿色或粉紫、天蓝色的衣缘，下身穿深绿或粉绿色裤。这种上下衣采用强烈的对比色，色调明快，服色绚丽。秦人的服色给的感觉、感情和精神力量是热烈、喜悦、活泼、而又深沉。秦人这种审美的情趣，反映了其积极的生活内容及蓬勃向上的人的正面精神价值。

服装的颜色代表着一个国家、一个民族的审美观和思想情感。服装的颜色又是随着时代的变化和生活习尚的变化而不断发展变化的。而同一时、同一民族又有时尚色和民间流行色的区别。中国历代的时尚色，传说的黄帝时代尚黄、夏代尚青、商代尚白、周代尚红、秦代尚黑、汉代及其以后各代均尚黄。时尚色是当时认为最尊贵的颜色，绝不是说全国人们都穿一样颜色的衣服。秦始皇统一全国后把黑色作为最尊贵的颜色，有重大的祭典活动皇帝要穿黑色的服装。从兵马俑坑出土的武士俑的服装颜色，可以说明民间流行的衣服颜色与时尚色很不相同，民间喜爱的是颜色鲜艳的服装。时尚色多含有政治或道德、伦理、传统性习惯等诸方面的因素。而流行色则是反映人们审美情趣的艺术潮流趋向的单纯的色彩倾向的表现。所以兵马俑的服色反映了当时人们审美艺术潮流的趋向。

在阶级社会里，什么阶层的人穿什么颜色的衣服是有严格规定的，一般庶人只能穿白色、青色的衣服。而秦王朝时期却打破了这个限制。这是因为自春秋战国之际开始，随着

奴隶制度的瓦解，旧的一套反映奴隶制的等级观念的服饰制度已随之崩溃。战国以至秦王朝时期是封建社会的初级阶段，一套适应封建地主阶级等级制的服饰制度尚未完全确立，因而反映在服饰的颜色上"与民无禁"，没有严格的等级限制。这种情况一直延续到西汉初期。到西汉后期在衣服的颜色和质地上才有不同的禁限，等级差别才较明显。

Yuan Zhongyi

The Costume Colours of Qin Terracotta Warriors

The originally coloured warriors bear different colours of red, green, blue, yellow, black, white, etc., each with various tints. The application method of the diverse colours is as follows: the first coating serving as the background followed by different colours for the diverse pieces of clothing. Characteristics of the costume colours of Qin warriors are:

(1) Their costumes are brightly coloured with green, red, violet and blue as the chief colours and white and black as auxiliary tints. The clothing for the upper and lower body are in sharp contrast with coloured laces. The colours are warm and bright. In the Qin Dynasty, there was no uniform for the soldiers. They were expected to prepare their own clothes, hence the variation of colours. People at the time were interested in bright colours.

(2) There was no remarkable difference between officers and simple soldiers in the colour of their dress. Nor was there a strict distinction between generals and inter-mediate and low-ranking officers. Everyone was free to choose his dress colour out of red, green, blue, violet, etc. It is a reflection of the free atmosphere of the Qin people at a time when the hierarchy of the old slavery had been broken and the new feudal system had not yet been established.

(3) Even for the three ranks of the Qin army: chariot soldiers, mounted soldiers and foot soldiers, there was no unified costume colour. The cavalrymen were beginning to wear slightly different clothes than the chariot and foot soldiers (Hu clothes), but there was no distinction in colour.

(4) Warriors from the pits wore different armours in different colours if they were of different ranks. Only the high-ranking officers like generals and the intermediate-ranking officers wore armour with exquisite patterns whereas the low-ranking officers and common soldiers wore black armours.

The Qin Dynasty used a conscription system under which armours and weapons were issued by the government while clothes were prepared by the soldiers themselves. Most of the soldiers were farmers. The forms and colours of the warrior's costumes reflect the taste and life style of the time.

Erwin Emmerling

Aims and Results of the Chinese-German Project for the Preservation of the Terracotta Army

"How the Ancients Portrayed Death" is the title of a famous work of literature written by the German poet Gotthold Ephraim Lessing in 1769. In this essay, Lessing gives a detailed description of the *"Ancients"* (the Greeks and Romans) depicting death not as a macabre skeleton but instead personifying it as a winged genius. The horrible and drastic depiction of the skeleton as a "dead man" is a post-Antique conception, influenced by Christianity and especially prevalent in the Middle Ages. At this congress, I hope to learn more about how the ancient Chinese conceptualised death.

Despite its massiveness and huge dimensions, the terracotta army was "only" a burial furnishing which until now has often been misunderstood. For many years now, Professor Yuan has done research on the discovery as well as on the function of the terracotta army of the First Emperor. Furthermore, he has also published the existing descriptions concerning the content as well as the arrangement of the actual burial chamber or tumulus grave. How death was conceptualised is still not known. We merely know about the burial rites, rituals and fashions. Since we are dealing with "colour" in our joint project, it would of course be very interesting to learn more about the colour of "death" in China.

In burial sites found in Germany from the same period no known life-size sculptures have been discovered. Similarities may be found in the grave goods such as weapons, vessels, textiles and bronze objects required for daily use.

The antique sculptures in Germany are almost exclusively an inheritance from the Roman Empire. Nevertheless, a joint project between the Terracotta Museum and the Bavarian State Conservation Office concerning the conservation of the polychrome terracotta soldiers has been realised. The state restoration workshops of Bavaria have intensively studied the conservation of sculpture polychromy of the last 100 years. Conservation work has been done on countless wooden and stone sculptures dating from 1000 AD and later in the state restoration workshops.

In comparison with medieval sculptures, the restoration of polychrome surfaces of antique sculptures is a topic that has only been dealt with superficially. For the majority of sculptures from Greek and Roman civilisations as well as Near East civilisations, research on polychromy has until now remained an unfulfilled desire. This is due to the fact that polychrome surfaces from these civilisations have rarely survived, were lost during excavation, or were removed shortly thereafter to show the "pure form" of the sculpture. Even though the polychromy of the terracotta army is in a very fragmented state, the impressive artistic quality has been preserved on countless fragments. For the first time in the history of archaeology, one of the main goals of an excavation is to also preserve the polychromy, which has been partially possible due to the exemplary excavation. Archaeologists in China have taken the opportunity and responsibility and have avoided the errors that were committed during excavations of Mediterranean civilisations in Europe. The practice of erecting huge protective structures over excavation sites, so that all archaeological treasures can be left where they were found in their own excavation museums is firmly established in China (e.g. with Neolithic objects in Bambo). The opportunities and possibilities of this type of preservation of the stratigraphy of the excavation and presentation of the findings can be observed in the very difficult situation in Pompeii, where great efforts will have to be made to save the original situation there before it deteriorates further.

Countless conversations during preparation for this congress confirmed that, at present, research concerning the polychromy of antique sculptures does not receive a great deal of academic attention. Summaries on this complex topic concerning iconography, knowledge of materials, restoration and scientific aspects do not exist. Even today "colour" used for the design of antique sculptures is still a "blank" on the map of archaeology. This lack of attention might almost give the false impression that we are grateful to earlier generations of archaeologists and restorers who, in their work, attempted to eliminate the problem of preserving the polychromy on sculptures by removing every last bit of paint with great effort. Upon discussing the future of the terracotta army, one encounters astonishment when one explains that these thousands of life-size sculptures originally bore a colourful polychromy.

In the following presentations at this congress, the composition of pigments and binding material of the terracotta army as well as possible ways of preserving the polychromy will be discussed. In retrospect, our joint research is not only a success story but also a story of mistakes and failures. If one considers that the chemical composition of a fresh Chinese Chi-lacquer is complex, then one can imagine how difficult it would be to analyse a 2000 year old sample that has been preserved, "stored", under very poor conditions. Today only a few research institutes in the world are capable of analysing such aged material.

For those readers who are not chemists it might be helpful to know that, at the beginning of this century, an artificially produced product called "bakelite" showed certain chemical similarities to "Chi-lacquer". In the 19th century, "Chi-lacquer" could be found in every professional chemical laboratory. It was completely resistant to most chemicals and an extremely durable surface on laboratory tables. Under good conditions, dry atmosphere and no damp ground contact, lacquer particles composed of this material will last thousands of years. Numerous findings in China dating from the Neolithic period and later, prove the amazing ageing qualities of this material. Even more durable is natural resin amber which was originally an organic material whose contents are important, allowing us to reconstruct the ancient DNA structures of organisms trapped in the amber. This represents an ideal data bank. The resilience that these natural resins have shown over thousands of years is amazing.

The use of Chi-lacquer in China is a very old tradition. Cultivating the lacquer tree plantations as well as obtaining the resin has been a tradition since primitive times. Accounts record that the Second Chinese Emperor wanted his City Wall to be painted with lacquer. But, even considering Chinese standards, this idea, which had a streak of megalomania was not carried out. Similar to silk production lacquer production and craftsmanship is one of the oldest Chinese techniques. It has fascinated Europeans since Antiquity. One only has to recall the enthusiasm for Chinese culture in the 17th and 18th centuries in Europe. The European lacquer technique of the "New Age" is the result of an unsuccessful attempt to imitate the Chinese prototype.

The work we have done together over the years in Lintong and Munich has often focused on very small corroded lacquer particles. The despair we experienced with this very obstinate material often threatened our enthusiasm for the project. Most relevant and even some questionable techniques were tested in order to conserve the lacquer-ground of the terracotta-soldiers. In most cases these attempts failed or had minimal success. The analysis and determination of the pigments of the polychromy was relatively easy in comparison to the treatment of the lacquer-ground, which led to a number of negative results. The identification of the so-called "Han-Purple", previously an almost unknown pigment, was one of the small highlights of our analysis. Progress over the years was only made by disqualification. May I say a few words to my European colleagues concerning the pigments used, especially cinnabar, a main component of the flesh colours of the terracotta sculptures.

As is well-known, cinnabar is won as a mineral in large deposits which are also found in China. It has served since Antiquity as a pigment, especially for the colour red in lacquerware. At the same time, cinnabar is also an important material in Chinese alchemy and is probably the oldest man-made "chemical" product. Even though the First Emperor was not the first one to show a special interest in this material, he encouraged studies on and production of this "magic elixir". He also strove to obtain more knowledge on the reproducible and reversible reactions of elements such as sulphur and mercury, which generated a great variety of black, red or "silver" coloured effects. Cinnabar, a product of protochemistry, has been known in ancient China since primitive times. Compared to European products the Chinese product is far superior in quality because of the use of very old preparation techniques with natural cinnabar. Even today, it is still extremely difficult to determine which cinnabar (natural or man-made) was the original product. Mercury, a component of this "elixir", was found in extremely high quantities in the burial chamber of the grave site. As a result of this finding, traditions and rites from the so called "Seas and Oceans" of the Antique World, which describe the mortuary world of the Emperor in the tumulus, become credible. If the tumulus of the grave should ever be opened, it is very difficult to imagine how one would be able to preserve the volatile substance, mercury.

Considering the sound knowledge of the participating conservators regarding painting techniques, this project would still have been inconceivable without the crucial and decisive information from the participating scientists. I do not know of any other exemplary restoration, where the cooperation between chemists, mineralogists and physicists together with conservators and archaeologists has been so extensive. In addition, I know of no other project where all of the different disciplines involved were so interdependent. For most experts, the cooperation of those dealing with the material Chi-lacquer was a new experience that had to be learned. This included not only the restoration studios and institutes in Germany but also the cooperation on an international level.

Last, but not least, the experience and knowledge gained from this joint venture shows that "archaeology", as a field in conservation, should be perceived in a new light. Furthermore, the status of natural science in conservation should be re-evaluated. It should be taken even more seriously than to date, because we can only adequately treat and protect monuments with the aid of natural science methods. With the conservation work on the terracottaarmy the sciences succesfully interacted as equal partners. I know of only few projects which have taken place in the restoration studios of the Bavarian State Conservation Office that have been based on such intensive cooperation. Our work with Japanese colleagues on the research project on Baroque and Rococo lacquer techniques should be mentioned here in addition to certain aspects of the conservation of bronze objects.

Cinnabar and lacquers are materials that the conservator is relatively familiar with even though in Europe the raw materials come from different sources. The common link for this congress lies in Arabian traditions, where the origin of modern western chemistry has its roots. Indeed, it is most likely that the origin of Arabian traditions can be traced back to the first contact Arabian scholars had with Chinese traditions. Such cross-references concerning the exchange of knowledge and culture make Chinese Antiquity, as a topic, particularly interesting. It even gives a non-sinologist a notion of the complex structure of ideas in ancient China. The notion of "colour", pigments, dyestuffs and their production process as conduits for the exchange of knowledge in Antiquity is not new. Recent research emphasising and expanding upon this topic will be presented at a later time by Mr. Berke. Similar conclusions can be drawn in even greater dimensions concerning dyestuffs which were necessary to colour textiles. The parallelism of these developments and the application of these dyestuffs is quite amazing. They suggest that the ancient trading routes transported far more than just pure goods and merchandise.

"Colour" and "polychromy", used as keys for a deeper understanding and interpretation of antique civilisations, have not been important topics. This congress offers the chance to better understand "colour" and its symbolic function.

Ovid describes amber as "Tears of the Gods" in his collection of myths called "Metamorphosis". In one of the myths, the daughter of the Sun-God mourns the loss of her brother Phaidon by shedding "amber tears". To process raw amber for lacquer, it first has to be melted in heated oil in order to apply it. This was discovered around 1000 AD in the western world. The use of Chi-lacquer as a protective coating on metal to hamper corrosion has been a tradition in China for the last 4000 years. Shortly after the birth of Christ, monumental statues were made consisting of countless layers of lacquer on a support containing hemp. The clay core used in manufacturing was removed after the lacquer had dried and hardened. Considering all that we know about this topic, the use of lacquer as a ground for clay sculptures with a polychromy is very unusual and probably unique to the terracotta army. The lacquer, as material, first became an uncommon and unusual conservation problem due to a combination of a pigmented layer (polychromy) bound by an aqueous binding medium. This binding medium, used together with the pigments has not yet been successfully identified. There is a good chance that the material has totally disintegrated.

In the first few years of our research project, we thought that this unusual combination of materials was an error in the painting technique. Spending years on this problem and realising that we have very incomplete knowledge of ancient Chinese technology has taught us that we need to be much more careful when forming our conclusions. We need to look for mistakes in our lack of understanding instead of looking for errors in the ancient painting techniques.

(translated by Mark Richter)

艾默林

中德保护兵马俑项目的经验和成果

“古人如何表现死”，系德国作家戈特霍尔德·埃弗拉伊姆·莱辛于 1769 年发表的一篇著名文章的标题。莱辛在文中详细地描述了，“古人”，即古希腊和古罗马人并不是把死表现为令人毛骨悚然的骷髅，而是把它塑造成带翅膀的守护神。拿一具赤裸裸的骨架作为死的化身，乃是与古代晚期和中世纪受基督教影响的观念一脉相承的。至于中国的“古人”如何反映死，西方对此所知甚微。

兵马俑的规模虽然庞大，但它们“只”是陪葬品，呈现赫赫“礼仪”，这一点，西方人常常没有真正地意识到。中国皇帝陵墓中如何以及是否塑造和表现了死，人们还不清楚。我们所知的只是墓葬形式和葬礼。

修复古代雕塑的表面彩绘，是一个有待深入的领域。对大多数古希腊、古罗马包括近东的古代雕塑的彩绘，均匮乏研究，主要原因在于保存下来的彩绘表面极其罕见，这些彩绘常常是有意去掉的，以求显现雕塑的“真胎”和“纯形”。无数的兵马俑残片上残留着原始彩绘，艺术质量突出。能保护和妥善保存秦始皇兵马俑的彩绘，把它作为发掘的纲领性目标来实现，这在考古史上尚数首次。中国考古界因此获得了机遇也是任务，避免重犯欧洲地中海沿岸国家在发掘古代高度文明时所经历的过失和疏忽，从而为抢救出土文物作出榜样。

即使今日，“色彩”依旧是古代雕塑的一个“空白点”，对于颜料和粘合剂的组成成份，我们的认识十分有限。兵马俑身上涂有化学结构相当复杂的漆，由于地下埋置条件不利，2000 年后去查明这种材料谈何容易。在中国，漆的使用具有悠久的传统，种植漆树和割取树脂远古便有流传。据记载，秦二世曾欲漆其城。类似丝绸的织造和加工，生漆的获取和加工亦属中国最古老的工艺之一，自古希腊和古罗马以来，一直使欧洲人心醉，这里我们只需回想一下 16 至 18 世纪欧洲掀起的中国热。

如果说分析和确定兵马俑彩绘的颜料不太复杂的话，一种迄今(几乎)未知的颜料，即所谓的汉紫也成功地得到了证实，那么处理漆底色层却充满艰辛。

朱砂是陶俑肉色的主要成份，众所周知，这种矿物在中国的不少矿床都有开采，自古以来一直作为颜料使用。同时，朱砂亦是中国炼丹方士所钟情的材料，而且可能是人类制造的最早的化学产品。让人研究“摄生”仙丹的，秦始皇并不是第一个，但他对此却格外倾心。作为原始化学的产品，朱砂在古代中国便已流行，经过数百年对自然材料的处理，获得的质量是欧洲无法想象的，即使今日，只有克服许多困难，才能确定无论是自然的还是人工的原产品。

在兵马俑的保护上，化学家、矿物学家、物理学家同修复师以及考古学家进行了出色的合作，这对考古发掘来说很不寻常。进行这种合作，按最佳准则解决考古修复的问题，既是挑战，也是喜悦。对所有参与者来说，保护兵马俑及其彩绘，无论过去还是现在，甚至在未来的几十年里，都是一种挑战。

令人兴奋的是，正象贝尔克教授在报告中所证实的那样，在近东、埃及和中国文化中，颜料生产方面的情况存在某些令人感兴趣的类似。利用色彩尤其是彩绘作为加深理解古代高度文明的钥匙，为了作新观察对它们进行阐释，乃是一个尚未深化的课题。也许在获得这些经验后，未来能在这些方面予以更多的关注。

公元初年之际，奥维德在他的古老神话集《变形记》中将琥珀视之为“神的眼泪”，即太阳神的女儿们为悲恸她们的兄弟法厄同所抛洒的眼泪。将琥珀作为漆原料来加工，在烧热的油中使它融化，从而能够使用，是西方公元 1000 年左右的发明。将漆材料涂在金属上防锈，在中国已有 4500 年的悠久历史。至少从东汉初年始，中国已用麻布与漆层层相叠，制成高大的夹纻漆像。制作时需要泥模，俟漆层干后脱模。据我们迄今所知，用漆作为彩绘陶俑打底的材料，实属异常。漆这种材料只是在与涂绘的带水粘合剂的颜料结合时，才成为保护的难题。迄今未能找到彩绘颜料的粘合剂，也许该材料已彻底分解了。

在我们研究的头几年，我们趋向把这种异常的材料结合看作涂绘工艺上的失误。经过多年对这个问题的探索，很遗憾，我们对中国古代工艺依旧认识不全，但是我们今天判断更谨慎了，这一失误，与其说是在古代的绘画工艺中，倒不如说是应在我们残缺的认识中去寻找。

张志军

秦始皇兵马俑彩绘保护研究回顾

秦始皇兵马俑彩绘保护研究，是随俑坑的发掘而开始的，至今已近25年了。现逢彩绘保护国际研讨会召开之时，对秦兵马俑彩绘保护研究予以回顾，以便有助于文博工作者对其保护研究状况的了解。

秦始皇兵马俑三个坑内埋藏着真人真马般大小的兵马俑近8000件，这些兵马俑原来都通体绘有彩绘。由于俑坑在塌陷之前，曾遭受火焚和洪水的浸泡，以及塌陷以后，兵马俑被埋于潮湿的填土之中，受到地下有害介质的长期侵蚀，因而彩绘受到了很大的损害。出土时，附着在兵马俑体上的颜色残迹，也由于上述原因，已变得非常脆弱，暴露到自然空气环境下很快发生起翘、剥落(彩图I, 1)。

为了妥善保护这些珍贵的彩绘残迹，在一号坑前五探方发掘期间，单炜、韩汝芬、李亚东等人就彩绘的物质成分分别进行了测试分析，单炜老师还对彩绘的加固保护进行了实验研究，并处理了一些俑头上残存的彩绘。在三号俑坑发掘期间，我和周铁对彩绘剥落原因进行了试验研究，采用研究出的综合保护工艺处理了一些俑上的彩绘残迹。1992年，陕西省文物局和巴伐利亚文物保护局开展了合作研究秦兵马俑彩绘保护的项目，中方人员先后有4次、9人次、累计16个月在巴伐利亚州文物保护局，与德方同事共同就兵马俑彩绘保护问题进行系统研究。下面就各阶段的保护研究情况予以回顾。

1. 一号坑前五探方发掘期间彩绘的研究和保护

这期间(1974年-约1982年)所做的工作，根据已发表的文献资料来看，有两个方面：一是对彩绘材料的调查；二是对彩绘加固的探索。在彩绘材料分析方面，除紫色和黄色颜料层以及底层物质未查明外，其它颜色层物质都已查明。在彩绘加固方面，最先采用大分子量的聚已二醇(以下简称PEG)水溶液进行加固，效果欠佳，后来改用水溶或醇溶性聚丙烯酸酯类等加固剂进行加固处理，保护了一些俑头上的残存彩绘。综合来看，这时期做的工作还不够系统全面，尤其在彩绘的加固保护上，做的实验研究还不够充分，属于秦兵马俑彩绘保护研究的初期探索阶段。

2. 三号俑坑发掘期间彩绘的研究和保护

在三号俑坑发掘期间(1988年底-1989年9月)，起初采用聚丙烯酸酯乳液对出土后的彩绘进行加固处理，但发现处理过的彩绘，在自然环境下，还会发生剥落。为了查明彩绘剥落的原因，对经过加固和未经过加固的一些彩绘陶残片进行了跟踪调查，结果发现：环境湿度变化，引起彩绘陶片失水，与彩绘剥落有密切关系。为了证明这点，将一些未经处理的彩绘陶片分别放置于一系列相对湿度不同的恒湿器内进行干燥实验，结果表明：恒湿器内的相对湿度越低，彩绘剥落得就越快；在恒湿器内湿度高于93 %R.H.的条件下，彩绘可较长期附着于陶基础上而不发生剥落。另外，调查发现，凡对环境湿度有影响的自然和人工因素都会加速彩绘的剥落。这时期，为了配合俑坑的展出，还探索出了潮湿状态下兵马俑的修复工艺。基于彩绘剥落原因的调查结果，结合潮湿状态下的陶俑修复工艺，提出了一套秦俑彩绘的综合保护措施，主要包括用水性加固剂加固、潮湿状态下仔细修复、稳定环境下缓慢干燥等，并对一些俑上的彩绘残迹进行了保护处理，取得了一定的成绩。但这阶段的工作，总的来看，还显得较粗糙，缺乏对彩绘保护问题的系统研究，也未能从根本上解决兵马俑彩绘的保护问题。

3. 中德合作以来彩绘的保护研究

自1992年中德合作以来，对兵马俑彩绘保护问题进行了全面深入的研究，取得了丰硕的成果：

3.1 对彩绘构成和施彩工艺的研究

3.1.1 彩绘构成

对彩绘构成的调查主要是通过显微镜技术进行的。调查结果表明：秦兵马俑彩绘在层次结构上很不统一：有的由一层生漆层和一层颜料层构成，这种结构类型的彩绘在秦俑彩绘中占绝大多数，并出现在除褐色涂层以外的各种颜色涂层当中；有的由两层生漆底层和一极薄颜料层组成，该类型主要出现在一些俑袍部的红色涂层上；有些由一层生漆底层和两层不同颜色的颜料层构成，这种类型主要涂在一些俑的脸、手或脚部；个别俑的局部涂层是由双生漆底层和双颜料层组成的；也有的彩绘仅由一或两层生漆层构成，这种纯生漆层涂层主要出现在甲俑的铠甲上以及某些俑的发髻和足履上。单层生漆层厚约0.03毫米；粉红颜料层最厚，0.09-0.20毫米；红色颜料层最薄，0.01-0.04毫米。

3.1.2 施彩工艺

关于施彩工艺的调查是基于发掘现场的实际观察和对一些彩绘残片的显微调查得出的。观察结果表明：兵马俑彩绘是用涂刷法实施的(彩图I, 2)。彩绘工艺过程是：第一步，用腻子对陶基础表面进行抹光处理(彩图I, 3)。这一处理步骤具有部分性，并不是所有兵马俑都经过这一处理步骤。所有兵马俑在制作泥胎时，表面都经过抹光、压光处理，出窑后

绝大多数兵马俑表面细腻光滑，彩绘时就直接在陶表面进行，而对表面凹凸不平的，才采用这一处理步骤。第二步，在陶体或腻子表面通体涂刷1-2层生漆。第三步，配好与对象要求色调基本相符的颜料，用稀胶水调和均匀，平涂于生漆底层之上。有些部位，如表现皮肤和指甲盖等部位，一些俑涂了两层不同颜色的颜料层。第四步，对细部进行描画或晕染。例如，眉毛、胡须等。

3 .2 彩绘物质成分研究

3. 2. 1 底层物质成分研究

关于底层材料的构成物质，在中德合作项目开始之前，曾进行了一些分析、推测，结论不一：有人通过分析，判定为金合欢胶；有的认为是用明胶打底；有人根据我国的绘画传统，将其认为是我国古代特有的一种处理绘画材料的方法——施用胶矾水的痕迹；也有人提到过生漆材料，但缺乏科学检测依据。

中德合作项目开始以后，对底层的物质成分进行了多种科学分析。起初，将底层的红外谱图与新制漆膜以及可能用到的动植物胶的图谱进行比较，发现底层与新制漆膜的红外图谱非常相似。然而，由于底层在地下埋藏了两千余年，已经老化，老化过程的氧化作用会引起漆膜的红外光谱发生变化。鉴于这个原因，对底层又进行了更加细致的对比分析研究。选定的参考样品是与底层的时间相近、老化程度相当、具有确切出土时间和地点的徐州汉代楚王墓出土的漆棺上掉落下来的漆层。分析结果显示：它们的红外谱图几乎完全一致；热解气相色谱也显示出高度的相似性。结合底层对溶剂表现出的极强的抵抗能力以及底层与新制漆膜固态核磁共振波谱的相似性，从而证明底层是用生漆材料制作的。

同时，还对生漆成膜机理及其特性，以及生漆使用的历史进行了文献研究，认为用生漆涂饰兵马俑是完全可能的。

3.2.2 颜料层物质成分分析

颜料物质成分分析主要是采用X–射线粉末衍射法和发射光谱分析法进行的。经过多次分析已明确了彩绘颜料的成分，归纳如表1。

表1. 彩绘颜料成分

颜　色	成　　分
粉　红	磷灰石+朱砂*或铅白+朱砂或磷灰石+铅白+朱砂或铅白+朱砂+铅丹
红　色	朱砂*或铅丹
绿　色	石绿
蓝　色	石青
紫　色	朱砂+硅酸铜钡*或朱砂+硅酸铜钡+铅白(白垩)
黄　色	雌黄+磷灰石
白　色	磷灰石*或铅白
黑　色	炭黑

*：表示在兵马俑彩绘颜色成分分析中出现频率较大的成分。

从表1中可以看出，除紫色硅酸铜钡颜料外，其它颜料在我国古代绘画中普遍使用，并出现也很早。其中铅白和铅丹被认为是用化学方法制造的以外，其它颜料都是天然矿物颜料。

3.2.3 颜料调和剂的分析

对于秦俑彩绘颜料调和时，可能使用何种调和剂，采用了微量化学分析法对其进行了试验研究。由于古代使用的颜料调和剂都是溶于水的有机质材料，并长期处于潮湿的地下，受地下水等因素的长期侵蚀和传输，调和剂已经分解并严重流失，加之受生漆底层的影响以及分析方法的局限性，该项分析未能得出具体结果，仅给出有动物胶和植物胶存在的初步结论。

3.3 彩绘损坏原因研究

彩绘损坏原因是基于对彩绘层损坏形式和在不同状况下(彩绘自身状况和环境状况)的损坏行为的观察得出的。其主要原因是老化的生漆底层在失水干燥过程中发生严重收缩、继而破裂、起翘或卷曲造成的。其次由于原有颜料调和剂老化或流失，颜料层结构变得松散，干燥时易于碎化、剥落。

3.4 彩绘加固保护的实验研究

寻找适当的保护措施，阻止彩绘剥落一直是秦兵马俑彩绘保护当中重点探讨的问题，尤其中德合作以来，对这一问题进行了大量的试验研究，使实验一步步地向成功逼近。中德合作彩绘加固问题方面的研究可分为下列四个阶段：

第一阶段(1992年/1993年)

这阶段首先试验了各种加固剂加固彩绘的有效性和适用性。试验结果表明：仅通过涂刷加固剂的方法，只能防止具有较厚颜料层的彩绘的剥落，而对纯生漆层彩绘和生漆层上带有很薄颜料层类型的彩绘，这种只通过涂刷加固剂的方法，是达不到防止彩绘剥落目标的，彩绘在干燥期间，仍会产生较严重的剥落。鉴于彩绘剥落是在彩绘陶片失水干燥时才发生的，特别是当把彩绘陶片从高湿度环境中移到较干燥的环境下时，生漆底层快速失水，引起底层起翘、卷曲，从而连同其上的颜料层一起从陶基础上剥落下来。于是，采用了下列不同的失水方式进行了对比试验：

(1) 把经过加固处理的彩绘陶片，逐次置于由不同盐溶液控制的湿度系列恒湿器内，让其在环境湿度逐步微小降低的条件下缓慢失水，以减小彩绘层失水时的表面张力和生漆底层的收缩、变形应力。

(2) 将经过处理和未经过处理的彩绘陶片，先于-20 °C以下进行预冻，然后置于冻干机的干燥室中进行冻干，以便彩绘陶片的内含水分通过升华方式扩散出去，防止底层变形、剥落。

(3) 为了使彩绘陶片的内含水分从表面蒸发变为其它覆盖物表面进行蒸发，以减慢彩绘陶片的干燥速率和避免内含水分从彩绘层表面蒸发时对脆弱的彩绘造成破坏作用，试验了包扎干燥法和沙浴去湿法。

以上这些试验结果均未能阻止生漆底层的起翘、剥落问

题。对其原因调查发现： 1) 加固剂难于渗过生漆底层而进入到陶表面，只能通过底层边缘渗入少量加固剂，加固强度不足； 2) 生漆底层干燥时产生严重收缩。在渗入加固剂的部分，产生许多裂纹，甚至出现起翘现象；在未加固住的部分，便发生严重起翘或卷曲。

实验结果还表明：非水溶性加固剂不适宜秦俑彩绘的加固，因其不能使起翘或卷曲的底层恢复原位或展平，并防障二次加固处理；比较好的加固剂是水性的鱼鳔胶和聚丙烯酸酯乳液。

第二阶段(1995 年)

基于第一阶段的实验研究结果，这阶段的加固试验工作主要集中在探讨各种预处理剂对底层性能改善效果的研究上。该项工作分两种情况进行了试验研究。首先选用一系列试剂在生漆底层碎片上进行了试验。选用的试剂被认为可能具有下列某一性能：(1) 挥发时在彩绘层表面产生的张力远比水小；(2) 渗入底层后，将在其内部形成网状结构，起到固定和填充底层，减小底层干燥时的运动；(3) 具有影响底层内含水分扩散或保湿的性能，达到减缓干燥的作用；(4) 具有增塑的作用。方法是：将底层碎片直接浸入稀释或未稀释的试剂中，数天之后，取出展平在玻璃片上，通过视频全息摄影技术测量、记录处理试剂对底层性能的作用情况，并进行外观检查。结果表明：未处理的底层对湿度变化(94.5%-95.5%R.H.) 产生的变形量是 13 微米，而用叔丁醇处理过的底层碎片的变形量是 8 微米：用甲基三甲氧基硅烷处理过的变形量是 3 微米；用 PEG 处理过的变形量为 1–3 微米等等。由此得出，对底层进行适当处理能够提供较好的保护效果。

为了使该项实验更接近实际情况，又在彩绘陶片上进行了试验。方法是先用试剂进行预处理，然后再进行加固，或是在加固剂中加入一定量的试剂。结果表明：用加有少量 PEG200 的加固剂处理过的彩绘陶片，其彩绘层可以保持稳定更长的时间。从而表明 PEG200 具有改善底层在干燥期间行为的作用。

第三阶段(1996 年/1997 年)

由于在前阶段的实验中，在加固剂中加入少量 PEG200 获得了较好的保护结果，所以，这阶段的工作继续集中在寻找适当的防止底层收缩的方法上。考虑到在木材保护处理上施用的逐步处理法，以及通过浸渍渗透方式可以使加固剂更深更多地渗入到彩绘层和陶基础物中，本期实验采用 PEG200 和一些保护效果较好的加固材料进行了多种试验。实验结果表明：用 PEG200 作防收缩剂，聚氨酯乳液或聚丙烯酸酯乳液作为加固剂，通过逐步晋升 PEG200 浓度，并于第一步时加入加固剂溶液的分步处理法，具有钝化底层对环境湿度变化的敏感性和稳定底层的显著作用，可避免底层在自然环境下很快变形、剥落的问题。经过这种方法处理过的一些彩绘陶片，在室内环境下已放置了两年多时间，彩绘层仍较完好(彩图 I, 4)。但陶片长时间处于潮湿况态，并且颜色加深。据研究，这主要是由于 PEG200 具有强烈的吸湿性和很低的蒸气压，从而降低了彩绘陶片内含水分朝外扩散的速率，使陶片在相当长时间内有较多水分的缘故。推测经过长期缓慢干燥以后，陶和彩绘层的颜色将会恢复到自然状态。

第四阶段(1998 年)

鉴于经过 PEG200 处理过的彩绘陶片长期处于潮湿状态，推测可能将对兵马俑的修复和长期贮存构成影响。另外，由于生漆层的难渗透性，如何在达到有效加固强度的情况下，避免加固剂在彩绘表面的积累，保持其自然的外观状态。这些问题是本阶段研究工作探讨的重点。该阶段首先对经过 PEG200 处理过的彩绘陶片进行了环境湿度变化时其反应情况的实验。实验表明：用 PEG200 溶液通过浸入法处理过的彩绘陶片，在处于相对湿度约 75%以上的环境下，强烈吸收空气中的水分，表面出现含 PEG200 的水滴。推测这主要是由于陶片结构内渗入了大量 PEG200 的原因。于是，采用了不同配方、不同步骤的敷渍渗透法进行了一系列的实验，取得了下列实验结果：

(1) 直接用纯 PEG200 试剂进行敷渍处理，会导致生漆底层发生严重起翘、卷曲。推测这是由于具有强烈汲湿性的 PEG200 很快吸收了生漆层结构内部的水分，导致其迅速脱水的原因。

(2) 在 PEG200 处理液中不可加入较大量的加固剂组分，否则加固剂会于彩绘表面成膜而发亮。适当的加入量为加固剂的固体含量在 2%以下，并需于第一步处理中加入。

(3) 一般采取下列三步敷渍处理较好：第一步：聚氨酯乳液： PEG200:水=5:30:65；第二步： PEG200:水=60:40；第三步：纯 PEG200 。每步处理时间 1-2 天。并需在陶片潮湿状态下进行处理，当陶片较干燥时，处理前应先用水喷湿，否则，加固剂会在表面成膜，影响外观。

另外，为了检验陶片经过 PEG200 处理以后，是否会影响其粘接修复性能，用模拟陶片进行了试验。结果表明：处理过的陶片仍可实施粘接技术，对初始粘接强度也基本没有影响。

这期间，还积极探讨，以寻找其它更好的加固方法。采用易渗透的小分子量单体材料(PLEX6803-10)，通过晋升浓度的三步敷渍方式，使单体渗入彩绘层和陶表层，然后利用电子束引发内部聚合，取得了加固强度和外观状态均很好的保护效果(彩图 I, 4)。

4. 结论

秦兵马俑彩绘保护课题，经过大量分析、实验，明确了彩绘颜色的成分、彩绘的有机底层是由生漆制作的；搞清了彩绘的剥落机理；基本找到了防止俑上残存彩绘剥落的加固方法。这为以后进行兵马俑彩绘的保护工作奠定了良好的技术基础。然而，兵马俑彩绘保护是一项系统工程，不仅仅是把彩绘稳定在残片上，还需要将处理过的残片恢复成完整的彩绘俑，并使其得到长久妥善保存。另外，发掘期间，防止脆弱的彩绘层剥离陶基础而粘于填土上，以及如何将一些粘于填土上的彩绘恢复到原来陶的位置上，等等。这些问题都需要今后给予认真关注，并进行积极探讨。

Zhang Zhijun

Review of the Conservation of the Polychromy of the Terracotta Army

The polychromy on the 8000 terra-cotta warriors, which were originally coloured from head to toe has largely fallen off due to artificial and natural causes. The remains of the paint layers are very sensitive and react extensively when excavation takes place. Extensive research and work have been done in China and Germany to protect the valuable pigments that remain. Much headway has been made in this respect. This paper gives, from a technological angle, a stage-by-stage review of the colour preservation and the progress made on the research of the polychromy of the warriors since their excavation. It includes components of their colouring, coating technology, causes of the damage and techniques for the protection from the environment. It also mentions some problems, which need further investigation. *See colour plate I.*

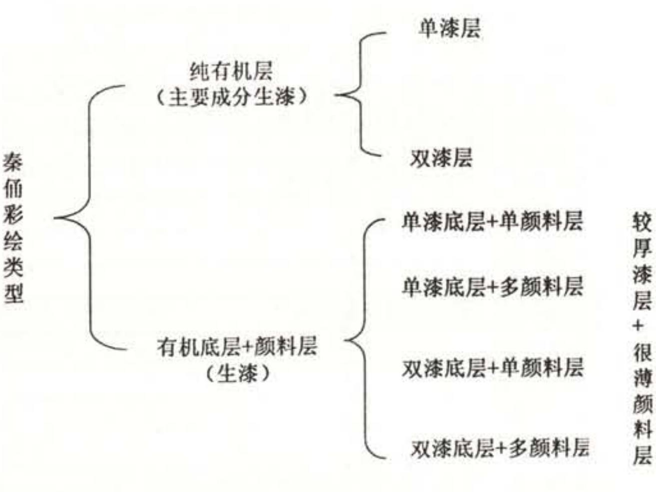
周铁

秦俑彩绘保护研究的新进展

秦俑在原制作时都是通体彩绘，在随后的几千年岁月中，经火烧、水淹及地下各种因素的影响，出土时，只有一些俑体表面残存彩绘，个别还较完整。但隔不久，便出现颜色蜕变、彩绘脱落问题。其中以脱落更为严重。为解决这些问题，自80年代中期至90年代初，中方做了许多工作，对彩绘的物质组成、损坏原因等方面都有了初步了解，在保护措施的探索上也作过实验，虽然保护效果还不理想，但获得了不少宝贵经验。1991-92年，秦俑彩绘保护研究项目列为中国陕西省文物局与德国巴伐利亚州文保局《文物技术合作研究》的重要项目。自此，双方专家进行了卓有成效的合作。截止1995年底，完成了前期研究工作，较为系统、深入地了解了秦俑彩绘的层次结构，物质组成，损坏机理，进行了大量的保护方法试验，但尚未获得理想效果。1996-97年度，在前期研究的基础上，提出了重要的保护思路，开展了一系列的保护实验，至1998年基本完成了保护方法的实验研究工作，使该研究项目取得了重大突破。本文将简要的介绍前期研究结果，着重报告1996-1998年在保护方法方面实验研究的新进展。

1. 前期研究简介

秦俑彩绘的层次结构类型，就目前所看见到的情况来讲，可粗分为两类，细分为六种：



以上各种层次结构类型均含有主要成分为生漆的有机层，这是秦俑彩绘的重要特点之一。

我们对其分类的目的无非是两个：一个是研究彩绘工艺，更重要的是考虑对其保护。那么从保护的角度考虑：纯有机层和较厚有机层+很薄的颜料层保护难度大于其他类型。相对来讲，有机层越厚越难保护，颜料层越厚越易保护。这是因为彩绘脱落主要是有机底层失水收缩造成的，有机层越薄收缩应力越大。颜料层对底层有一定的屏蔽作用，从而减缓外界对底层的影响，底层失水速率减慢，收缩变缓。

1.1 分析出了彩绘的物质组成

彩绘颜料一般都是无机矿物质颜料。单色颜料成分见下表，其它间色颜料是由两种或多种颜料混合而成。

表1. 秦俑彩绘颜料成分

红　色	HgS 、 $PbCO_3$
黄　色	As_2O_3
绿　色	$CuCO_3(OH)_2$
蓝　色	$Cu(CO_3)_2(OH)_2$
紫　色	$BaCuSi_2O_6$
白　色	$Ca_5(PO4)_3OH$ 、 $PbCO_3$

有机层或底层的主要成分为中国生漆。

1.2 查明了彩绘脱落的主要原因

颜料颗粒之间、彩绘各层之间、底层与陶体之间粘附力很微弱；特别是底层(生漆层)对失水非常敏感，在干燥过程中漆层剧烈收缩，引起漆层起翘卷曲，造成彩绘脱离陶体(图1，彩图II, 1-2)。

1.3 试用过多种物理方法，结果证明对漆层脱水均不适用。

1.4 试验过多种加固方法，未获得理想效果。如单一加固剂加固、加固剂中加入一定量柔化剂等等。

2. 1996-1998的研究思路

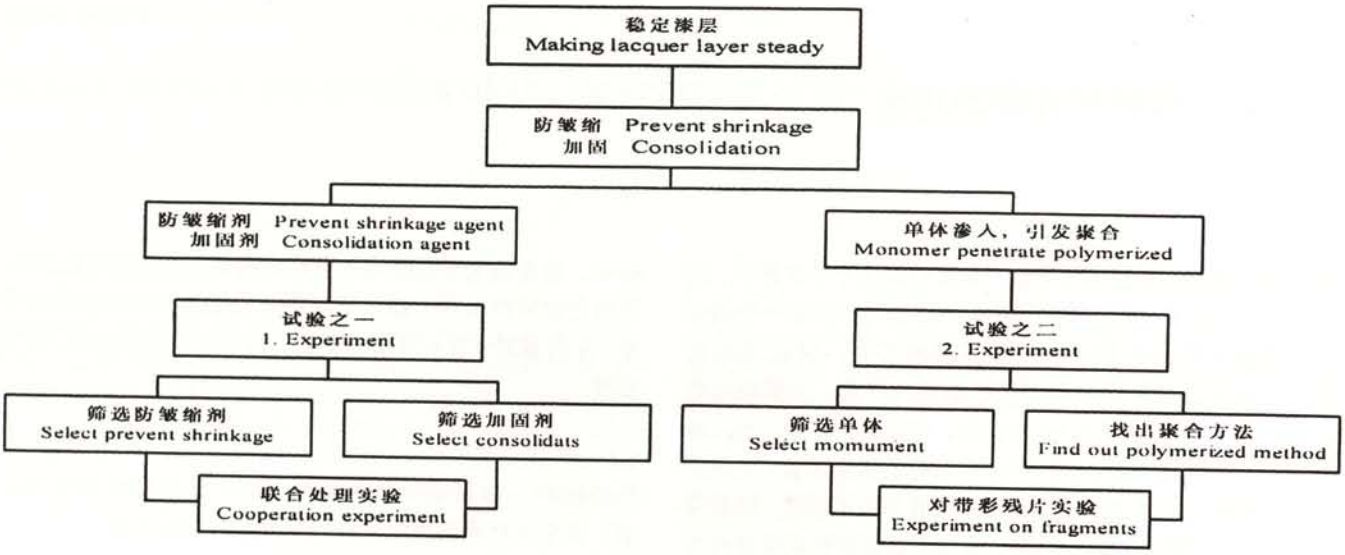
经过近十年的探索，进行了大量的实验之后，为何还不能对彩绘实施有效地保护呢？对此，我们对以往的实验进行了认真的反思和总结。认真思考彩绘脱落、损坏的原因，不难得出：保护彩绘的关键是稳定漆层。根据秦俑彩绘中漆层的特性，保护方案应该包含加固和抗皱缩两个方面的处理。

为此，我们设想了以下两个途径：

(1) 采用具有抗皱缩作用的材料置换漆层中的水分，进行抗皱缩处理，同时采用合适的加固剂加固。

(2) 用单体浸入漆层中置换水分，渗过漆层到达漆层与陶体之间，然后设法引发单体交联聚合，聚合物在漆层中减弱皱缩，在漆层与陶体之间起加固作用。

按照这些思路，安排了以下实验。



3. 保护实验之一

3.1 抗皱缩剂的对比实验

为了找到合适的抗皱缩剂和方法，开展了这项模拟实验，本实验对可能有抗皱缩效果的 21 种试剂进行了对比实验，其中 4 种试剂及方法给出了很好的抗皱缩效果。

3.1.1 试样

为了使这项模拟实验的结果尽量接近真实情况，我们选取了已经脱离陶体的原始生漆层作为试样，它们色泽、厚度的大小约为 0.5 x 0.5mm 。

3.1.2. 试样处理

对所有的试样分别用相应的抗皱缩剂采用浸润或滴加润湿的方法进行处理，处理方法和试剂见表 2 。

Table 2: Materials and treatment methods.

可溶于水或常态下为液体的材料，采用浸泡法；其它的采用滴加浸润法。其中 A1, A2, A3, A4, A13 采用了从低浓度至高浓度的浸润方法(13 、60 、80 、100%)。

No.	Treatment Agent	Application
A1	Glycerin / Water	soaking: 30 % 5d; 60 % 7d; 80 % 10d; 100 % 10d
A2	PEG 400 / Water	soaking: 30 % 5d; 60 % 7d; 80 % 10d; 100 % 10d
A3	PEG 200 / Water	soaking: 30 % 5d; 60 % 7d; 80 % 10d; 100 % 10d
A4	D-mannit / Water	soaking: 5 % 9d; 10 %; 16 %
A5-1	Phenol / Water (1st step)	soaking: 90 % 5d
A5-2	Formaldehyde (2nd step)	gas over solution (30 %) 10d
A5-3	Acetaldehyde (3rd step)	soaking: 10d
A6	Triethanolamine	dripping
A7	Gloyxal / Water 40 %	dripping
A8	hygroscopic Salt: LiCI / Water	dripping: saturated solution
A9	PEG 200 / DAP 80:20	dripping
A10	PEG 400 / DAP 80:20	dripping
A11	PEG 1500 / DAP / Water 66:17:17	dripping
A12	1,3-Propylammonium-dichloride (PAD+HCl)	dripping
A13	MEG (ethylen glycol) / Water	soaking: 30 % 7d; 60 % 10d; 80 % d; 100 % d
A14	pre-PMMA / Acetone, 50:50	dripping
A15	n-Hexadecylammonium-chloride / Acetone+ Water (20:80)	soaking
A16	Colophonium / Acetone 1:2	dripping
A17	Tetramethylammonium-hydroxide / Water	dripping
A18	Tungoil (300 C) / Ethylacetate	soaking
A19	Tungoil / Ethylacetate	soaking
A20	PEG 1500 + Glycerin 1:1	soaking

可溶于水或常态下为液体的材料，采用浸泡法；其它的采用滴加浸润法。其中 A1, A2, A3, A4, A13 采用了从低浓度至高浓度的浸润方法(13 、60 、80 、100%)。

3.1.3 评估

所有评估项目都是在体视显微镜下观察评估的。评估项目的主要关注点为抗皱缩效果。底层漆膜脆性变化、抗皱缩能力的持久性等等。评估内容选择是根据彩绘保护的实际需要而定的。处理后的外观效果也应作为重要的评估内容之一。然而，由于漆层碎片是深棕色的，处理后色调的变化情况难以分辩，因而这一重要的评估内容在这个初步的实验中没有进行。该项内容在进一步的彩绘陶片的实验中进行了研究。

抗皱缩项目的评估方法如下：先用软纸吸干处理过的漆片表面的残余液，然后观察漆片是否平展，再给漆片表面滴加水并观察其形状是否发生变化。如果处理后不平展，而且滴水后其形状发生了变化，说明处理剂及其处理没有抗皱缩效果，这样我们便给出"–"符号；相反地，就说明用此处理方法和处理剂有抗皱缩效果，便是"+"符号。利用这种现象，作为评估的依据是基于彩绘漆层对水的反应特性。秦俑彩绘漆层在其含水量的变化过程中会引起其形状的剧烈变化，(见秦俑彩绘保护项目 1995 年度研究报告)这种形状的剧烈变化即所谓的皱缩。

脆性变化项目的评估：

先使处理后的小漆片表面干燥，方法如前项所述。然后用小镊子轻触潮湿的、未处理的小漆片，再分别轻触各组已经处理过的小漆片，并相互比较其脆性。如果脆性相似，便是"+"符号。如果某个处理后的小漆片脆性被认为高于对照样，则是"–"符号，其他情况则为"+–"符号。

长期效果的评估：

处理后的漆层的抗皱缩效果持久性如何以及处理剂蒸发后曾被增强了的抗皱缩性的底层有什么变化也是我们所关注的问题之一。为此，我们也设计了这项评估，评估方法如下：清理处理后的小漆片表面，再给该漆片表面滴加丙酮，仔细观察小漆片的变化直至丙酮完全蒸发，然后给小漆片滴加水并观察之。如果漆片形状发生变化，则意味着这种试剂的耐久性不好，评估为"–"符号，反之，则为"+"。

3.1.4 结果讨论

所有的评估结果见表 3 (见 26 页)。

3.2 加固剂的对比实验

该项实验的目的是找到最适于漆层加固的加固剂。根据以往的测试结果，结合有关资料报导，我们选用了 21 种加固剂进行对比实验，通过一系列的评估对比筛选出了适于漆层加固的 3 种加固剂(见 26 页表 4)。

3.2.1 试样

为了使对比实验更接近真实情况，而又不至于用真实带彩绘的陶片试验，我们选取了已经脱离陶体的原始生漆层碎片作为试样，它们厚度的大小约为 0.5 x 0.5mm 。

3.2.2 对比实验及评估

(1) 加固剂对漆层的对比实验

为了了解不同加固剂对漆层的适应性及加固效果，而安排了这个实验。

具体做法是：将漆层碎片放在玻片上，滴加加固剂，观察反应情况，然后对下列项目进行评估对比。

是否会引起漆层卷曲

是否会造成破碎

是否会改变颜色

是否产生光泽

加固效果如何

评估符号

卷 曲	破碎	加固效果	色泽	光泽
+ = 没有卷曲	+ = 无裂纹	+ + = 很强	+ = 无影响	"+" = 无光泽
+/– = 有些微卷曲	+/– = 轻微裂纹	+/– = 有一定强度	+ /– = 轻微改变	+/– = 轻微光泽
– = 卷曲严重	– = 明显碎裂	– = 很弱	– = 明显改变	– = 有明显光泽

对比实验结果见表 5 (见 27 页)。

(2) 加固剂在潮湿陶片上的对比试验

将现代制作的陶片放入相对湿度为 84 %RH(原始彩色陶片在保护前的近似值)的环境中至不再增重，涂刷加固剂于潮湿陶片上观察结果 (见 27 页表 6)。

(3) 各种加固剂在玻片上的对比实验

将加固剂涂在玻片上，干燥后观察其结果 (见 27 页表 7)。

综合以上三项试验结果，可以得出以下结论：加固剂 C1 的综合性能和对漆层的适应性最好，其次为 C5b 和 C12 等等。

3.3 在真实陶片上的实验

3.3.1 抗皱缩实验

虽然 PEG200 、PEG400 、甘油对漆层都有较好的抗皱缩效果，但甘油容易在彩绘表面形成一层粘潮的物质， PEG400 粘度明显大于 PEG200，因此，选定 PEG200 作为彩绘保护的抗皱缩剂。

处理方法：用敷浸方法， PEG200 浓度逐级升高(40、60、80、100 %)每个梯度为 5 天。

处理带彩绘的残片 F-005a/96 和 F-003/ 96

彩图 II, 3. 陶片 F-003/96 ，处理后。

该陶片曾用 PEG200 经过逐级提高浓度包敷处理，然后在临潼的室内环境中暴露了 4 个季节。连甲带上的红色颜料层与底层黏附良好。颜料层有部分损失。大多数甲片上的漆

No.	Shrinkage Prevention	Brittleness	Long Time Effect	Overall Appraisal	Note
A1	++	+	+/-	++	
A2	++	-	+	+	
A3	++	+/-	+	++	
A4	-	+/-	-	+/-	
A5-1	+	+/-	-	-	
A5-2	-	-	-	-	
A5-3	-	+/-	-	-	
A6	-	+/-	-	+	yellow
A7	+	+	+	-	
A8	-	+/-	-	-	
A9	+/-	+	-	+/-	yellow
A10	+/-	+	-	-	yellow
A11	-	+	-	-	yellow
A12	-	+/-	-	+	
A13	+	-	-	+/-	
A14	+	--	+	-	
A15	-	--	-	-	
A16	-	--	-	-	
A17	-	+	-	-	
A18	-	-	-	-	
A19	-	-	-	-	

Table 3: Evaluation result: A1 = A3 > A2 >A7 > A13.

综合各项评估结果，可以得出下述结论：用 A1(甘油)及相应方法， A2(PEG400)方法， A3(PEG200)方法， A7(乙二醛 40 % 水溶液)方法，以及 A13(乙二醇)方法有保护结果。其中最好的为 A1 和 A3，其次 A2、A7、A13。

Table 4: Consolidation agents.

No.	Consolidation Material	Solvent	PH	No.	Consolidation Material	Solvent	PH
C1	Polyurethandispersion (Kremer 7680)	Water	5-6	**C12**	Buthylmethacrylatdispersion (Motema WPC)	Water	6-7
C1b	Cl in Ethanol 1:2	Water / Ethanol	7-8	**C13**	Bologna-Cocktail	Xylene / Acetone	
C2	Colophonium + Acetone 1:2	Acetone		**C14b**	Beeswax C14 (fine) / Dispersion (Ultrasonic)	Water	7-8
C3	Laquergum + Glycerine	Water	5-6	**C15b**	Urushiol C 15	tBuOH	
C5	Polymethylmetacrylatdispersion 1:2 (Primal AC 33)	Water	7-8	**C16**	C14b + C13b / Beeswax (Ultrasonic) + Polyurethane (in Ethanol) 1:3	Water	7-8
C5b	Primal AC 33 in Ethanol / Dispersion	Water / Thanol	7-8	**C17**	Acrylkleber (48 %) + Ethanol 1:9 (Kremer 360 HV)	Ethanol	
C7	Polyacrylatdispersion 1:2 (Motema Finish)	Xylene		**C18**	Plexisol P 550 40 % (42 %) + White Spirit 1:2	White Spirit	
C7b	Molema Finish + tBuOH	tBuOH		**C19**	Paraloid B 72 9 % + MTMOS 7 % in tBuOH	tBuOH	
C8	Wacker Steinfestiger OH	Ethyl-Acetate		**C20**	Shellac (in Borax-solution)	Water	
C9	BCP (Bologna-Cocktail) + PEG 200	organic		**C21**	Water-based Epoxy-Resin-Dispersion (Sikafloor 2520)	Water	
C10	Polyacrylate-microparticle-dispersion (from Sichuan)	Water					

No.	Rolling	Cracks	Adhesion	Colour	Gloss	Conclusion
C1	+	+	++	+	+	very good
C1b	+ / -	+	+ / -	+	+ / -	good
C2	+	+ / -	+	+	-	good
C3	-	-	-	+	+	bad
C5	+ / -	--	+	+	-	bad
C5b	+ / -	--	+	+	+ / -	ordinary
C7	-	+	+ / -	+	+ / -	good
C7b	+ / -	+	+	+	+ / -	good
C8	+ / -	-	-	+ / -	-	very bad
C9	-	+ / -	+ / -	+	+	good
C10	+	-	+ / -	+	-	ordinary
C12	+	-	+	+	-	good
C13	+ / -	-	-	+	+	ordinary
C14b	+ / -	-	+	+ (some white)*	+	good
C15b	+	+	--	-	-	very bad
C16	+ / -	-	+	+	+	bad
C17	-	+	-	+	-	bad
C18	+	+	+	+	+	very good
C19	+ / -	+	+	+	+ / -	good
C20	-	-	-	+ / -	--	very bad
C21	-	+ / -	+ / - slowly**	+	-	bad

Table 5: Comparsion tests on the separate ground layer flakes.
* : The colour of the laquer flake was slightly white.
**: The epoxy-resin hardens very slowly.

由上表可以看出：该实验结果最好的是 C1>C18>C7b

Table 6: Conclusion of the experiments on damp terracotta pieces.
C3 > C1 = C5b = C9 = C13 = C14b = C20

No.	Colour	Gloss
C1	+	+
C1b	+ / -	+ / -
C2	-	-
C3	++	++
C5	+ / -	+ / -
C5b	+	+
C/7	+ / -	+ / -
C7b	-	+ / -
C8		
C9	+	+
C10	-	+ / -
C12	+ / -	+ / -
C13	+	+
C14b	+	+
C15b	--	+
C16	-	+
C17		+ / -
C18	+	-
C19	-	+
C20	+	+
C21	-	+

Table 7: Conclusion of the experiments on glass pieces.

评估结果：C1 = C2 = C5b = C12 = C19

No.	Appearance
C1	+
C1b	+
C2	- (not dry)
C3	-
C5	-
C5b	
C7	-
C7b	+ / - (brittle)
C8	-
C9	+ / -
C10	+
C12	+
C13	-
C14b	-
C15b	--
C16	-
C17	+ / -
C18	+ / -
C19	+
C20	-
C21	+

层平展且与陶的黏附性良好。个别甲片上的漆层有轻微其翘。这种处理取得的抗皱缩效果较好，颜料层及漆层稳定。但是该陶片看上去仍有些潮湿，表面残留有颗粒较细的土壤，这对外观效果有一定的影响。

彩图 II, 4. 陶片 F-005a/96，处理后。

该陶片曾用 PEG200 经过逐级提高浓度包敷处理，然后在临潼的室内环境中暴露了 4 个季节。连甲带上的红色颜料层与底层黏附良好。虽出现了一些很细的裂纹，但没有卷曲。甲片上的漆层大部分很平展，但与陶的黏附力较弱。这种处理所取得的抗皱缩效果显著。该陶片外观潮湿。

用这种方法处理过的彩绘残片，取得了很好的抗皱缩效果，但于陶的黏附力较弱，正如前文所述，保护过程必须包括加固和抗皱缩两个环节。于是我们又用以下方法对一些彩绘残片进行了处理，取得了较好的保护效果。

方法：敷渗方法

第一步：聚氨酯乳液(PU): PEG200: H_2O=12.5: 40: 47.5, 3 天

第二步: PEG200: H_2O=60: 40, 3 天

第三步: PEG200: H_2O=80: 20, 3 天

第四步：纯 PEG200, 3 天

用此方法处理的陶片为 F-002/96、F-006/96; F-008/96 第一步处理中的加固剂为聚丙烯酸酯乳液，其他步骤与 F-002/96 相同。

彩图 II, 5. 陶片 F-002/96，处理之后。

用聚氨酯乳液(PU)+PEG200 混合液逐级提高浓度包敷处理之后，在临潼的室内环境中暴露了 4 个季节。彩绘层的黏附性很好。外观新鲜纯净。漆层平展，色调自然，有些泛光的区域可能是加固剂的不均匀聚集造成。漆层紧紧贴在陶体上，黏附性很好。因此这种处理结果是成功的。

彩图 II, 6. 陶片 F-006/96，处理之后。

该陶片曾用聚氨酯乳液(PU)+PEG200 混合液逐级提高浓度包敷处理之后，在临潼的室内环境中暴露了 8 个季节。经观察底层和袍部色彩自然，且无卷曲，与陶的粘接力较强。腰带上和袍部漆层出现了许多细小裂纹。漆层表面有些许泛光点，可能是加固剂的不均匀聚集造成。该陶片外观干燥，抗皱缩剂和加固剂的效果在这一实验中得到了充分的体现。我们认为这种方法在陶片上取得了成功。

彩图 II, 7. 陶片 F-008/96，处理之前。

出土时，该陶片上的漆层较为完整、较厚，不久便发生皱缩、卷曲，出现较大裂缝。

彩图 III, 8. 陶片 F-008/96，处理之后。

该陶片曾用聚丙烯酸酯乳液(Motema WPC)+PEG200 混合液逐级提高浓度包敷处理之后，在临潼的室内环境中已暴露了 2 年。漆层大部分平展，与陶体的粘合力很强，但也出现裂缝。参比该陶片在处理前的状态，保护的效果是显著的。由此看来，即使对严重开裂的漆层，这种方法也可以使其粘接于陶上并且很平展。

在取得初步成果的基础上，我们又通过对这种加固剂和抗皱缩剂联合敷渗的方法进行进一步优化。目的在于减少陶质对 PEG200 的吸收，简化处理过程，防止加固剂在彩绘表面形成不均匀聚集等等。

优化的方法为：

第一步：使陶片处于饱水状态。

第二步: PU: PEG200: H_2O=2.5: 30: 67.5, 2 天

第三步: PEG200: H_2O=60: 40, 2 天

第四步：纯 PEG200, 1 天

用这种方法处理一批彩绘陶俑，已经在自然室内环境中暴露了 4 个多月，保护效果良好。

彩图 III, 9. 陶片 F-007/98，处理之后。

彩图 III, 10. 陶片 F-003/98，处理之后。

彩图 III, 11. 陶片 F-012/98，处理之后。

彩图 III, 12. 陶片 F-013/98，处理之后。

3.4 结论

(1) 针对秦俑彩绘中的漆层，聚乙二醇(PEG)具有良好的抗皱缩作用。

(2) 在一系列实验中，我们发现若用一种纯的浸润剂与潮湿漆层接触，漆层中的水分与该种浸润剂的交换将不协调。这种情况下漆层将会皱缩和卷曲，与漆层自然干燥的现象相似。根据漆层对水的反应特征，只有运用逐级升高抗皱缩剂浓度的方法，置换过程才可以安全进行。用这种方法处理秦俑彩绘，实现了彩绘漆层中的水分与抗皱缩剂的安全交换。

(3) 平均分子量为 200u 的 PEG(PEG200)在渗透速率和置换稳定性方面表现出了最好的效果。同时，与加固剂联用时也表现出了最好的协同效应。

(4) 两种化学结构不同的聚合物乳液在联用保护处理中产生了相似的加固作用。相比之下，聚氨酯(PU)乳液(Kremer 7680)比聚丙烯酸脂乳液(Motema WPC)有更好的加固效果。

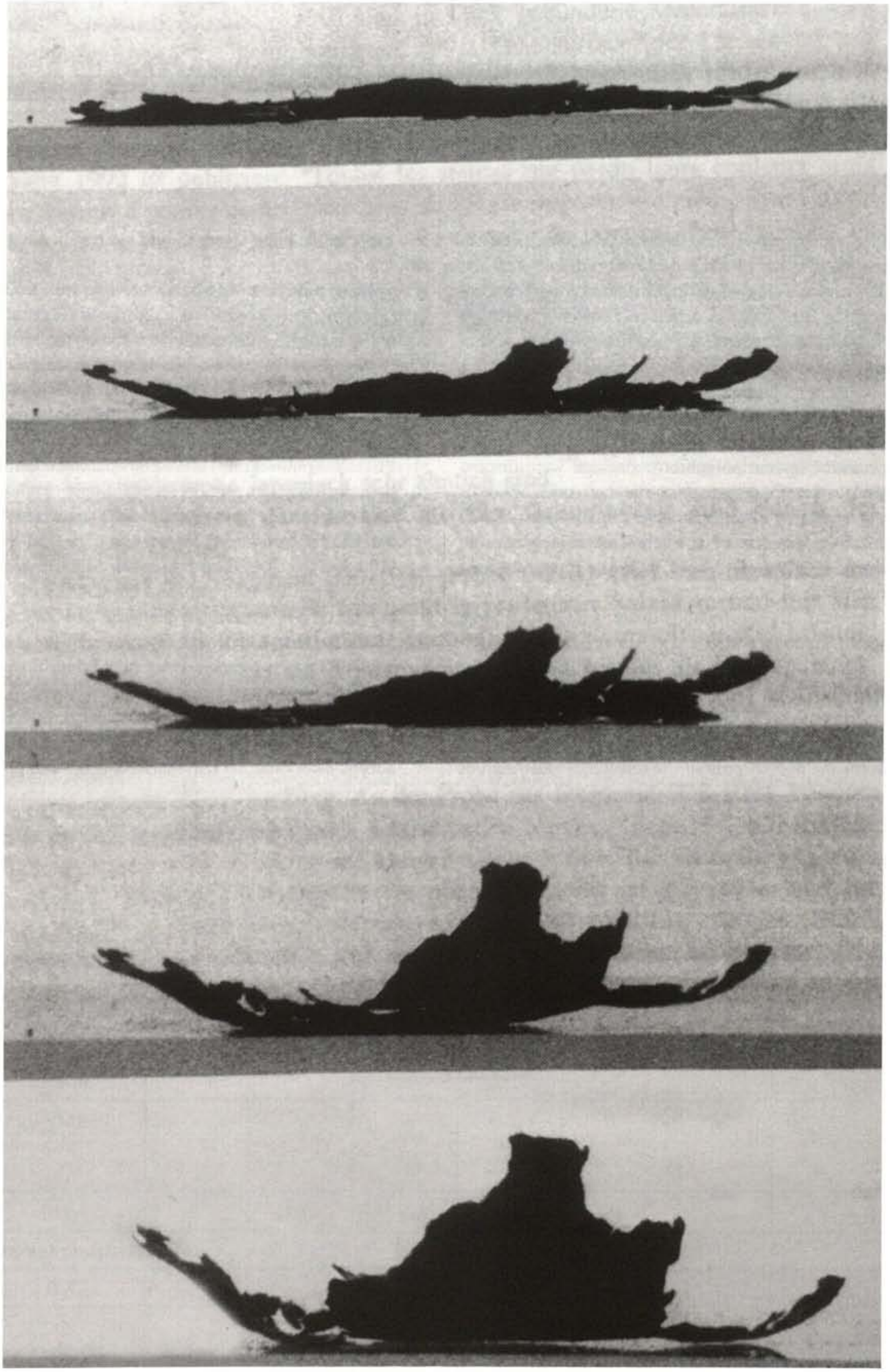
(5) 经过这套保护方法处理过的彩绘残片有的已经在临潼的自然室内环境中暴露了 2 年多，最短的也已经暴露了近 4 个月，这些残片彩绘状态良好，生漆层仍保持稳定。因而可以说，这套保护方法已经在实验室取得了成功。

4. 单体渗透，引发聚合的保护实验

1996/97 年度便开始的这项实验，在对 20 多种单体进行聚合性质的模拟实验后，选择出了适用的单体，(一种可以溶于水的甲基丙烯酸甲脂)。对于引发剂、UV 光引发等多种方法的实验，选定了电子束(EB)辐射引发聚合的方法。该方法处理过的彩绘陶片，达了理想的保护效果(详见 ROGNER 的报告；彩图 III, 13)。目前，我们已在西安附近找到了这种仪器设备，即将开展进一步实验研究，以完善这种保护方法。

5. 总结论

经过几年努力，我们初步完成了几年前提出的实验思路，在两条重要的保护途径上，均获得了成功。但这只是实验室阶段成果，还有许多问题需要深入研究，要将这些成果转化为实际应用的保护技术还要做大量工作。



1
2
3
4
5

Fig. 1. This set of five photos shows the movement of the lacquer layer during the drying process. This lacquer layer (has peeled off from the terra cotta) was taken from a box (100 % RH) to an open room (60 % RH). It happened in four minutes. (Photos: Cristina Thieme)
1: The phase of the beginning: 100 % RH; 2: The phase after 1 minute, under 60 % RH; 3: After 2 minutes; 4: The phase after four minutes; 5: After five minutes

图 1. 这组 5 张照片是对湿度变化非常敏感的漆层在干燥过程中发生的运动。这块漆片(已从陶体上脱落)从相对湿度 100 %的保湿箱中取出，放到 60 %(RH)的室内环境中，反应过程为 4 分钟。(摄影：蒂美)
1) 湿度 100%(RH)时的初始状态; 2) 湿度 60 %(RH)下，一分钟后的状态; 3) 两分钟后; 4) 两分半钟后; 5) 四分钟以后的状态。

Zhou Tie

New Developments in the Conservation of the Polychromy of the Terracotta Army

This paper (see colour plates II, III) is on the progress of research on the conservation of the polychromy of the terracotta warriors which was carried out by the Museum of the Terracotta Warriors, and the Bayerisches Landesamt für Denkmalpflege. A large amount of work has been done on this project:

(1) The structure of the paint layer was investigated.
(2) The components of pigments were analysed. Chinese lacquer was considered the main component of the ground layer.
(3) The key reasons for the polychrome damage were discovered: the adhesion of the pigment particles to one another is very weak; especially the ground layer is very sensitive to the loss of water. It shrinks extensively when drying, causing a detachment of the ground layer from the terracotta base and a rising of the pigments.
(4) Several physical drying-methods were tested, but were proved not fit for conservation.
(5) Various methods of consolidation were tested, but not found appropriate.

Based on previous research, the key to the conservation of the paint layers is to steady the ground lacquer layer. The conservation methods for the polychromy of the terracotta must include two aspects: the paint layers should not shrink and must be consolidated.

Applying a monomer to penetrate into the ground layer, so that a polymerised reaction can take place, the consolidation between the lacquer layer and the terracotta base ensues.

The following two experiments were carried out from 1996-1998.

(1) 21 consolidation agents and 19 agents preventing shrinkage were tested and evaluated. Polyurethane dispersion (PU) and PEG 200 (anti-shrink) were considered as better conservation shrinkage prevention agents. Some original fragments with polychrome layers were treated stepwise with PEG 200 and PU dispersion after application of the last treatment step (100 % PEG 200). The fragments could be exposed to the environment for two years and the stability of the preserved polychrome layers did not change.
(2) 20 monomers were tested. By means of these experiments, suitable monomers were determined. Various polymerising methods were tested (such as starter UV, etc.) The EB polymerisation method was finally selected, the fragment was treated with the monomer PLEX 6803-20 (water-soluble acrylic ester) and EB polymerised. It showed perfect results.

Christoph Herm

Methods in Organic Archaeometry and their Application to the Terracotta Army

Introduction

Since the 1950s, the application of science to the study of the past is named archaeometry.[1,2] The main tasks of archaeometry are prospection, material analysis and dating. The scientific results ought to be discussed in the context of and together with the disciplines that ask the questions, e. g.archaeology, art history and conservation. This presentation tries to give a survey of methods for organic archaeometry. In this sense, organic archaeometry means the application of scientific methods to organic archaeological objects or residues. These materials mostly originate from natural products, such as oils and fats, waxes, bituminous materials, carbohydrates and cellulotic materials, proteins, natural resins and dyestuffs.[3]

Chemical analysis reveals the composition of a given material and in most cases either serves the identification or the preservation of an archaeological or artistic object. The classical chemical analysis must be considered out-dated and its application to objects of archaeology and art should be avoided. Particularly for organic chemical analysis a too large amount of sample material is required. On the other hand, the exactness of the results is generally low. Similar to infrared spectroscopy, only groups of substances can be found. It is useful to divide instrumental methods for organic analysis into spectrometric identification and substance separation by chromatography. The most prominent methods are shown in fig. 1 together with a very general view over the field of application in archaeology and art.[4]

Fig. 1. Methods of organic analysis and their application to archaeological and art objects (compiled from Mills & White, 1994[3]).

图 1. 有机化学的分析方法及其在研究艺术和考古学中的应用 (Compiled from MILLS & WHITE 1994[3])。

↓ method / application to →		oils fats	waxes	bituminous materials	carbohydrate/ cellulotic materials	protein	natural resins	dyestuffs	synthetic resins
Spectrometry									
infrared	IR, FT-IR		v		v	v	v	v	v
nuclear magnetic resonance	NMR	v	v	v			v		v
mass	MS		v					v	
Chromatography: separation									
thin layer	TLC				v	v	v	v	
liquid	LC, HPLC					v		v	
gas	GC	v	v	v	v		v	v	v
Hyphenated methods									
GC-MS		v	v	v	v	v	v	v	
HPLC-UV/vis							v	v	

sample	description	species
M-001/95	rotten wood with soil (scraped)	conifer?
M-002/95	core of rotten beam	conifer?
M-008/95	charred wood relics	family: *Ulmaceae* genus: *Celtis, Zelkova, Ulmus* (elm)
M-009/95	charred wood relics	family: *Pinaceae* genus: *Picea* (spruce), *Larix* (larch)

Fig. 2. Wood relics from Lintong excavation pit no. 2 (Hans-Georg Richter, University of Hamburg).

图 2. 考古挖掘坑道 2 号中的木头残片。

The need of isolated samples is a common characteristic of the majority of organic analytical methods. In the case of the investigation of valuable archaeological and art historical objects of course, this is a severe disadvantage. However, many methods nowadays require only tiny samples of some nanograms, an amount which can hardly be seen by the bare eye. Thus, the sampling technique is the most important step of analysis, when the care of the object is concerned.

Some of the methods discussed here have been applied to problems of the Lintong Terracotta Army in the joint research programme by a number of collaborators.[4] An overview of the results is given here. The investigations focused on the ground layer of the polychromy. This paint layer was found to be mainly responsible for the conservation problems of the polychromy on the Terracotta Warriors, due to its extreme sensitivity to changes in humidity. Some of the scientific results of the joint research programme are published in greater detail elsewhere.[5]

Microscopy

Optical Microscopy

Light microscopy was probably the first technical tool for investigating works of art and archaeology. It is yet today an important method. By light microscopy magnification up to 1500 times is possible. Transmittant illumination techniques as well as top light illumination are commonly applied in the arts and archaeology, using a great number of different technical setups and certain optical effects.

Identification of Fibre and Wood

Polarised light microscopy is a well known transmittant illumination method for the identification of pigments. Furthermore, fibres exhibit optical effects under polarised light as well.[6] These can be used to identify natural fibres from plants as well as from animals. Transmittant light microscopy is also used for botanical identification of wood which is prepared as a thin section.[7]

Application

The Terracotta Army was set up in a giant wooden underground construction. Most of the timber has rotted or been charred. The determination of the tree species from which the timber was produced is of interest for archaeological studies. Two charcoal pieces and two samples of rotted wood from excavation pit no. 2 were botanically determined,[8] as shown in fig. 2. Surprisingly, the charred samples revealed different types of wood. Obviously not much attention was paid to the origin of the wood during construction work.

Stratigraphy

Samples from the surface of an object are commonly prepared as cross sections. In order to investigate their layer structure the polished cross section is examined under the top-light microscope. Some of the layers may appear bright in ultraviolet light due to fluorescence.[9]

Application

The stratigraphy of the polychrome painting layers of the Terracotta Warriors was examined by top light illumination microscopy. Under visible light the ground layer on the Terracotta Warriors looks rather dark and dense. Under UV-light the lacquer exhibits only a weak, greenish-yellow fluorescence.

Fig. 3. Cross section of ground layer on Terracotta Warrior under UV-light (photo: Cristina Thieme).

图 3. 在紫外线照射下的兵马俑表面色彩基层的横切片(图片制作: Cristina Thieme)。

However, here two layers with a total thickness of about 0.1 mm can be recognised (see fig. 3.). Furthermore, the microscopical picture shows a lot of holes and pores in the dryed-out ground layers. In contrast, other examined ground layer samples possess a more dense structure and sometimes also only one layer.

Scannning Electron Microscopy

General

Scanning electron microscopy (SEM) is known as a powerful tool for looking at tiny samples. In the field of art and archaeology magnification up to 10'000 times are common. The particular advantages of SEM cover the field of inorganic material, including elementary analysis. Further advantages of this technique are high magnification and resolution of the topography. Whereas the usual SEM needs totally dry samples, cryo-SEM is capable to visualise damp structures and even water itself. "Cryo" means that sample preparation as well as microscopy are carried out at very low temperatures. Before introducing it into the microscope, the damp sample is shock frozen in melting nitrogen at -210 °C. This allows the water content to solidify into an amorphous state, so that the damp structures are preserved. The investigation itself is carried out at temperatures far below 0 °C, where the partial water vapour pressure lies below the working pressure of the microscope.

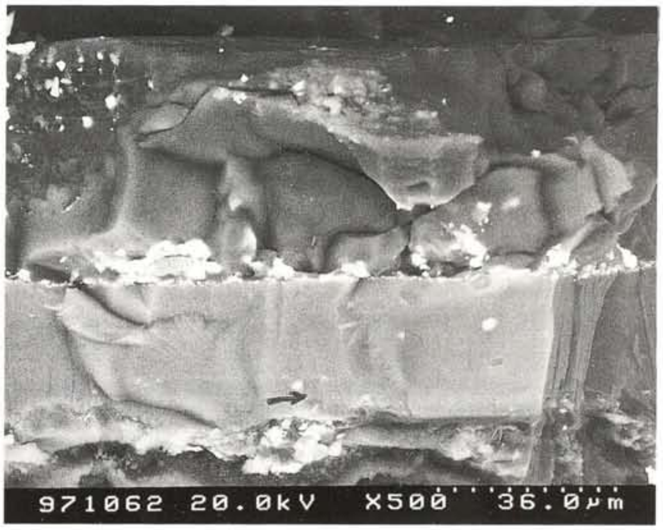


Fig. 4. Cryo-SEM picture of the sectional view of a double "Qin" ground layer in water soaked condition (magnification 500x), (Herbert Juling, MPA Bremen).

图 4. 潮湿的双秦基层截面的低温扫描电子显微图片(放大倍数为 500x)。

Application

Original ground layer samples from the Terracotta Warriors were investigated with cryo-SEM in order to visualise the microstructure of water soaked specimens in comparison to those in dry condition.[10] Fig. 4 shows a double ground layer in damp condition. Two layers can be clearly seen. They exhibit a dense structure and typical brittle fracture forms. Under higher magnification micropores with diameters below 0.1 µm were visible.

Subsequently the cooling of the SEM chamber was stopped and the sample thus dried under the high vacuum. This process led to a total collapse of one of the layers (see fig. 5). This behaviour could probably explain the rolling of the ground paint during drying although this process was much more extensive than under normal pressure. In the remaining layer bigger cavities with diameters above 10 µm have formed. This appearance of the layers closely corresponds to the structure of the air dried ground layer (see fig. 5.).

Fig. 5. SEM picture of the cross-section after drying in the high-vacuum chamber, magnification 800x (Herbert Juling, MPA Bremen).

图 5. 高真空状态下干燥后的横切片的 SEM 图片(放大倍数为 800x)。

Spectrometry

Introduction

Spectrometry is in general based on the interaction of electromagnetic radiation with the analysed material. Radiation can lose intensity by absorption, reflection, or scattering. A wide range of the electromagnetic spectrum is used for analytical methods. The high energy x-rays are not suitable for organic analysis, but are very useful for elementary analysis by x-ray fluorescence (XRF) as well as for x-ray pictures. For the identification of dyestuffs the choice method is ultraviolet-visible spectrometry (UV/vis). Infrared spectrometry (IR) uses radiation of lower energy than visible light. It is applicable to inorganic as well as to organic substances. The range of radio waves is used for nuclear magnetic resonance spectroscopy (NMR). In this case a magnetic field has to be additionally applied. In a more general sense, the distribution of particles with respect to their mass can be regarded as spectroscopy as well. This principle is used in mass spectrometry (MS).

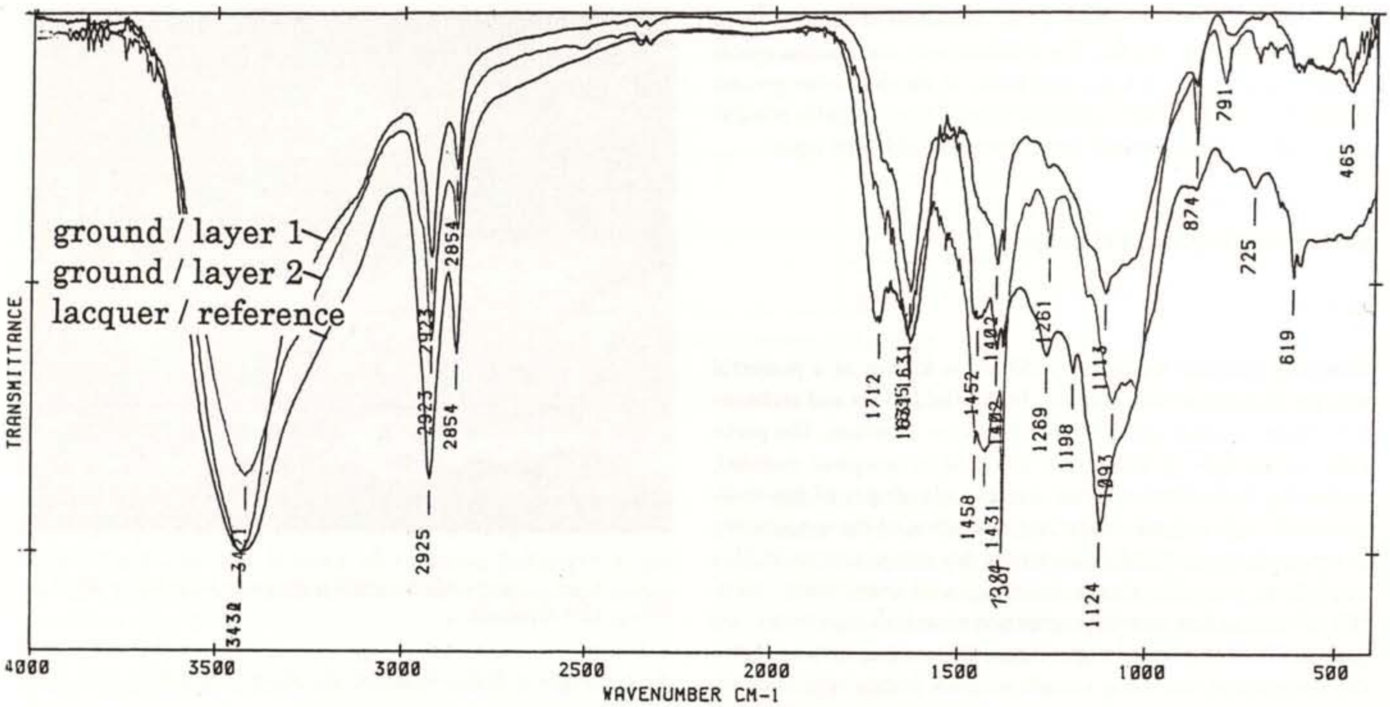


Fig. 6. FT-IR-spectra of ground layers on terracotta fragments and lacquer reference sample (KBr-pellet).

图 6. 兵马俑残片的底色层及参照样品漆(KBr 晶片)的 FT-IR-谱图。

Infrared Spectrometry

General

Infrared spectrometry is based on the absorption of infrared radiation by the chemical bonds in molecules. In an IR spectrum the absorption or transmission is displayed as a function of the energy of radiation and noted as "wavenumber" in reciprocal centimetres. IR spectrometry is applicable to detect a wide range of materials. For pure substances information on the precise molecular structure is obtained. On the other hand, mixtures can be generally characterised only according to the functional groups present. Therefore, in general, it is impossible to distinguish resins, oils or proteins more precisely by IR spectrometry. IR spectrometry is particularly capable for the identification of synthetic polymers. Usually the measured spectrum is compared to reference spectra of known substances.

Nowadays mostly Fourier-transform infrared spectrometry (FT-IR) is used. FT-IR made possible the introduction of microscopy to infrared spectrometry. This technique only requires very small samples in the range of 30 micrometers in diameter or about 30 nanograms of mass. Commonly a so-called diamond anvil cell is used together with this technique. The advantages of FT-IR-microspectroscopy are low sample size, rapid data recording and a wide area of application. Because this technique is non-destructive, the sample once taken may be used for further analysis.

Raman spectrometry is closely related to infrared spectroscopy.[11] Here, the sample or object is illuminated with laser light and the scattered light is recorded. Sample spectra in the infrared range are obtained. Because the scattered light is registered, this technique does not necessarily require isolated samples. Indeed, Raman spectroscopy seems to be the only method up to now revealing information of the organic chemistry of an object without destruction. However, as the Raman effect is very weak, a lot of instrumental problems still have to be solved before Raman spectroscopy can become a routine method of investigating objects of art and archaeology.

Application

In the case of the Terracotta Warriors microchemical test reactions failed in determining the composition of the ground layer. At first by FT-IR it was proved that the ground layer had been prepared from oriental lacquer (Qi-laquer). The FT-IR spectra of the two tested ground layers originating from one fragment show a high degree of similarity to one another as well as to the spectrum of the lacquer reference sample (see fig. 6). By investigation of artificial lacquer samples mixed with different binding media, it was found that the determination of additives to oriental lacquer is hardly possible by FT-IR-spectrometry.

NMR

Nuclear Magnetic Resonance Spectroscopy (NMR) is based on the response of certain atomic nuclei to electromagnetic radiation when exposed to a magnetic field. The most important types of nuclides are hydrogen (^{1}H, proton) and carbon (^{13}C). Each particular type of atom or functional group produces a characteristic signal which is expressed as the chemical shift "delta" in ppm. Furthermore, quantitative information can be deduced from an NMR-spectrum.

Proton- and 13C-NMR-spectroscopy is mainly suitable for determining the structure of organic molecules. In the field of archaeology and conservation NMR spectroscopy has successfully been applied to the identification of resins and ambers, waxes, tar and pitch. Furthermore, the state of decay of wood

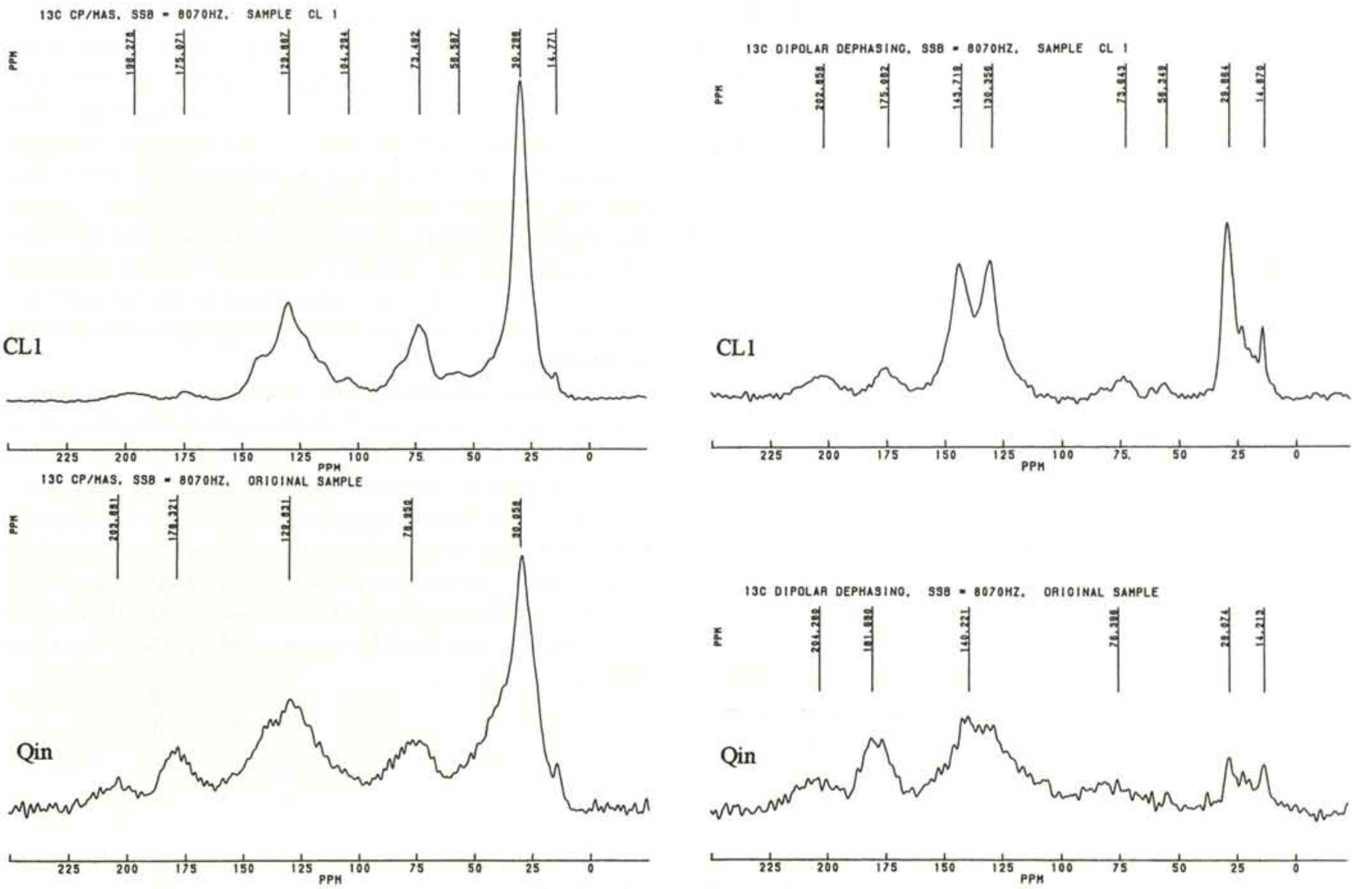


Fig. 7. ^{13}C CP/MAS NMR-spectra of original ground layer sample (Qin) and raw lacquer reference (CL1), (Angelika Sebald, University of Bayreuth).

图 7. 基层底色样品(秦)和原始参照漆的 13C CP/MAS-谱图(CL1)。

and bone has been investigated using this method. More generally, this technique was employed to detect the distribution of water or consolidants inside archaeological objects.[12]

Advantages of NMR-spectroscopy are simultaneous data acquisition and high resolution in discrimintaing functional groups. On the other hand, resolution is poor when investigating mixtures. The former disadvantage of NMR, that only liquid samples could be analysed, has been overcome by special measurement techniques. Solid-state 13C-NMR is performed using cross polarisation and magic angle spinning (13C CP/MAS). Compared to 1H-NMR spectroscopy, the sensitivity of carbon-13 is much lower. This requires longer measuring time and relatively large samples of 50 to 250 mg that need to be powdered. For application in archaeology it is a problem that NMR measurements are strongly disturbed by paramagnetic impurities such as iron salts.

Application

Original ground layer from the Terracotta Army as well as an artificial lacquer sample were measured by solid-stated-carbon-13-NMR.[13] The general shapes of the spectra of both samples are quite similar (Figure 7). This strongly supports the assumption that the ground layer of the Terracotta Warriors consists of oriental lacquer. Differences between the samples can be seen, especially in the content of oxygen-bearing groups (oxygen-bearing aromatic carbons at 145 ppm, carbonyl groups at 175 to 200 ppm). This is attributed to an oxidative weathering of the original lacquer.

Mass Spectrometry

Generally, in a mass spectrometer the analyte is transformed into electrically charged particles. These ions are accelerated and separated according to their mass and their electrical charge. The resulting diagram shows the relative abundance of the particles having a certain mass-to charge-ratio (m/z). It is impossible to present the great variety of MS techniques[14] nor their application on organic archaeometry here. Gas Chromatography e.g. commonly is combined with quadrupol-MS.

In direct temperature-resolved mass spectrometry (DTMS) the sample is vaporised by heating. This method has been introduced to the analysis of resin coatings in the last few years.[15] In contrast to pyrolysis, here the final temperature is reached more slowly, which leads to a separation of low molecular weight parts of the sample from polymeric components. The advantages of DTMS are low sample requirement, short analysis time and no need of sample pretreatment.

Matrix Assisted Laser Desorption and Ionisation (MALDI) is a special method for soft vaporisation and ionisation in MS. It is particularly advantageous for investigation of high molecular and low volatile substances, such as Asian lacquer. MALDI-MS has been applied to some lacquer samples including ground layer of the Terracotta Warriors.[16]

Chromatography

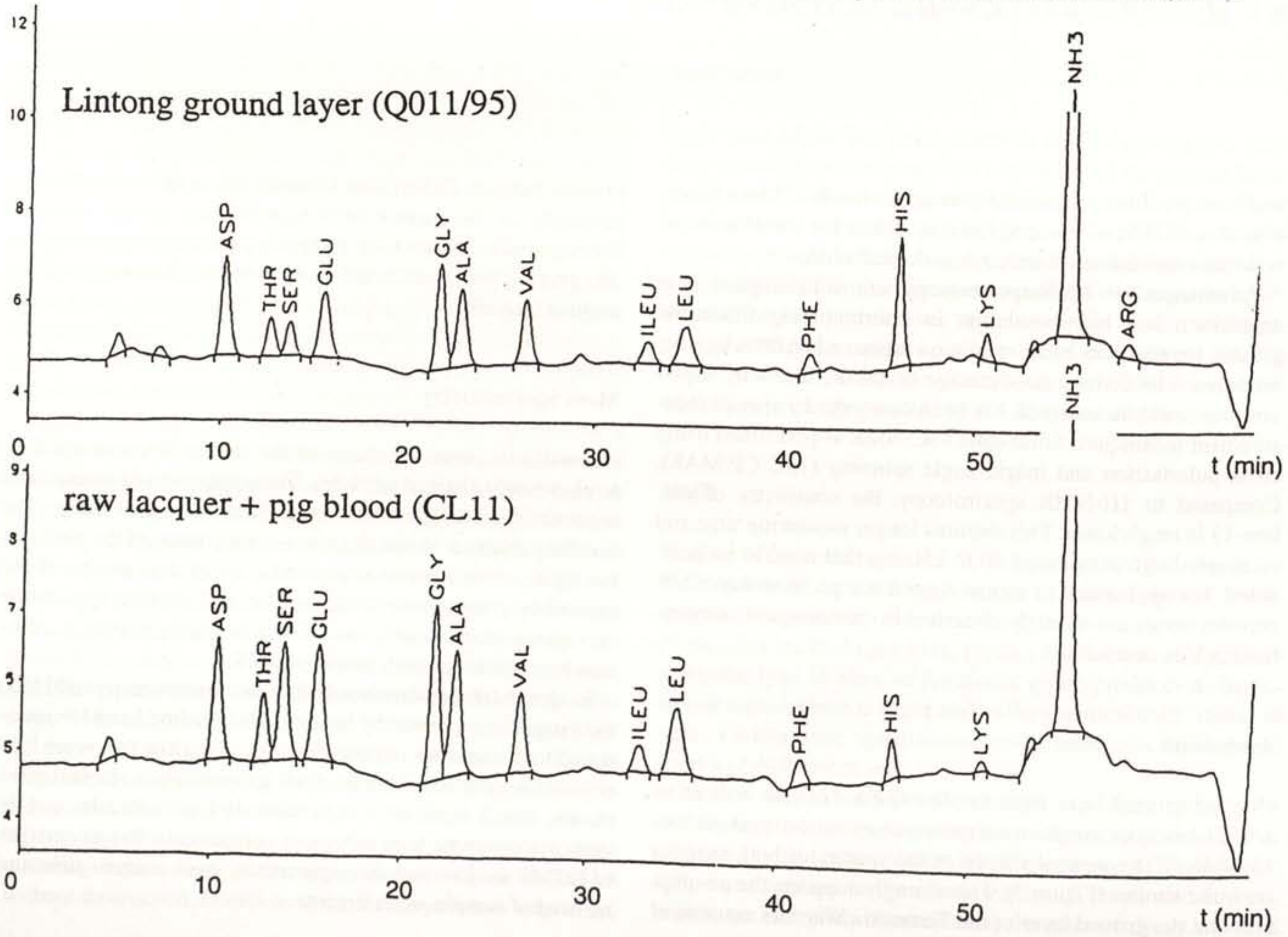
Introduction

Chromatography is a group of analytical techniques for separation, identification and quantification of substances. The common principle is the migration of the substances on the basis of their different distribution on two immiscible phases. One of these is the stationary phase, the other one is the mobile phase. Depending on the arrangement of the stationary phase, planar chromatography can be distinguished from column chromatography. Planar chromatography was begun with paper sheets, later coated glass plates appeared. Now for analytical purposes mostly Thin Layer Chromatography (TLC) is applied using thin plastic or aluminium sheets covered with a finely grained mineral, mostly silica. Planar chromatography has been applied to art and archaeology for almost 50 years, especially for dyes, polysaccharides, resins, and proteins. This method has been revived today in the form of High-performance-TLC (HPTLC) which is characterised by a very thin stationary phase of extremely fine grained particles.[17] In the case of planar chromatography, the separated analyte remains on the stationary phase forming a so-called "internal chromatogram". Each component is characterised by the travelled distance in relation to the front of the moving phase, expressed by the R_f-value.

The column chromatographic techniques, actually using a thin capillary, are commonly further classified depending on the nature of the mobile phase. Different techniques of liquid chromatography (LC) as well as Gas Chromatography (GC) and Supercritical Fluid Chromatography (SFC) have been developed.[18] The column techniques produce external chromatograms, which means that the substances are detected at the end of the column. The resulting chromatogram shows the signal from the detector as a function of time. The characteristic value is called Retention time (t_r).

Fig. 8. Ion-exchange-liquid-chromatograms of: a) hydrolised insoluble part of original ground layer with adherent clay (Q011/95) and b) lacquer reference sample containing pig blood (CL11), (Irene Fiedler, Doerner Institut, Munich).

图 8. 离子交换液相色谱图: a) 带有粘土的原始基层(Q011/95)在水解之后的不溶解的部分; b) 含有猪血的参照漆样品(CL11)。



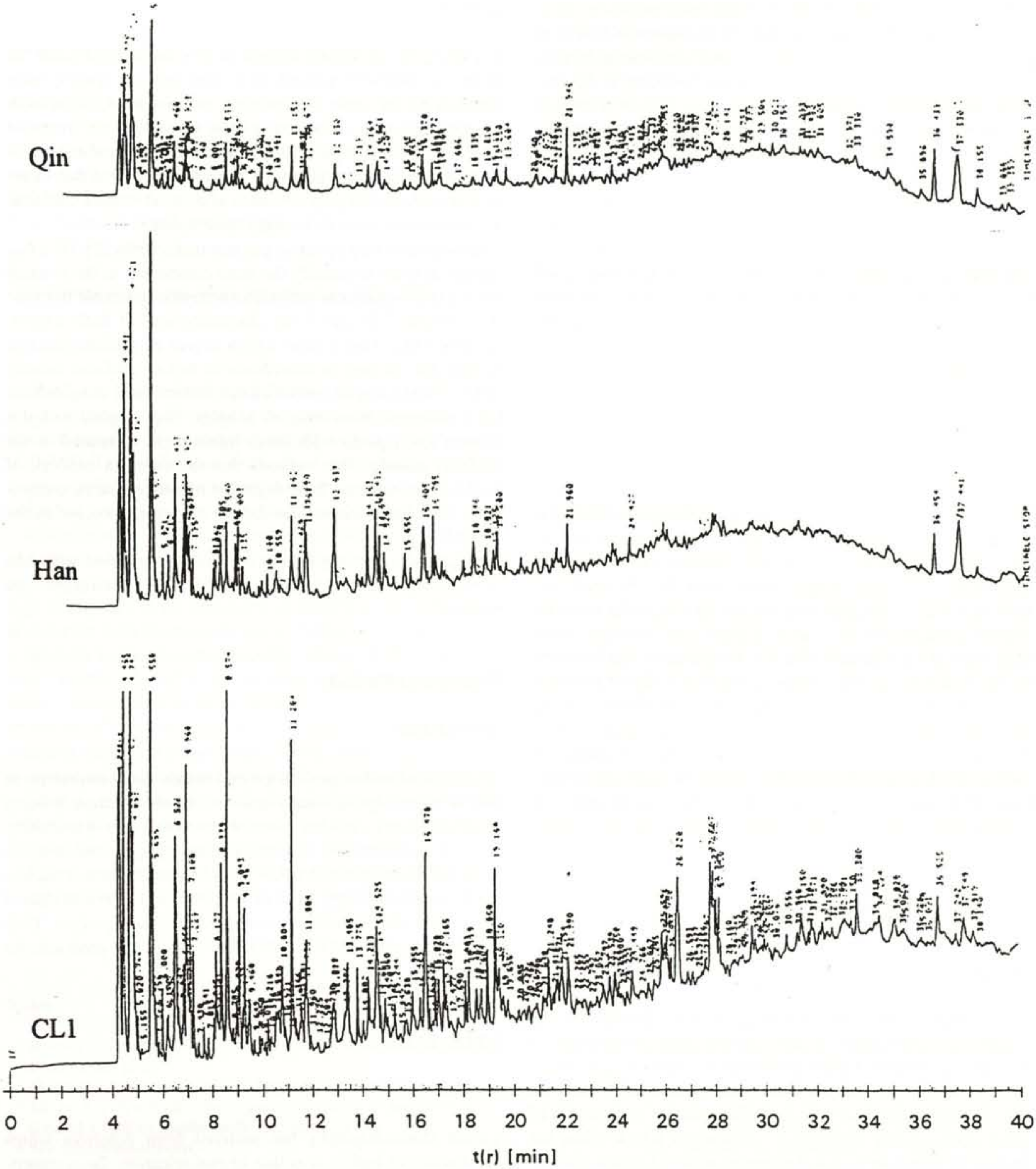


Fig. 9. PyGC chromatograms of original lacquer sample from Lintong ("Qin"), a Han dynasty sample ("Han") and the lacquer reference sample "CL1" Gerhard Heck, Rathgen-Institut Berlin).

图 9. 热解气相色谱图：来自临潼(秦)的原始漆，来自汉代的及参照漆的样品(CL1)。

The material being analysed by a chromatographic technique has to move. Therefore it must be either soluble in the case of TLC and LC or volatile in the case of GC, respectively. Natural polymeric materials (proteins, carbohydrates, dried oils) have to be broken down chemically into their low molecular building units – mostly by hydrolysis in aqueous solution.

Liquid Chromatography

General

Liquid chromatography can be used for the separation of soluble and polar or high molecular substances. High Performance

Liquid Chromatography (HPLC) works with relatively short time spans using high pressure and a thin column. Whereas in the beginning of HPLC the column material was more polar than the solvent, now the most frequently used method is the "reversed phase"-HPLC where the mobile phase is more polar than the column. In the field of archaeometry HPLC is applied to the analysis of amino acis from proteins, dyes, and carbohydrates.

Proteins can be identified by their amino acid composition, which is characteristic for the different types of proteins used as binding media. After hydrolysis of the protein the resulting amino acid mixture is separated and identified by liquid chromatography. A column packed with ion exchange resin is used. In the form of a special "amino acid analyser" this method has been applied to problems in art and archaeology for many years.[19] More recently a HPLC-method for detecting proteins, was described in the literature using special methods of hydrolysis and derivatisation.[20]

Application

Ion-exchange LC was applied to samples of original paint layer of the Lintong Terracotta Warriors as well as to lacquer reference samples in order to detect a possible protein content.[21] It was found that neither the original samples nor the reference contained any water soluble protein components. From the water insoluble residues of two original ground layer samples amino acid profiles were gained, which were similar to that from the lacquer reference sample containing pig blood. This preliminary result hints to the addition of blood to the ground layer painting material of the Terracotta Warriors. Animal glue was not detected in any original sample. However, more original samples as well as different reference material should be analysed in order to confirm this assumption. Contrary to the ground layer, two analysed paint layer samples contained only a few amino acids of low concentration.

Gas Chromatography

General

Gas chromatography (GC) has been used for decades for the separation of mixtures of volatile and low polar components. In this chromatographic technique the moving phase is a gas, while the stationary phase is liquid. In the field of archaeology and art, gas chromatography has been broadly applied to the analysis of most of the organic materials.[3/22] A common way to make the analyte volatile is to treat it chemically, which is called "derivatisation". Another possibility of vaporisation is to decompose high molecular materials by heating, which is called pyrolysis (Py-GC). Successful applications have been reported to the analyses of amber[23] as well as fossile bitumens (jet).[24]

In GC the vaporised sample is forced by means of a carrier gas through a long, thin capillary called "column". The inner surface of the column is filled with the stationary phase, which is a high boiling liquid. Usually, the column is heated. At the end of the column the separated fractions of the sample are registered by the detector. The most commonly used type is the flame ionisation detector (FID). Nowadays, often a mass spectrometer is used as a detector in gas chromatography, as shown below. Like in liquid chromatography, the resulting diagram depicts the time.

Application

In a first step an original sample of the ground layer from the Terracotta Warriors as well as a Han lacquer sample were analysed by GC after conventional derivatisation. Since both samples remained almost completely insoluble only traces of fatty material and of polysaccharides were found without possibility of further identification.[25] This clearly showed that in the case of cross-linked polymers such as oriental lacquer chemical derivatisation is not able to make them volatile.

In the second step pyrolysis gas chromatography (Py-GC) was applied in order to identify the main component in the original ground layer samples as well as in a comparison sample from the Han Dynasty.[26] In fig. 9. the chromatograms of both original samples ("Qin, Han") show a high degree of similarity to one another and are also in accordance to that of artificial lacquer "CL1". Thus it can be concluded that both original samples have been produced from oriental lacquer. The original samples showed fewer peaks with lower intensity as compared to the artificial sample. This suggests that the complex network of hardened lacquer has been degraded or perhaps some components have been leached out during the ageing process in the ground.

Meanwhile, the application of Py-GC combined with MS to asian lacquer has been published in the literature (see below).[27]

Hyphenated Methods

Introduction

"Hyphenated techniques" in general means the combination of two or more separate analytical techniques. Because column chromatography requires external detection, it is particularly useful to combine gas or liquid chromatography with a spectroscopic technique such as UV/visual, infrared, mass or nuclear magnetic spectroscopy. Most of the powerful modern analytical techniques are one of these multi-dimensional systems. They usually are connected to a computer to handle the great amount of data.

HPLC-UV/vis

General

Liquid chromatography has suffered from detectors which are either not highly sensitive or not selective. To overcome this disadvantage, LC is commonly combined with other analytical methods.[28] For the detection of organic dyes in objects of archaeology and art ultraviolet-visible spectrometry (UV/vis) is obviously the best method[29]. After having passed the HPLC-capillary the solution is analysed by the diode-array detector (DAD) which repeatedly generates UV/vis-spectra of the separated substances. The results are normally given as liquid chromatograms. Furthermore, for each retention time a complete UV/vis-spectrum is recorded. So each peak in the chromatogram can be identified by its spectrum, which is typical for certain dyes. The sensitivity of this method for organic dyes lies in the range of a few nanograms.

Application

In the case of the Terracotta Warriors HPLC-UV/vis was employed to samples from pink-coloured parts of the polychromy, representing bare skin. This type of paint was supposed to contain organic dyes because it seemed to bleach out upon being exposed to light after excavation.[30] However, it has to be reported that no organic dye was found in the pink paint layer sample under investigation. Therefore the light-sensitive pink tone is generated by the inorganic pigment cinnabar rather than by an organic dye.[5]

Gas Chromatography-Mass Spectroscopy (GC-MS)

General

Probably the most valuable tool for the analysis of mixtures of low molecular weight organic components has become the online combination of gas-chromatography and mass spectrometry (GC-MS). This is also true for the field of archaeology and art. Numerous investigations of materials from artifacts have been published, including resins, oils, waxes, and proteins.[3, 31]

In this system, the gas chromatograph serves as the separation technique, while a quadrupole mass spectrometer is used for the molecular identification of the components. One great advantage of GC-MS is the capability of detecting extremely small amounts of individual substances in complex mixtures – thus it is ideal for archaeological and artistic works. On the other hand, only volatile substances can be analysed directly. This sometimes requires sophisticated methods of enrichment and pretreatment of the substances to be analysed. Furthermore, the resulting mass spectra are often complicated because of fragmentation of the analyte molecules during ionisation.

From the two-dimensional data resulting from GC-MS set the following diagrams can be deduced:

1. Total Ion Current Chromatogram: For each retention time the signal of all m/z are summed up. Here, the MS just works as a detector similar to the conventional column chromatography.
2. Mass Chromatogram: Here, the intensity for a certain m/z value is plotted over the retention time, so that the occurrence ions characteristic for certain compounds can be extracted from the chromatogram.
3. Mass Spectrum: For a given retention time, the mass spectrum helps identify the compound or structure. An example has been shown before.

py-GC-MS

As already described, polymeric organic material can be vaporised by quick pyrolysis. For analysis of different oriental lacquer samples – however not from the Lintong Terracotta Army – two-step pyrolysis was used prior to GC-MS by Miyakoshi and co-workers.[27] By this means not only the botanical sources of the lacquers could be distinguished, but the polymerisation and crosslinking mechanisms of the lacquer hardening could also be elucidated.

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赫尔姆

有机考古计量学的分析方法及其在研究兵马俑中的应用

简介

自从19世纪50年代以来，一门用来研究过去的应用学科被称之为：考古计量学[1,2]。它的主要任务是：勘探，材料分析和数据处理。科学的分析结论是建立在与考古学，艺术历史及保护科学相互紧密联系，并共地进行讨论的基础上的。这个报告的主要意图是想在有机考古计量学的方法上给出一个全面的观察和研究综述。从这个意义上讲，有机考古计量学意味着一种科学方法的应用，对于在考古对象及挖掘残骸中的有机物的鉴定。这些物质大多数是来自于原始的天然产物，如：油、脂肪、蜡、沥青材料、碳水化合物及纤维素、蛋白质、天然树脂和染料[3]。

化学分析显示出这些材料的物质组成，多数情况下甚至可以帮助用来辨别并保护考古对象和艺术品。经典化学分析方法所提供的数据已经被认为是很陈旧的，所以应该避免继续在考古过程中加以利用。对于大量的样品进行详细地分析是很有必要的，然而另一方面，分析结果的准确度一般来说很低。利用红外光谱只能对物质在种类上加以区分。出于实用的原则，可将有机化学仪器分析手段分成光谱鉴定和物质的色谱分离两部分。图1展示出几种极为重要的分析手段并对它们在研究艺术和考古学中的应用进行了简要的概括[3]。

在大多数有机分析方法中，通常需要隔离样品。但在研究极有价值的考古对象和艺术品的时候，这往往是一个严重的缺点。尽管如此，现今的许多分析方法所需要的样品量，少到只有纳克数量级(ng)。这样少的样品量，是我们很难用肉眼看到的。这样一来，取样技术就成了分析过程中最重要的一步，这直接关系到研究对象的维护问题。

在这里进行讨论的一些方法，是在和许多科技同仁[4]合作研究临潼秦始皇兵马俑过程所应用到的。这里给出的是一个结论综述。这项研究的重点集中在复合彩的基层上。由于这一涂层对湿度的变化极其敏感，所以它对复合彩的保护起着决定的作用。一些在这个联合研究项目所作出的科学结论已经被更详细地发表在其它一些地方[5]。

显微镜检测法

光学显微镜检测法

尽管光学显微镜检测法几乎是在艺术和考古的研究工作中最早使用的技术工具，然而迄今为止，它的重要性仍丝毫未减。光学显微镜检测法的放大倍数可达到1500倍。在利用大量的各种各样的技术装备及特定的光学效应的情况下，无论是穿透照射技术还是表面照射技术的应用都是在艺术和考古工作中极为常见的。

纤维和木制品的鉴别

偏振光显微镜检测法，是一个众所周知的穿透照射法，应用于色素的鉴定。此外，纤维在偏振光下也同样展示出特定的光学效应[6]。这种特性可以用来鉴别自然的动植物纤维。将木制品制成切片样品之后，可使用穿透照射光学显微镜检测法来对它进行植物学的鉴定[7]。

应用

兵马俑被设置在地下很大的木制结构中。其中大部分的木材至今已腐烂或炭化。鉴定这些木材所属树木的种类便成为考古研究的一大主要兴趣。对从2号坑取出的两块木炭和两块腐木的样品，我们进行了植物学的鉴别[8]，如图2。令人惊奇的是，炭化的样品展示出不同的木材种类。很显然，在当初的建造工作中，木材的来源并没有得到很多的重视。

地层学

来自物品表面的样品一般是被进行横截面的制片。为了研究它们层的结构，通常将打光的横截面在表面光照光学显微镜下对其进行研究。一些物质层在紫外线下由于它们的荧光特性而发亮[9]。

应用

兵马俑复合彩的涂层，是通过表面光照光学显微镜检测法进行检测的。在可见光下，兵马俑表面基层的色彩看上去很深很密。但在紫外线照射下，这层漆却显示出微弱的黄绿色荧光。从这里可以辨别出厚达0.1mm的两个涂层(图3)。另外，从显微图片上可以看到在完全干燥的基层上有许多洞和毛细孔。正相反的是，其它被检测的基层样品却拥有较密的结构，而且有时只有一个涂层。

扫描电子显微检测法

概论

扫描电子显微检测法(SEM)是一个用以观察细微样品的有

力工具。在艺术和考古研究领域中，它的放大倍数通常可达到一万倍。在无机材料，包括元素分析的领域中SEM具有特殊的优点。这项技术还具有高分辨率和高放大倍数的优点。然而普通的SEM要求使用完全干燥的样品；使用cryo-SEM (低温扫描电子显微检测法) 能够看到潮湿样品的结构，甚至于水本身。Cryo的意思是指，无论是样品的准备过程，还是显微检测过程，都是在极低的温度下进行的。在将潮湿的样品送入显微镜之前，先将其在液氮(-210 °C)中骤然冷却。在此过程中，样品中所含水的成分处于固体的无定形状态。这样一来，就使得样品的潮湿结构得到了保护。

应用

使用cryo-SEM对兵马俑的原始基层彩进行了研究，用以展示其潮湿的微观结构相对于其干燥的微观结构[10]。图4展示出潮湿状态下的双底色层。在这里，可以清楚地看到两个涂层，它们显示出一个紧密的结构和典型的易裂纹的形状。在高倍显微镜下，可看到它的直径低于0.1 μm。

将真空室的冷却切除后，样品在高真空状态干燥。这个操作过程导致其中一个涂层的彻底毁坏(图5) 。底色在干燥过程中的卷曲或许能够解释这一现象，尽管这一过程要比在常压下进行得更激烈。在幸存的那一涂层上形成了一些直径大于10 mm的孔洞。这一层的出现和被空气干燥的基层结构(见图3)紧密相关。

光谱检测法

简介

光谱检测法通常是建立在电磁波辐射与分析物的相互作用的原理上。电磁波的辐射强度在经过吸收，反射，及散射过程之后会被衰减。在电磁波谱中，很大的波长范围被应用于各种不同的分析手段：高能量的X-射线虽不适合用于有机分析，但对于使用X-射线荧光法(XRF)和X-光片进行的元素分析还是很有用途的。用于鉴别染料可选择紫外-可见光-光谱法(UV/vis)。红外光谱法(IR)使用的辐射能量低于可见光。它不仅可以用来分析无机物，也可以分析有机物质。核磁共振法(NMR，简称：核磁) 所使用的波长在无线电波范围内。在这种情况下要使用外加磁场。从更广泛的意义上讲，不同的粒子，可根据它们质量的不同加以区分。这种因质量不同而引起的粒子分布也同样可以从光谱学的角度来进行处理。这就是质谱法(MS)的原理。

红外光谱法

概论

红外光谱法是建立在分子中化学键对红外线吸收的原理上。在红外光谱中，吸收和透射光强度被作为辐射能量变化的函数，辐射能量由波数给出，单位是cm^{-1}。红外光谱法适用的范围很广。它可用来获得纯净物的准确的分子结构信息；对于混合物可使用官能团的特征表现来进行区分。尽管如此，在通常情况下这种方法却无法用来更精确地鉴别树脂、油、或者蛋白质。红外光谱法有能力来鉴别人工合成的聚合物。通常情况下，将测量的谱图与已知物质的参照谱图进行比较。

现今主要被使用的是经过傅里叶变换的红外光谱法(FT-IR)。傅里叶变换的红外光谱法使得显微镜检测法和红外光谱法的结合成为可能。这项技术只需要直径为30微米，或质量为30纳克的样品量。通常与这项技术一同使用的是一个叫作钻石锻压腔的配件。傅里叶变换红外光谱-显微镜检测法的优点在于：样品需量少，数据处理迅速，应用范围广。由于这项技术不损坏物质结构，所以分析过的样品可以用来作为下一步的分析使用。

拉曼光谱法是很接近红外光谱法的一种分析手段[11]。在这里，分析物在激光照射下所产生的散射光线被进行捕捉和记录。由此而获得的样品谱图可在红外波长范围内。由于所记录的是散射光，所以这项技术不需要使用被隔离的样品。事实上，拉曼光谱法是迄今为止唯一的用来获取物质的有机化学信息而不进行任何结构损坏的分析方法。然而，拉曼效应非常微弱，所以在拉曼光谱法成为艺术和考古研究工作中的常规方法之前，还有很多设备技术上的问题有待解决。

应用

在处理兵马俑的具体问题上，微观化学试验反应在鉴定基层底色的组成上失败了。首先由FT-IR证明：基层底色是来自东方的“生漆”。将从一个基层样品上断裂下来的两个碎片进行FT-IR的测试。这两个碎片的FT-IR-谱图看上去不仅相互间具有高度的近似性，而且和参照样品漆的谱图也极为相似(见图6)。在研究和不同的粘合介质相混和的人工合成漆的时候，发现，对于添加物的鉴定是很难用FT-IR-光谱法来实现的。

NMR

核磁共振谱检测法(NMR)的原理是建立在，当某种特定的原子核暴露在磁场中时对电磁波辐射所产生的反应上。最重要的“核”应数：氢核(^{1}H, 质子)和碳核(^{13}C)。每个不同类型的原子及官能团都会产生不同的特征信号。这种特征信号用“化学位移”- δ (delta) 的方式表达，其单位为ppm。此外，从NMR-谱图上可获取“定量”的信息。

质子和13C的核磁检测法主要适用于对有机分子结构的鉴定。在考古及维护领域中，核磁检测法曾被成功地应用于鉴定树脂、琥珀、焦油、蜡和硬柏油脂。此外，这种技术手段也已用鉴定木头和骨的腐烂程度。这项技术被更普遍地应用于检测水或加固剂在考古对象中的分布[12]。

核磁检测法的优点在于：测量及数据获取可同时进

行，高分辨率(区分官能团)，但在另一方面，在研究混合物时，其分辨率却很低。以前的核磁只可以分析液体样品。这个缺点如今已被特殊的测量技术所克服：交叉极化和磁角自旋的固态13C-NMR(13C CP/MAS)。与1H-NMR相比，13C-NMR的灵敏度要低很多。这就需要较长的测量时间，和相对较大的样品量：50至250 mg。而且，样品需要事先被粉末化。在考古学应用中出现的问题是：核磁的测量会受到顺磁的杂质如铁盐的强烈的干扰。

应用

对来自兵马俑基层底色的样品及人工漆的样品进行了固态-碳13-核磁法的检测[13]。两个样品谱图的基本形状十分相似(图7)。这就证明了，兵马俑基层底色的组成是来自东方漆的假设。两个样品的不同之处在于含养官能团的含量上(带氧的芳香碳原子的化学位移通常在145 ppm，而羰基官能团的化学位移是175至200 ppm)。这是由于原始样品漆的氧化层所引起的。

质谱检测法(MS)

通常情况下，在质谱仪中的分析物被转化成带电荷的粒子。这些带电粒子在电场中得到加速，并能根据它们本身不同的质量和所带电荷数而被区分开。在因此而得到的谱图上，展示出这些具有一定质荷比(m/z)的粒子的相对丰度。质谱技术种类繁多[14]，展示这些技术及其在有机考古计量学中的应用在这里是不可能做到的。常见的有气相色谱与四极场-质谱结合。

"直接温度解析质谱"(DTMS)中的样品被加热汽化。这种办法在过去曾被用来进进行树脂覆盖层的分析[15]。和高温分解相反的是，这里进行逐渐缓慢的升温至最终温度。这样，便可分离在人工聚合化合物样品中低分子量的化合物。DTMS的优点在于：样品需量少，分析时间短，样品不需要进行预前处理。

"载体支持的激光解析粒子化"(MALDI) 是在质谱法中一个非常和缓的汽化-离子化的方法。这种方法在对高分子量，低挥发性的物质，如亚洲漆，的分析中具有特殊优点。在一些漆的样品，包括兵马俑基层底色的分析中曾使用了MALDI-MS[16]。

色谱法

简介

色谱法是一系列用于物质的分离，鉴定和定量的分析技术。这项技术的基本原理是：物质的迁移，这种迁移是建立在物质在互不相容的两相中的不同分布的基础上的。混合物在层析系统中的分离决定于该混合物的组分在这两相中的分配情况。在这两相中的一相是：固定相；另外的一个是流动相。根据固定相的安装可区分平面层析法和柱层析法。早期的平面层析法使用的是纸片，以后出现了涂有玻璃覆盖层的。目前，出于分析目而进行应用的大多数薄层层析法(TLC)是使用通常表面被极细的硅砂所涂盖的塑料片或铝片。平面层析法在艺术和考古工作中的应用已有近50年的历史。特别是应用于染料、多糖、树脂以及蛋白质。高效薄层层析法(HPTLC)的出现使得原有的分析手段更具生机。这项技术的特征在于，由极其精细的颗粒构成的非常薄的固定相[17]。在分平面层析法中，分析物停留在固定相上，并形成一个所谓的"内部层析"。每一个混合物中的组分都是由它们的相对于流动相前峰行程距离，(由Rf-value来表达)来进行区分的。

在通常情况下，柱层析技术(实际上使用的是毛细管)的种类，是根据固定相的固有特征而进行区分的。在液相色谱(LC)，气相色谱(GC)，以及超晶体流动色谱(SFC)中有很多不同种类的技术得到发展[18]。由柱层析技术所得到的是"外部层析"。它的意思是指，分析物的检测是在柱尾进行的。层析结果是由检测器所显示的信号作为时间的函数来表达的。它的特征值被称为"滞留时间"(t_r)。

在色谱技术中被分析的物质要进行移动，这就要求该物质要么在使用TLC和LC时可溶解，要么在使用GC时易挥发。自然的聚合产物(蛋白质、糖类、干燥的油类)必需使用化学手段进行降解至它们低分子量的结构单元－大多是在水溶液中进行水解。

液相色谱

概论

液相色谱可用于分离可溶、极性和高分子量的物质。高效液相色谱(HPLC)的分析时间短，使用高压，细层析柱。早期的HPLC层析柱所使用的物质要比溶剂更具极性。现今最频繁使用的方法是：逆转相-高效液相色谱。这里的固定相要比层析柱更具极性。在考古计量学领域中，HPLC被用于分析来自于蛋白质的氨基酸、染料及碳水化合物。

蛋白质可由其氨基酸的组成来进行鉴定。不同种类的蛋白质使用其特有的氨基酸来作为连接媒介。蛋白质在水解之后所产生的氨基酸混合物被通过液相色谱进行分离和鉴定。所使用的层析柱的填充物是离子交换树脂。许多年来，这种以"蛋白质分析"为形式的分析手段被应用于解决艺术和考古学科中所出现的问题[19]。一种近来用以检测蛋白质的 HPLC-分析方法曾在一篇文献中得到具体的描述。在这篇文献中使用了特殊的水解和派生方法[20]。

应用

使用离子交换液相色谱来分析兵马俑原始涂层的样品及两个参照漆的样品，其目的在于检测样品中可能含有的蛋白质[21]。结果发现，无论是在原始样品还是参照样品中都不含有水溶性的蛋白质组分。从水不溶性的原始基层残片样品

中得到了氨基酸的结构，这与含有猪血的参照漆样品极为近似。这个初步的结论暗示着，兵马俑的基层涂料中曾被加入了猪血。在任何一个原始的样品中都没有检测到动物胶。尽管如此，还是应该对更多的原始样品及不同的参照材料进行分析，用以证实这个假设。和基层样品相反的是，两个被分析的涂层样品中含有一些低浓度的氨基酸。

气相色谱

概论

气相色谱(GC)在近几十年来被用于分离具有挥发性和低极性的混合物中的组分。在这项色谱技术中，是以气体作为流动相的，其固定相是液体。在艺术和考古学领域中，气相色谱以被广泛地应用于有机材料的分析[3,22]。使分析物气化挥发的常用方法是将其进行化学处理。这就是所谓的"派生法"；另外的一种气化方法是将高分子材料进行加热使其分解，叫做：热解(PY-GC)。关于其成功地应用于分析琥珀[23]和沥青化石(jet)[24]已有报导。

在气相色谱中被气化的样品借助于载气的推动下通过一个又细又长的，被称为"层析柱"的毛细管。层析柱内部表面上装有固定相，这是一种具有高沸点的液体。层析柱在通常情况下被进行加热。在层析柱的末端，可将从样品中分离的组分用检测器进行检测。最常用的检测器的类型是：火焰离子检测器(FID)。目前常使用质谱仪作为气相色谱的检测器，如底下将要进行介绍的。如液相色谱法，气相色谱的结论谱图也是由时间曲线来表达的。

应用

在第一步对兵马俑的原始漆层样品及汉漆样品进行气相色谱的分析之前，使用了常规的派生法。由于两种样品几乎都完全保持不溶解，在没有可能做进一步鉴定的情况之下，只找到了一些油脂物质以及多糖的痕迹[25]。这就显示出，对于交联聚合物，如东方漆的化学衍生物，是无法使其气化的。

在第二步中，为了鉴别兵马俑的原始底层漆样和一个汉代的对照样品[26]中的主要成份，使用了热解-气相色谱(PY-GC)。在 图9中，两个原始漆样("秦"、"汉")的色谱图不仅在其相互间展示出的高度近似性，而且与人工漆"LC1"也具有一致性。由此可得出的结论是：两个原始漆样都来自东方漆。和人工漆样品的谱图相比，原始漆样谱图的峰较少，强度较低。这暗示着，对硬化的漆进行的复合网络工作曾被简化，或者，也许样品中的一些组分在地底下的老化过程中有所流失。在此期间，关于使用热解气相色谱法结合质谱法对亚洲漆进行分析的应用已在文献中进行了发表(见下)[27]。

级联的方法

简介

"级联法"一般是指两个或多个独立的分析技术手段的结合。因为柱层析需要外加的检测器，所以气相或液相色谱与光谱技术的结合就更有意义。如，紫外/可见光谱、红外光谱、质谱、及核磁。大多数强有力的现代分析技术都是一种这类的多维系统。它们通常都是与计算机连接用来处理大量的数据。

高效液相色谱-紫外/可见光谱法(HPLC-UV/vis)

概论

液相色谱由于检测器的非高灵敏度，非选择性而受到阻碍。为了克服这个缺点，经常将液相色谱与其它分析手段相结合[28]。对于在考古及艺术领域中有机染料的检测，很显然是紫外/可见光谱(UV/vis)当选的手段[29]：在溶液通过HPLC-毛细管之后，由一个对不同物质重复进行紫外/可见光谱检测的二极管阵列检测器(DAD)将其进行检测。结果一般是由液相色谱图给出。此外，对每一个滞留时间都有紫外/可见谱图的记录。所以在液相色谱图上的每一个峰都可以通过其用来表达某一特定染料的特征光谱图来进行鉴别。这一分析手段的灵敏度可达到纳克级(ng)。

应用

在兵马俑的研究中，高效液相色谱-紫外/可见光谱法(HPLC-UV/vis)被用来进行来自复合色中展示裸露皮肤的粉红色部分的样品的分析。这种类型的涂料猜测可能含有有机染料，原因是，在其出土后暴露在阳光下而似乎完全脱色[30]。然而，在研究中还没有报导过在粉红色层中发现有机染料。尽管如此，与其说这种对光敏感的粉红色陶来自于某种有机染料[5]，不如说它是由无机色素硫化汞矿(朱砂)制成的。

气相色谱-质谱法(GC-MS)

概论

很多有价值的、用来分析低分子量有机组分混合物的分析工具，都是气相色谱和质谱的在线组合(GC-MS)。在考古和艺术领域也是如此。大量的对来自艺术品的材料进行的研究工作已经得到发表，其中还包括树脂、油料、蜡和蛋白质[3,31]。

在这个系统中，气相色谱法作为分离技术，一个四极质谱仪则是用来对各组分进行分子鉴别。GC-MS的一大优点是它对络合混合物中极其少量的个别物质进行检测的能力。这对考古和艺术研究工作是十分理想的。但在另一方面，只有可挥发的物质能够被直接地进行分析。这就需要有时使用高尖端的技术手段对要分析的物质进行浓缩和预前处理。此外，结论中的质谱图经常是很复杂的。这是由

于在离子化过程中被分析分子的断裂而造成的。

从GC-MS 装置而得出的二维数据可推得如下的谱图:

1. 总离子流色谱图: 对每一个滞留时间都将质荷比(m/z)信号进行叠加。在这儿, 质谱只是作为一个检测器, 类似于传统的柱层析法。
2. 质量色谱图: 在这儿, 质荷比信号强度是在建立在滞留时间的基础上绘制出的。借此, 可将某一特定化合物产生的离子特征从色谱图上分离出来。
3. 质谱图: 对于给定的滞留时间, 质谱可以帮助鉴别化合物或其结构。前面已经介绍了一个这样的例子。

热解气相色谱-质谱法(py-GC-MS)

正如所描述, 聚合有机材料可通过热解的办法进行气化蒸发。Miyakoshi 和他的同事们在对不同的原始漆样品(并非来自临潼兵马俑)进行分析时, 曾在GC-MS之前使用了两步热解法[27]。使用这种手段, 不尽可以对来自于植物的漆进行研究, 而且硬化漆的聚合及交联机理也可得到阐述。

致谢

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注:

尾注请见英文文本。

Ingo Rogner

New Methods to Characterise and to Consolidate the Polychrome Qi-lacquer of the Terracotta Army

Abstract

A method for the conservation of aged qi-lacquer layers on silicate material such as terracotta is described. Detachment of the layers would result in the loss of the paint layer. The terracotta army of the Chinese emperor Qin Shihuangdi in Lintong / China is a prominent example of this problem because the paint layer is bound to the surface by an intermediate qi-lacquer layer. This layer has aged 2200 years, buried in wet clay and will detach from the surface if relative humidity drops below 84 % after the excavation. Methacrylic monomers were of special interest as solidifying materials because of their long lifetime and their excellent transparency. Lacquer samples were treated with watersoluble 2-hydroxyethyl-methacrylate (HEMA) which was polymerised by electron-beam radiation with an electron energy of 1.0 MeV. In the experiments the dose was administered in three steps of 20 kGy. Micro-organisms and mould are destroyed by the electron-beam radiation. Infra-red- and mass spectroscopical evaluation shows no damaging effect of electron-beam radiation (300 kGy) on the qi-lacquer. Original qi-lacquer and lacquer consolidated with the method described above were characterised by laser desorption mass spectroscopy (LD-MS). The formation of HEMA polymers with 4-6 monomer units within the lacquer was proved by laser desorption MS. Infrared spectroscopy reveals that the degree of polymerisation is proportional to the applied dose.

Three original polychrome fragments were successfully treated by electron beam curing. The qi-lacquer is bound to the terracotta, the fragments can be dried, a natural look (not shiny) of the polychrome surface is obtained. Laser video holography was employed to investigate if drastic changes in humidity will affect the consolidated polychrome layer. No damage could be detected after four humidity cycles (35-83 % r. h.). The long term stability will have to be evaluated.

The application of electron-beam polymerisation seems to be a promising method for the conservation of the terracotta army of Qin Shihuangdi and other works of art.

Introduction

The change of polymeric bindings with time is an important factor for the ageing of art objects. The detachment of qi-lacquer layers (urushi) from the basic material would result in the loss of paint layers and solidifying such layers is a central point in the conservation of such works of art. The terracotta army of the Chinese emperor Qin Shihuangdi in Lintong / China is one of the most important archaeological objects and is a prominent example of this example because the paint layer is bound to the terracotta surface by an intermediate qi-lacquer layer[1]. This layer has changed during the long time span of 2200 years, buried in wet clay so that it detaches from the surface if relative humidity drops below 84 %. This condition occurs during excavation of the coloured fragments. Until now, the conservation of the paint layers is an unsolved problem.

Results and Discussion

We tried to rebind the qi-lacquer layer to the terracotta by the application of organic polymers. This seems to be an extraordinarily difficult problem if the support is not an organic material, but a highly hydrophilic surface of a silicate such as terracotta. The application of radical initiators and monomers such as methacrylic esters solidified the qi-lacquer, but could not bring about a firm connection of the lacquer to the terracotta support. Inorganic pigments constitute the polychromy of the conserved works of art. A second problem was the lustrous surface of the solidified material which impairs the visual impression by changing the tonality of the colours.

We wanted to avoid these problems by the application of a two-step process. Firstly the terracotta and the overlying layers were impregnated with cotton wool compresses containing the liquid monomer. The monomer concentration in water was increased to 100 % in several steps. During this process unwanted polymerisation was inhibited by the stabilisers which are generally added to the monomers to allow storage (up to 650 ppm hydroquinone-monomethylether). Thus the monomer had enough time to penetrate all organic and in organic material.

Secondly the polymerisation was induced. This could be done neither by conventional thermal radical initiators nor by photopolymerisation which was prevented by the dark colour of the lacquer layer. Therefore we tried initiation by penetrating radiation with which we could start polymerisation from within the terracotta support.

Polymerisation by the application of X-rays gave very poor results. The photons were not absorbed properly within the thin qi-lacquer layer and the silicate material to induce polymer formation.

However, good results were obtained by the application of an electron beam for initiation. This forced the start of the polymerisation within the terracotta propagating toward the outside through the monomer impregnated qi-lacquer to the outside air. After the electron radiation is switched off, there is no radioactivity left within the irradiated material; of course there is a very intense X-ray radiation during the application of the electron beam which must be thoroughly shielded. Methyacrylic monomers were of special interest as solidifying materials because of the long lifetime and excellent transparency of their respective polymers. Methylmethacrylate seemed to be less suitable because of its low polarity so that watersoluble 2-hydroxyethyl-methacrylate (HEMA) gave even better results. It was applied as a commercial formulation Plex 6803-1 (Röhm). Detachment of consolidated qi-lacquer by volume shrinking of HEMA cannot occur because of the thin HEMA layer.

Polymerised HEMA can take up water up to 40 % of its own mass. This implies that the polymerised product lets water penetrate. If applied to wet terracotta water can cross the polymerised HEMA film and evaporate. In contrast to a film which seals the surface, the formation of blisters can be avoided.

The application of an electron beam (EB) initiates a radical polymerisation which is inhibited by molecular oxygen contained in air[2]. Therefore oxygen must usually be thoroughly excluded to obtain a smooth and solid surface. On the other hand, the influence of oxygen is desirable for obtaining a lustreless surface of the solidified works of art. Therefore one should initiate the polymerisation with electron beam radiation with air surrounding the monomer soaked qi-lacquer layer. After the EB cure small residues of monomer can easily be removed from the surface by wiping off or by evaporation of the monomer at room temperature.

A central difficulty in conserving paint layers by the application of electron beam polymerisation is the potential damage of the lacquer by radiation. Ions and radicals remaining after the radiation process can be starting points for further decay. The qi-lacquer, however, contains ortho-hydroxy phenyl moieties[3] which are known to be radical scavengers.

Electron beam curing experiments were carried out at the Institut für Polymerforschung (IPF) in Dresden with the Russian electron accelerator ELV-2, INP Nowosibirsk. A sketch of the electron accelerator is shown in fig. 1. Electron energies can be varied between 0.6 to 1.5 MeV, the maximum radiation current amounts to 25 mA. For further experiments in Xi`an the electron accelerator ELV-8 can be used. This apparatus is from the same Russian producer and provides a wider range of electron energies.

The electron beam (EB) is focused and scans the substrate. Extensive shielding is required due to "bremsstrahlung". The absorbed dose the sample receives as a result of passing under the beam is obtained by integration of the Gaussian function for the beam shape. The sample speed is thus inversely proportional to the absorbed dose. In the experiment the dose was administered in steps of 10 and 100 kGy. The total dose absorbed is the sum of all the individual doses.

For all experiments an electron energy of 1 MeV was used. This value determines how deep the radiation can penetrate into a substrate. At an energy of 1 MeV electrons can penetrate up to 5 mm into a medium of density 1 (water), with a maximum intensity at 1.6 mm. At longer EB exposures if all monomers are consumed by the polymerisation reaction main chain scission is possible.

Preliminary Experiments

In preliminary experiments original qi-lacquer ground layer flakes were flattened on a terracotta support with H_2O dest. and were impregnated during three days with various consolidants before electron beam irradiation.

The HEMA formulations polymerised at an energy dose of 50 to 60 kGy. Polymerised Plex 6803-1 shows the best results concerning the mechanical strength of the binding of the qi-lacquer. Unreacted monomers on the surface evaporated after a few days. After three years the original Qin-dynasty qi-lacquer is still firmly bound to the terracotta, the surface is not shiny or lustrous and the terracotta has completely dried.

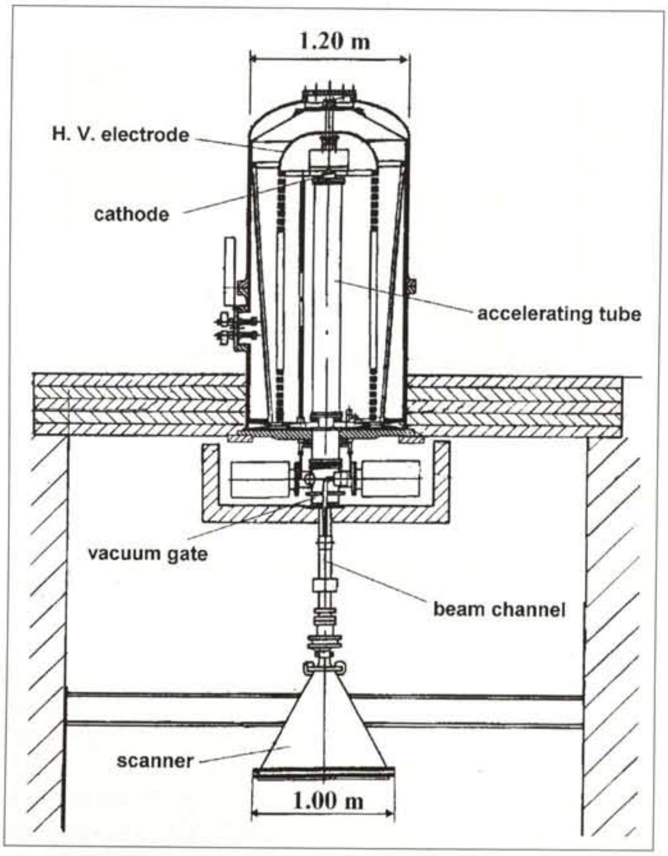

Fig. 1. Sketch of the electron accelerator ELV-2, INP Novosibirsk.

图 1. ELV-2, INP Novosibrsk 电子加速器示意图。

Analytical Methods

Among the methods that we have used, I want to focus shortly on the following three:
Infra-red spectroscopy, cross sections / microscopical evaluation and laser desorption mass spectroscopy.

Infra-red Spectroscopy

Infra-red Spectroscopy does not show damaging effects of the electron radiation up to 300 kGy. Spectra taken from irradiated and not irradiated samples were alike. No damage by electron beam irradiation can be detected by infra-red spectroscopy.

Infra-red Investigation of the Degree of Polymerisation of Pure Monomer

In order to find the best conditions to consolidate the monomer soaked samples a multitude of preliminary experiments were carried out. Test tubes were filled with equal amounts of the respective consolidant. Some of the test tubes were filled with the inert gas argon to exclude oxygen which is known to be a radical scavenger and polymerisation inhibitor. The test tubes were exposed one or more times to a certain dose of electron beam radiation to evaluate differences in the effect of the irradiation.

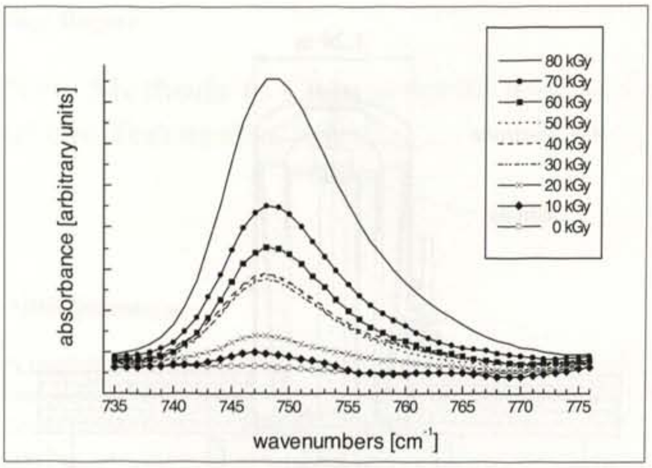

Fig. 2. Electron beam curing of Plex 6803-1 at different doses (one step treatment).

图 2. Plex 6803-1 经不同量电子辐射的处理(一步处理)。

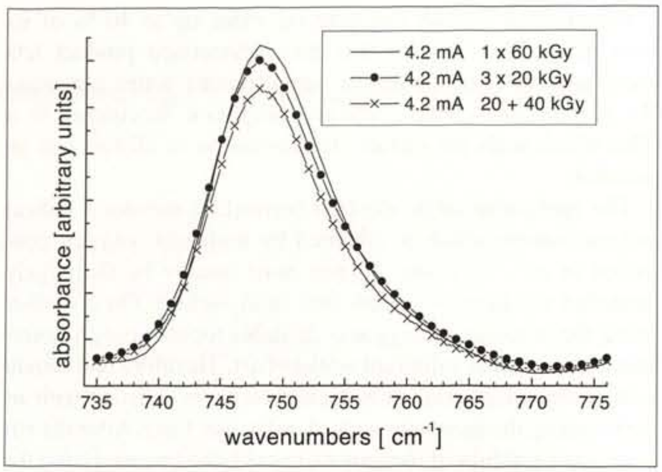

Fig. 3. Electron beam curing with 60 kGy dose

图 3. 用 60 kGy 的剂量电子辐射处理。

The effect of argon to exclude air (which contains oxygen and thus inhibits polymerisation) is only minimal. If Plex 6803-1 is irradiated in argon atmosphere the dose necessary for consolidation is only lowered by 10 kGy down to 50 kGy. The exclusion of oxygen can lead to the formation of a transparent and shining film on the surface of the consolidated original qi-lacquer. The use of argon "blanketing" is thus not recommended.

Pure HEMA cannot be polymerised as easily as the HEMA formula Plex 6803-1, which contains a few percent of cross-linker. Plex 6803-1 is therefore found to be superior to pure HEMA.

The dose necessary to obtain the solidification of Plex 6803-1 was found to be 60 kGy. In different experiments the dose was administered in one step, in two steps (20 kGy + 40 kGy) and in three steps (3 x 20 kGy). All experiments proved the Plex 6803-1 to be solid after the irradiation. It can thus be confirmed that the overall dose given is of importance, independent of the number of steps it is accumulated in.

During all experiments the accelerating voltage is kept constant at 1 MV. In the last set of experiments the radiation current of the electron beam was varied. The lower the radiation current the less electrons penetrate the monomer soaked samples. The lower the amount of electrons initiating a polymer chain, the longer the polymer chains grows. This means that longer polymers form at a lower radiation current. At 2.4 mA a dose of 60 kGy resulted in solidification and evaporation of monomer. Too much energy is transferred in this one step treatment. At the lowest radiation current of 0.6 mA the maximum dose obtainable in a single step is 25 kGy. This treatment led to the formation of a very hard solid.

The solidified samples of Plex 6803-1 were further investigated by quantitative infrared spectroscopy with a Perkin-Elmer IR-1420 FT-IR spectrometer. This method allows to determine the degree of polymerisation. The samples investigated had very different consistencies: liquid, viscous, rubber like and rock hard. It was preferred to monitor a peak that was linearly proportional to the degree of polymerisation. The polymerisation of Plex 6803-1 afforded the formation of linear chains like: $-[-CH_2-CR_2-CH_2-CR_2-]-$.

The newly formed methylene group (CH_2) is found at 748.5 cm^{-1} and its peak is proportional to the degree of polymerisation. The longer the chain the more methylene groups are formed, the higher the absorbance at this wavenumber.

After thorough investigation the IR-spectra were normalised for the $-CH_2-H$ valence vibration at 2957 cm^{-1} (methyl group is not affected in the reaction). The baseline was corrected and the wavenumber 780 cm^{-1} was set to zero. Fig. 2. presents IR spectra focusing on the peak at 748.5 cm^{-1} taken after a single step electron beam curing with doses from 0 to 80 kGy. The proportional relationship between dose rate and absorbance is evident.

At a dose of 80 kGy the Plex 6803-1 became solid, independent of the number of steps. The single step electron beam treatment leads to a higher degree of polymerisation. Fragment F009-98 was consolidated with a dose of 4 x 20 kGy.

The lowest dose necessary to obtain solid Plex 6803-1 was found to be 60 kGy. The dose was applied in a single step, in two steps (20 kGy + 40 kGy) and in three steps (3 x 20 kGy). The resulting spectra are shown in fig. 3. All three curing methods afford about the same degree of polymerisation. This dose was to be used for one of the original polychrome fragments (Fragment F011-98).

In another set of experiments the electron beam current was varied. The lower the beam current, the longer the polymer chains, the higher the absorbance at the CH_2 rocking vibration (748.5 cm^{-1}). Fig. 4. shows the spectra taken from samples irradiated with an electron beam with a beam current of 0.6, 2.4 and 4.2 mA.

The highest degree of polymerisation was obtained at 0.6 mA. The solidified Plex 6803-1 was rock hard. The original fragment F006-98 was treated in this way. Irradiation with a beam current of 2.4 mA (60 kGy) resulted in the evaporation of the consolidant. Although longer polymers are formed the detrimental effect of the heat-up of the polychrome lacquer and the fragment disqualifies this curing method for further experiments.

Although FT-IR Spectra allow for a quantitative measurement of the relative polymer length, further experiments will have to be done to determine the distribution of the absolute length of

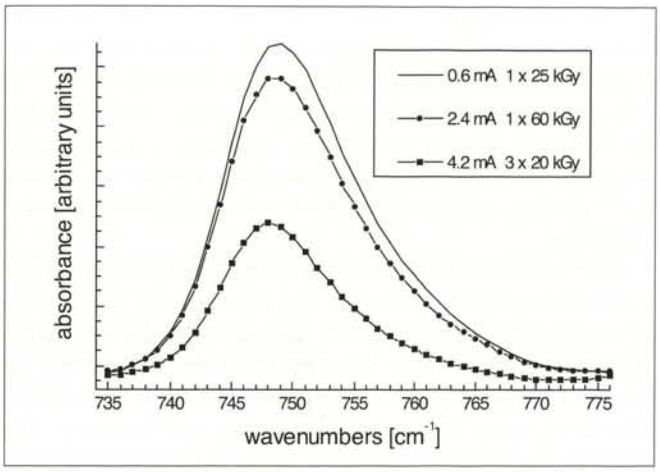

Fig. 4. Electron beam irradiated samples with a beam current of 0.6, 2.4 and 4.2 mA.

图 4. 使用 0.6, 2.4 和 4.2 mA 的辐射电流辐射试样。

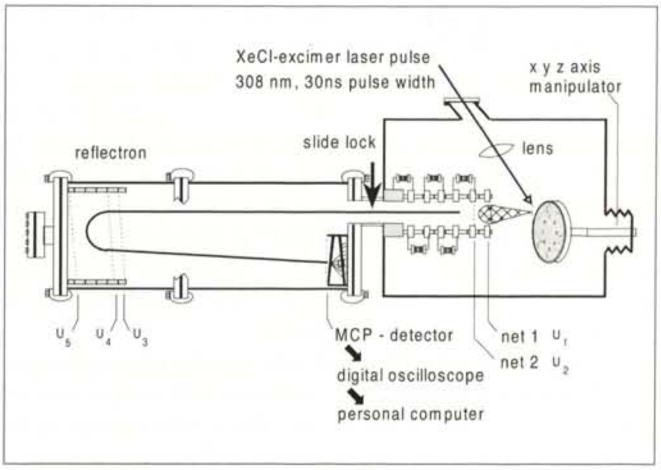

Fig. 5. Section of the laser desorption mass spectrometer.

图 5. 激光解吸质谱仪示意图。

the polymer chains after electron beam curing. Laser desorption mass spectroscopy (LD-MS) is an elegant method to obtain the exact mass distribution.

Cross Sections and Microscopical Evaluation

Light microscopical investigation and cross sections provide another possibility to evaluate the penetration of the consolidant into the lacquer and the terracotta. Original qi-lacquer samples consolidated with electron beam and the HEMA formulation Plex 6803-1 were used. At magnifications of 50 x to 200 x a colourless transparent polymer film of Plex 6803-1 can be detected between terracotta and qi-lacquer. This can be clearly seen in the cross section. However, on top of the qi-lacquer no polymer film is found. Owing to this the surface of the consolidated qi-lacquer appears dull, it does not shine.

In this cross section the polymerised HEMA layer is thicker than the original qi-lacquer layer. This is due to the fact that detached original flakes were consolidated onto a new terracotta support. Original samples, where the lacquer layer still adheres to the original terracotta, do not show an intermediate HEMA layer after consolidation.

Laser Desorption Mass-spectroscopy

Laser desorption mass spectroscopy (LDMS) was carried out on irradiated samples at the Max-Born-Institute in Berlin, Adlershof, Germany. The degree of polymerisation of the applied monomer and possible EB cure damaging effects were monitored. For laser desorption a XeCl excimer laser LPX-100 Lambda Physik (308 nm, 30 ns pulse width) was used. The positively charged ions generated were separated by a non-commercial reflectron time-of-flight mass-spectrometer (RETOF-MS, see fig. 5.) with a mass resolution[4] of $m / \Delta m = 2000$. In contrast to most commercial systems, the laser desorbed ions were allowed to drift for ca. 2 cm before being extracted by a pulsed electric field. The ions were detected by dual multichannel plates and the signal was collected by a digital oscilloscope. The spectra were then transferred to a PC for further evaluation. The delay between laser pulse and ion extraction allows one to preselect the mass of the ions detected.

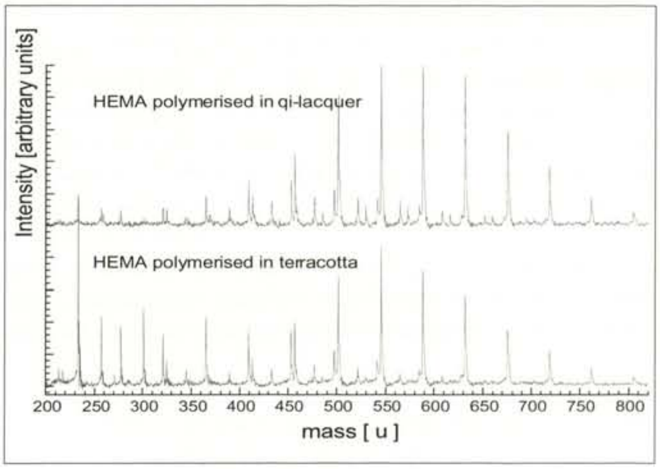

Fig. 6. Laser desorption mass spectra of 2-hydroxyethyl-methacrylate (HEMA) polymerised by electron beam irradiation. Upper spectrum: HEMA polymerised in hardened qi-lacquer. Lower spectrum: HEMA polymerised in the terracotta support.

图 6. 电子束辐射聚合的 2 羟乙基-异丁烯酸盐(HEMA)的激光解吸质谱。上谱: HEMA 在硬化的漆中聚合。下谱: HEMA 在陶体中聚合。

Mass-spectroscopical evaluation shows no damaging effect of the EB radiation (300 kGy) on the qi-lacquer. To prove the polymerisation of the applied monomers within the terracotta and the original qi-lacquer LDMS spectra were taken. LDMS of HEMA polymerised by electron beam curing usually determines the average polymer chain length in the terracotta support and within the qi-lacquer. The spectra are depicted in fig 6.

In the terracotta support only polymer fragments mainly consisting of 2-4 monomer units were detected. Within the solidified original qi-lacquer layer solely fragments with 4-6 monomer units were found. Unfortunately the LDMS spectra do not show long polymer chains, but only fragments of these. The reason for this is the three-dimensional cross-linking, which occurs during the polymerisation. A large network is formed and the laser pulse can only desorb small parts of this network. For every polymer a combination of peaks can be observed. This is due to sodium and lithium adduct peaks[5] and because of the cleavage or addition of a hydroxyethyl fragment (small bond dissociation value). In the mass spectrum of HEMA polymerised in terracotta fewer lithium adduct peaks can be found. Furthermore hydroxyl endgroups are detected which were formed through EB radiation by reaction with the terracotta.

Investigation of the influence of electron radiation on qi-lacquer by IR and mass spectroscopy confirmed that even a dose of 300 kGy (30 Mrad) does not result in a detectable damage of the qi-lacquer. However this dose is far beyond the dose which is necessary for polymerisation. Additionally the radio-biological effect of electron beam and "bremsstrahlung" destroys micro-organisms and can be used to disinfect contaminated lacquer[6].

After the promising preliminary experiments we started experiments with original samples. The experiments were performed at the Institute for Polymer Research in Dresden, Germany by the Bavarian State Conservation Center and three Chinese colleagues from the Museum of the Terracotta Warriors and Horses: Zhou Tie, Rong Bo and Zhang Zhijun.

Before the irradiation with the electron beam three original samples (Fragment 6-98, 9-98 and 11-98) were pre-treated as follows: During three days the samples were impregnated with the commercial formulation Plex 6803-1 which was applied with compresses. The concentration of Plex 6803-1 in water was raised from 33% on the first to 66% on the second and finally to 100% on the third day. Thus the consolidant had enough time to penetrate the qi-lacquer, its overlying paint layer and the terracotta. In order to evaluate different electron beam curing methods every original fragment was treated with a different method.

Fragment F006-98

Part of body armour with qi-lacquer and red iron oxide.
Treatment: 1 time 25 kGy at 1 MeV and 0.6 mA.
The fragment was not cleaned after the irradiation. Surplus consolidant was allowed to evaporate for several days. After irradiation the sample was stored under ambient conditions.

Fragment F011-98

Part of body armour with qi-lacquer and stripes of red cinnabar.
Treatment: 3 times 20 kGy at 1 MeV at 4.2 mA.
The fragment was not cleaned after the irradiation. Surplus consolidant was allowed to evaporate for several days. After irradiation the sample was stored under ambient conditions.

Fragment F009-98

Collar with Han blue, cinnabar, pink colour and qi-lacquer
Treatment: 4 times 20 kGy at 1 MeV and 4.2 mA.
Surplus consolidant was removed between the irradiation experiments with a laboratory tissue. Along rims and creases liquid consolidant collected to form a pool which can harden and lead to shiny spots on the treated fragment. These pools were drained by pressing the edges of the tissue into the rims and creases. The fragment was immediately freed from surplus consolidant after the last irradiation by pressing the laboratory tissue onto the lacquer. The result was a fragment with virtually no shining spots on the surface. The sample was stored under ambient conditions.

After irradiation all fragments showed a good mechanical fixation of the original qi-lacquer and the overlying polychrome layer. A rub test was performed. The terracotta dries out completely after a few days, the stability of the polychrome qi-lacquer is retained. All three fragments are in good condition after three years at ambient temperature and humidity. The coloured lacquer layers are bound tightly to their original terracotta support. A natural look (not shiny) of the polychrome surface is obtained. Laser video holography was employed to investigate if drastic changes in humidity will affect the consolidated polychrome layer. No damage could be detected after four humidity cycles (35-83 % r. h.). We are all looking forward to seeing the effect of long-time storage under ambient conditions in Lintong, China.

Finally I would like to repeat all advantages offered by the new method:

- The consolidant is watersoluble in every ratio.
- The consolidant is similar to water in viscosity, colour and density, it has only a faint odour.
- Only two solutions of consolidant in water are required for the whole preparation. No more chemical operations needed.
- The consolidant is a commercial formulation of HEMA (Plex 6803-1) which is commercially available.
- It is used in very hostile environment for long term sealing of broken canal pipes.
- The consolidant is stable under normal conditions, no auto-polymerisation occurs.
- Monomer treated samples can be stored because the polymerisation starts with the electron beam irradiation only.
- The polymer has an excellent transparency like most methacrylates, but treated samples do not have a shiny appearance.
- The polymer binds to qi-lacquer and terracotta alike.
- The polymer is not poisonous, it is the main component of contact lenses for the eye.
- Irradiation with an electron beam can be carried out in Xi'an, China with a suitable electron accelerator like the ELV-8. This apparatus was produced by the same company as the accelerator used in Dresden.
- Electron irradiation effectively destroys bacteria, micro-organisms and most important: mould.

The application of the rapid electron beam polymerisation is therefore a promising method for the conservation of the terracotta-army of Qin Shihuangdi and other art objects.

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罗格纳

鉴定和加固兵马俑彩绘漆的新方法

摘要

本文介绍的是一种保护硅酸盐材料如陶俑上的老化漆层的方法。漆层的剥离会导致彩绘层的损失。这方面一个著名的例子即中国临潼秦始皇兵马俑，因其表面彩绘层与一层漆中间层相连。这些漆层在湿土下埋置了 2200 年，出土后一旦空气湿度降到 84 %以下，漆层便会与表面分离。作为固化材料，甲基丙烯酸单体值得特别重视，因为这种单体的寿命长，透明度好。漆样的处理，是通过 1.0 MeV 的电子能量来聚合水溶性羟乙基-异丁烯酸盐(HEMA)进行的。实验中分 3 步用 20 kGy 的剂量辐射。微生物和霉菌会被电子辐射杀死。红外线光谱和质谱分析显示，辐射(300 kGy)并不会对漆层造成损坏。原始漆块和漆样用上述方法加固后，再经过激光解吸质谱(LD-MS)分析。激光解吸质谱证实漆中有 4-6 个单体单位的 HEMA 聚合物。红外线光谱展示，聚合度系与使用的量成比例的。

我们用电子辐射成功地处理了 3 块原始彩绘残片。漆与陶体附着，残片可以干燥，彩绘表面视觉效果正常(不发光)。利用激光视频全息摄影，对剧烈的湿度变化是否会影响加固后的彩绘漆层作了观察。经 4 组湿度变化(35-83 %的相对湿度)，没有发现任何破坏。长期稳定性还有待进一步评估。

用电子辐射聚合看来是一种大有前途的保护秦始皇兵马俑以及类似艺术品的方法。

(英译中：陈钢林)

Cristina Thieme

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.), 9th 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。

程德润 郭宝发

秦陵铜车马彩绘及保存环境湿度条件的研究

1. 概况

一九八零年十一月，秦俑考古队在秦始皇陵西侧发掘出土了两乘大型彩绘铜车马。这两乘铜车马均为青铜铸造，由各种零部件组装而成，并饰有大量金银饰件。

两乘铜车马均通体彩绘，所用的颜色有朱红、粉红、绿、粉绿、深蓝、白、黑、赭等。其中以蓝、白、绿三色用量较多，颜料均为矿物质。出土时多数彩绘已剥落。彩绘色彩品种很多，但明显的特征是以白色为基调并将纹样全部绘在白色底层上。八匹马通身涂有白色彩绘涂层，只有鼻孔、口腔等粘膜处施以粉红。

彩绘纹样有变相的夔龙、夔凤纹、云纹、各种菱花纹以及多种多样的几何纹样。菱形、方格纹等几何纹是两乘车的基本纹样，一号车马车舆上的纹样、二号铜车马的车舆上的一些边饰纹样，以及舆底、车扉、车轼、马轭、车窗等处的图案纹样都是以几何纹为母题组成各种各样绚丽多彩的二方连续或四方连续的图案。在几何纹这种基本纹样之上，秦始皇陵铜车马又突出了一种由夔龙、夔凤纹发展来的变相夔纹图案，在二号车的车舆内外、车盖上，到处装饰着这种大朵蓝色、绿色、黄色似云似夔的纹样。在白色底调的衬托下，它们上下翻腾，如行云流水。黑线条的外轮廓内，填饰着白、黑、朱等色的鳞甲，色彩对比协调鲜明，极富立体感。这种夔纹是铜车马的主体装饰纹样，并有意识地与云纹掺和，代表了皇权的神圣。

秦始皇陵铜车马其他施彩的地方也很多，比如御官俑，身穿天蓝色长襦，白色的领袖口，在领缘与襟缘绘着朱红色的几何型纹样，脸、手表面涂有粉红色；再如轮、轴、伏兔等处，涂有朱砂。整组车马看上去华幻多彩，一派富丽堂皇。彩绘对秦始皇陵铜车马起了很大的作用，它简化了造型及浇铸的程序，而且彩绘层还保护了作为金属器物的铜车马本身。

2. 实验部分

2.1 秦陵铜车马结构、特征

铜车马的基材为 Cu 、 Sn 、 Pb 合金，外饰彩绘，当时已经过防腐处理，其防腐涂层为天然磷灰石。分析证实，天然树脂加上磨细的白色填料组成涂料被涂于铜基体上，经阳光与空气的作用，天然树脂基本交联、固化形成膜，对铜车马起到保护作用，埋入地下后，受到水分和微生物的综合作用，使固化了的树脂非常缓慢地水解，其致密性和附着力下降，甚或局部脱落。出土后，由于受空气、水份、氧、微生物、光照等作用，使其不断被侵蚀，彩绘不断褪色变色甚至脱落。

伞盖上有纹饰，打磨后，发现为金黄色纹样，很像“错金”。在现场用微量迁样仪取样，塞曼石墨炉光谱定量和电子探针测定，均未找到金，仍与青铜本体一致。笔者判断是颜料与树脂胶混匀描绘于铜质基体上，由于交联固化形成保护膜，有效抵抗了环境对青铜基体的腐蚀过程。未被彩绘覆盖之处，尽管也进行了防腐处理，仍有不同程度的化学和电化学过程所致。

我国古代颜料多来自天然矿物组份。在埋藏条件下，长期受水份、氧、二氧化碳等综合作用，部分发生缓慢水解和微生的破坏。发掘后，主要由于光照、 CO_2 及 SO_2 对其影响。彩绘成分如表 1 所示。

颜　料	成　　份
红	$Pb_3O_4 \cdot Fe_2O_3$
绿	$CuCO_3 \cdot Cu(OH)_2$
兰	$2CuCO_3 \cdot Cu(OH)_2$ 蓝铜矿
紫	铅丹+蓝铜矿
褐	$Fe_2O_3 \cdot nH_2O$
白	$2PbCO_3 \cdot Pb(OH)_2$
墨	无定形碳
填料	高岭土、云母、粘土、蒙脱石

表 1. 彩绘成份。

变色主要是受光、水份、 CO_2、 SO_2 等影响，土红是相当稳定的红色颜料，光照和湿度均影响不大，但本身受氧化还原作用而变色。对于朱砂，长期光照会变黑，但湿度影响很小，不同湿度时，朱砂变暗的比率几乎相同。而对于含铅颜料影响很大。白色($Pb(OH)_2 \cdot 2PbCO_3$)、红色(Pb_3O_4)在光照和一定湿度下会发生反应:

$$2PbCO_3 \cdot Pb(OH)_2 \rightarrow 2PbCO_3 \cdot Pb(OH)_2{}^* \rightarrow PbO_2 + H_2O + CO_2$$

$$Pb_3O_4 \rightarrow Pb_3O_4{}^* \rightarrow 3PbO_2$$

另外，由于紫外线的高能量，许多可见光不能引发的反应，均可被紫外线引发。因而，光照和湿度对变色有很大影响。

铜车马的不同部件 ，其合金配比不尽相同，归纳起来，如表 2 。

青铜器的特点是，锡含量高，熔点低，硬度大。相反，熔点高，韧性大。

有人曾做过试验1，在纯铜中加 15 %的锡和铅，熔点可降到 960° C (纯铜熔点 1083° C)。若加 25 %， 可降到 800° C ； 纯铜布氏硬度 35 ， 若加 7-9 %的锡和铅， 硬度增到 65-70 ，加 9-10 %，硬度达 70-100 。

构件名称	主要化学成份 (%)			
	Cu	Sn	Pb	总量
马	85.75	7.49	0.51	93.75
车构件	83.86	13.14	0.59	96.59
连绳	90.01	9.24	0.55	99.80
铜镞	85.42	13.79	0.79	99.00
弓弦	86.75	10.03	0.46	97.34

表 2. 铜车马构件成份。

由表 2 看出，对车的构件要求有良好的铸造的性能，又有一定的强度，其锡含量达 13.14 %，而马仅变 7.49 %；铜镞头，要求硬度大，则锡含量为 13.79 %；连绳、引绳等饰件，由细小环节组成，要求必须韧性大，其锡含量为 9.24 %，弓弦为 10.03 %。

整体合金配比，与现代青铜合金 ZQSn10 及 ZQSn6 基本相同，可见当时青铜冶铸技术已相当成熟。

2.2 湿度对秦陵铜车马彩绘的影响

2.2.1 湿度的控制

湿度是环境的一个重要因素。在一定湿度下，饱和盐溶液的蒸汽压与纯水的蒸汽压的比值称为该盐溶液的相对湿度 (RH %)，利用密封的干燥器配制饱和盐溶液，待平衡后，干燥器内的湿度将达到一定值。在一定温度下，不同盐溶液具有不同的相对湿度值，本实验采用 WHMI 型温湿度计测定了几种盐的相对湿度值。如表 3 所示。

2.2.2 色度的测量

色度的通过色差计来测量，笔者采用 SC-80 色差计。这是测量颜色变化的仪器，其原理基于国际照明委员会向各国推荐的(ZE1964X10Y10Z10)的表色系统。

自然界中的红、绿、蓝称为三原色，以 X、Y、Z来表示。测量色度实际上就是通过仪器定量测定三原色的成份。仪器以 D65 光源照明器来模拟标准观察者对颜色的三种响应，经过运算单元进行数据处理，得出的三个刺激值为(X、Y、Z)及其导出量(x、y、l、a、b)，从而定量地确定色度值，由仪器来分辨颜色的差异，而得到色差值的数据。

$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$

ΔL 明度差；Δa 红绿色品差；Δb 黄绿色品差。

由 L、a、b 三量可组成色空间，从色空间的三点距离差，就可以表示出颜色的色差，通过制作湿度—色差曲线，即可判断在何种温度下颜色变化(即ΔE)最小，为最佳环境。

2.2.3 湿度对颜色的影响

通过定期测量的彩绘板，得到测量值，经过运算，得到ΔE值，如表 4 。

以表 4 中ΔE 对 RH%作图。得图 1 、图 2 。

颜料	光照情况	RH %						
		33	43	54	63	72.8	81	96
白色	光照	4.09	1.13	0.53	3.81	3.15	4.82	1.94
	无光	0.19	0.88	0.61	2.51	1.30	0.84	18.40
红色	光照	2.00	0.97	1.17	4.18	1.47	2.63	1.67
	无光	1.37	1.98	0.92	1.30	1.56	1.24	36.63
褐色	光照	0.22	0.95	0.49	1.59	0.79	0.83	2.52
	无光	1.36	1.15	0.85	0.91	—	1.09	8.64
绿色	光照	1.09	1.24	0.85	0.81	0.63	1.21	1.59
	无光	0.39	1.01	0.18	0.91	0.76	1.21	7.52

表 4. 不同湿度时ΔE 值。

表 3. 湿度的控制。实验结果与文献[2]报道相吻合。

温度	项目	K_2SO_4	$(NH_4)SO_4$	$NaNO_3$	$NaNO_2$	$Na_2Cr_2O_7 \cdot 2H_2O$	K_2CO_3	$MgCl_2 \cdot 6H_2O$
30° C	理论值 (RH %)	96	81	72.8	63	54	43	33
	测量值 (RH %)	92	83	73	63	56	47	36
	S 理 (g)	13	78	94.9	87.6	177.8	113.7	56.5
	S 实 (g)	14	83	100	92	280	117	350
20° C	理论值 (RH %)	97	81	74	66	55	44	33
	测量值 (RH %)	92	82.5	74	66	54.4	46	37
	S 理 (g)	11.1	75.4	87.6	80.8	177.8	110.5	54.5
	S 实 (g)	12	78	93	86	280	115	320

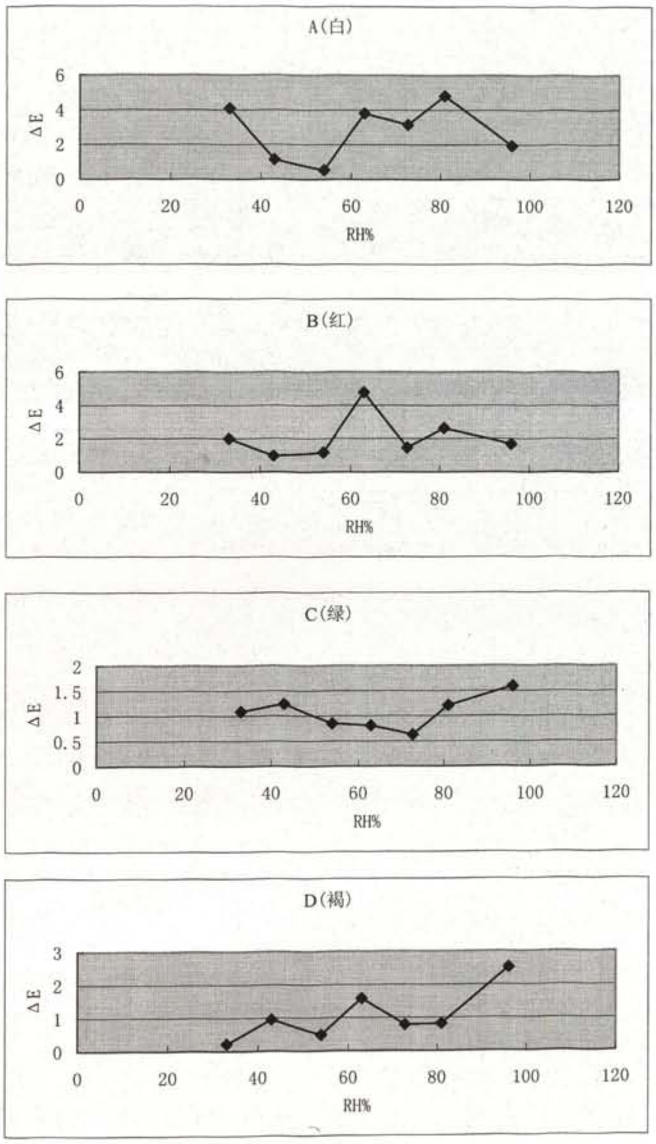


Fig. 1. Relation scheme of ΔE-RH % under room temperature and sunlight (84 days).

图 1. 室温、光照下的ΔE-RH %关系图(84 天)。

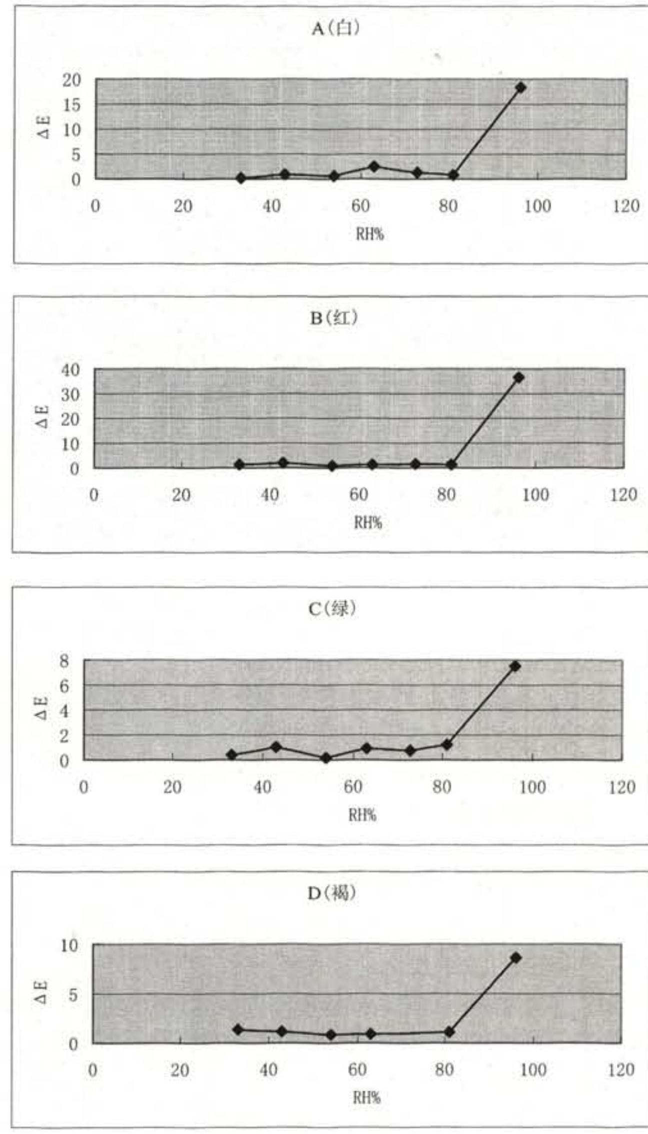


Fig. 2. Relation scheme of ΔE-RH % under temperature of 30 °C and without sunlight (63 days).

图 2. 30° C 时，无光照的ΔE-RH %关系图(63 天)。

2.2.4 结果讨论

2.2.4.1 综合分析图 1 、图 2 得到湿度对ΔE 影响。

白色颜料

(1) 由图 1A 所知，在光照条件下，不同湿度导致色度不同，在较干环境中(RH %在 33-55 %)，随 RH %增大而ΔE 减小, 在 RH %达 55 %时, ΔE 为最小, 在高湿环境中(RH % =55-81 %)，总的趋势是ΔE 随 RH %增加而增大，在 97 %接近饱和湿度时，ΔE 反而大大降低。

(2) 由图 2A 可知，在无光照射时，除 97 %湿度时产生霉变，引起强烈色变外，ΔE 随 RH %增大而缓慢上升。

综上述，选择 RH %在 44-55 %变化最小。

红色颜料

由图 28 知, ΔE 随 RH %的变化与白色颜料基本相同, 在 RH %为 33-81 %时ΔE 值变化不明显，只是在 97 %时，由于霉变而导致ΔE 的突变。所以，在 44-55 %仍变化较小。

绿色颜料

在图 2C 中，33-81 %的湿度区间内，ΔE 值基本不变，在高湿条件下，由于紫外线的杀菌防霉作用，使图 1C 没有太大的变化，而图 2C 则ΔE 巨变，因此，湿度范围在 44 - 81 %范围内，对绿色颜料亦适用。

褐色颜料

湿度与光照对ΔE 值影响，与绿色类似。

2.2.4.2 影响彩绘颜色变化的因素很多，在洁净环境中，忽略化学物质和灰尘的破坏作用，其色变主要是受光照和环境湿度的影响。

(1) 对光敏感的颜料，特别是紫外线，将使颜料发生光化学反应。以铅丹为例：

当在紫外光照射下，铅丹吸收光能变成激发分子 Pb_3O_4*，从而具有较高的能量，降低了反应活化能，使得原来不易发生的反应可能发生。在湿度较高时，单位体积里含

有的水份较多，就使得水分子和激发态的 Pb_3O_4*分子碰撞的机会增大，从而发生反应。干燥条件下，水份少，碰撞机会减小，难以发生反应，铅丹不变色。但湿度太高，虽然水分多，且单位体积水分子浓度高，吸收紫外线也越多。实验结果如表 5：

RH %	254 nm 紫外线辐照度 (μw/ cm^2)	420 nm 紫外线辐照度 (μw/ cm^2)
97	4.8	20.1
66	5.7	29.8
33	5.9	33.4

表 5. 不同湿度的紫外线。

因此，高湿(例如 97 %湿度时)，由于水分吸收紫外线太多，使得穿过空气到达颜料表面的紫外线辐照度降低，阻止了激发态 Pb3O4 的生成，故也难以发生变色反应。

变色过程应是:

$Pb_3O_4 \xrightarrow{h\gamma} Pb_3O_4$*……①

Pb_3O_4*$+H_2O+CO_2 \rightarrow 2PbCO_3 \cdot Pb(OH)_2+O_2$……②

反应①实际上是光化学反应，必须在光照下发生。

反应②是在高湿条件,水和空气中的 CO_2 参与的氧化还原反应。其依据是：铅丹可以看成由 PbO 和 PbO_2 组成。由铅丹变成铅白可看成是 PbO_2 被还原生成了 $2PbCO_3 \cdot Pb(OH)_2$。

查手册知:

$PbO_2+4H^++2e \rightarrow Pb^{2+}+H_2O \quad E_0=1.455V$

根据 log K SP($PbCO_3$)=-13.13，由公式算出 E^0 PbO_2/$PbCO_3$=1.685V，并且光照使 Pb_3O_4(PbO_2)活化，反应②越易向右进行，使 PbO_2/$PbCO_3$ 电对的电位变得更正，因此 PbO_2 足以使水分子氧化，本身被还原成二价铅，再和空气中的 CO_2 结合，生成 $PbCO_3$。

由此分析，实验中白色和红色两种彩绘的色变，由于发生了以上的光化学反应，使其ΔE 值起伏较大，即色变最显著。

(2) 在没有光照条件下，湿度对颜色变化影响不大，只是在接近饱和湿度时，由于霉变使ΔE 值增大。

在光照条件下，湿度对颜色变化影响很复杂。一方面，湿度增加，色差增大；另一方面，湿度增加，对紫外线吸收增多，减小了光线的破坏力，因而，色差反而减小，两者的综合影响，决定了对颜色改变的程度。

由此实验亦可看出，对光敏感的红白两种颜料均有此规律。看图 3。

对光稳定的褐、绿两种颜料，在很宽范围 RH %不影响色差，只在十分潮湿环境中，由于霉变而强烈改变其ΔE 值。

通过以上讨论，确定区间湿度为 44-55 %，这样既防止了干燥条件下彩绘的剥落，又防止了高湿条件下，彩绘长霉，并且在此 RH %范围时彩绘的色彩的改变最小。

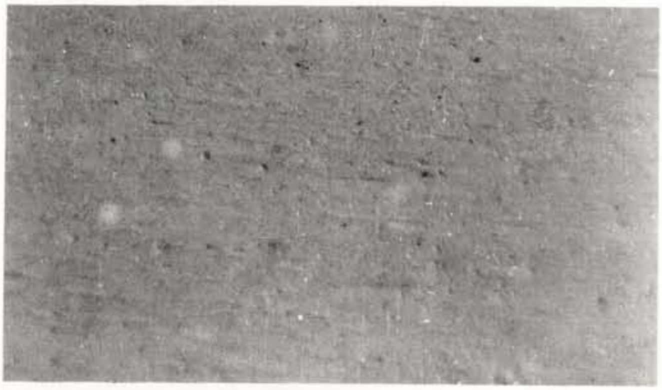


Fig. 3. Change of polychromy under different humidity. Top: RH 81 %; Below: RH 43 %

图 3. 不同湿度下的彩绘色变情况。
左图: RH81 %；右图: RH43 %。

2.3 青铜器的腐蚀

2.3.1 腐蚀条件的选择

青铜器腐蚀的基本条件是潮湿环境、可溶性氯化物和氧化气氛。

可溶性氯化物是加速青铜器腐蚀的主要因素。本文对处理好的样品浸泡于不同浓度的氯化钠溶液中，进行液相腐蚀，以光度法测其腐蚀速度。如表 6 和图 4。

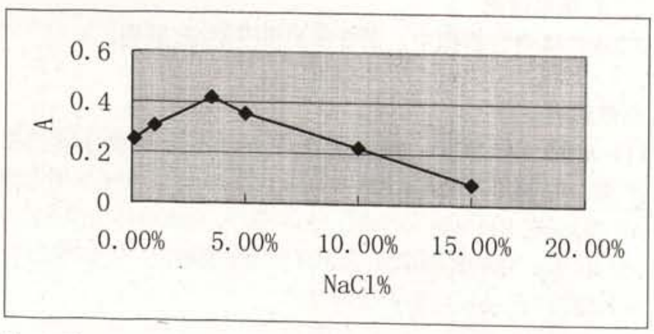


Fig. 4. The content of NaCl and time of corrosion . (A = absorbance)

图 4. NaCl 百分含量与腐蚀速度(吸光度以 A 表示)。

由图知, 3 % NaCl 溶液，青铜器腐蚀率最高，所以本实验选择了 3 %的 NaCl 溶液加速腐蚀试验。作者近来来研究了青铜器的腐蚀机理[3]。认为大气污染是青铜器腐蚀的重要因素。并测定了秦陵地区的大气状况，如表 7。

NaCl %	0.1 %	1.0 %	3.5 %	5 %	10 %	15 %
1	0.23	0.29	0.41	0.34	0.20	0.07
2	0.25	0.29	0.42	0.37	0.23	0.08
3	0.28	0.34	0.43	0.36	0.24	0.10
平均值	0.253	0.306	0.420	0.356	0.223	0.083

表 6. 不同浓度 NaCl 腐蚀溶液的吸光度(A)

项目 次数	SO_2 (mg/m^3)	No_x (mg/m^3)	降尘 (T/km^2· 月)
1	0.057	0.078	26.45
2	0.059	0.080	26.48
3	0.053	0.082	26.60
均值	0.056	0.080	26.50

表 7. 秦陵地区大气监测结果

RH %	33	43	54	63	72.8	81	96
ΔM(mg)	4.1	5.1	5.1	15.0	32.0	40.1	48.5

表 8. 不同湿度下样品的失重量

RH %	33	43	54	63	72.8	81	96
1	0.20	0.20	0.24	0.32	0.46	0.50	0.58
2	0.21	0.23	0.26	0.29	0.47	0.53	0.54
3	0.19	0.20	0.25	0.28	0.46	0.51	0.56
平均值	0.20	0.21	0.25	0.30	0.46	0.52	0.56
Cu^{2+}含量 (μg / ml)	13.5	15.0	17.5	21.5	34	39.5	42.5

表 9. 不同湿度下腐蚀溶液的吸光度

RH %	33	43	54	63	72.8	81	96
Cu^{2+}含量 (μg/ml)	13.5	14.5	18.1	22.2	33.1	36.5	39.0

表 10. 不同湿度环境中腐蚀溶液的 Cu^{2+}含量(AAS)

RH %	33	43	54	63	72.8	81	96
ΔM(mg)	5.0	6.1	6.3	29.0	35.1	47.3	62.0

表 11. 不同湿度下的失重

表 12. 不同湿度下产物的 Cu^{2+}含量

RH %	33	43	54	63	72.8	81	96
A	0.255	0.270	0.295	0.475	0.485	0.535	0.585
Cu^{2+}含量 (μg/ml)	18	19.0	21.0	35.5	36.5	40.5	44.8
AAS 分析 Cu^{2+}含量(μg/ml)	15.6	17.4	19.5	31.0	36.5	38.5	44.7

2.3.2 青铜样品在酸性条件下模拟试验

A) 重量法：将样品在设定环境中放置两周后，观测腐蚀失重后与 RH %的关系，如表 8 所示。

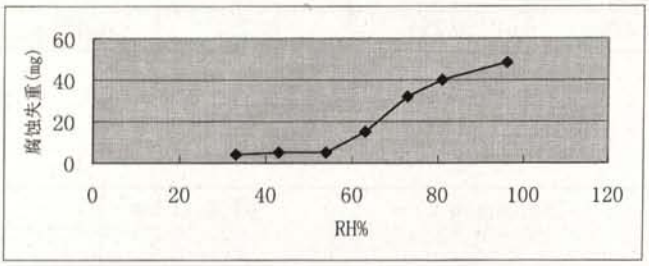


Fig. 5. Relation of time of corrosion to ΔM and to RH % (weight method).

图 5. 腐蚀速度与ΔM 与 RH %的关系(重量法)。

B) 分光光度法：将收集到的腐蚀液用光度法测 Cu^{2+}含量。如表 9 和图 6 。

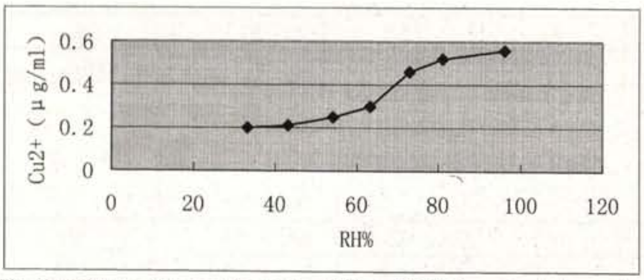


Fig. 6. Relation of time of corrosion A % to RH % (spectrophotometric method).

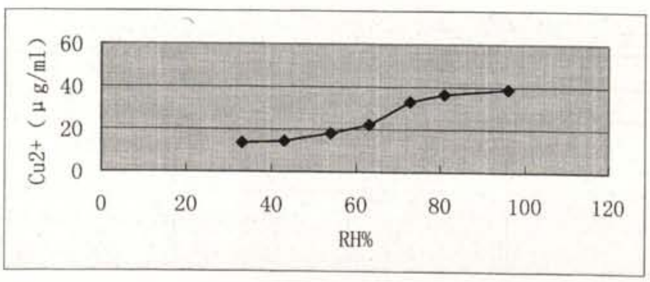
图 6. 腐蚀速度 A %与 RH %关系(分光光度法)。

C) 原子吸收法

将腐蚀产物收集于 25ml 比色管中，用 AAS 法测定如表 10 和图 7 。

Fig. 7. AAS Analysis Cu^{2+} content.

图 7. AAS 分析 Cu^{2+}含量。



2.3.3 样品在 NaCl 溶液中的腐蚀

同样用重量法、光度法、原子吸收度，观察腐蚀结果，如表 11 和图 8 、表 12 和图 9 、图 10 表示。

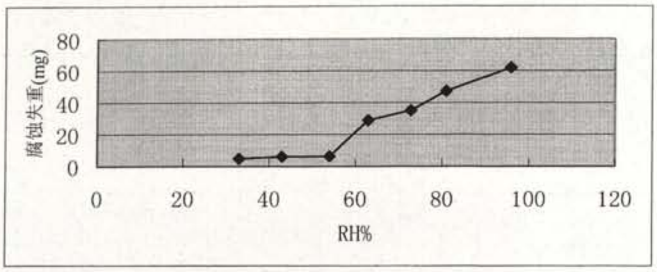


Fig. 8. Relation of time of corrosion to RH % (weight method).

图 8. 腐蚀速度与 RH %关系(重量法)。

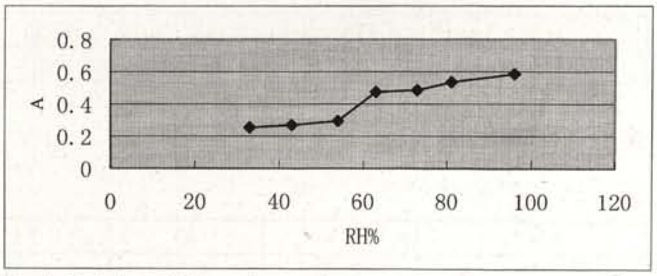


Fig. 9. Relation of time of corrosion to RH % (spectro photometric method).

图 9. 腐蚀速度与 RH %关系(光度法)。

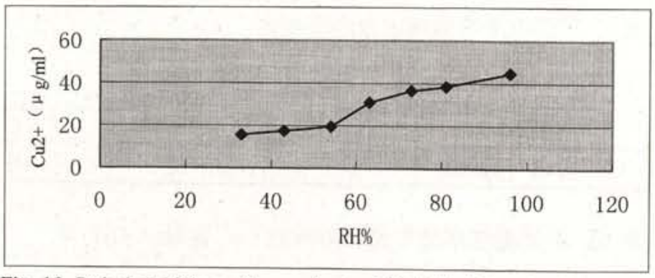


Fig. 10. Relation of time of corrosion to RH % (AAS method).

图 10. 腐蚀速度与 RH %关系(AAS 法)。

2.3.4 气相腐蚀实验

亦采用重量法、光度法观察腐蚀速度，如表 13 和图 11 、表 14 图 12 。

表 13. 腐蚀速度与湿度关系。

RH %	34	46	58	75	96
0.1 % SO_2 存在时 ΔM(mg)	1.1	1.1	1.2	2.9	4.0
0.1 % SO_2 及 3 % NaCl 存在时 ΔM(mg)	1.2	1.2	1.6	3.5	4.8

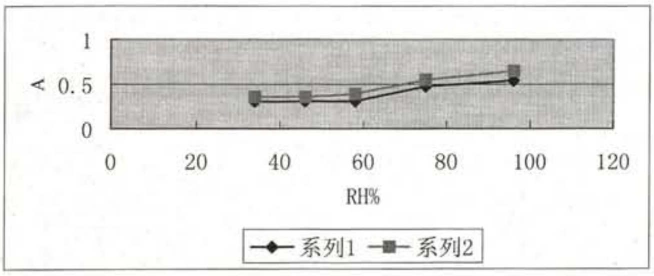


Fig. 11. Relation* of time of corrosion to RH % (weight method). In series 2 are 3 % NaCl. In series 1 there aren't 3 % NaCl.

图 11. 腐蚀速度与 RH %关系* 重量法。
系列 2 有 3 % NaCl 存在，系列 1 无 3 % NaCl 存在。

RH %	34	46	58	75	96
0.1 % SO_2 存在时腐蚀产生物(A)	0.305	0.306	0.310	0.475	0.540
0.1 % SO_2 及 3 % NaCl 存在时腐蚀产生物(A)	0.356	0.357	0.392	0.550	0.650

表 14. 不同腐蚀条件下溶液的吸光度(0.1 % SO_2)。

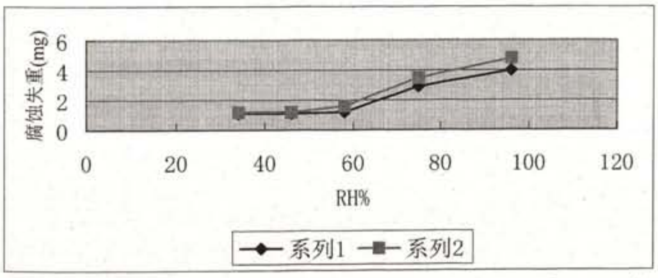


Fig. 12. Relation* of tempo of corrosion to RH % (spectrophotometric method). In series 2 there are 3 % NaCl. In series 1 there aren't 3 % NaCl.

图 12. 腐蚀速度与 RH %关系(分光光度法)。
系列 2 有 3 % NaCl 存在，系列 1 无 3 % NaCl 存在。

2.3.5 结果讨论

1) 由 Cu_2O 生成粉状锈的过程较为缓慢。但在酸性条件下及 Cl^- 存在下可发生此种反应，当湿度大于 66 %时，这是能够溶解氯化钠所需湿度，此种转化有一突跃值，表明 Cl^- 直接破坏了氧化亚铜层。

2) 通过模拟实验可知，青铜在没有外来电解质作用时，主要受氧的缓慢作用生成 Cu_2O，在酸性条件下，Cu_2O 则随环境湿度的变化逐渐转变为氯铜矿(粉状锈)。此种转变在相对湿度 70 %时有一突跃，这一方面是由于青铜吸附水膜所致；另一方面由于 H^+ 的存在，使 $Cu_2(OH)_3Cl$ 更易生成。

大气腐蚀时，当相对湿度小于 50 %时，此时的液膜厚度不足以实现氧化还原过程，因而腐蚀程度小。当相对湿度大于 70 %时，氧通过液膜传递到金属表面的速度很快，加速了腐蚀。

3) 在 SO_2 浓度一定的条件下，温度和湿度是影响青铜腐蚀的重要因素。温度的影响主要是水蒸汽的凝聚，凝聚水膜中各种腐蚀性气体和盐。当相对湿度低于金属临界相对湿度(<65 %)温度对腐蚀的影响很小，而当相对湿度达到金属临界相对湿度时，温度的影响很大。

3. 结论

1) 研究了相对湿度、光照和彩绘色变之间的关系。在无光照情况下，湿度对彩绘色变影响不大。只有在高湿情况下，由于霉变而影响Δ 值。而在有光照时，由于湿度和紫外线间的一定关系，对光敏感的含铅颜料(红、白)，湿度应控制在 44 %-55 %范围内。对于褐、绿两种适应湿度范围较宽的颜料来说，中等湿度下，其色变值ΔE 亦较小。

2) CuCl 是极不稳定的化合物，它可以在水蒸汽、氧气、酸性条件下，转变化氯铜矿和副氯铜矿[$Cu_2(OH)_3Cl$]，通过 XRD 分析可知：随相对湿度的增大，$Cu_2(OH)_3Cl$ 的衍射峰，强度也增大，在相对湿度 72.8 %左右时，转变有突跃值。

3) 在 20° C 和通常在大气压下，湿度大于 63 %时，NaCl 将与 Cu_2O 作用而生成 $CuCl_2 \cdot Cu(OH)_2$，此种作用亦随相对湿度的增大而加剧，因此，青铜器文物腐蚀层表面粘附的氯化物，会对 Cu_2O 起破坏作用。

4) 在模拟实验中，当 pH 值较低时，粉状锈生成趋势强，速度随相对湿度增大而增大；临界相对湿度值在 70 %左右。在有吸湿性盐类存在的情况下，由于 Cl^- 的大量存在而加剧，且腐蚀途径有所改变，致使临界相对湿度有所降低(60-70 %)，促使锈蚀更易产生，程度加剧。

5) SO_2 对青铜腐蚀的影响，主要由于它在吸附水膜下参加了阳极的去钝化作用。在模拟大气 SO_2 含量的气相腐蚀实验中，青铜样品的腐蚀随温度的升高而加剧，随湿度的增大而加速。

注:

1. 文葆:《文物保护技术》, 6, 51 (1991)。
2. Handbook of Chemistry and Physics (下册), 1596-1601 (1953)。
3. 程德润:《西北大学学报》, 1, 30 (1989)。

Cheng Derun and Guo Baofa

The Polychromy of the Bronze Chariots from the Mausoleum of Qin Shihuang

The bronze chariot unearthed from Qin Shihuang's mausoleum is eulogised as "the champion of bronze wares", for it is the biggest of its kind ever unearthed in China. Its surface is painted with mineral pigments whose major colours are white, red, green, etc. The brilliant patterns effected with the colours truly reflect the original look of the chariot. After being excavated, the paint layer began to peel off due to the sudden fluctuation of temperature and humidity. Very important here is an ideal environment to protect the chariot after a careful analysis of the pigment ingredients, a careful study of how the bronze alloy eroded and the paint layer has changed under different simulated conditions has taken place.

Simulated experiments show that the fading of colour is related to environmental humidity, the ultraviolet illuminant and the pigment variety. The chromatic aberration value (DE) of 4 pigments under different humidities determines the best humidity range of 44 to 55 %.

The corrosion products of the chariot have been analyzed by X-ray diffraction, which reveals that CuCl is the key factor of bronze ware corrosion. The three basic conditions that influence the corrosion are (1) damp environment (2) oxidised atmosphere and (3) soluble chlorides. A series of experiments have been done to determine the suitable temperature and humidity in which CuCl and Cu_2O changes into powder rust. Simulated experiments tested the correlation between the corrosion speed and the change of external conditions. Sample bronze wares were put under 7 kinds of surroundings of different humidity. As a result, the suitable natural conditions have been suggested for the preservation of bronze wares.

Hans van Ess

Symbolism and Meaning of Colours in Early Chinese Sources

What did colour mean to Chinese people more than two thousand years ago? Written sources seem to tell a different story regarding this subject than the archaeological record shows. Indeed, it is not very probable that there will be much agreement between the answers which philology and archeology can give to this question. Nevertheless, it remains important to look at texts when trying to understand why certain colours were displayed more prominently in ancient Chinese art than others. There is the possibility that, as in other cultures, sculptures were not designed to represent real life but to comply with ideals about how humans should look. Today such ideals can only be revealed by reading texts, not by looking at physical objects. However, this essay refrains from explaining why certain colours were used more often than others. Limited as our knowledge still is, such an attempt would for the time being certainly be doomed to failure. Therefore, this paper will confine itself to giving an idea on basic Chinese concepts concerning colours to those who are not acquainted with ancient Chinese sources.

Colour Terms

For several reasons Chinese colour-terms are interesting with regard to the subject of this paper. The most important reason to study terminology is that the graphs used to describe colours in ancient China can tell us a lot about the early development of Chinese culture. However, as there have been numerous very different interpretations of the original meaning of ancient Chinese characters, mainly by Chinese and Japanese scholars, the reader of the following lines should be aware that he is treading on very thin ice. Many assumptions about the meaning of ancient graphs do not go beyond the level of speculations.[1]

As early as at the time when oracle bones were inscribed at the end of the second millenium B.C. colours seem to have been important as part of the ritual system of the Shang. Apparently, even at this early date the use of colours sometimes related to a specific context. White, red and multi-coloured oxen were, for example, frequently sacrificed in the ancestral cult whereas black sheep were used in rain-making rituals. Yellow oxen seem to have been sacrificed mainly to the directions or to earthly gods.[2] Recent research suggests that the colour system of the Shang consisted of only four basic colour terms: those for red, white, yellow and dark.[3] The element which is certainly mentioned most often is red for which there are at least three different terms, namely chi 赤 which is used mainly to designate the colour of horses, xing 騂, which probably means yellowish-red close to orange and describes the colour of oxen, and xuan 玄 or you 幽, both of which seem to be words for a darkish red colour. Although xuan in later times came to be used for "purple" this cannot have been the original meaning of this character since in oracle bone inscriptions it is the colour of a dark oxen.

The character for the word "chi" is composed of the elements of a human figure, which was later, when the writing system developed, stylized as "da" , big, and of fire. It is not clear, however, whether we have to conclude that the human figure gave a semantic meaning to the character as did the element of fire or whether it was only a phonetic element of the graph.[4] In the case of xing it seems plausible to assume the latter, namely that one of the two elements which means "sheep" is a phonetic one whereas only the other element "oxen" gave a semantic meaning to the character. Xing, then, would simply be the normal colour of an oxen. Similarly to chi the character "you" seems to be composed of an element which represents fire (although the modern written form looks like the character for mountain) and a phonetic element which is the same that is also used for writing the other character meaning dark red, namely xuan. Other words for red, such as zhu 朱, a character which seems to be a graph of a tree from the trunk of which a red dye-pigment is obtained,[5] or dan 丹, cinnabar, do not occur as colour terms in the oracle bone inscriptions. Hence, it seems that the use of these terms dates to a later time. Dan has been thought to be a drawing of a globule of mercury on a pan or of a lump of mineral in a crucible.[6]

Hei 黑, the modern word for black, does occur in oracle bone inscriptions in sentences such as: "We do not use black sheep, there will then be no rain" or "we should sacrifice black dogs, the king will then receive assistance". It seems also to have been used for the word "drought" which may have been phonetically close to "huang" 黃, yellow.[7] This might be the reason for the fact that yellow and black are sometimes confused in the inscriptions. The character has been interpreted as a drawing of a human figure with face and body covered with spots of dark war-paint[8] or with a tattoed face, a punishment of criminals.[9] As has been pointed out, however, the bone graph does not have the ink spots which occur only in the later bronze-inscriptions and there the character is never used as a colour term.[10] It is, therefore, more plausible, that the pictograph for black shows two soot-collecting vessels over a chimney.[11]

According to two eminent Western scholars, huang, yellow probably shows a man with a large belt[12] or with gold nuggets.[13] However, Gao Hanyu says that the old graph for yellow clearly contains the character "fire" which suggests that this, again, is a character which was used to describe one of the colours of fire.[14] In oracle bones it describes most often the colour of oxen but sometimes also of bronze or gold.

There are several theories concerning the character for "bai" or "bo" meaning white, all of which have been rejected by modern scholars. There are not many convincing explanations at the moment for what this character may have represented.[15] As an example how complicated the business of interpreting characters can become, note the interesting explanation by Ulrich Unger who thinks that bai originally represented an acorn and was only later used as the word for "white" because of its phonetic value. Later it was incorcorated into the character for "oak" (li 櫟).[16]

Interestingly, there is no term for green or blue in the oracle bone inscriptions. Although the character qing 青 which has been explained as showing a plant, possibly indigo, with its juice being collected in a pan[17] does occur in these inscriptions, it is never used as a colour term - which makes this explanation implausible as far as early times are concerned. The character is, however, phonetically and graphically related to sheng, "to grow". Although there is ample archaeological evidence for the fact that the Shang knew the colour green, the lack of the colour-term "green" or "blue" on oracle bones seems to suggest that most probably there was no term for blue or green at that time and that this colour was subsumed under the category of "dark", "yellow" or "multicoloured". There is, however, also the possibility that there was a word for "blue" or "green" but that it was not mentioned because colours were usually referred to in these inscriptions in relation to sacrificial animals - and that there was simply no blue or green sacrificial animal. With regard to this problem it is, on the other hand, significant that, in a commentary to the *Book of Changes*, which might date back as late as the third century B.C., heaven is "xuan", dark, contrary to the earth's being yellow. It seems that the colours blue and green were latecomers, which emerged from the dark category from which, much later, the modern terms "lü" 綠, green, and "lan" 藍, blue also derived. The use of the terms "qing" or "cang" 蒼 for the colour of heaven in other texts also seems to be late against the passage in the *Book of Changes* which reflects the earlier situation.

A most interesting word is in our context the Chinese word for "thing", wu 物 which obviously originally consisted of two words, one clearly being an oxen and the other one meaning "multicoloured". This fact has been pointed out as early as the beginning of this century (by the noted scholar Wang Guowei)[18]. In Chinas first etymological dictionary, the *Shuowen* of Xu Shen 許慎, which was written at the turn of the first to the second century A.D. the character wu is defined as a general term for things. This usage seems, however, to start only during the late Zhou period, a fact which has led to many mistranslations of early Chinese texts by Western scholars. The part of the character which means multicoloured has been explained either as a plough breaking up earth, the meaning referring to the colour of the soil[19] or as a knife with dots representing the object it cuts apart. In the latter case the opinion has been expressed that the primary meaning was "to separate" or "select".[20] This interpretation is important because in some early texts "wu" quite clearly means "to select by colours". Only late the character wu developed to generally refer to a type of classification, whence it derives its meaning of "things".

For example, in the *Rites of the Chou*, *Chou-li* 周禮, which was probably written during the third century B.C. but which records a great number of ancient practices, there is mention of an official who is in charge of classifying the land in order to choose the right grain to be grown on each spot. The word for "to classify" is "wu", and it is explained by the second century A.D. scholar Zheng Xuan 鄭玄 as "to judge on colour and shape".[21] Elsewhere the same commentary says that to classify means to look at the colours.[22] Where the text says that it is possible to know in advance about coming disasters and catastrophies but also lucky events by watching the "categories of the five clouds", the word for category - which is again "wu" - is explained as colour. Yellow clouds mean, according to an early first century A.D. commentary, locusts, white colours mourning for a dead, red ones war, black ones inondations and yellow ones a good harvest.[23] In any case it seems quite plausible that the very word for "things" is closely connected to the word for "colour".

Five Elements Speculations and the Military

With this last passage we are, of course, in the realm of Five Elements speculations which probably started during the fourth or third century B.C. We find these speculations in the *Zuozhuan* 左傳, a historical text narrating the events from the period of the 8th until the fifth century B.C. In this work it is said that a good ruler of men has to make a display of his "things" which consist of objects in five colours. Again, a commentary, this time from the early 3rd century A.D., explains that the chariots, uniforms and weapons are arranged in order to symbolize the ruler' s power over heaven, earth and the four directions and that for this purpose they should be distinguished by the five colours, the best means to distinguish these things.[24]

It becomes quite clear that in the *Zuozhuan* "wu", things, are a word for the emblems by which status and rank are shown[25], and it seems that in this context colour played a very important role as early as at the time described in this text. For us this is important because from this time on in ritual and speculative systems colours began to become associated with certain objects or with directions. Partly we find similarities in these later systems with the early ones to be found in the oracle bone inscriptions. A relationship between the colour black and the element water can be seen in oracle bone texts (as mentioned above) as well as in five-elements theories. The same is true for the earth which is associated with yellow and for fire which - quite naturally - belongs to red. It is well-known that coloured animals were associated with directions, the green dragon being the animal or the essence[26] of the east, the red bird the one of the south, the white tiger the one of the west and the black warrior - sometimes also a turtle - the one of the north.

In the *Records of Rites*, the *Li-chi*, we read the following famous text:

> A fighting chariot has no cross-board to assist its occupants in bowing; in a war chariot the banner is fully displayed; in a chariot of peace it is kept folded round the pole. A recorder should carry with him in his carriage his implements for writing; his subordinates the (recorded) words (of former covenants and other documents). When there is water in front, the flag with the green bird on it should be displayed. When there is (a cloud of) dust in front, that with the screaming kites. For chariots and horsemen, that with wild geese in flight. For a body of troops that with a tiger's (skin). For a beast of prey that with a leopard's (skin). On the march the (banner with the) Red Bird should be in front; that with the Dark Warrior behind; that with the Azure Dragon on the left; and that with the White tiger on the right.[27]

Zheng Xuans commentary explains that the four animals mentioned last represent the different formations of the troups. It is not clear whether the uniforms of the soldiers had to be in the relevant colour or whether there were just animals represented on the flags. One thing becomes quite clear, however, namely that colours played an important role for the military. We do not know whether the technique of wearing uniforms with distinct colours, permitting the easy recognition in battle of the men of one's own side, which was definitely used at the time of the fifth century A.D. was known earlier, but recent archaeological discoveries suggest that this development might have started as early as the fifth century B.C.[28]

Textual data seem to support this hypothesis. In the *Mozi* 墨子 text, parts of which may be dated as early as the beginning of the fourth century B.C. the use of corresponding colours for dress, flags and banners, numbers, sizes, sacrifices and the like is recommended:[29]

> If the ennemy comes from the east receive him at the eastern altar. The altar should be eight feet high, the hall eight feet deep (?), and there should be eight people who are eighty years old. The host should sacrifice with a green banner, there should be eight green spirits which are eight feet long, sixtyfour crossbows should be raised and halted. The uniform of the general should be green, the sacrificial animal a chicken. If the ennemy comes from the south receive him at the southern altar. The altar should be seven feet high, the hall seven feet deep, and there should be seven people who are seventy years old. The host should sacrifice with a red banner, there should be seven red spirits which are eight feet long, fortynine crossbows should be raised and halted. The uniform of the general should be red, the sacrificial animal a dog.[30]

The text continues to make the same remarks for the west, associated with the colour of white and the number nine, and for the north with six and the blackboar.

Another text which describes events of the year of 91 B.C. writes that when the crown prince of Emperor Wu of the Han tried to overthrow the government, his army used the red insignia of the Han. Therefore the Han added yellow pennants in order to make it easy to recognize their own forces.[31]

That certain commands were expressed by the colour of flags has been demonstrated earlier in the passage from the *Book of Rites*. The Mohists developed this system further:

> In general, the standard procedure for defending cities is: Make grey-green flags for wood [i.e: if you need wood or if there is wood or for those who are in charge of wood]; make red flags for fire, make yellow flags for firewood and fuel; make white flags for stones; make black flags for water; make bamboo flags for food; make grey goshawk flags for soldiers, who will fight to the death; make tiger flags for mighty warriors; make double rabbit flags for brave soldiers; make youth flags for fourteen year old boys; make dog flags for crossbows, make forest flags for halberds feather flags for swords and shields; make dragon flags for carts; make bird flags for cavalry. In general, when the name of the flag that you are looking for is not in the book, in all cases use its form and name to make [the design on] the flag.[32]

The Mohists obviously had handbooks for the defenders which instructed them to decide on the colour and design of individual flags.

Cosmological Systems and the Statecult

It is well-known that in Five-Elements speculations there are the elements of earth which is yellow, fire which is red, metal which is white, wood which is green and water which is black. In the texts just quoted only four of these elements were mentioned, with the earth missing. Although yellow as the colour of the centre is alluded to in early texts[33] it seems that the systematization including five colours is late and that originally only the four directions belonged to the system.

The *Discussions from the White-Tiger Hall* (*Bohu tong*), a text which probably was written around 80 A.D., contains another passage mentioning the four animals of the directions. Here the yellow centre constitutes the fifth element but no animal is mentioned. It looks very much like this fifth colour had to be added because of the conventions of the day, but that this could not be done in a proper way because the original set did not include a fifth animal. That the fifth element is a late addition which is somewhat unnatural to the old system based on only four parts can also be seen by the fact that systematizing ritual texts of the time make the colours correspond to the four seasons: spring which is green like the east, summer which is red like the south, autumn which is white like the west and winter which belongs to black and the north. The centre is in an awkward way added to this system as the last month of summer and the colour yellow.[34] In the dictionary *Shuowen* 說文 the colours are usually defined as belonging to their directions.

There is more evidence which can serve as a basis for our assumption that originally the Chinese colour cosmos was constituted of only four primary colours: when the Qin started to challenge the supreme power of the Zhou dynasty, they step by step seem to have established a system of sacrifices to Supreme powers whom they called "Di" - a word which later became the designation of the Chinese emperors. As the territory of the Qin lay to the west of the Zhou it was only natural that the first of these sacrifices, established in the year of 756 B.C. was directed to the white power, the baidi 白帝, who controlled the west.[35] Eighty-four years later the Qin established a second sacrifice to a divine power, this time the green one.[36] According to our sources in the year of 422 B.C. the Qin added two more sacrifices to the yellow and to the red power on high.[37] No more sacrifices were added.

It is significant that, with the exceptions of the sacrifice established first, the sites where these sacrifices took place did in no way correspond to the cosmological prescriptions which we know from the *Record of Rites* and other semicanonical texts. The sacrifice to the white power lay northwest of the city of Yung, the one for the blue power to its south and the two for the red and the yellow powers to its west. This suggests that the speculations concerning a relationship between the directions and the colours were not universally acknowledged during the period of the rise of the state of Qin. On the contrary, it seems that the system was observed at the time of Emperor Wu of the Han (140-87 B.C.) when his sons at their enfeoffing ceremonies were presented with coloured earth from the central altar of the earth at the capital. Each son was given earth in a different colour, according to the direction from the capital in which his fiefdom lay.[38]

The careful reader will have noticed that a black power was missing from the adressees of the imperial sacrifices of the Qin. The following complicated argumentation might give a reason for this strange fact: Besides a cycle of four and of five colours the *Records of Rites* also mention a dynastic cycle of three colours, namely black, white and red. The Xia dynasty is said to have ruled under the colour of black, the Shang under the colour of white and the Zhou under the colour of red.[39] Because one dynastic cycle was over when the Zhou declined, the Qin were said to have again ruled under the colour of black and the power of water. This conclusion was also drawn from five-elements-speculations.[40] In the beginning of the Han there was some uncertainty regarding the colour which should guide the new dynasty. First, the founder of the Han thought that he was the son of the red power who had killed the son of the white power - which was quite natural because he came from the red southern state of Chu whereas the Qin were white and western. Only a year later, however, the first emperor of the Han asked:

"Whom did the Qin in former times sacrifice to as divine powers on high?" The answer was: "To the four powers. There were sacrifices to the powers of white, green, yellow and red." Gaozu asked again: "I have heard that in heaven there are five powers. Why did they [sacrifice] to four powers only?" When nobody knew the answer, Gaozu himself said: "I know it already. They are waiting for myself to complete the number of five." Thereupon [the Han] established sacrifices to the black power....[41]

Ritual Use of Colours

So the Han, after some initial wavering, began to rule under the power of black in the same way as their predecessors whose reign over the united empire had lasted only fourteen years and who were, therefore, not taken for a real dynasty. Under the influence of cosmological speculations they later changed their colour twice, first to yellow and then to red, which had been the initial idea of the first emperor of the Han.[42] This does not need to interest us here. What is important for the the history of the Qin is that this dynasty is said to have ruled under the element of water and to have honoured the colour of black - although elsewhere it is stated in the textual sources that the Qin officials wore white uniforms.[43] Needless to say that the system of adopting a colour governing the time of a dynasty has been observed ever since this time until the collapse of imperial China.

Of course, the rule to adopt a certain colour for the reign of a dynasty was only the tip of an iceberg of ritual obligations which had to be followed by officials, dignitaries and common citizens of imperial China. A fitting example for these rules is provided by the following passage which is taken from the chapter Yucao 玉傑 of the *Records of Rites*:

> At the ceremony of capping, the first cap put on was one of black linen. The use of this extended from the feudal lords downwards. It might, after having been thus employed, be put away or disused.
>
> The dark-coloured cap, with red strings and tassels descending to the breast, was used at the capping of the son of Heaven. The cap of black linen, with strings and tassels of various colours, was used at the capping of a feudal prince. A dark-coloured cap with scarlet strings and tassels was worn by a feudal lord, when fasting. A dark-coloured cap with grey strings and tassels was worn by officials when similarly engaged.
>
> A cap of white silk with the border or roll of a dark colour was worn by a son or grandson (when in a certain stage of mourning). A similar cap with a plain white edging, was worn after the sacrifice at the end of the year's mourning...
>
> A dark-coloured cap with the roll round it of white silk was worn by one excluded from the ranks of his compeers [because he had been refractory]....
>
> An ordinary officer did not wear anything woven of silk that had been first dyed. One [dignitary] who had left the service of his ruler wore no two articles of different colours.

After these sentences which clearly show that the wearing of coloured robes was, at least theoretically, reserved for officials there follows what are usually considered the most important lines concerning the colours in early Chinese sources:

> If the upper garment were of one of the correct colours, the lower garment was of the [correspondent] intermediate one.[44]

What are "correct colours"? For Zheng Xuan the "correct colour" was only one, namely xuan which can be rendered either as "black", "dark" or "purple". The "intermediate colour" is for him "xun 纁" which today means crimson. Kong Yingda 孔穎達, a seventh century commentator, explains that "xuan", "dark" is the colour of heaven and "xun" which he glosses as a mixture of red and yellow is the colour of the earth - Heaven had to be on top, the earth underneath, as far as the robes of dignitaries were concerned. However, Huangfu Mi 皇甫謐 (215-282 A.D.), another commentator, says that the "correct colours" are the five colours of the directions, namely blue, red, white, black and yellow. For the intermediary colours he mentiones green, jadegreen, bay-yellow, purple and somekind of pink - a mixture of red and white.[45]

Similar rules applied to the colours of girdles and even of knee-covers. Of course, according to the *Record of Rites*, the wifes of officers were not allowed to choose the colours of their robes freely. They wore robes in colours which were determined by the rank of their husbands. In many later dynastic histories we find treatises with detailed prescriptions for the colours of chariots, clothing and seals.

Red

A high predilection for the colour of red is to be found throughout these texts. For example, the highests seals of state always contained an element of red,[46] the wheels of the chariots of high officials were painted red, and so were their houses. We may see here an influence of red as the kingly colour of the Zhou as well as the imperial colour of the Han - or the other way around: the Zhou and the Han may have chosen this colour because of their high social status. Two examples from the Han period relating to religious and political contexts may suffice to demonstrate this here. The Taiping jing, a Daoist text dating probably at least partly from the first and second century A.D. says:

> If today the correct miasma arrives one will not for long be able to nourish evildoers. This is as if a Yang miasma arrives which has the effect that the Yin-miasma vanishes. Now if on top of utmost Yang the red miasma comes this is the essence of the fire-king. The fire-king is the sun which is the brightest [object].[47]

The second example belongs into the sphere of semimetaphysical apologetics of the Han dynasty shortly before its final collapse at the end of the second century A.D. It is a fine example of how five elements colour symbolism was understood at that time. The end of the *Spring and Autumn Annals*, a chronicle of the kingdom of Lu traditionally ascribed to Confucius is explained by He Xiu in a subcom-mentary:

> The master since long times knew... that a commoner named Liu Ji [the founder of the Han] would replace the Zhou dynasty. When he [Confucius] saw that a gatherer of firewood captured a unicorn he knew that it had come because of this [man]. Why that? The unicorn has the essence of wood [green]. A gatherer of firewood is a commoner. The meaning is that he wants to make fire [red]. This means that the red emperor was going to replace the Zhou and to take their position. Therefore the unicorn was captured by a gatherer of firewood...
>
> ...
>
> After the unicorn had been captured Heaven sent down a bloodscripture and wrote at the capital gate of Lu the following words: "Quickly create laws because the sage

> Confucius is going to die and the Haus Ji of Zhou will perish... When Zi Xia, [a student of Confucius] the next day went to see what happened the bloodscripture flew away becoming a red bird which transformed itself into a white scripture...[48]

Red, associated with magic blood was to continue to be in favour for centuries, as it is still today. That the mining of mercury, which is needed for producing the read substances cinnabar or vermilion was a very profitable business from quite early times on, is suggested by a story to be found in the second century B.C. *Records of the Historian*, an account of a widow from Sichuan:

> There was a widow of Ba by the name of Qing whose husband's ancestors had found mercury mines and monopolized the profits for several generations. The family wealth was beyond counting. This woman had the ability to look after her enterprises, using much of her wealth as protection so that no one molested her or them. The first Qin emperor considered her a virtuous widow, treated her as a protégée and caused to be built in her honour a monument called the Tower of the Women's Remembrance of Mistress Qing.[49]

Because of evidence such as the one just quoted, it is quite clear that red was the dominant colour in China from very early times on.[50]

Much earlier than this story was another event in which cinnabar played an important role: There is an entry in the *Spring and Autumn Annals* (670 B.C.)[51] which reports that the pillars in the temple where the ancestral tablet of duke Huan 桓 of Lu 魯 (710-693 B.C.) was enshrined were painted in vermilion. He Xiu explains that this was done because the son and successor of Huan was going to marry a woman from the neighbouring state of Qi and that he wanted to show off in front of Qi - he probably wanted to demonstrate how much luxury he could afford.[52] It should be pointed out that together with azurite cinnabar later become a word for loyalty: both materials, do not decay. None of the other materials, which are systematized in much later sources such as Wang Tao's *Wai Tai biyao* (dating to the year of 752 A.D.), such as malachite for green, east and wood, arsenolite for white, west and metal, magnetite for black, north and water and realgar for yellow, the centre and earth seem to have played a similar role as cinnabar.[53] Apparently, yellow became an important colour for the statecult only at the time of the Sui dynasty at the end of the sixth century A.D. It should also be noted that the Chinese did, as far as our written sources are concerned, not perceive themselves as a yellow race until very late - probably as late as the seventeenth or eighteenth if not even the nineteenth century.

Critical Statements Against the Use of Colour

Finally, all ideological characterizations of colours notwithstanding, it should be pointed out that all the attempts at systematizing certain aspects of colours must be seen in the right of a very strong sense among erudites of ancient China, that the use of colours in itself was deemed a negative thing.

A remark of Confucius runs:

"Fine words and an insinuating colour are seldom associated with true virtue."[54], a remark which is repeated thrice in the *Confucian Analects*. And Laozi says:

> The five colours make blind the eyes of men
>
> The five sounds make dull the ears of men,
>
> The five tastes make apathetic the mouth of men....
>
> Therefore the sage ... does not act for the eye. (Laozi 12)

Warning statements against the evil influence of the five colours for good government and public order are too numerous in ancient texts to be counted. What is the reason for this strange rhetoric? First of all, of course, many literati feared that too much money would be spent on things which were only superficial and not substantial. Secondly, the word for colour itself and its Chinese character provide a clue: the word "se" does not only mean "colour" but also "appearance", "eros" or simply "sex". *Shuowen* says that it is the "mood which is expressed in the face"[55] because "se" is used to express feelings of anger, joy and the like. One scholar even thinks that the basic meaning of the pictograph has to be interpreted as "sexual intercourse"[56], and indeed, in later texts the character very often simply means men's desire for the opposite sex. - Confucius said: "I have never seen a person who loved virtue more than sex or the beauty of women" (LY 9.18 and 15.13). It is possible that the double meaning of the word "se" results from the fact that since the earliest times women used coloured cosmetics for beautifying themselves. The word for colour could as a *pars pro toto* have taken the meaning of "eros". If this is true, then there would be small wonder that Chinese philosophers, who often warned that a ruler who neglected the state business because of his appetite for material goods and sensual pleasures would eventually lead the world into ruin, despised the use of colours altogether. This scheme could also explain why there were so many complicated rules regulating the use of colours. - Only with systematized and ritualized rubs could the negative effects, which the costly luxury of colours produced, according to the erudites be mastered.

Notes

1 C. f. Paul Serruys, "Basic Problems Underlying the Process of Identification of the Chinese Graphs of the Shang Oracular Inscriptions", *Bulletin of the Institute of History and Philology, Academia Sinica* (*Zhongyang yuan lishi yuyan yanjiusuo jikan*) 53 (1982), pp. 455-494.

2 Wang Tao, "Colour Terms in Shang Oracle Bone Inscriptions", Bulletin of the School of Oriental and African Studies, 1996.1, pp. 63-101. Throughout its first part this paper owes very much to Wang Tao's findings.

3 Wang Tao, 1996, pp. 98. Compare W. Baxter, "A look at the history of Chinese color terminology", Journal of the Chinese Language Teachers Association, XVIII, 2, 1983, pp. 1-25. Compare, however Gao Hanyu 高汉玉 who believes that "blue"/"green" belonged to the Chinese colour system as early as during the Shang. S his "*Zhongguo secai mingwu shu* 中国色彩名物疏" ("Commentary to names and objects of Chinese colours", in *Liuxing se* 流行色 (Fashionable Colours), 1978/4 pp. 10f and 1979/1, pp. 30-33, and 2, pp. 28-31.

4 Gao Hanyu, *Liuxing se* 1979/1, pp. 31, explains chi as the colour of a big fire.

5 Needham, Joseph, *Science and Civilization in China* (6 volumes, 41 sections, Cambridge University Press 1954-1999, ongoing), V.2, pp. 157, based on Karlgren, Grammata Serica Recensa number 128.

6 Ibid. Compare Karlgren, op.cit., pp. 157, number 150.

7 Wang Tao, op.cit.

8 Karlgren, Nr. 904.

9 Tang Lan, *Wenwu* 1976, no. 5 pp. 63.

10 Wang Tao, pp. 92.

11 Needham V.2, based on *Shuowen* 10A/55b.
12 Paul Serruys, "On the System of the Pu Shou 部首 in the Shuo-wen chieh-tzu 说文解字", *Bulletin of the Institute of History and Philology, Academia Sinica* 55 (1984), pp. 651-754, pp. 739.
13 Karlgren 707.
14 *Liuxing se* 1979/1, pp. 31.
15 For Gao Hanyu, op.cit., pp. 31, the character for bai again shows an aspect of fire.
16 Ulrich Unger, "Hundert, Tausend, Zehntausend und Weiteres", *Hao-ku* 好古, 29 (1985), pp. 264-267.
17 Karlgren 812 c', d'. Needham V.2, pp. 157 says that "there is not much doubt that the pictograph shows a plant of some kind, very possibly indigo, with its juice being collected in a pan". He does not, however, give a source for this assumption which would put a very early date for the Chinese knowledge of indigo. Gao Hanyu, op.cit. pp. 31, once again says that the original meaning of the character qing had something to do with fire.
18 Wang Guowei 王国维, "shi wu 释物", in *Guantang jilin* 观堂集林, in *Wang Guowei yishu* 王国维遗书, Shanghai 1983, vol. I, juan 卷 6, pp. 13a.
19 Xu Zhongshu, in *Jiagu wen jishi*, ed. Li Xiaoding, Taibei 1965, 0317-18, quoted in Wang Tao, pp. 81.
20 Qiu Xigui, *Guwenzi lunji*, pp. 70-74, quoted in Wang Tao, ibid.
21 Ed. Sun Yirang, Peking 1987, pp. 1181f.
22 Ibid., pp. 937.
23 Ibid. pp. 2124.
24 *Shisan jing zhushu* 十三经注疏 (SSJZS, Peking, Zhonghua shuju 1980) pp. 1742.
25 Compare for example Duke Xuan 宣, SSJZS 1879A.
26 *Baihu tong shuzheng* 白虎通疏证, (ed. Peking 1994) 4/175ff.
27 *Liji* 礼记, SSJZS 1250A, translated by J. Legge 1, pp. 90f.
28 Robin D.S. Yates, in Needham 5.6, pp. 8-9.
29 Ibid., pp. 57ff.
30 Mozi chapter 68, *Mozi xiangu* 墨子闲诂, Peking 1986, pp. 528ff. Translation by Yates, op.cit.
31 *Hanshu* 汉书, Peking 1962/1983, 66/2881.
32 Ibid, translation by Yates, pp. 281ff. Mozi, chapter 69, *Mozi xiangu* 15/534f.
33 *Zuozhuan*, SSJZS 2063B and *Liji*, Jiaote sheng 1455A.
34 See the chapters Yueling 月令 of the *Liji*, Shize 时则 of the *Huainanzi* 淮南子, pp. 171f, and *Lüshi chunqiu* 吕氏春秋, chapter 6.
35 *Hanshu* 25A/1194, *Shiji* 28/1358.
36 *Hanshu* 25A/1196, *Shiji* 28/1360.
37 *Hanshu* 25A/1199 and *Shiji* 28/1364.
38 See the relevant entries in *Shiji* 60.
39 *Liji*, Tangong 1276A.
40 *Shiji* 28/1366, *Hanshu* 25A/1200.
41 *Shiji* 28/1378 and *Hanshu* 25A/1210.
42 M. Loewe, "Water, earth and fire - the symbols of the Han Dynasty." *Nachrichten der Gesellschaft für Natur- und Völkerkunde Ostasiens*/Hamburg, 125 (1979), 63-68.
43 *Shiji* 28/1377 and *Hanshu* 25A/1208.
44 *Liji*, Legge II, pp. 9ff.
45 *Shisanjing zhushu* 1477C. The explanation of Huangfu Mi is the one accepted by Gao Hanyu, op.cit. who adds that the five "correct" colours correspond with mineral substances whereas the intermediate colours are organic ones.
46 Compare for example *Hou Han shu zhi* 30/3763f.
47 *Taiping jing* 109/682.
48 *Shisanjing zhushu* 2353A and 2354A.
49 I follow the translation in Needham V.3 pp. 6 which is based on Nancy Swann, *Food and Money in Ancient China*, pp. 431. Cf *Shiji* 129/3260 and *Hanshu* 91/3686.
50 Lao Gan 劳干, "Zhongguo dansha zhi yingyong ji qi tuiyan 中国丹砂之应用及其推演", *Bulletin of the Institute of History and Philology, Academia Sinica* 1936 (7.4), pp. 519-531.
51 Zhuang 庄 23.8.
52 *Shisanjing zhushu* 2237B.
53 See for the systematization Needham 5.4, pp. 287.
54 *Lunyu*, ed. Harvard Yenching Index 1.3; 17.15 and 5.25.
55 *Shuowen* 9A/431B-432A.
56 Serruys, "On the Pu Shou...", number 340, pp. 717f.

凡 · 埃斯

从中国古代史料看颜色的象征和意义

摘要

对这篇论文的标题《**从中国古代史料看颜色的象征和意义**》需要作些说明。首先，这次研讨会有两篇专门探讨文字史料，而不涉及原材料即艺术品的论文，本篇即其中之一。

此外，由于本文论述的是观念而非工艺，其范围便得以限制：当然，为了推断古代*工艺*的发展，使用较近的史料亦非不可，但就*观念*而言，这样作却不无危险。由于肇始于汉代末年 — 倘若不是更早的话 — 并至六朝(公元 200-600 年)两种新的宗教，即佛教和道教的出现，中国文化在这个阶段经历了大的改革。鉴于此，在探索中国古代思想史的研究中，语言学家通常将他们的注意力集中在所谓"佛教传人之前"时期的文献。这同样适于我们的研究课题，依靠公元 200 年之后的材料，对生活在秦代的文人和艺术家于颜色所持的看法下定论，未免过于冒失。因为我们知道，一些颜色在隋、唐时期和在汉代或更早的时期乃具有不同的意义。

本文试对文字史料，即从甲骨文开始到公元一、二世纪的哲学著作，作一番审视，为的是了解在探索不同课题时，如中国古代颜色术语的起源、五行学说中的颜色角色、礼仪中使用的颜色或一些颜色的社会意义，这些史料究竟能提供什么帮助。另一个目的是揭示那些记载颜料的生产原料的出处。最后我想侧重谈谈中文颜色名词的内涵以及文人对使用颜色的看法的转变。在西方汉学界，既无人对大部分这些课题作充分论述，也匮乏对重要材料作有条理的描述。本文唯一的奢望是对材料进行初步的概括，以便大家讨论。

(英译中：陈钢林)

蒋采蘋

中国古代绘画技术及颜料

古代人类绘画的技术和颜料基本上是同步发展的，至 15 世纪以后，东方与西方的绘画技术才拉开了距离。古代亚洲、中亚、欧洲各国的绘画都是以线造型、平面构图的技巧，所使用的颜料也都采自自然界的物质，如矿石颜料(彩图 V，5)、植物颜料、土质颜料、金属颜料以及少量的简单化学颜料等。我曾在欧洲 4 个国家考察过他们古代绘画，我认为欧洲的宗教题材作品，远至希腊罗马时期的绘画，还有印度的古代绘画，他们画家的技术和所使用的颜料是十分相似的。相似的原因有三:

1. 人类绘画的原发行态势不约而同的相似的;
2. 人类在古代，即 16 世纪以前科学上不发达，画家自能选择天然的有机或无机颜料;
3. 人类古代已有各国、各洲之间的文化艺术交流。(通过丝绸之路)

关于古代文化交流，例如中国古代画家所使用的蓝色颜料(青金石 lapis-lazuli)就是当时从西域传过来的。青金石产在阿富汗，是由古代的丝绸之路带到中国来的，当时称“回青”。中国古代石青色为蓝铜矿(azurite)。

我曾在欧洲的巴黎、伦敦、阿姆斯特丹、布鲁塞尔等地看到了许多博物馆，重点参观欧洲古代和中世纪绘画，我是去寻找西方与东方绘画的共同点的，不是去找区别的。瑞典汉学家罗多弼认为应该强调中西文化的相同性，如果过分强调文化的相异处，会使文化冲突的危险更大。我很高兴参加这次会议，因为它会促进世界许多国家对彼此文化的了解，从而找到更多的相同性。

下面介绍古代中国从汉代(公元前 200 年)到明代(公元 15 世纪)的绘画(主要是壁画)及其技术与颜料。

西汉帛画(比公元前 210 多年前的秦俑约晚 100 年左右)

1972 年出土于中国湖南长沙马王堆一号汉墓一幅 T 字形帛画，保存完整，是中国迄今为止所发现的最早的一幅完整的绘画作品。同时出土的还有墓主人—女尸和许多漆器、木俑随葬品。

此帛画帛(丝织品)地原应为乳白色，现已变为墨褐色，但经历 2100 多年并未残破，历史证明天然织物是持久的。

装饰性构图，画面对称、均衡、色彩华丽协调。颜料主要使用矿石颜料，有朱砂、石青、赫红，植物颜料有花青(蓝色)、胭脂(红色)等，白色估计为蛤粉或白垩(白土)和墨(黑色)。

绘画技术，造型用墨勾线，略有渲染，不求太立体。(展示西汉帛画版和中国矿石标本图片， 石青-青金石、蓝铜矿、朱砂、蛤粉化石等)。

中国古代 4 世纪-7 世纪的绘画，敦煌北魏、西魏、北周壁画，新疆克孜尔(古龟兹国)壁画。

敦煌位于古代丝绸之路之上，古丝绸之路是中国通过阿拉伯、欧洲诸国的重要通道。敦煌的莫高窟 490 多个洞窟壁画就是东西方文化交流的结果，它们的作品已融合了东西方绘画的技术和颜料。

敦煌莫高窟壁画都是佛教题材，佛教本身从印度传到中国的，它的绘画题材和绘画技术很自然地结合了中国和印度的两方面。

敦煌早期(4 至 7 世纪)的洞窟壁画与印度阿旃坨壁画风格与绘画技术。有北魏、西魏、北周的壁画。其画为佛教故事画为主，亦有佛像。故事画画法比较自由，不讲究对称，但自然形成或均衡。色彩强烈，颜料以矿石颜料和土质颜料为主。有石青、石绿(malachite)、朱砂、红土、赭石、蛤粉或白垩(白土)、墨(黑色)及部分植物颜料花青、胭脂等等。但氧化铅颜料、硫化汞(银朱)等化学颜料日久变成黑褐色。

克孜尔壁画，风格与绘画技术、颜料相似，是公元 7 世纪的作品，壁画以青、绿、红色为主。

敦煌莫高窟唐宋时期壁画(公元 7 世纪至 12 世纪)以及唐李重润墓室壁画(7 世纪)。

唐朝 7 世纪李重润墓室壁画，为 7 世纪建。李重润死后封为懿德太子，皇家所修造，规模宏大，墓室壁画精美、宏大、用色讲究。壁画大量使用矿石颜料朱砂、石青、石绿等，使画面华丽壮美。唐代用石色比 7 世纪前有进步，如石色已分成多种色阶，至作较精良。

敦煌莫高窟唐代和宋代的壁画(7-12 世纪)

此阶段绘画颜料已将化学合成的氧化铅、硫化汞等易变色的红色、白色、桔黄色的颜料废弃不用。故墓室壁画保留了较鲜明的色相效果，历时一千多年不变色。桔红色和桔黄色用朱砂的色的最细部分，用在女性面部很合适。植物颜料花青、胭脂等用于石色的打底部分。在 12 号唐代洞窟中佛像身体、面部还用了白云母粉(MiCa)。

壁画色调多用暗色调，如红、绿、赭等色，青色较少(彩图 V，1，2，4a，b)，而克孜尔壁画中的青绿色较多，红色亦不少，比敦煌色调对比强烈，绘画技术趋于精制，画面装饰性强，北魏时期的较自由的、随意的勾线和设色的方法

减少。

贴金箔的粘合剂为桐油或蒜糖合剂，后者与欧洲贴金发相同。

元朝(13-14 世纪)的壁画

元朝虽为蒙古民族统治，但文化上蒙古对汉族的影响不大，从壁画方面看，永乐宫道教壁画完全保留了唐宋壁画的风格与特点。

道教是中国的传统的宗教，所以神像的造型与服装全是汉族唐宋时样式。

敦煌也有一部分元代壁画，但多用透明色，更加注意线条的美感，大约多文人画影响。

元永乐宫壁画绘画技术纯熟，三青殿气势雄浑，笔者从 50 年代至 70 年代三次去过永乐宫临摹，约 6 个月。后二殿为道教故事画。

三青殿颜料中有金属颜料，多为"堆金沥粉法"，即将壁画做成凸出的白粉线条，干后再在上面贴上金箔，形成金色花纹或图案，增强壁画的华美效果。

明代法海寺壁画(公元 15 世纪)

明代法海寺在北京西郊，为明代初皇家所建，由皇家的画家绘制壁画，费时数十年。画技精湛，颜料十分考究。几乎全部使用矿石颜料，包括加少的白云母粉(MiCa)。在云气、荷花、牡丹花、人物的面部和皮肤上，水月观音的纱飘带上都用细云母粉罩过或画过，形成微微闪光的效果(彩图 V，3)。我从巴黎一位教授那里了解欧洲也用云母粉作画。

法海寺大量使用金箔，其技巧复杂，与同时期欧洲尼德兰画家凡 · 埃克在祭坛画上所用的贴金箔图案的方法相同。我在荷兰根特城见过凡 · 埃克的作品，不止贴金箔，他的石青、朱砂的绘制技艺十分高超。

至明朝末年，东西商贾贸易多了起来。绘画技术和颜料交流较多，属于另一研讨题目。

Jiang Caipin

Painting Technique in Ancient China

The author of this paper (see colour plate V), who has not only copied from frescoes in ancient Chinese Dunhuang caves and Yangle Palace but has also visited many European museums and churches, holds that ancient Chinese and Europeans were synchronical in the development of painting. There were similarities in their painting techniques and the pigments they used. This paper explains the history and characteristics of the development of ancient Chinese painting and also offers a comparison with historical European painting (till 15^{th} century). The following two historical stages will be explained:

(1) Pigment used in China and Europe before Christ
China: Period from Zhou to Han Dynasties
Europe: Period of Ancient Greece and Rome

(2) The Middle Ages
China: Period from Han to Ming Dynasties
Europe: Period from the Middle Ages to the 17^{th} century.

Petra Rösch

Colour Schemes on Wooden Guanyin Sculptures of the 11th to 13th Centuries, with Special Reference to the Amsterdam Guanyin and its Cut Gold-foil Application on a Polychrome Ground

Fine threads of gold-foil are a special mode of surface decoration, and up to now have been considered typical for Japanese Buddhist works of art.[1] On numerous sculptures and paintings in Japan a decoration with thinly cut gold-foil, called 'cut gold' (Japan: kirikane), adorns the skirts and scarfs of holy beings in the Buddhist world.

In China these geometric patterns, made from extremely thin gold threads, do not seem to have been very common and are rarely found nowadays, even though gold-foil applications, generally called 'applied gold-foil' (Chinese: *tiejin*), are known at least since the 6th century dynasty. Until now it has been assumed that this skillful surface decoration had its origins in China, but reached its highest refinement in Japan. However, because of the scarcity of known material, the circumstances of the Chinese cut gold-foil decorations have so far not been properly investigated.

With the help of new material which has become available through closer examination and the restoration of Chinese wooden sculptures of the Song, Liao and Jin dynasties in Western Museums, not only the assumption that *kirikane* originated from China can now be confirmed, but furthermore the close relationship between Japanese decoration techniques and their Chinese predecessors can now be established as well. As Japan offers a well-studied and adequate range of examples of *kirikane*, I will refer to Japanese sculptures to illuminate the Chinese development of cut gold-foil applications.

After a short introduction, I will consider some technical questions. To examine the relationship between Chinese and Japanese cut gold-foil decorations, it will be necessary to take a short look at the development of cut gold-foil in both countries. In the second part of the paper, the emphasis will be laid on the Water-Moon Guanyin, kept in the Rijksmuseum in Amsterdam, which shows a complex surface decoration with cut gold-foil.

Today, most of the wooden sculptures of the 11th, 12th and 13th centuries no longer show the original polychromy, because of more recent redecorations. Many of them have, however, preserved coats of paint which are datable to the Ming dynasty.[2] They now appear in an overall golden colour, with additional relief or pastiglio patterns on their skirts and scarfs. A short comparison of the front and back of the Guanyin sculpture in the Art Institute of Chicago (fig. 1) shows the different colour schemes: a completely golden surface on the front and a more colourful and varied rendering on the back (fig. 2), which probably reflects the original decoration of the 11th to 13th century.[3]

A similar situation can be observed on the Amsterdam Guanyin (fig. 3 and colour plate VI, 2), where the golden Ming period surface decoration was removed in the 1940s, to reveal a more realistic surface decoration underneath.[4] Hopefully, many more original surface decorations of this period will come to light in the future through close examination and restoration of these sculptures. In any case, from what is known today we can safely assume that all sculptures of the Song to Jin dynasties – including the Amsterdam Guanyin – were originally decorated in a more 'realistic' and more colourful rendering.

Cut gold-foil was obviously an important component of this realistic conception. To proceed further, it is necessary at this point to focus briefly on the meaning and on some technical aspects of cut gold-foil applications.

Gold-foil was applied on Buddhist sculptures and paintings in order to give them a precious appearance. Gold itself was not seen as mere decoration, but as a gift to Buddha. Thus the decoration of Buddhist works of art with gold and silver was a way of expressing ones devotion to Buddha. Gold or silver paint was conceived as more precious than ink or paint , and in turn cut gold-foil was more precious than painted gold and thus expressed greater devotion.[5]

Gold-foil applications on sculptures most probably represent gold-thread embroidery or designs rendered in colour or gold-foil imprints on textiles. They most likely imitated not only Chinese textiles, but also those influenced by Central Asian clothes. In the future it needs to be considered how far cut gold-foil patterns did in fact refer to textiles, and where they developed their own effects, through, for example, straight lines and sharp angles.[6]

Technically, Japanese *kirikane* or cut gold-foil decorations need a careful preparation of the material. Three layers of thin gold-foil leaves are joined together through heating (fig. 4). Thus the foil becomes thicker and does not tear as easily. Next, a sharp bamboo knife is used to cut threads of gold-foil up to 3mm width. With glue made out of seaweed and a brush to pick them up, the gold threads are applied to a coloured surface or an unpainted wooden ground. While carefully applying the threads to the surface, the patterns, consisting of bent-lines or geometrical schemes, are developed.[7]

In the following section of the paper I will trace the development of cut gold-foil decoration in China and Japan. Cut gold-foil decorations existed in China prior to the Song dynasty, and influenced Japanese works of art. The origins of gold-foil applications on sculptures go back at least to the Northern Qi dynasty (550-577), as examples from recent excavations in Shandong province, Qingzhou, have shown.[8]

One of the earliest examples of cut gold-foil decorations representing textile patterns can be seen on the clothes of Bodhisattvas in Dunhuang. Until now, the art of cut gold-foil decorations in Dunhuang has not been analysed in detail, but recent research into patterns on the dresses of the Bodhisattvas in Dunhuang demonstrates conclusively that cut gold-foil was used in various ways from at least the Sui dynasty onward.[9] These patterns included designs of applied cut gold-foil which are very similar to the early *kirikane* patterns found in Japan. In the Sui dynasty cave No. 427 bands of rhomboid patterns of cut gold-foil (fig. 5) are interspersed between fields of coloured patterns. Although these early Chinese cut gold-foil patterns do appear a bit crude, they make apparent that the technique of imitating golden textile patterns on sculptures was already well-known in China at the time.

Fig. 1: Guanyin, 11th-13th century, front; Art Institute of Chicago (Photo: author).

图 1. 观音, 11-13 世纪, 正面, 芝加哥艺术学院(摄影: 本文作者)。

Another Chinese example showing early Chinese cut gold-foil decorations is the marble sculpture of Da Anguo si at Xi'an, consisting of a marble base and a Buddha, now in the Shaanxi History Museum (fig. 6). This time it is not textiles which are imitated; instead, the edges of the lotus throne are highlighted with lines of cut gold-foil, and the lotos-leaves decorated with flowers made out of tiny cut gold-foil rhomboids (fig.7).

In the following examples it should become clear that the Chinese patterns were the inspiration for Japanese works of art, as Japanese sculptures show comparable patterns of tiny lozenge-shaped pieces of gold-foil which are combined with threads of cut gold-foil. One of the earlier gold-thread decorations still preserved today can be seen on the trousers of Bishamonten from the 9th century (colour plate VI, 1) in the former Ordination Hall (J: *Kaidanin*) at Tôdaiji Temple in Nara from the 9th century. On a green ground we see a geometric pattern of cut gold-foil threads, with flower-motives of lozenge-shaped pieces inbetween. Motif and technique are not only comparable to the Da Anguo Si marble base, but also to the patterns we have just looked at on Bodhisattvas' dress in Dunhuang. This cross-reference confirms that already at this early stage cut gold-foil patterns on Japanese sculptures were inspired by Chinese works of art. To sum up so far, the early patterns in cut gold-foil in Japan, as well as in China, consisted of simple geometric patterns of fine lines and rhomboid shapes.

For Japanese *kirikane* decorations it is generally accepted that the simpler patterns gradually developed into more complicated forms, which in this case means that simple patterns of a few lines grew into dense, net-like patterns. The development of more complicated motifs began in the 11th century, but during the 12th and 13th century the art of *kirikane* decorations had reached its peak. As the technique was by then fully understood and mastered, thin threads of gold-foil could be used more freely. From that time on, bent lines were *en vogue,* forming motifs like clouds or waves, and many flower and leaf patterns or complex geometric patterns appeared.[10]

This summit of achievement in the 12th and 13th century clearly coincides with new influences in carving styles and decorations from China. Japanese Buddhist sculptures not only bear influences from China in their carving, but also show surface decorations and patterns of cut gold-foil which are obviously influenced from China.[11] The sitting Kannon (C: *Guanyin*) of the 12th and 13th century kept at the Senyûji Temple in Kyôto is just one example which clearly records this connection; with its grape-leaf garlands of cut gold-foil on its knees and coat, it recalls features which appear in Japan with the beginning of the Kamakura period (fig.8). Patterns on Kaikei sculptures appear to be modern for the time and had not previously been used in Japan in this way. Kaikei is a sculptor whose style is said to have been influenced by Chinese art of the period.[12] Grape-leaf design on the borders of the Kaikei'st Amitâbha's dress show up in a new variation during this period, as well as a complex hemp-leaf pattern, which covers, for example, wide areas of this sculptures attire (fig.9). The complex geometric, net-like patterns and the more natural ones with complicated bent-lines had their origin in Song China, too, an observation, which will be supported by the following Chinese examples.

Fig. 2: Guanyin, 11th-13th century, back; Art Institute of Chicago (Photo: author).

图 2. 观音, 11-13 世纪, 背面, 芝加哥艺术学院(摄影: 本文作者)。

Fig. 3: Guanyin, 11-13th century, front; Amsterdam, Rijksmuseum.

图 3. 观音, 11-13 世纪, 正面, 阿姆斯特丹皇家博物馆。

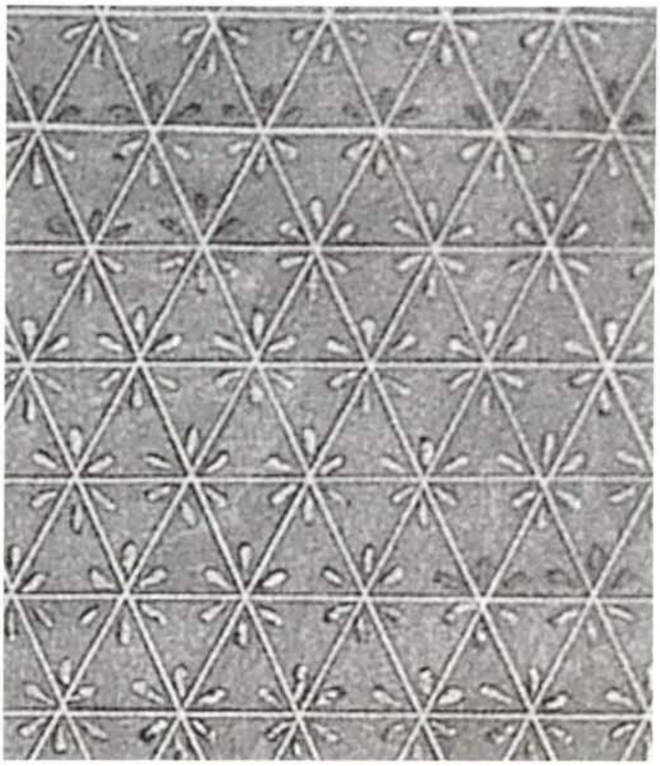


Fig. 4: Three layers of thin gold-foil leaves are joined together through heating (Repro from: YOSHITAKA).

图 4. 加热使 3 层金箔合为一体(取自: 义孝有贺)。

Fig. 5: Bodhisattvas, two examples of garment decoration; Dunhuang (Repro from: YOSHITAKA).

图 5. 菩萨, 外衣装饰两例; 敦煌(取自: 义孝有贺)。

Until recently very few Chinese sculptures which could confirm the hypothesis that the patterns of 11th and 12th century decorations were influenced by Chinese sculptures have been found. The examples of Chinese sculptures to be presented next will demonstrate that the variety and complexity of Chinese cut gold-foil-patterns was more than capable of inspiring the refined patterns seen on Japanese sculptures. Due to improved photography and recent restorations, or the removal of later coatings, it has become possible to thoroughly document Chinese wooden sculptures with cut gold-foil decorations. The richest example in this respect is the Water-Moon-Guanyin of the Rijksmuseum in Amsterdam. Fine geometrical and bent-line patterns in complex arrangements can be appreciated on this sculpture, and with it we can gain an impression of how high-quality pieces were decorated in China during the Song to Jin dynasties.

The sculpture of the Water/Moon Guanyin in the Rijksmuseum, Amsterdam, dated to the 11th/13th centuries, was one of the first Chinese works of art on which a cut gold-foil decoration

Fig. 6: Da Anguosi-Buddha, marble; Shaanxi History Museum (Repro from: YOSHITAKA).

图 6. 大安国寺-佛，大理石，陕西历史博物馆(取自：义孝有贺)。

Fig. 7: Da Anguosi-Buddha, detail of marble base; Shaanxi History Museum.

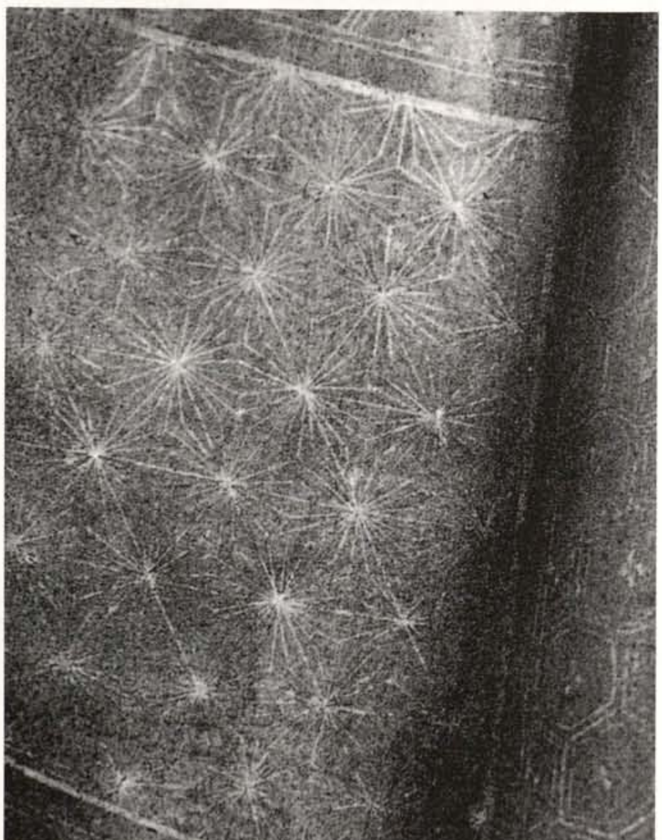
图 7. 大安国寺-佛，大理石宝座局部，陕西历史博物馆。

Fig. 8. Kannon, 12th/13th century, detail of the left knee, floral spandrel decoration; Senyûji Temple, Kyôto.

图 8. 观音，12/13 世纪，左膝局部，蔓花装饰；京都泉涌寺。

Fig. 9. Buddha Amitâbha, Shunjôdô, Tôdaiji, 1208, detail of the garment, hemp-leaf-decoration.

图 9. 阿弥陀佛，东大寺，1208，外衣局部，大麻叶装饰。



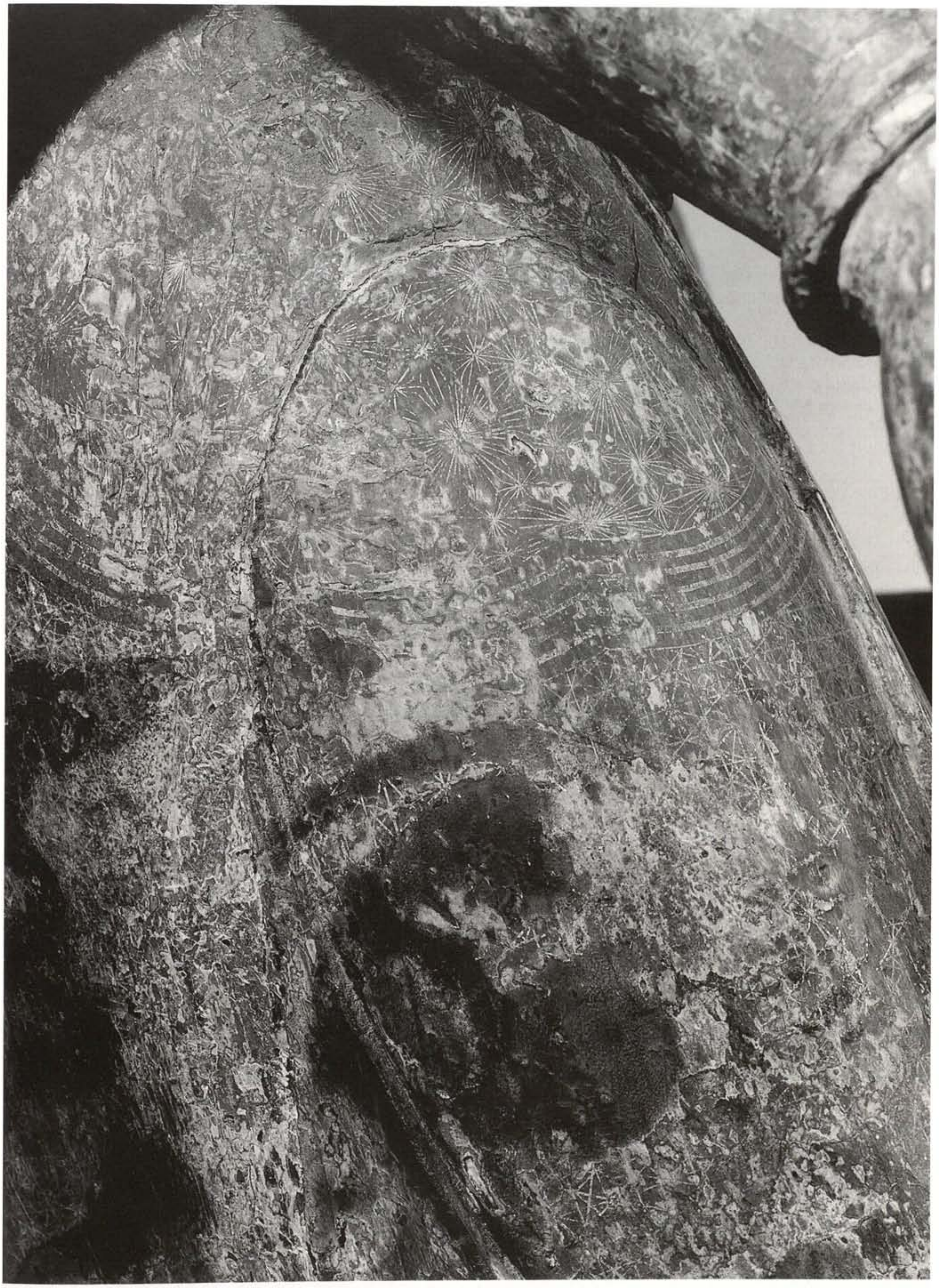


Fig. 10. Guanyin, detail around the knee; Amsterdam, Rijksmuseum (Photo: Rijksmuseum).
图 10. 观音，膝处局部；阿姆斯特丹皇家博物馆(摄影：皇家博物馆)。

comparable to Japanese examples was found (comp. fig. 3 and colour plate VI,4). The sculpture of 'Guanyin sitting in Royal Ease' has already been discussed by Dietrich Seckel, Heidelberg University. He praises the sculpture not only for its refined style, but especially for its well-preserved cut gold-leaf applications.[13]

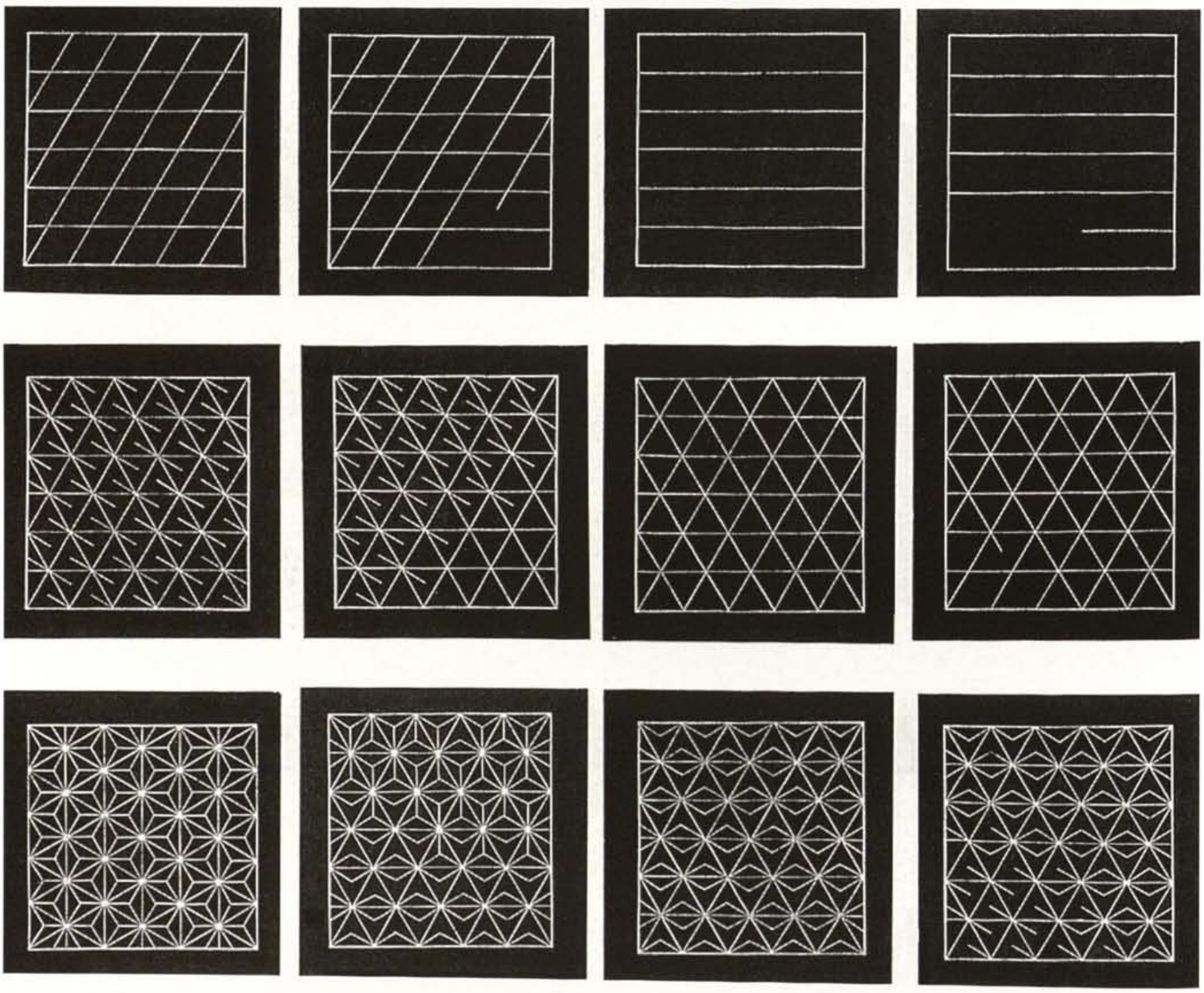
The gold-foil-decoration on the skirt was discovered in the 1940s when the sculpture received a surface treatment. During a second investigation conducted in 1998, a more detailed picture of the paint layers could be achieved and close-up shots of the cut gold-foil decoration could be taken; these allow us now to get a clearer impression of the patterns on the skirt. The *dhoti* or skirt of this sculpture offers three different, complex cut gold-foil applications, all consisting of extremely thin threads of gold-foil on a bright red coloured ground.

The area of the knees (fig. 10) is separated from the rest of the skirt through five wavy lines of cut gold-foil. Here, the impression is of a net of stars covering the area. The pattern was probably developed geometrically according to a checquered board; this can be seen best in a drawing made by Eri Sayoko, one of the few *kirikane* masters in Japan today (fig. 11).[14] A comparision makes clear that the pattern on the Amsterdam Guanyin can be described as a hemp-leaf pattern, very much comparable to the Japanese examples discussed above.

But the Amsterdam Guanyin is not the only Chinese sculpture with such an application known today. This kind of cut gold-foil pattern was obviously quite common in China. It can be seen too, for example, on the sleeves of a sculpture of Weituo Tian, the protector of relics and books (colour plate VI,3). This sculpture, dated to the Southern Song dynasty (1127-1278), is kept today in Chôryuji Tempel in Gifu province. It is generally accepted that it was brought there from China in the 12th century.[15] In another variation, the hemp-leaf pattern is interspersed with small cross-shaped flowers.

Another sculpture, also dating to the 12th century or earlier, also comes from the southern part of China. In the Provincial Museum at Hangzhou a little clay sculpture, about 40-50 cm high, is on display. It can be roughly dated to the 10th to 12th century and is assumed to come from Baixiangta Pagoda, west

Fig. 11. Geometrical pattern development (Repro from: YOSHITAKA).
图 11. 几何图案发展图示(取自: 义孝有贺)。



of Wenzhou City, in the southern part of Zhejiang province (fig. 12). In its lap, on a red coloured ground, it shows a hemp-leaf cut gold-foil pattern, very much comparable to the one we've encountered on the Amsterdam Guanyin (fig. 13).

The above-mentioned three examples of hemp-leaf pattern clearly show that this kind of cut gold-foil pattern was prolific in China from at least the 12th century onwards.

The largest area of the skirt of the Amsterdam Guanyin is covered by a net-like pattern of connected hexagonal shapes (fig. 14 and colourplate VI,4). Again, this is a pattern quite common on Japanese sculptures since the early Kamakura period (colourplate VI,5). An interesting fact worth noting here is that the hexagonal pattern on the Amsterdam Guanyin's skirt is obviously not only just laid over the red coloured ground. It would appear as well that the green clouds and phoenixes or cranes, which also decorate the skirt, are covered by the cut gold-foil pattern too. This seems unusual in comparision with Japanese examples, which always differentiate clearly between polychrome patterns and a cut gold-foil decoration on the ground layer. As could first be stated as a result of a recent analysis by Aleth Lorne, the cut gold-foil decoration of the Amsterdam Guanyin could also be a later over-decoration, applied after the first coating of a red ground colour with interspersed clouds and phoenixes.[16]

Another pattern belonging to the Amsterdam Guanyin's cut gold-foil decoration can be seen on a wide band or border along the edge of the skirt (fig. 15). As far as one can judge from the detail photograph, it consists of spade-like leaves set one beside the other. The pattern seems not to be one of any geometric consistency, but made instead of freely-set, bent or curved lines. The distribution of lines is not very dense, standing rather in the tradition of naturally distributed grape-leaf garlands known from Japanese sculptures at the beginning of the Kamakura period, like the above mentioned Buddha Amitâbha from Kaikei or the Kannon from Senyûji temple.

Non geometrical, bent-line patterns do not only turn up on the Amsterdam Guanyin, but also on other Chinese sculptures datable to the 12th century and earlier. On the already mentioned Weituo Tian, for example, we find next to the hemp-leaf pattern a decoration of wave or cloud-like cut gold-foil application (comp.colourplate VI,3). Furthermore, I would like to consider the small sculpture sitting in 'royal-ease' which came up for sale in the Eskenazy summer exhibition of 1990 and was published in the catalogue (fig. 16 and 17): as can be deduced from the detail, while the arrangement of single threads of gold-foil is like an arm of a hemp-leaf-pattern, the lines next to it suggest that this was part of a more complex motif, perhaps flowers, as can be seen on the coat of Amida's dress. That flower and leaf motifs out of cut gold-leaf were used on Chinese sculptures as well is demonstrated in a further example. On the skirt of a nearly life-size sculpture of a sitting Guanyin cut gold-foil decoration has come to light under a Ming dynasty coating (fig. 18). The piece was exhibited in a Deydier sales exhibition in 1996 and is now in a private collection in Taiwan. The detail (fig. 19) clearly shows the naturally rendered leaves of a flower, belonging to a pattern which obviously covered a larger part of the skirt, as the pattern seems to continue adjacent to the flower. The distribution of flower leaves even seems comparable to the grape-leaf pattern shown already on the Japanese sculpture of Chôryuji in Gifu province, where flowers were organized in a border-like band.

From what we have seen of Chinese cut gold-foil decorations on the Amsterdam Guanyin and on other examples it is obvious that complex net-like and geometric patterns as well as bent-line, flower-leafpatterns were firmly established by the 12th century and could thus have influenced the Japanese Kamakura patterns. The covering of the dresses with a system of cut gold-foil patterns, as could be observed on the skirt of the Amsterdam Guanyin, is also very similar to Japanese examples.

In conclusion cut gold-foil decoration had its origin in China and influenced the Japanese patterns at least twice, in the 7th/8th centuries and in the late 12th/13th centuries. Decorations with complex patterns of cut gold-foil were no isolated phenomenon, but frequently employed on Chinese sculptures in a highly

Fig. 12. Sitting Guanyin, 10th/12th century; Hangzhou Province Museum.
图 12. 端坐观音, 10/12 世纪; 杭州浙江省博物馆。

Fig. 13. Sitting Guanyin, 10th/12th century; detail of the skirt; Hangzhou Province Museum.

图 13. 端坐观音, 10/12 世纪；裙子局部；杭州浙江省博物馆。

Fig. 14. Guanyin, detail of the skirt; Amsterdam, Rijksmuseum.

图 14. 观音，裙子局部；阿姆斯特丹皇家博物馆。

Fig. 15. Guanyin, detail of the border of the skirt.

图 15. 观音，裙子滚边局部。

Fig. 16. Eskenazi Guanyin.

图 16. 埃斯克纳齐观音。

Fig. 17. Eskenazi Guanyin, detail of the skirt.

图 17. 埃斯克纳齐观音，裙子局部。

skilled manner. The cut gold-foil designs discovered on Chinese sculptures during recent years are in quality and variation comparable to Japanese pieces. Further research and technical examination of sculptures kept in the collections of museums or still *in situ* in Chinese temples will be necessary in order to support and develop these observations.

Fig. 18. Deydier Guanyin.
图 18. 戴伊迪尔观音。

Fig. 19. Deydier Guanyin, detail of the skirt.
图 19. 戴伊迪尔观音，裙子局部。

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11 Itô, Shirô: Keiha sakuhin ni miru sôshokusei: Kaikei butsu no kirikane o chûshinmonyōni (The Decorativeness seen in the Sculptures by the Keiha-School, focusing on cut Gold-foil Decorations of the Buddhist Sculptures made by Kaikei), in: *Henkakusei no Bukkyo Geijutsu. Bukkyo Geijutsu kenkyû Ueno kinen zaidan – Buddhist Art During the Transitional Period. The Ueno Memorial Foundation for the Study of Buddhist Art*, Report Vol. 25, Kyôto 1994, pp. 1-6.
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勒施

11 至 13 世纪木制观音像的彩绘结构：以阿姆斯特丹观音及其金箔在彩绘表面上的应用为重点

宋、金、辽雕塑的装饰问题，我想在我的博士论文中进行探讨。这里我想重点讨论在西方博物馆收藏的结跏趺坐的自在观音木雕像。

关于宋、金、辽时期雕塑彩绘的研究不多。重要的出版物有约翰·拉森和罗斯·克尔编著的保护报告"观音 - 展示一件杰作"(伦敦，1985 年)，作者关注的是维多利亚和艾伯特博物馆的雕塑。除此之外，只有极少的且大多没有发表的在西方博物馆所做的观察工作。

佛教雕塑是宗教环境的组成部分，受时尚的影响，它们中的大多数都被重新修饰过多次。原始表面常常隐藏在全然不同的覆盖层之下。随着研究方法的改进，愈来愈多的雕塑彩绘结构的真相暴露出来，引人入胜的细部得到揭示，这些为了解彩绘概念提供了新的线索。

我在报告中着重介绍 3 座在西方博物馆收藏的结跏趺坐的自在观音木雕像，它们分别藏在维多利亚和艾伯特博物馆、芝加哥艺术学院和阿姆斯特丹皇家博物馆。

在仔细观察这几件雕刻时，我讨论和分析了其彩绘，特别是阿姆斯特丹的观音像的切金装饰。

我将围绕下列几点对这些雕刻进行探讨：

－重新装饰阶段的全部金色覆盖层。

－ 3 座雕像的围巾、披巾和罩裙上的彩绘。

－阿姆斯特丹的观音像上的切金装饰。

初步结果：

所有金色重新装饰，3 件雕刻的做法类似，均以"压地隐起"之法(pastiglio)构成浮雕花卉图案。覆盖层可能是辽代之后产物，看来反映了不同的宗教雕塑思想。

－原始彩绘结构大多受到纺织品的启示。阿姆斯特丹的观音像的装饰看来最为先进。

－在阿姆斯特丹的观音裙子上看到的切金装饰也许并不象迄今所想象得那么独特。一大批宋至辽代雕塑的图案影响了日本平安和镰仓时代的木雕。

这项研究的目的在于更好地理解彩绘的发展，获得更好的断代方法，确定这些雕刻在中国艺术史中的地位。

(英译中：陈钢林)

Sylvie Colinart and Sandrine Pagès-Camagna

Egyptian Polychromy: Pigments of the "Pharaonic Palette"

Introduction

Paint was widely used in Ancient Egypt for the decoration of both large-scale monuments and small objects. Colour performed a complex function here: it imitated nature, but it also conveyed symbolic meanings. The pigments of the "Pharaonic palette" consisted mainly of natural minerals whose ores were widespread in Ancient Egypt (Colinart, et al., 1996).

There is ample literature on the subject, but Lucas's *Ancient Egyptian Materials and Industries*, first published in 1922, remains the starting point for most research in this field (Lucas, 1962). Data going beyond Lucas can be obtained by systematic scientific investigation of polychromed objects. The Research Laboratory of the Museums of France (LRMF) therefore performed tests on selected monuments and artefacts in the Department of Egyptian Antiquities (DAE) at the Louvre with a view to identifying the chemical constituents of various colours and determining the processes by which they were made.

The tests were carried out using a set of techniques, including optical microscopy, scanning electron microscopy coupled with an X-ray analysis system (SEM-EDXS), Raman microscopy and X-ray diffraction. Materials were investigated in the form either of small chips taken from the objects or of samples produced in accordance with experimental recipes. The samples were embedded in resin in order to facilitate observation and analysis of their cross-sections. The results presented here focus on the yellow colour (Colinart 2001) and on a green copper silicate synthetic pigment known as Egyptian green.

Yellow

For the Ancient Egyptians, yellow derived from the sun and therefore signified life and growth. In their painting, they used it to depict vegetal materials, some foods and women's flesh. Tests performed on yellow polychromy revealed the materials traditionally employed in this context and mentioned in the literature: gold, orpiment, ochre and iron oxides.

Traces of gold were found on the face of a painted sandstone image of the goddess Satis from the chapel Elephantine, which dates from the reign of Thutmose III (1479–1425BC, Louvre, B69), and on coffins. In the latter case, the sheets of gold either covered the entire coffin (coffin of King Antef, 17th dynasty, 1650–1550BC, Louvre, E3019/N712) or were found only in flesh areas or in certain ornaments (coffin of Mesre, 18th dynasty, Louvre, N2673; coffin of Tamoutnefret, late New Kingdom, 1186–1069BC, Louvre, N2571). Gold, easily obtainable in Ancient Egypt, was used because of its symbolic, not its material value. Associated with immortality, it was employed to represent the flesh of Re and all other divine beings. It was thought to assist the dead in speaking and eating in the afterlife. Such powers were also attributed to orpiment and sometimes to yellow pigment.

Owing to its bright yellow colour, orpiment could be used as a gold substitute symbolizing Re's spirit. A natural arsenic sulphide, As_2S_3, it is more intense in colour than ochre or iron oxides. Its use in the Middle Kingdom (2033–1710BC) is attested, but we found it on the 2nd dynasty (2900–2700BC) stone stele of Nytoua and Nytneb from Saqqara where it would seem to belong to the original polychromy (Louvre, E27157).

The pigments encountered most often on polychromed objects from our period of study were ochres and iron oxides, the most widespread in the world. These natural minerals were found in flesh areas, in the backgrounds of hieroglyphs and in many decorative patterns. The composition of materials generally termed "ochres" has not always been defined precisely. They usually consist of clay with variable amounts of such iron oxides as goethite (α-FeO·OH) and limonite ($FeO \cdot nH_2O$).

Our analyses revealed some less familiar minerals among the yellow pigments. These anhydrous hydroxyl iron sulphates belong to the jarosite group of minerals (Colinart, 1998), which in turn form part of the alunite group. Their colour varies from light to brownish yellow. The best known among them, encountered on some objects, are the yellow components jarosite, $KFe_3(SO_4)_2(OH)_6$, identified by Le Fur in Middle Kingdom pigments in Karnak (Le Fur, 1994), and natrojarosite, $NaFe_3(SO_4)_2(OH)_6$. Ornaments painted with these pigments show layers more lemon in colour and with more crystallization than in pigments made from ochre, iron oxides or orpiment (colour plate VII, fig. 1). An example is found in the mastaba of Akhethetep from Saqqara (5th dynasty, 2500–2350BC, Louvre, E10958; colour plate VII, fig. 2). Backscattered electron images of sample cross-sections reveal the morphology of these minerals. Frequently cubic or hexagonal, they are of medium size, generally 2 to 6 micrometres, but sometimes reaching 15 or 20 micrometres (colour plate VII, fig. 3).

Scanning electronic microscope analysis indicates that the composition of these sulphates is more complex than that of jarosite and natrojarosite. Their SEM-EDSX spectra show the presence of much sulphur and iron, associated with potassium in jarosite and with sodium in natrojarosite. Substitution of sodium by potassium gives rise to intermediary components. The proportion of these two alkaline elements can vary within a single mineral grain or layer of paint, as was found in the yellow used on the mastaba of Akhethetep. Another phenomenon may be observed on the coffin of Henem from Asyut (Middle Kingdom, Louvre, AF9757): the partial substitution of iron by aluminium, giving the mineral a different hue. The yellow decoration inside the coffin contains little aluminium, whereas that outside shows approximately 50% of the iron substituted by aluminium, producing a whitish tone.

This jarosite group of minerals was identified on artefacts dating from the Old Kingdom (2700–2200BC) to the Ptolemaic period (332–30BC) and on the later Fayyum portraits. They reportedly occur in nature as a result of alterations in iron oxides or pyrite caused by dry climatic conditions (Wallert, 1995), the

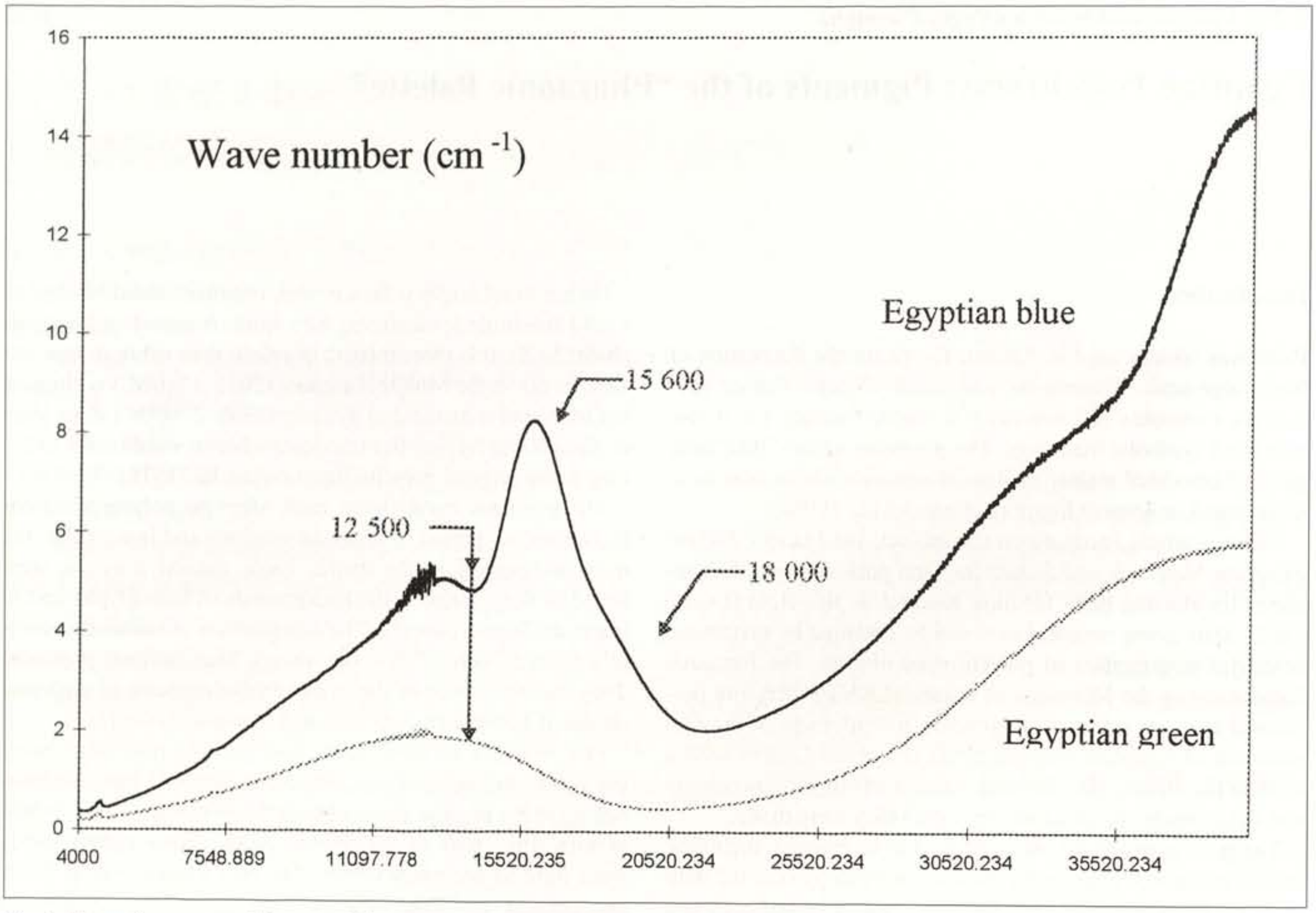

Fig. 1. Absorption spectra of the two calcium copper silicates. © LRMF, S. Pagès-Camagna.
图 1. 两种硅酸铜钙的吸收光谱。© LRMF, S. 帕热斯-卡玛纳。

type of iron sulphate produced depending on the geological context. Another opinion, based on research into the deterioration patterns of pigments found on Ancient Egyptian monuments, explains the presence of jarosite as resulting from the advanced decomposition of an iron-bearing glass pigment containing potassium and sulphur (Schiegl et al., 1992). According to this view, the result would be complete substitution of the glass pigment and a green or red-brown colour.

Samples examined in the LRMF showed no traces of characteristic marker elements from iron-bearing glass pigments. The thickness of the yellow layers averages 20 to 50 micrometres. The backscattered electron images often reveal sulphate grains with a disorganized orientation, which proves their natural origin. For most of these yellow minerals, associations of potassium, sodium and aluminium would seem to provide an additional criterion of natural origin.

Our investigations also showed that painters used these minerals in conjunction with other yellow pigments on one and the same object, including the coffin of Henem. Some motifs leave no doubt that the colour intended was yellow. The drapery of Nefertiabet in the eponymous relief from Giza, for instance, is clearly meant to be made from panther's fur (4th dynasty, 2620–2500BC, Louvre, E15591).

Our tests, made on nearly 40 objects from the DAE, confirm that the presence of minerals from the jarosite group resulted from decisions made by Ancient Egyptian craftsmen to paint certain areas yellow. However, those tests do not permit us to exclude entirely the possibility that jarosite may have been produced by the alteration of iron-bearing glass pigments.

Egyptian Green

In addition to natural minerals the Ancient Egyptians made synthetic pigments. The best known of these pigments is Egyptian blue, similar in structure to the Han blue found on the soldiers of the terracotta army (Wiedemann, 1998). With the exception of cobalt blue – another synthetic product, discovered on some painted ceramics from the 18th dynasty (Noll, 1981) – Egyptian blue was used for all blue decoration. The first such pigment is thought to have been made in Egypt itself, where it is found from the 4th dynasty through to the Roman period. It was in use throughout the Mediterranean area until the 7th century AD. Thereafter, knowledge of the recipe seems to have been lost. No Egyptian sources describe the process, but Latin recipes are recorded by Vitruvius, Pliny the Elder and Theophrastus. Following the discovery of Egyptian blue in the wall paintings at Pompeii, the first attempts to investigate Egyptian blue recipes were made in the 19th century.

The Egyptians also made a light green synthetic pigment, less well known than Egyptian blue and less frequently analysed (colour plate VII, fig. 4). This pigment, used as a substitute for turquoise colour and identified in the second half of the 20th century, has the same constituents as Egyptian blue – silicon, calcium and copper – and has been given an analogous name: Egyptian green. No recipe has been found or suggested, not even in Antiquity.

The first hypothesis offered to explain the origins of Egyptian green was that a chemical process used to make Egyptian blue failed, producing instead a green colour owing to the unexpec-

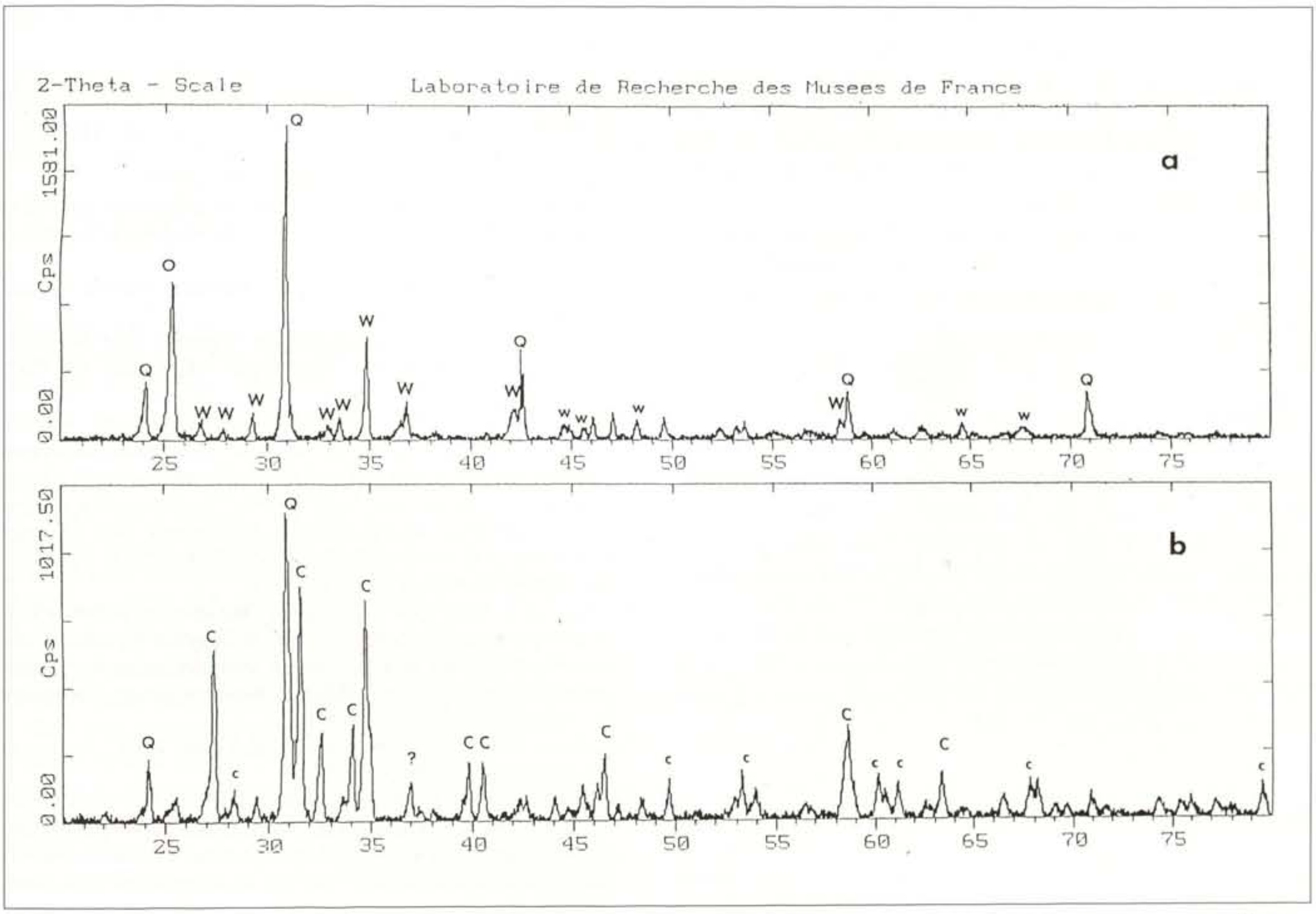

Fig. 2. X-ray diffraction of samples of Egyptian green (a) and Egyptian blue (b). W = parawollastonite, C = cuprorivaite, Q = quartz, T = tridymite. © LRMF, S. Pagès-Camagna.

图 2. 埃及绿(a)和埃及蓝(b)试样的 X 射线衍射。 W = 硅酸钙, C = 硅酸铜钙, Q = 石英, T = 鳞石英。© LRMF, S. 帕热斯-卡玛纳。

ted presence of iron in the raw materials, to mixing the ingredients in incorrect proportions or to the firing conditions. Egyptian green has also been seen as an intermediary product obtained during the making of Egyptian blue and as the result of alterations in Egyptian blue itself (Schiegl et al., 1989). The latter theory has not withstood analysis, which showed that the alteration products were copper chloride or copper carbonate, neither of which occurs in Egyptian green. In fact, there is no evidence that Egyptian green resulted from a physical transformation of Egyptian blue. Moreover, the presence of both pigments on one and the same object but in different patterns indicates that both were used deliberately for distinct iconographical purposes.

Despite this evidence, Egyptian green is still generally held to be a derivative of Egyptian blue. Indeed, the two copper silicate pigments are frequently confused with one another and with the items of faience and glass named after their colour. It was thus essential to eliminate all misunderstandings about these various copper-coloured materials.

Analysis of ancient pigments from the DAE collection of samples, and our own specially made pigments, enabled us to define the physico-chemical properties and their relation to each another. In order to understand better how they were produced, experimental recipes were prepared in the LRMF consisting of a mixture of calcium carbonate, copper oxide, pure silicated sand and sodium carbonate, heated together (Pagès-Camagna, 1999). The powders were ground and mixed together with a little water. Structural analyses of green and blue archaeological samples and of our experimental samples revealed the great complexity of the materials after sintering. In fact, they appear to be composites, the result of a mixture of amorphous and crystalline phases:

- Egyptian blue is characterised by the presence of cuprorivaite ($CaCuSi_4O_{10}$), a blue tabular crystal, firing residues such as silica (quartz and/or tridymite) and an amorphous silicate phase. The blue sample absorption spectrum shows two thin bands at 12800 and 16200 cm^{-1} and a shoulder at 18800 cm^{-1}. The colour of Egyptian blue derives from the presence of Cu^{2+} in a square-plane environment in the crystalline cuprorivaite. It results from a mixture of compounds containing copper, calcium, silica and 1% flux around the cuprorivaite stoichiometry, sintered in an oxidizing atmosphere at a temperature of 850–1100°C.
- Heating different amounts of the same compounds – more calcium and flux, less copper – at 950–1150°C under the same atmospheric conditions produces Egyptian green. It contains a copper-bearing parawollastonite ($CaSiO_3$) with 2% copper, residual silica (quartz and/or tridymite or cristobalite) and firing residues, embedded in a silicated amorphous phase. At 950°C and with up to 7% flux, tridymite replaces quartz. Cristobalite appears at higher levels. Tridymite and cristobalite never exist together. The amorphous phase induces a green absorption spectrum completely different from the blue one. The green spectrum has a unique broad band that reaches its maximum width at approximately 12000 cm^{-1}. This is consistent with the absorption spectrum of Cu^{2+} in an octahedral environment in an amorphous phase (fig. 1).

The firing residues of both pigments included metallic elements, among them tin and lead, indicating that metallurgists and pigment-makers worked together. It is also notable that, with Egyptian green, X-ray diffraction, TEM and Raman microscopy revealed no visible deformation of the crystalline structure owing to the presence of copper in the parawollastonite (fig. 2), unlike with iron-bearing wollastonites.

Our research thus shows that, although Egyptian blue and Egyptian green are provided from the same components and are produced in very similar conditions, each is made by its own distinct process.

Summary

The Research Laboratory of the Museums of France examined polychrome objects in the Department of Egyptian Antiquities at the Louvre using such techniques as optical microscopy, scanning electron microscopy coupled with an X-ray analysis system (SEM-EDXS), Raman microscopy and X-ray diffraction. This article presents new findings with regard to yellow and to the green synthetic pigment known as Egyptian green. They show that new data is still obtainable and that Lucas's standard work on the subject is in need of revision.

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科利纳 帕热斯-卡玛纳

埃及的彩绘：法老调色板上的颜料

摘要

绘画材料在古代埃及艺术中得到了广泛的使用，大型的纪念性作品和博物馆收藏的小艺术品上都可看到它们的痕迹。色彩本身所起的作用很复杂：它模仿自然，但也用于突出具有象征意味的所绘对象的特殊含义。

法老调色板上的颜料大多取自于大自然中的矿石，这些矿石遍布古代埃及地区(科利纳等， 1996 年)。

绘画材料方面的文献十分丰富，卢卡斯的《古代埃及材料》(卢卡斯等， 1962 年)是我们大多数人使用的参考书。不过由于对彩绘制品作不断的系统研究，我们始终能获得新资料。法国博物馆的研究实验室(LRMF)对一些施彩的大型纪念性作品和人工制品(木棺、石刻浮雕和雕像)进行了研究，这些实物保存在卢浮宫古埃及艺术部(DAE)。

这些研究实验系借助于一系列分析手段完成的，其中包括光学显微镜、连接 X 光分析系统的扫描电镜(SEM-EDXS)、拉曼显微镜和 X 光衍射。这些研究的目的在于确定单色的不同化学成分，弄清一些颜料的生产过程。

这里主要介绍的是对黄色和绿色合成颜料即埃及绿的新的认识。

除传统的黄色材料如黄金、氧化铁和雌黄之外，我们揭示出一组材料，这些材料作为颜料鲜为人知：即混有无水碱式硫酸铁的黄钾铁矾(科利纳， 1988 年)。这些矿物资是在不同的石质制品和一些木棺上发现的，时间上均沿着法老的年代顺序(公元前 2700-2200)。

用这些颜料所绘的装饰表现为黄色层，看来似覆有晶状物，与其说是赭石和氧化铁色，毋宁说是用的柠檬色。我们的研究表明，它们的出现不是含铁玻璃颜料的变化，而是使用了自然的地下矿石，是出于它们不同的色彩才用的。

除了自然的矿石之外，古代埃及还合成了新材料作为颜料：它们中最著名的乃是埃及蓝，整个古代地中海流域的古埃及蓝。这种颜料的特色是它含有硅酸铜钙($CaCuSi_4O_{14}$)。另一方面，还使用了一种过去所知和分析甚少的绿色合成颜料。它经常与埃及蓝弄错。埃及绿通常被看作自然降解或不成功的蓝。我们的研究显示了埃及绿有它自己的生产过程：加热与埃及蓝相同的化合物，只不过比例不同，在氧化的环境下加热至几乎相同的温度范围。与埃及蓝相似，这是一种被合成的复杂产品，是变形阶段和结晶化与混合了 2 %黄铜的 b-硅灰石的混合物。后一种材料代表了埃及绿的特色(帕热斯-卡马那， 1999 年)。

这项研究工作揭示了埃及艺术家的调色板，为我们了解颜色的意义和艺术工艺史提供了新的认识。

(英译中：陈钢林)

Detlef Knipping

Le Jupiter olympien and the Rediscovery of Polychromy in Antique Sculpture: Quatremère de Quincy between Empirical Research and Aesthetic Ideals

In an article published in 1827 in the *New Monthly Magazine* Stendhal, later to achieve fame with his novel *Le Rouge et le noir,* reported on a meeting of the Académie des Inscriptions et Belles Lettres. At one point he remarks that 'le grand M. Quatremère de Quincy fit son apparition. C'est le plus ennuyeux de tous les membres de l'Institut.'[1] This low opinion of the archaeologist and art theorist no doubt resulted from Quatremère de Quincy's championing of the Classicists in their often heated aesthetic dispute with the Romantics, a cause to which he was able to lend powerful support as an important official of the Académie des Beaux-Arts. Pace Stendhal, Quatremère is among the most interesting and original archaeologists of his time, not least by reason of his pioneering research of the polychromy of Antique sculpture, in particular that of Ancient Greece.

Born into a respected merchant family in Paris in 1755, Quatremère studied sculpture in Guillaume Coustou's Paris studio, but broke off his training when the death of his mother in 1776 left him in the fortunate position of receiving a small pension.[2] This enabled Quatremère to visit Rome to study the sculpture of Antiquity (colour plate VII, fig. 1).[3] He did not return to France until 1785. The following year a tract he had written on the influence of Egyptian art on that of Ancient Greece won him the *Prix de Caylus* and, during the first years of the Revolution, he was appointed to a number of influential political posts due to his energetic support in the battle for artists' rights. In 1794, however, he was denounced and arrested, yet, after being created a member of the Académie des Inscriptions et Belles Lettres in 1804, he re-entered the public arena as a loyal follower of the monarchy during Napoleon's Hundred Days rule in 1814–15. Inundated with offices and honours, Quatremère became Royal Censor, a member of the Legion of Honour, Inspector of Public Arts and Monuments, a member of the Conseil Honoraire des Musées près de la Maison du Roi, editor of the *Journal des Savants*, Professor of Archaeology at the Bibliothèque du Roi and, for the second time, Deputy for the Département of Paris. His most important post, however, was that of Permanent Secretary of the Académie des Beaux-Arts in Paris, a position he held without interruption from 1816 to 1839 (fig. 1). This key office made Quatremère the most influential and the most hated cultural personality in France, for it enabled him, a pugnacious archaeologist and Classicist, to control artistic activity in the country for over two decades.

Quatremère's significance in the present context is as the author of *Le Jupiter olympien, ou L'Art de la sculpture antique considéré sous un nouveau point de vue* (The Olympic Jupiter, or The Art of Antique Sculpture Considered from a New Point of View), which he published in 1815 and dedicated to Napoleon as the Emperor's 'very humble and loyal subject'.[4] This volume, its title concealing almost as much as it reveals, contains nothing less than the first history of polychromy in Antique sculpture, with the emphasis, natural at the time, on Greece. Discussions of colour in Antiquity rarely fail to mention *Le Jupiter olympien*, so it comes as something of a surprise to discover that

Fig. 1. Julien Léopold Boilly, *A. Ch. Quatremère de Quincy,* 1820; lithograph; Bibliothèque Nationale, Paris.

图 1. 布瓦伊：卡特勒梅尔 · 德 · 坎西， 1820 年，石版，巴黎国家图书馆。

its methodology and place in the historiography of the subject have never been studied in detail.

In *Les Mots et les choses: Une Archéologie des sciences humaines* (*The Order of Things: An Archaeology of Human Sciences*) the historian and philosopher Michel Foucault used disciplines as various as biology, linguistics and economics to draw attention to a rupture in the intellectual life of the eighteenth century. Caused by a lack of confidence in the possibilities of pure knowledge and the feasibility of depicting the world in linguistic terms, this rupture gave rise to two different movements – positivism, a continuation of eighteenth-century empiricism in a more radical form, and idealism, an attempt to revive metaphysical interpretations of the world.[5] Quatremère's position between these two poles is ambiguous, the result of his own role as both an archaeologist and a theorist.

His history of coloured Antique sculpture, the product of over thirty years' work, represented an attempt to enrich Classical archaeology by an entirely new topic of study, which, in turn, would revolutionize the discipline as a whole. It thus formed part of a wave of new sciences and specialist subjects that began in the second half of the eighteenth century and continued into the first decades of the nineteenth.[6] Archaeology itself had been given an impressive foundation by Johann Joachim Winckelmann's *Geschichte der Kunst des Altertums* (History of the Art of Antiquity) of 1764, which tried to place the study of Antique art on a scientific footing.[7] Quatremère noted in *Le Jupiter olympien* that, together with the Antique works of art that he himself had seen in Rome and Naples, it was Winckelmann's writings that had awakened his passion for the sculpture of Antiquity[8] and he paid tribute to the German's importance as the founder of modern archaeology: 'Winckelmann donna une grande impulsion à l'étude de l'antiquité...par la seule conception synthétique de son ouvrage'.[9] Quatremère, too, aimed at a 'synthetic conception', a study that united countless individual observations in a single overall picture. If he wished to equal Winckelmann's achievement he would need to modify, even deconstruct, both the latter's findings and the work of Winckelmann's French counterpart, the Comte de Caylus, to whom Quatremère, as a recipient of the prestigious *Prix de Caylus*, indirectly owed his academic career.

The present-day reader will be surprised by the programmatic single-mindedness and confidence with which Quatremère set about re-inventing the discipline of Classical archaeology. To use the terminology of the philosopher of science Thomas S. Kuhn, he sought deliberately to introduce a shift of paradigms, an approach that can be studied in exemplary fashion in his work. Kuhn showed that crises occur again and again in 'normal' science, which is defined by certain paradigms and exhausts itself in the 'determination of significant facts, matching of facts with theory, and articulation of theory'.[10] Inexplicable anomalies lead to uncertainty in a discipline and to the need for new explanatory models. These cannot gain acceptance among specialists, however, until they have been promoted to the extent that new paradigms are created.[11] In Quatremère's day and field the unsettling anomalies were Antique sculptures that showed traces of colouring and that were made of materials of various colours, for they did not accord with the accepted view that sculpture in Antiquity had been monochrome. Propagation and establishment of the new paradigm necessarily entailed the downfall of the proponents of current orthodoxy. In his work of 1815 Quatremère did not hesitate, therefore, to follow his praise of Winckelmann by excusing the German's failings: 'Winckelmann n'avait pu embrasser, ni peut-être soupçonner tous les points de sa circonférence.'[12] Quatremère then delivers the crushing blow: 'le nouvel historiographe de l'art antique [i.e. Winckelmann] n'avait pas pénétré fort avant de la connaissance des divisions que comporta jadis le domaine de la sculpture...il n'avait jété qu'un coup-d'œil incertain, et répandu que de faibles lumières sur ce qui constitua les diverses manières, les différentes sortes de travail des productions de l'art, les diversités de gout, d'effet, de composition, et de génie propres à chaque genre d'ouvrage.'[13]

Quatremère's criticism was not without justification. In *Geschichte des Altertums* Winckelmann mentions Greek clay figures that were painted red and figures that were partly gilded; sculptures made of gold and ivory or constructed from wood for the torso and marble for the head, hands and feet; figures that were clothed and, finally, a statue of Diana found at Herculaneum that had painted hair and garments. Yet he either dated these pieces to the early period of Greek sculpture or simply declared them to be exceptions that proved the monochromatic rule, thus failing to recognize their true significance.[14] For him and his contemporaries, sculptures of white marble were both the rule and the ideal in mature Greek art, for, as Winckelmann argued in his characteristically sensuous vein: 'Da nun die weisse Farbe diejenige ist, welche die mehrsten Lichtstrahlen zurückschickt, folglich sich empfindlicher macht, so wird auch ein schöner Körper desto schöner sein, je weisser er ist.'[15] In *Mémoires de l'Académie des Inscriptions et Belles Lettres* and *Récueil des Antiquités* the Comte de Caylus, who was important to Winckelmann by reason of his comparative approach to Antique art, also mentioned sculptures bearing remains of polychromy or made of different-coloured materials, but he considered these pieces peripheral and, even more strongly than Winckelmann, rejected them as aberrations of Antique taste. Of the statue of the Parthenon Athena, which has survived in literary descriptions only, Caylus writes: 'Cette statue de Minerve présente encore une difficulté, elle était d'or et d'yvoire, et elle avait à ses pieds un serpent et un sphinx de bronze. Quel alliage de couleurs et de matières!'[16]

Behind this rejection of coloured Antique sculpture lay the Neoclassical theory of art, which enjoyed general acceptance at the time. According to this view, a strict division existed between sculpture and painting: the former was defined by form, which, like the 'dessin', the drawing or line in painting, was alone capable of reflecting the genius involved in the act of creation and, above all, the idea of a work of art. Fully conscious of these attitudes, Quatremère presented himself as the bringer of enlightenment who would overturn ideas and scholarship based on prejudice. Confidently, he wrote: 'Je me flatte...à étendre ce nouveau domaine de l'antiquité, et à détruire des préventions dont quelques-unes me paraissent avoir leur source dans le défaut absolu d'observation, et dans l'ignorance même des faits.'[17] As a dispassionate observer, Quatremère found the causes of this ignorance not only in the Neoclassical theory of art, but also in contemporary artistic practice: not only did polychrome Antique sculpture contradict orthodox opinion; sculptors of his own day created works only in white marble and thus set the seal on aesthetic convention. This prevented archaeologists, strongly influenced by artistic theory and practice, from recognizing that Antique sculpture had been coloured: 'Car...la connaissance [de l'art polychrome] n'a manqué jusqu'ici à l'histoire de l'antiquité, que parce que les artistes n'ont jamais dirigés par la pratique de la sculpture moderne, vers la recherche de l'art des assemblages ou les ouvrages à compartiment.'[18] Quatremère here voices the relativist opinion, astonishing for the time, that thinking is determined by experience gained during a particular time.

It was this very knowledge of historical determinants that enabled Quatremère to break through the vicious circle of theory and artistic practice. Exaggerating, one might even claim that it was only the type of historical consciousness developed in the aftermath of the Enlightenment and the French Revolution that permitted the phenomenon of coloured Antique sculpture to be accepted and appreciated.[19] A crucial part of this consciousness consisted in recognizing the difference between one's own times and Antiquity. Quatremère expresses this with exceptional clarity when he says 'le monde ancien...venait se mettre en parallèle avec le monde moderne'[20] or speaks of the 'vide immense, que le temps et la destruction ont laissé entre les anciens et nous'.[21]

Fig. 2. The Acropolis, Athens, with the Parthenon, 447-438/32 BC; view from the north-west.
图 2. 雅典卫城，帕台农神庙，从西北方向看，公元前 447-前 438/32 年。

This historical awareness of difference culminates in Quatremère's much quoted saying (which is often misunderstood as pure empiricism): 'Il faut se persuader que les anciens employèrent les arts tout autrement que les modernes.'[22] Antique art was so different because, Quatremère held, it came to being in a different social context. Hence, art can be understood, and should be judged, only with reference to its time and to the other conditions under which it arose: 'On doit donc...pour bien juger, rapprocher l'espèce de goût qui fut particulier à ces ouvrages, du genre des causes qui les produisirent et des effets qu'on en exigeait. Il ne faut pas isoler les monuments des opinions, des sentiments, des affections avec lesquels ils étaient nés.'[23] These thoughts lead to a statement that would seem to anticipate the tenets of the famous nineteenth-century German historian Leopold von Ranke: 'Il faut...juger seulement en elles-mêmes, des choses.'[24]

This remarkably dispassionate, historical view of Antiquity had its roots in France in the 'querelle des anciens et modernes' (dispute between the Ancients and the Moderns) sparked off during a session of the Académie Française on 27 January 1687 by a poem of Charles Perrault's in which, contending that the age of Louis XIV equalled that of Emperor Augustus of Rome, he wrote: '[Les anciens] sont grands, il est vrai, mais hommes comme nous.'[25] In its early eighteenth-century continuation as a quarrel between Homer's admirers and detractors, this dispute finally led to the 'historicization' of both Antique and contemporary literature and to a 'relativization' of both Antique and modern models.[26] These attitudes inform the second part of Winckelmann's *Geschichte der Kunst des Altertums*, in which the history of art is connected with historical and political events to produce a survey of the familiar growth–flowering–decay type,[27] a cyclical biological model to which Quatremère also remained true. Quatremère could scarcely have adopted such a detached view of history, however, had he not experienced at first hand, as a participant in the French Revolution, the speed with which the world can adapt to altered political and social circumstances.

Returning to the subject of polychromy, we note that three inexplicable anomalies gave rise to Quatremère's revolutionary revision of notions of Antique art: references to coloured sculpture by the Ancient writers Pausanias and Pliny the Elder; reports by travellers of new discoveries in Athens; and the observations that Quatremère himself had made at the excavations of Herculaneum and Pompeii, in various Italian museums, particularly in Rome, and in the Musée Napoléon (now the Louvre) in Paris.[28] It was above all Pausanias' mention of lost chryselephantine cult statues by Phidias that aroused Quatremère's interest, awakening in him a desire to explore the phenomenon of polychrome sculpture. Aware that, in order to achieve success as the brilliant founder of a science, as a 'second Winckelmann', he would need to appear as a discoverer, Quatremère placed himself in the best possible light in *Le Jupiter olympien*: 'En me représentant ces grands ouvrages de l'art, la haute célébrité dont ils jouirent, la rénommé de leurs auteurs, je fus de plus en plus frappé, et du silence des critiques modernes sur une si noble partie de l'art antique.'[29]

Antique mentions of lost cult images were complemented by first reports of remains of colouring found on sculptures from the Parthenon and the 'Theseion' in Athens. Quatremère, who never visited Greece, was in contact with the collector Choiseul-Gouffier, the engineer Fougerot and the French ambassador in Athens, Fauvel, all of whom had assisted in the removal of the Elgin Marbles from the Parthenon in the early years of the century and told Quatremère on several occasions that the sculptures bore traces of colour (figs. 2, 3).[30] Further support for the idea that the sculptural decoration of the Parthenon had originally been coloured was provided in *The Antiquities of Athens* (1787) by the Englishmen James Stuart and Nicholas Revett, who drew attention to the many holes drilled in the sculptures for the attachment of metal reins and various attributes.[31] These, Quatremère felt, confirmed that the traces of colouring were original.[32] From his informants' observations on the polycromy of the Parthenon sculptures he concluded: 'Sans être ce qu'on peut appeller peinte...elle [la sculpture] avait des parties teintées dans différentes manières, qui tantôt la détachaient du fond sur lequel les couleurs étaient appliquées, tantôt indiquaient les plans des figures par les différents tons, soit des draperies, soit de beaucoup d'autres détails.'[33] In Paris Quatremère could acquire for himself possible confirmation that the sculptures had been coloured, for the Musée Napoléon possessed a fragment from the Parthenon frieze. Since the significance of traces of colour was not recognized, they would have been removed during the customary cleaning, yet Quatremère vaguely remembered having seen such traces when the piece was still in the crate in which it had been transported from Athens.[34] Further evidence of Antique polychromy was provided in 1811 and 1812 by the archaeologists Johan David Åkerblad and 'Eduardo' Dodwell, who reported remains of colouring on the 'Theseion' in Athens.[35]

Not relying solely on the polychromy of sculpture from prominent Athenian temples, Quatremère listed all pieces known to him that bore traces of paint, the discoveries made in Herculaneum and Pompeii being particularly welcome in this respect. References to coloured sculpture in the writings of Antiquity completed his material.[36] Quatremère proceeded similarly in the case of polylithic sculpture and of coloured bronze pieces,[37] amassing an impressive amount of evidence in favour of his theory, which reversed previous ideas and judgements by claiming that polychromed sculpture in all its various manifestations, and not sculpture of white marble, was the chief form in Antiquity: 'On observe alors que la sculpture en pierre ne fut pas celle qui donna jadis le ton aux travaux et au goût des statuaires; qu'au contraire elle le reçut elle-même des autres parties de l'art de sculpter; de sorte que la matière de ses propres ouvrages ...

Fig. 3. Poseidon, Apollo and Artemis from the eastern section of the Parthenon frieze, *c*. 440 BC; Athens.

图 3. 雅典，帕台农神庙东面饰带，波塞冬、阿波罗、阿耳忒弥斯，约公元前 440 年。

participa plus qu'on ne pense, du goût de variété, de richesse extérieure et de parure qu'expriment les mots de Sculpture Polychrome.'[38]

Quatremère thought that the key to determining which techniques were used in Antiquity to polychrome marble sculptures was provided by a particular philological interpretation of the well-known passage in which Pliny the Elder reports that the sculptor Praxiteles valued especially highly those of his statues that had been coloured by the painter Nicias: 'Hic est Nicias, de quo dicebat Praxiteles interrogatus quae maxime opera sua probaret in marmoribus: Quibus Nicias manum admovisset. Tantum circumlitioni eius tribuebat.'[39] The painted decoration is here denoted by the term 'circumlitio', which Quatremère's predecessors, including the Comte de Caylus and the sculptor Etienne-Maurice Falconet, had interpreted as signifying varnish. Yet since Nicias painted in encaustic, Quatremère concluded that this must have been the technique employed to colour sculpture.[40] Again, he supports his hypothesis by quoting other passages from Antique writings and by adducing the empirical evidence of traces of paint on Antique sculptures that he himself had examined in Rome and Paris.[41] Quatremère describes the encaustic technique as a way 'de colorer et de teinter les marbres, sans y produire aucune épaisseur'.[42] He adds: 'Ces teintes incorporées par l'encaustique, n'ayant aucune épaisseur, et n'étant qu'une approximation du ton réel des objets, ne détruisaient pas l'opinion d'unité dans la matière, et pouvaient semble n'être que le jeu des nuances d'un marbre que la nature se serait plue à diversifier.'[43] Time and again Quatremère insists that Antique marble sculptures were not painted in the conventional sense but bore only 'teintes légères'.[44] In his opinion the Parthenon and 'Theseion' sculptures were also tinted, in a way comparable to the hues displayed by cameos: 'sans être de la sculpture peinte, [ils] étaient ce que j'appelle de la sculpture polychrome, c'est-à-dire, qu'ils jouaient quelques-unes des apparences de la peinture, sans prétendre en contrefaire les effets'.[45] Quatremère supposed the latter type of painted sculpture to have existed only during the early period of Greek sculpture, which had thus attempted to satisfy the instinctual 'eye of a savage or child' by producing a complete illusion of reality.[46]

We now know that this monolithic view of the colouring of Antique sculpture, which permits works from the mature phases of Greek sculpture to be only lightly tinted rather than painted, is false. The fact that certain especially well preserved examples of polychromed Antique sculpture, such as the statue of Augustus from Prima Porta, were unknown at the time and that suitable methods of scientific investigation were not available no doubt explains this error.[47] Even so, it is surprising that Quatremère – someone who otherwise always bore in mind the problems posed by the age of the sculptures and the loss of their polychromy[48] – never seems to have considered the possibility that what presented itself in his time as a light tinting could originally have been a far stronger colouring. Moreover, it is striking that not once does he describe in detail colour traces that he himself saw, preferring instead to report on their general effect. One suspects that Quatremère's view of the polychromy of Antique sculpture was ultimately guided by notions he entertained as a Classical theorist of art, that the primacy of line and form and the strict separation of painting and sculpture simply did not allow him to conceive of Antique sculpture as 'painted'. He attacked his predecessors as subject to preconceptions because they had largely ignored the colouring of sculpture in Antiquity, but one could equally well accuse Quatremère himself of prejudice: he would seem to be interpreting evidence, even if less completely so than his predecessors, in subjective terms that, governed by specific notions of taste, represent an attempt to bring the results of empirical study into line with a particular theory of art. Hence, the term 'polychromy', coined by Quatremère in 1806 as an alternative to 'painting',[49] originally possessed Classical connotations of which we are no longer conscious.

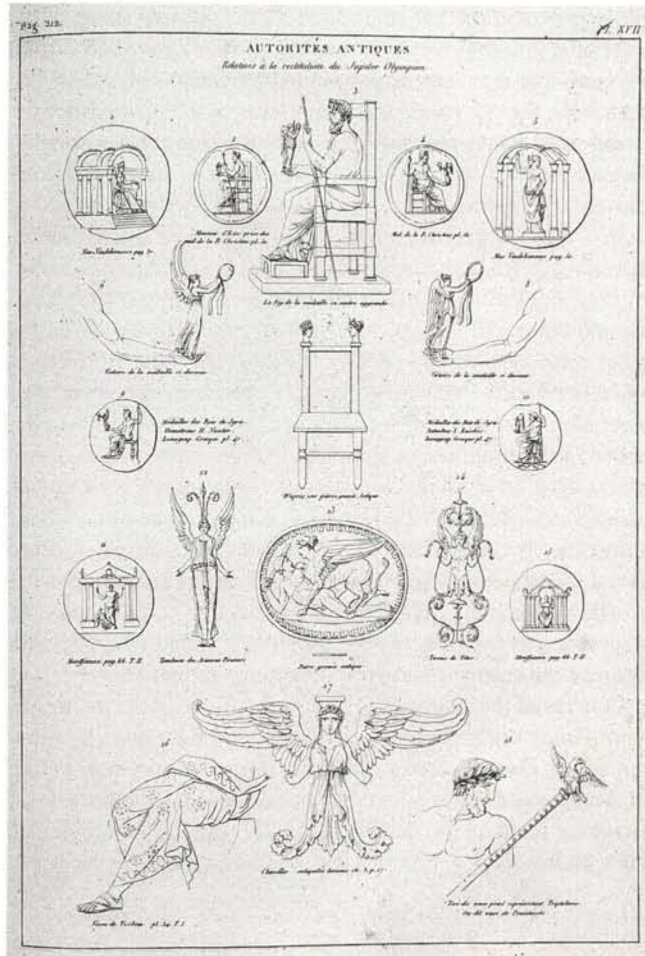


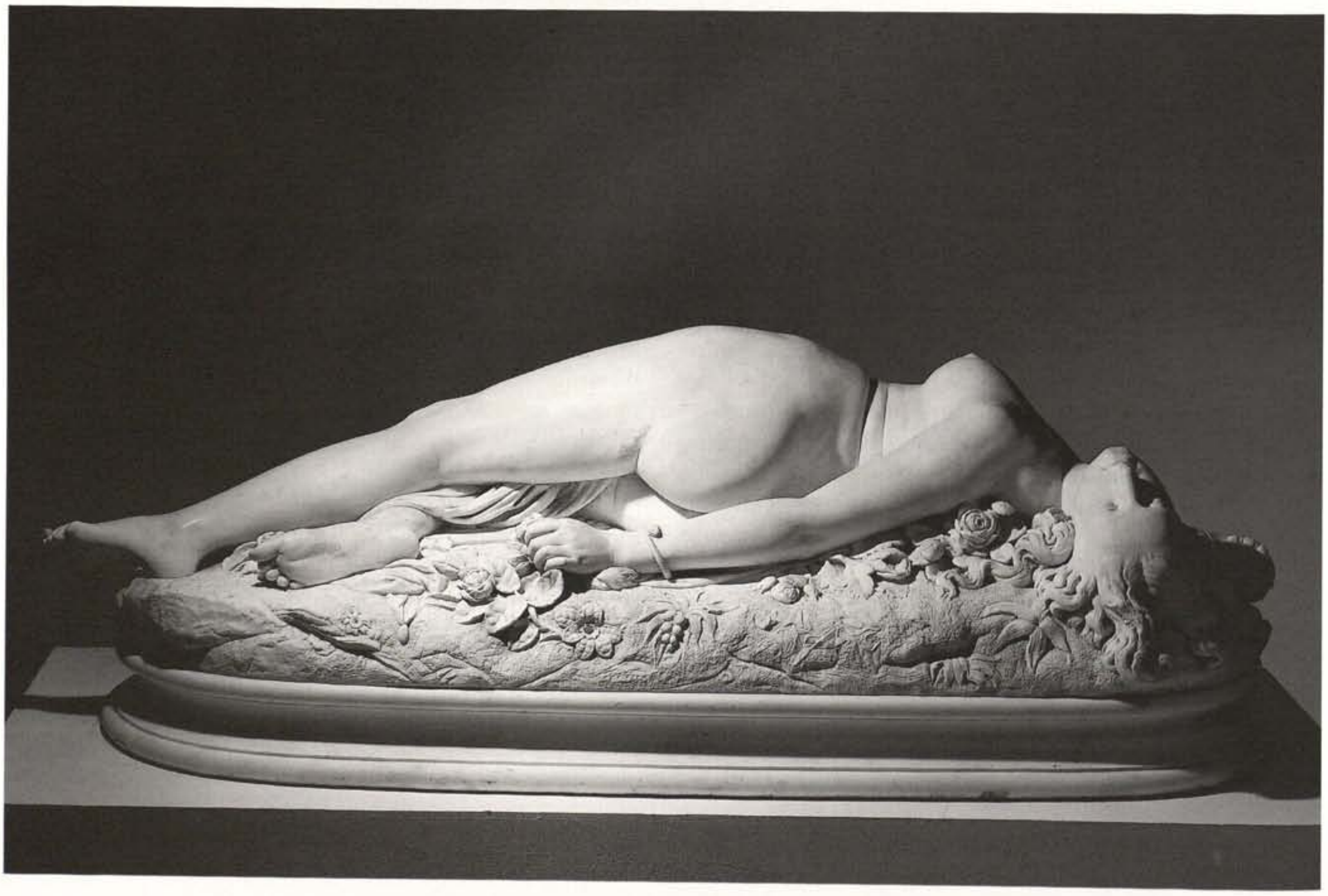
Fig. 4. Items used in reconstructing the 'Olympic Jupiter'; coloured lithograph from A. Ch. Quatremère de Quincy, *Le Jupiter olympien*, Paris, 1815, plate XVII; Bayerische Staatsbibliothek, Munich, Res. Arch. 218m.

图 4. 复原奥林匹斯的朱庇特像所参考的式样图，卡特勒梅尔 · 德 · 坎西:《奥林匹斯的朱庇特像》，巴黎, 1815 年，图版 XVII, 彩色版画，慕尼黑巴伐利亚州国家图书馆， Res. Arch. 218m 。

The culmination of *Le Jupiter olympien*, prepared for throughout the book, is the attempted reconstruction of famous examples of the goldsmith's art from Antiquity, such as the legendary shield of Achilles, described by Homer and believed by Quatremère to have actually existed, and the cult images of gold and ivory from the time of Phidias, all known only from the writings of Antique authors.[50] Quatremère's intention was not purely archaeological: his reconstruction of these works, which he terms 'incomparably the greatest masterpieces of Greek art',[51] was to provide contemporary artists with a hitherto lost source of inspiration and models.[52] He therefore illustrated his text lavishly with hand-coloured lithographs of the pieces he had reconstructed, turning the volume into a precious artefact.[53] Pride of place went to the 'Olympic Jupiter', the colossal statue of the enthroned god that had been created for the Zeus sanctuary at Olympia and that lent its name to Quatremère's study (colour plate VIII, fig. 3). Its reconstruction was based on the brief description by Pausanias and on coins, gems and other, comparable statues (fig. 4).[54] Without his admitting as much, the polychromy – gold reliefs on variously coloured backgrounds and so forth – were largely the product of Quatremère's imagination. Revealingly, the author encourages readers to understand his reconstruction of the statue's colouring by thinking of Raphael's decoration of the Vatican loggias.[55] Quatremère employed the same method in reconstructing the other famous cult images, whether it be the Parthenon Athena or Polyclitus' renowned statue of Hera at Argos (colour plate VIII, fig. 2), both of them described by Pausanias and Tertullian.[56] Such masterpieces of Ancient Greek art form the keystone of Quatremère's book and he uses them to establish that Antique sculpture had always been coloured: 'l'éxecution de ces sortes d'ouvrages ont existé, et se sont soutenus dans tout les siècles, et à toutes les périodes des arts de l'antiquité'.[57] With the notion that in Antiquity coloured sculpture was the rule, not the exception,[58] Quatremère revolutionized the conventional view of Antique sculpture.

Convinced that the idea of beauty itself was reflected in Ancient Greek sculpture and needed only to be imitated by modern artists, Quatremère saw his comprehensive survey of colour in Antique sculpture as a contribution to contemporary art.[59] However tenuous the link between the two, he continued to view archaeology as the servant of modern art or, as he put it: 'nous appellons l'érudition au secours de l'art'.[60] He was naturally aware that, as already noted, coloured sculpture contradicted Classical ideals of art. At the end of *Le Jupiter olympien* he therefore marshalled a wealth of arguments to reconcile archaeological findings with modern artistic doctrines, but his tortuous thought processes and often purely rhetorical language served only to make more apparent that the two were in fact irreconcilable.[61] While accepting the principles of Classical theories of art, Quatremère time and again pleaded for exceptions to be made and for the theories not to be applied all too rigorously. His arguments encompass aesthetic effects, as when he claims that an affinity exists between the colour of gold and of ivory that annuls the chromatic monotony of a sculpture – what he calls, polemically, 'the law of monotony'.[62] He agrees in principle with the opposing view, that external lavishness obscures the idea embodied in a work of art, but feels that the importance of such abstract notions should not be exaggerated. In any case, an iconology of materials exists that can enhance certain of the work's ideas. The beauty of colour is only an addition, but it does not detract from the beauty of the sculpture.[63] Further, to the argument that sculpture is governed by form and not by colour, which in three-dimensional work can only blur the distinction between painting and sculpture and lead to excessive illusionism, Quatremère replies that, although this opinion is basically correct, the Ancients used colour not in the manner of illusionistic painting but simply to tint their sculptures.[64] Here he confirms indirectly the suspicion expressed above that he interpreted empirical findings so as to bring them into har-

Fig. 5. Jean-Baptiste Clésinger, *Woman Bitten by a Snake*, 1847; coloured marble, Musée d'Orsay, Paris.
图 5. 克莱桑热：被蛇咬的女子，上色大理石，巴黎奥赛博物馆。



mony with an existing theory of art. Having set out to legitimize the use of coloured Antique sculpture as a model, Quatremère ends up by cutting the argumentational ground from under his own feet: in the concluding section of his book he points out that the ultimate purpose of colouring sculptures had been to provide convincing evidence of the existence of the gods, that art was practised in the service of religion, that it was therefore a part of history and, as such, could be understood only by applying historical criteria.[65] It seems not to have occurred to him that, in thus allowing relativism to have the last word, he destroyed the very connection with modern art that he had wished to strengthen.

I think it will have become clear that archaeology and the theory of art are here incompatible. In fact, Quatremère's book provides an exemplary demonstration of the epoch-making rupture between empirical study and metaphysical theory that characterizes the post-French Revolution world. Not only could the results of empirical research not be reconciled with the tenets of an idealistic theory of art; they actually called that theory into question, since they had shown that the Classical model differed from conventional views of it. The contradictions become even more glaring if one takes into account Quatremère's theoretical writings. In *Essai sur la nature, le but et les moyens de l'imitation dans les Beaux-Arts* of 1823, for example, the Neoplatonic theorist of art even went so far as to promote the total lack of colour in sculpture, for, in encouraging imitation that consists solely in producing a similarity to the imitated objects, it aspires to a complete illusion, and that goes against the idea of beauty.[66] The rift between Quatremère the archaeologist and Quatremère the theorist[67] has here became quite obvious. Indeed, the findings of archaeology actually undermined his Neoclassical theories of art, developed as a vehement riposte to the Romantics and their notion of the Picturesque.

Quatremère's inconsistency, ultimately the result of the increased historical and empirical awareness that marked the pursuit of knowledge in the second half of the eighteenth century, caused his theories about polychrome sculpture in Antiquity to meet with a mixed response. Staunch supporters existed alongside opponents, among them the German art historian Friedrich Theodor Kugler who, himself a Classicist, claimed that the Ancients painted their sculpture in an even more restrained manner, not including the flesh in their colour schemes.[68]

The limitations and contradictions inherent in Quatremère's approach also become apparent in the discussions of colour in Antique architecture that were sparked off by reports of discoveries made in Sicily. Gripped by enthusiasm for *Le Jupiter olympien*, Jacques-Ignace Hittorff, a pupil of Charles Percier and a colleague of François Belanger, used finds made during excavations in Selinunte and Agrigento to propose that not only sculpture had been completely painted in Antiquity but architecture too,[69] giving visual form to his ideas in an 1851 colour lithograph depicting the Temple of Empedocles at Selinunte (colour plate VIII, fig. 4). This was far too radical for Quatremère. However, instead of taking part himself in the heated debate that ensued throughout Europe, he enlisted the services of Raoul-Rouchette in attacking Hittorff. This was a matter of considerable delicacy because Raoul-Rouchette, a younger colleague who hoped to become Quatremère's successor as Permanent Secretary of the Académie des Beaux-Arts, had already published an article expressing complete agreement with Hittorff's theories.[70] Despite Raoul-Rouchette's intervention, the ghosts that Quatremère had aroused continued to haunt him: the idea

Fig. 6. Edgar Degas, *Little Dancer of Fourteen Years*, 1878-81; bronze, cotton, satin and wood; Musée d'Orsay, Paris.

图 6. 德加：十四岁的舞女，青铜、棉、丝和木，巴黎奥赛博物馆。

that Antique architecture had been entirely coloured gained rapid and widespread acceptance.[71]

Le Jupiter olympien also had an effect on contemporary art, although in 1815 widespread polychroming of sculptures lay many years in the future. A major early exponent of coloured sculpture was Jean-Baptiste Clésinger who, in *Woman Bitten by a Snake* (*Femme piquée par un serpent*) of 1847, used the encaustic method of painting marble described by Quatremère (fig. 5). Artists such as Edgar Degas (fig. 6), Gustav Klimt and Max Klinger were to follow suit in the second half of the nineteenth century.[72] Quatremère's work had caused a general increase in awareness of colour in three-dimensional contexts, leading eventually to research into, and reappraisal of, coloured sculpture in epochs other than Classical Antiquity. As late as 1866, for example, Eugène-Emmanuel Viollet-le-Duc, the great promoter of the Gothic Revival, explained his interest in the polychromy of medieval sculpture by referring to the fact that the Ancient Greeks had coloured their sculpture.[73]

By proving that Antique sculpture had been coloured, Quatremère's *Le Jupiter olympien* revolutionized modern images of Antiquity. I do not think it is claiming too much to say that, ultimately, we owe it to Quatremère that we are discussing with our Chinese colleagues methods of conserving Emperor Quin's army of clay warriors and the history of Antique polychromy. Yet the work of this archaeologist and theorist of art, full of contradictions as it is, should also make us aware of how much we are tied to the times in which we live, of how relative each of our ideas and activities must be. Although all research and restoration work should aim to be free of preconceptions, Quatremère de Quincy reminds us this goal can never be attained completely.

(translated by Michael Foster)

Notes

1 'the great monsieur Quatremère de Quincy put in an appearance. He is the most tedious of all members of the Institute.' STENDHAL, 'Esquisses de la société parisienne, de la politique et de la littérature: Esquisse XV [1827]', in idem, *Paris-Londres: Chroniques*, ed. Renée Dénier, Paris, 1997, p. 807. See ibid., p. 767, for a scathingly ironic description of a lecture given by Quatremère during a meeting of the Académie des Beaux-Arts in 1826.

2 For Quatremère's life, see esp. RENÉ SCHNEIDER, *Quatremère de Quincy et son intervention dans les arts (1788-1830)*, Paris, 1910, and the brief account in SYLVIA LAVIN, *Quatremère de Quincy and the Invention of a Modern Language of Architecture*, Cambridge and London, 1992, pp. 2-4.

3 See HANS KÖRNER and FRIEDRICH PIEL, '"A mon ami A. Quatremère de Quincy": Ein unbekanntes Werk Jacques-Louis Davids aus dem Jahre 1779', *Pantheon*, vol. 43, 1985, pp. 89-96.

4 ANTOINE CHRYSOSTOME QUATREMÈRE DE QUINCY, *Le Jupiter olympien, ou L'Art de la sculpture antique considéré sous un nouveau point de vue*, Paris, 1815, dedication.

5 See MICHEL FOUCAULT, *Les Mots et les choses: Une Archéologie des sciences humaines*, Paris, 1966, pp. 256-8.

6 See WOLF LEPENIES, 'Der andere Fanatiker: Historisierung und Verwissenschaftlichung der Kunstauffassung bei Johann Joachim Winckelmann', in *Ideal und Wirklichkeit der bildenden Kunst im späten 18. Jahrhundert*, ed. Herbert Beck, Peter C. Bol and Eva Maek-Gérard, Berlin, 1984, pp. 22-4.

7 See JOHANN JOACHIM WINCKELMANN, *Geschichte der Kunst des Altertums* [1764], Darmstadt, 1993, p. 9: 'meine Absicht ist, einen Versuch eines Lehrgebäudes zu liefern.'

8 See QUATREMÈRE DE QUINCY (note 4), p. I. For Winckelmann's influence in France, see EDOUARD POMMIER, 'Winckelmann et la vision de l'Antiquité classique dans la France des Lumières et de la Révolution', *Revue de l'art*, no. 83, 1989, pp. 9-11.

9 'Winckelmann lent a great impulse to the study of Antiquity...by the single synthetic conception of his work.' QUATREMÈRE DE QUINCY (note 4), p. VIII.

10 THOMAS S. KUHN, 'The Structure of Scientific Revolutions', in *International Encyclopedia of Unified Science*, vol. 2/2, Chicago, London and Toronto, 1962, p. 33.

11 See ibid., esp. pp. 143-58. For a critical discussion of Kuhn's theories, see the essays by ISRAEL SCHEFFLER, WOLFGANG STEGMÜLLER AND LORENZ KRÜGER in *Theorien der Wissenschaftsgeschichte: Beiträge zur diachronen Wissenschaftstheorie*, ed. Werner Diederich, Frankfurt am Main, 1974, pp. 137-246.

12 'Winckelmann could not encompass, perhaps not even sense, all the points surrounding his field of study.' QUATREMÈRE DE QUINCY (note 4), p. VIII.

13 'The new historiographer of Antique art [i.e. Winckelmann] did not progress far in knowledge of the genres that make up sculpture...he cast only an uncertain eye and threw only a weak light on that which determines the various manners, the different techniques used to produce the works of art, the diversity of taste, of effect, of composition and of the genius of each genre.' Ibid.

14 See WINCKELMANN (note 7), pp. 30-2.

15 'Since white is the colour that sends back the greatest number of light-rays, and is thus most sensitive, a beautiful body will be more beautiful the whiter it is.' Ibid., p. 148.

16 'This statue presents another difficulty: it was of gold and ivory and it had at its feet a snake and sphinx of bronze. What a mixture of colours and materials!' ANNE-CLAUDE PHILIPPE DE CAYLUS, *De la Sculpture et des sculpteurs anciens, selon Pline*, Mémoires de l'Académie des Inscriptions et Belles Lettres, vol. 25, Paris, 1759, pp. 318-19. For the historical importance of the Comte de Caylus and his methods, see CARL BERNHARD STARK, 'Systematik und Geschichte der Archäologie der Kunst', in idem, ed., *Handbuch der Archäologie der Kunst*, vol. 1, Leipzig, 1880, pp. 147-9; ALEX POTTS, *Flesh and the Ideal: Winckelmann and the Origins of Art History*, New Haven and London, 1994, pp. 76-8; and DETLEF RÖSSLER, 'Archäologie in der ersten Hälfte des 18. Jahrhunderts', in *Von der Schönheit weissen Marmors: Zum 200. Todestag Bartolomeo Cavaceppis*, ed. Thomas Weiss, Dessau, 1999, pp. 6-7.

17 'I flatter myself...that I have extended this new domain of Antiquity and destroyed prejudices, some of which seem to me to have their source in a complete lack of observation and in ignorance even of facts.' QUATREMÈRE DE QUINCY (note 4), p. XX.

18 'For...knowledge [of polychrome art] has hitherto been lacking in histories of Antiquity because artists have never been guided by the practice of modern sculpture to search for an art of assemblage or for works made of various materials.' Ibid., p. XIII.

19 In spite of the statement of his just quoted, Quatremère could have found support for his study of Antique polychromy in the sculpture of his own day, which was gradually beginning to introduce colour. One thinks, for instance, of Antoine-Denis Chaudet's personification of Peace, made from variously coloured metals in commemoration of the Treaty of Amiens and displayed in 1806 in the Salon de la Paix in the Tuileries Palace. For detailed discussion of this and other examples, see SCHNEIDER (note 2), pp. 126-8; DAVID VAN ZANTEN, *The Architectural Polychromy of the 1830's*, New York and London, 1977, pp. 24-7; and ANDREAS BLÜHM, 'In Living Colour: A Short History of Colour in Sculpture in the 19th Century', in idem, ed., *The Colour of Sculpture (1840-1910)*, exh. cat., Amsterdam, Van Gogh Museum, and Leeds, Henry Moore Institute (Zwolle, 1996), p. 16.

20 'the ancient world is starting to form a parallel to the modern world'. Quatremère de Quincy (note 4), p. II.

21 'the immense void that time and destruction have left between the Ancients and us'. Ibid., p. III.

22 'One must persuade oneself that the Ancients used the arts quite differently from the Moderns.' Ibid., p. 32.

23 'One must...in order to judge well, come close to the type of taste peculiar to these works, to the causes that produced them and to the effects demanded of them. One ought not to isolate the monuments from the opinions, feelings and affections that gave birth to them.' Ibid., p. XXV.

24 'One must...judge things solely on their own terms.' Ibid.

25 '[The Ancients] are great, it is true, but human beings like us.' Quoted in HANS ROBERT JAUSS, 'Ästhetische Normen und geschichtliche Reflexion in der "Querelle des Anciens et des Modernes"', in Charles Perrault, *Parallèle des Anciens et des Modernes en ce qui regarde les arts et les sciences*, Theorie und Geschichte der Literatur und der Schönen Künste, vol. 2, ed. Max Imdahl, Wolfgang Iser, Hans Robert Jauss, Wolfgang Preisendanz and Jurij Striedter, Munich, 1964, p. 10.

26 See ibid., pp. 8-10.
27 See WINCKELMANN (note 7), pp. 295-7.
28 See QUATREMÈRE DE QUINCY (note 4), esp. pp. 34-6, 40-2 and 54-5.
29 'Imagining these great works of art, the fame they enjoyed, the celebrity of their creators, I became more and more astonished, also by the silence of modern critics about such a noble area of Antique art.' Ibid., p. X.
30 See ibid., p. 31. The latest, highly informative history of the Elgin Marbles and of Lord Elgin himself is WILLIAM ST CLAIR, *Lord Elgin and the Marbles*, Oxford and New York, 1998. For the Pantheon and its sculptures, see KARL SCHEFOLD, *Die Griechen und ihre Nachbarn*, Propyläen Kunstgeschichte, vol. 1, repr. Berlin, 1984, pp. 180-2 and 252-4.
31 See JAMES STUART and NICHOLAS REVETT, *The Antiquities of Athens*, vol. 2, London, 1787, p. 14, commentary on plate XXX.
32 See QUATREMÈRE DE QUINCY (note 4), p. 31.
33 'Without being what one might call painted...[the sculpture] had parts tinted in various ways, sometimes placing it in contrast to the background to which the colours were applied, sometimes indicating the plane in which the figures were situated by various hues, whether on the drapery or on any of the many other details.' QUATREMÈRE DE QUINCY (note 4), p. 31.
34 See ibid., p. 31.
35 See JOHANN D. ÅKERBLAD, *Sopra due laminette di bronzo, trovate ne' contorni di Atene: Dissertazione d'un membro ordinario dell'Academia libera d'Archeologia di Roma*, Rome, 1811, pp. 9-10, and EDUARDO DODWELL, *Alcuni bassirelievi della Grecia*, Rome, 1812, p. VI. Quatremère de Quincy (note 4), p. 32, cites only Åkerblad's work.
36 See QUATREMÈRE DE QUINCY (note 4), pp. 33-5.
37 See ibid., pp. 37-9.
38 'One sees, therefore, that it was not stone sculpture that once set the tone for the works and the taste of sculptors, but that, on the contrary, sculptors in stone took from other areas of the art of sculpture, so that the materials of their own work...played a part, larger than hitherto supposed, in a taste that was governed by variety, by external richness and by decoration, and that is denoted by the words Polychrome Sculpture.' Ibid., p. 44.
39 'This is the Nikias of whom Praxiteles, asked which of his marble works he liked best, replied: those in which Nikias had a hand. That is how he valued his colouring.' PLINY THE YOUNGER, *Historia Naturalis*, XXXV, ed. Roderich König, Darmstadt 1997, p. 133.
40 See QUATREMÈRE DE QUINCY (note 4), pp. 45-6.
41 See ibid., pp. 49 and 52-4.
42 'of colouring and tinting marble sculptures without producing any thickness'. Ibid., p. 49.
43 'The tints provided by encaustic had no thickness whatsoever, were no more than an approximation to the actual colour of the objects, did not destroy the impression of the material's unity and could appear simply as a play of nuances in a piece of marble that Nature had been pleased to diversify.' Ibid., p. 50.
44 For mention of these 'light tints', see ibid., pp. 29, 31, 33, 36, 53 et passim.
45 'without being painted sculpture, [they] were what I call polychrome sculpture, that is to say, they enjoyed some of the features of painting without pretending to imitate its effects'. Ibid., p. 32.
46 'l'oeil d'un sauvage ou d'un enfant.' Ibid., p. 3.
47 The fundamental study of Antique polychromy remains PATRIK REUTERSWÄRD's *Studien zur Polychromie der Plastik: Griechenland und Rom – Untersuchungen über die Farbwirkung der Marmor- und Bronzeskulpturen*, Stockholm, 1960.
48 See QUATREMÈRE DE QUINCY (note 4), esp. p. 29.
49 See ROBIN D. MIDDLETON, 'Hittorff's Polychrome Campaign', in idem, ed., *The Beaux-Arts and Nineteenth-century French Architecture*, London, 1982, p. 176, and VAN ZANTEN (note 19), pp. 83-4, n. 33.
50 See QUATREMÈRE DE QUINCY (note 4), pp. 64-387.
51 'sans aucune comparaison les chefs-d'oeuvre de l'art des Grecs'. Ibid., p. XVIII.
52 Ibid., pp. XVI-XVIII.
53 For the lithographs, see MICHAEL GREENHALGH, 'Quatremère de Quincy as a Popular Archaeologist', *Gazette des Beaux-Arts*, vol. 71, 1968, pp. 249-51.
54 See QUATREMÈRE DE QUINCY (note 4)., pp. 268-70.
55 See ibid., p. 279.
56 See ibid., pp. 219-21 and 326-8.
57 'works executed in this way existed, and they existed throughout all the centuries and periods of the art of Antiquity'. Ibid., p. XIX.
58 See also ibid., pp. XX-XXI.
59 See ibid., pp. IV, XXIII and 29.
60 'we appeal to learning to help art'. Ibid., p. IV.
61 See ibid., pp. 388-90.
62 'la loi de la monotonie'. Ibid., p. 390.
63 See ibid., pp. 390-1.
64 See ibid., p. 391.
65 See ibid., pp. XXIII-XXV and 392.
66 See ANTOINE CHRYSOSTOME QUATREMÈRE DE QUINCY, *Essai sur la nature, le but et les moyens de l'imitation dans les Beaux-Arts*, Paris, 1823, pp. 39-41, and, for a general discussion, RENÉ SCHNEIDER, *L'Esthétique classique chez Quatremère de Quincy (1805-1823)*, Paris, 1910, pp. 33-5.
67 See SCHNEIDER (note 66), esp. pp. 29-31 and 75-7, and KARINA TÜRR, *Farbe und Naturalismus in der Skulptur des 19. und 20. Jahrhunderts*, Mainz, 1994, pp. 13-15.
68 See REUTERSWÄRD (note 47), pp. 28-9.
69 See MIDDLETON (note 49), pp. 175-7.
70 See JACQUES-IGNACE HITTORFF, *Restitution du Temple d'Empédocle à Sélinonte, ou L'Architecture polychrôme chez les grecs*, Paris, 1851, pp. 10-11, and MIDDLETON (note 49), pp. 185-6.
71 See MIDDLETON (note 49), pp. 185-7; VAN ZANTEN (note 19), pp. 119-21; idem, 'Architectural Polychromy: Life in Architecture', in Middleton (note 49), pp. 197-9; HANNO-WALTER KRUFT, *Geschichte der Architekturtheorie: Von der Antike bis zur Gegenwart*, Munich, 1985, pp. 316-18; and WOLFGANG DORST, 'Colour, Sculpture, Mimesis: A 19th-century Debate', in Blühm (note 19), pp. 67-9.
72 See SCHNEIDER (note 2), pp. 121-3, and TOM FLYNN, 'Amending the Myth of Phidias: Quatremère de Quincy and the Nineteenth-century Revival of Chryselephantine Sculpture', *Apollo*, vol. 145, no. 419, 1997, pp. 6-10.
73 See EUGÈNE VIOLLET-LE-DUC, *Dictionnaire raisonné de l'architecture française*, vol. 8, Paris, 1866, p. 275: 'Le moyen âge a très-fréquemment coloré la statuaire et l'ornementation sculptée. C'est encore un point de rapport entre ces arts et ceux de l'antiquité grecque.'

克尼平

奥林匹亚的朱庇特像及古代雕塑彩绘的再发现：在经验研究和审美理想之间徘徊的卡特勒梅尔·德坎西

后来通过其小说《红与黑》闻名的司汤达，在 1827 年给《新月刊》写的一篇文章中，对铭文和纯文学学院的一次会议做了报导，他以贬低的口吻评论考古学家和艺术史家卡特勒梅尔·德坎西："...... 伟大的卡特勒梅尔先生露面了。此人系整个学院所有院士中最无聊者。" 这轻蔑之词掩盖着一场浪漫派和古典派之间进行的、有时颇为激烈的有关艺术理论之争，卡特勒梅尔在官方美术学院任职，他在这场争论中自然固守古典派的立场。而在考古学领域，卡特勒梅尔无疑属于 – 这里我们不禁要反对司汤达的意见 – 最有意思而又最具创新精神的人物，他的意义首先在于他是研究古代雕塑彩绘的先驱。

但是我们下面要关注的乃是他的著作《奥林匹亚的朱庇特像，以新眼光看古代雕塑艺术》，此书于 1815 年出版，作者将它作为"非常谦恭和真诚的主题"献给了皇帝陛下拿破仑。在这含糊其词的书名之后所隐藏的正是第一部古代雕塑彩绘史。按照时人的观点，此书的重点自然放在古希腊的雕塑。探讨古代彩绘的论文，几乎无不引用此书，尽管如此，事实还是令人惊讶，因为迄今为止，还无人特别是从方法论和在科学价值和意义上对这本著作作出评价。

历史学家米歇尔·福柯在他那给人印象至深的《词与物。人文科学考古》一书中，依据对不同领域如生物学、语言学和经济学的研究，展示了 18 世纪中思想的变革，这一变革后来走向怀疑认识和用语言表现世界是否可能，并激发了两个朝彼此相反的方向发展的思想运动：即作为 18 世纪经验主义之继续但更为激进的实证主义和作为复兴形而上学地解释世界之尝试的唯心主义。这当中，卡特勒梅尔·德坎西采取的是奇特的模棱两可的立场，其原因在于他扮演考古学家和艺术理论家的双重角色时所发生的冲突。

卡特勒梅尔·德坎西完成他的多彩雕塑史耗费了 30 多年的精力，他以此试图对考古学进行革命并想为它增加一门新的、要整个改变这个学科的专科。他身处新建科学和专科的时代浪潮之中，这股浪潮从 18 世纪下半叶一直持续到 19 世纪上半叶。在考古学领域，约翰·约阿希姆·温克尔曼实现了这一目标，他 1764 年出版的《古代艺术史》给读者留下深刻的印象，温克尔曼借此要"对学科的整个体系进行尝试。" 卡特勒梅尔也了解温克尔曼作为现代考古学奠基人的革命意义。在他那论奥林匹亚的朱庇特像的专著前言里，他承认除了那些他在罗马和那波利所见的古代艺术品之外，正是温克尔曼的著作唤起了他对古代雕塑的激情。他在评价他对考古学的意义时说："通过他著作的独一无二的综合性构思 ...... 温克尔曼对研究古代起了巨大的推动作用。" 卡特勒梅尔也在试图进行综合性构思，即采取一种总括各项观察结果并对其彼此联系进行综述的描述方式。他若要作出与温克尔曼同样的建树，他就得对温克尔曼做相对的评论，在某种程度上对他还要象对法国考古学创始人物凯吕斯伯爵那样做解构处理，卡特勒梅尔在学术上取得的成功甚至还要间接地感谢后者，他曾获著名的凯吕斯奖。卡特勒梅尔尝试新建考古学，目标及其明确，意识及其坚定，今日的读者对此会感到诧异。他想有目的地引入 – 借用库恩的术语 – 范式的转换，他的著作为了解他的这一思想恰恰提供了一个范例。科学理论家托马斯·库恩指出，"正常科学"系由某种范式确定，它不停地"确定重要的事实、事实和理论的联系以及理论的描述"，在"正常科学"中不时会出现不确定和危机的时刻。不能解释的异常情况会给这个专业带来不安，这种情况下便需要寻求新的解释模式。这些模式只有通过相应的宣传，然后建立起新的范式，才有可能在一个研究群体中得到贯彻。在卡特勒梅尔的时代，令人不安的异常情况是古代雕塑上的彩绘残迹以及由不同颜色材料制成的雕塑，它们无法与当时广泛流行的古代雕塑为单色的形象相吻合。说到成功地宣传和贯彻新的范式，必然少不了专业带头人的"众神的黄昏"。与此相应，卡特勒梅尔在他 1815 年的著作中先是毫不犹豫地赞赏温克尔曼，接着对他的不足表示谅解："温克尔曼在他研究的领域未能面面俱到，也许也未能意识到。" 可是随后他又发出了致命的一击："...... 新的古代艺术史学家尚未达到把握雕塑的认识深度； ...... 他的眼光并不敏锐，至于各种做法取决于什么，艺术品的不同工艺、趣味、效果、构图乃至不同门类的天才的各异，对这些问题，他均未能说透。" 卡特勒梅尔的批评并非胡诌。温克尔曼尽管在他的《古代艺术史》中提到涂着红色的希腊陶俑，包括部分包金的雕像，由黄金和象牙作的雕刻和躯干由木材、头和手脚却由大理石组成的雕像，他还提及着衣的雕像以及一座 1760 年在海格立斯城发现的狄安娜像，其头发和长袍均彩绘。然而这些艺术制品不是被粗略地归于希腊雕塑尚不发达的早期就是被简单地称为例外，证实单色雕塑乃是常规，这样彩绘意义便未得到正确的认识。对温克尔曼而言，就象对他的同时代人那样，白色大理石雕刻不啻希腊成熟艺术的常规和典范。就是以他带有比较性质的古代研究而对温克尔曼有重大影响的凯吕斯伯爵也偶尔在《铭文和纯文学学院的论文集》或是在他那于 1752-1767 年间发表的代表作《古代埃及、伊特拉斯坎、希腊和罗马艺术集》中提到彩绘痕迹或是不同颜色材料的雕刻，但他认为这些现象并不重要并把它们作为偏离正道的古代趣味加以拒绝，态度上比温克尔曼还要坚定。对古代彩色雕塑无动于衷和拒绝的态度，归根结底还是受到当时占统治地位的古典艺术理论的影响。古典艺术理论对雕塑和绘画作严格的门类等级区分，雕塑以形式界定，如同素描或线条，形式本身便能反映出天才

般的创造活动尤其是艺术品的思想。卡特勒梅尔对此深有所悟，他以启蒙的姿态登台，意在摧毁研究中的偏见思想。他自信地写到："我可以自夸说，我要扩展古代研究的这一新领域，消灭偏见，看来有些偏见的根源就在于完全匮乏观察和对事实无知。"作为有保留的分析家，卡特勒梅尔认为造成这种无知除了有当时艺术理论的影响，另外也与同时代艺术家的实践有关。不仅是因为古代彩绘雕塑与艺术理论相矛盾，而且由于当时现代雕塑只认白色大理石雕刻，从而确认了审美习惯，深受艺术理论和艺术实践影响的考古学家因此便不可能看到古代彩绘雕塑的现象。对于当时的时代来说，卡特勒梅尔阐述的这些正是令人惊讶的、相对主义的认识，即思想乃是由受时代制约的经验决定的。

正是由于有了这种对历史制约的敏锐意识，卡特勒梅尔才有可能冲出这种循环论证。可以不过分地说，幸亏有了现代早期的历史意识，古代雕塑彩绘的现象才得到了认识以及相应的评价。历史意识的一个十分重要的组成部分就是对自己时代和古代之差别的意识。这一点在卡特勒梅尔身上表现得再清楚不过了，他这样说过，"古代世界正好与现代世界对照"，他强调，"从古迄今所流逝的时光和带来的破坏留下了无法估量的空白。"卡特勒梅尔有一段常被引用的话，但被误解为纯粹的经验之谈，它再充分不过地表达了对差别的这种历史意识："要确信，古代人对艺术的利用与现代人完全不一样。"按卡特勒梅尔的观点，古代艺术不同于今日，是因为它是在不同的的社会环境下产生的，因此艺术只有通过其产生的时代和历史条件才能理解和评价："为了判断正确，就得设法从作品产生之因及其当时所具有的作用来了解这些作品特别含有的趣味种类。"这些想法最后汇集到看来说在利奥波德·兰克之前的一句话："判断事物必须从事物本身出发。"在法国，这种看待古代明显带有历史性保留眼光的思想史根源在于"古代和现代之争"。卡特勒梅尔是法国 1789 年大革命的积极参与者，倘若他本人没有经历其间由政治社会条件所决定的世界迅速变化和可变性，他对历史也不会采取这么一种保留的态度。

让我们回到彩绘问题上来：促使卡特勒梅尔对古代雕塑的历史形象进行革命的是那些无法解释的异常情况，古代作家保萨尼阿斯和普林尼在他们的著作中便提到古代雕塑的色彩，介绍雅典新发现的游记也有这方面的报导，卡特勒梅尔自己在海格立斯城和庞培发掘现场、在意大利尤其是罗马的众多博物馆以及拿破仑博物馆，即今日巴黎卢浮宫，也观察到了这些异常情况。特别是保萨尼阿斯对今已不存的由菲迪亚斯用黄金和象牙制成的神像的描述，唤起了深入研究多彩雕塑现象的兴趣和热情。对已失神像的描绘还包括第一批对雅典帕台农神庙和忒修斯神庙组雕色彩残迹的报导。卡特勒梅尔从未到过希腊，但他与 19 世纪初参与拆卸帕台农神庙所谓埃尔金大理石雕的舒瓦瑟尔-古菲耶、工程师富热龙以及驻雅典的法国大使福韦尔有联系，他们多次向他证实色彩残迹的存在。帕台农神庙的雕刻装饰原来敷彩的看法也通过斯图尔特和里维特的观察结果得到了证实，1787 年出版的《雅典古迹》一书记载了他们的观察结果，其中提到许多用于加固金属缰绳和标志的钻孔，卡特勒梅尔由此作出推论，颜色痕迹是原有的。卡特勒梅尔从他的情报人士对帕台农神庙的雕刻色彩的观察得出结论："这些雕刻不能称之为画过，它们有的地方以不同方式上了色，时而使雕刻突出于涂了颜色的背景，时而又通过不同的色调，这或是衣褶的色调，或是通过许多其它的局部来显示雕像的层面。"即使在巴黎，卡特勒梅尔也使自己确信色彩的存在，这是因为拿破仑博物馆藏有一块帕台农神庙饰带的残块，按习惯作法，人们对残块做了除污处理，将当时其意义尚未被认识的所有颜色痕迹一并清除。不过卡特勒梅尔想起，当残块还在运输箱中时，他曾见到色彩痕迹，只是记得不那么清楚罢了。1811 至 1812 年间，考古学家阿克布莱和多德韦尔的著作问世，书中亦指出，雅典忒修斯神庙有色彩遗迹。

除了提及雅典著名神庙的雕刻装饰的色彩之外，卡特勒梅尔将他当时所知具有彩绘痕迹的所有雕刻作了汇编，并引用了古代文献，材料翔实。在使用多块石料制作雕刻的领域，在彩绘处理的青铜塑像领域，他也作了同样的尝试，尤其是海格立斯城和庞培的发现让他高兴，这样他便为他的论点排好了确凿的证据，从而将在此之前的观点和价值标准一举颠倒了过来。在古代雕塑种类中，占主导地位的不是白色大理石雕刻，而是各种各样的多彩大理石雕刻。确定大理石雕刻着色技术的关键，卡特勒梅尔认为可以在著名的普林尼那段文字说明中找到，普林尼讲，雕塑家波拉克西特列斯对他的那几座由画家尼基亚斯彩绘过的雕像别有钟情。那儿使用了概念"circumlitio"来形容彩绘，卡特勒梅尔的前辈如凯吕斯伯爵或者雕塑家法尔科内把它解释为清漆。由于尼基亚斯是一位使用蜡画法的画家，卡特勒梅尔推断，雕刻的彩绘也必然使用的是这一技术。这一假设也在其他古代作家的著作中，同时通过对收藏在罗马和巴黎的古代雕像上的颜色遗迹的经验验证得到证实。卡特勒梅尔将用蜡画法彩绘雕刻的效果描绘成一种"给大理石染色和上色而又不造成颜色堆积"的技术。他在他的著作中一再固执地认为，古代大理石雕刻不是绘有重彩，而是仅含淡妆。他将帕台农神庙和忒修斯神庙的雕刻装饰与浮雕宝石作色彩结构上的比较，象业已流露的想法，他认为这些雕刻装饰上了色，"但不是浓绘的雕刻，我称它们为彩饰雕刻，也就是说，它们有些绘画的表象，却不刻意模仿绘画的效果 …… "。后种意义上涂绘的雕刻，在卡特勒梅尔看来，当属古希腊雕刻的早期，那时的人们本能地以"一个野蛮人或一个孩子的眼睛"试着借此造成一种彻头彻尾的幻觉。正象我们今天所知，就古代雕刻彩绘而论，这种只许古代盛期有淡抹而不容许有浓妆的观点乃是单一和错误的，造成错误认识的原因在于，一些保存状态甚佳的古代彩绘雕刻如普里码坡尔塔的奥古斯都像还未被发现，再就是广泛缺乏合适的技术检测手段。同时这也是怪事，卡特勒梅尔完全清楚雕刻褪色和老化的问题，但他却不考虑，此时的浅色在当时有可能表现为强烈的色彩。还有一点十分明显，他在谈论颜色残迹时，从未作过近观技法上的描述，所表达的不过是他对色彩总的印象而已。这不免使人疑窦丛生，把古代雕刻的彩绘估计为淡彩浅色的终究不是别人，而是艺术史家和古典主义者卡特勒梅尔，他重线条和形式，区分雕塑和绘画的门类等级，自然不能允许"彩绘的"古代雕刻。因此人们也可以用他在反对他的无视色彩的前辈时所说的话来指责他：偏见！我们将会看到，虽然比他的前

辈更有限，为了使艺术理论和经验相一致，他也赋予经验科学一种与趣味判断相关的、受时代制约的主观性解释。卡特勒梅尔 1806 年第一个使用多彩概念，它初期作为与“彩绘”相对的概念而具有古典主义艺术理论的涵义，今天使用它时，我们已经意识不到这层涵义了。

其书的高潮，乃是卡特勒梅尔尽各种努力对古代著名的金银制品的复原所作的尝试，这些作品包括传奇性的由荷马描述过、但卡特勒梅尔却信以为真的阿喀琉斯的盾牌，尤其是菲迪亚斯时代完成的由黄金和象牙制成的神像，这些神像已无一存世，现仅见于古代作家的记载。位于中心的乃是标题提到的奥林匹亚的朱庇特像，这座端坐的巨像是菲迪亚斯为奥林匹亚宙斯神庙制作的。该像的复原是借助于保萨尼阿斯的简短描述以及参考硬币、浮雕宝石和可作比较的雕像完成的。复原的色彩，多为各色衬托的金色浮雕等等，在很大的程度上出于想象，虽然作者并没有承认这一点。

卡特勒梅尔坚信，在希腊雕刻作品中，美的观念会自行再现，现代人只需模仿即可，他想用古代雕刻的彩色史为当时的艺术发展作贡献。尽管站不住脚，他还是坚持他的考古学是现代艺术的仆人的观点不放，如他说到：“……我们呼唤学识为艺术服务。”这当中他当然意识到，－ 这已让人感觉得出 － 在原则上，雕刻的色彩与古典的艺术教条是矛盾的。因此他在他的著作的结尾处找了不少和解考古认识和现代艺术教条的理由，这些缠绕一团、常常停留在修辞上的论证反而更加清楚地表现出两者的不可调和。在论证方式上引人注目的是，卡特勒梅尔接受古代艺术理论的原则，但他又一再为规则的例外辩护，而且叱骂理论上的严肃主义。可是他也在美学上初涉色彩的作用，如在黄金和象牙中间存在色调的“友谊”，它可以扬弃雕刻色彩的单调作用，这种作用被他论战式地称作“单调原则”。反对雕刻外表的华丽及奢侈的理由，因为这与艺术品的思想格格不入，他认为在原则上是正确的，但是抽象的原则不应过分夸张。决定雕刻的是形式而不是仅逾越门类界限而造成极大错觉的色彩，他承认，从根本上来说，纵使这种论点也是正确的，只不过古人给雕刻上色并非要追求错觉绘画的效果，他们用色是只想对其淡妆素裹而已。他这样一来便直接使怀疑得到了证实，为了取得与艺术理论的和谐，他对实践成果作了主观解释。

我想，考古学和艺术理论在这里不再配合，这一点已显而易见。对现代早期而言，经验研究和形而上学理论之间的分离乃是意味深长和具时代意义的，卡特勒梅尔的著作恰恰为我们了解这个时期实践和理论的分离提供了一个范例。经验研究的结果和艺术理论的理想不再协调一致，它甚至还向后者提出了质疑，很清楚，古典艺术理论从前的榜样与人们那时想象的有出入。

这种在 18 世纪下半叶由对科学进行历史化和经验化造成的内在矛盾，也是造成接受卡特勒梅尔关于古代彩色雕刻理论时意见相左的原因。除了热情的拥护者之外，也有象德国艺术史家弗里德里希 · 特奥多尔 · 库格勒这样的反对者，库格勒虽然同样是古典主义者，但他更为严厉，他只赞成非常有限的、大理石局部的彩绘，连肉色部分都不提。

卡特勒梅尔 1815 年发表的著作也在同时代的雕塑界掀起了波澜，可是还要等几十年，彩色雕塑的艺术问题才得到了广泛的探讨。1847 年创作《被蛇咬的女子》(巴黎奥赛博物馆)的让-巴蒂斯特 · 克莱桑热属于彩色雕刻的前驱，他在给大理石上色时使用的就是卡特勒梅尔描述过的蜡画法。他的继承者有 19 世纪下半叶的艺术家如德加、克里姆特和克林格尔。卡特勒梅尔 · 德坎西以其论奥林匹亚的朱庇特像的著作，提出了古代雕刻是有色彩的证据，从而为现代的古代形象的革命作出了贡献。当今，我们同中方同事一起探讨保护兵马俑的方法和古代彩绘史，这还要特别感谢卡特勒梅尔，说这话当未言过其实。同时，作为考古学家和艺术史家的这么一个充满矛盾的人物，也应提醒我们，我们的努力要合乎时代潮流和它的相对性。毫无成见应该成为所有研究和修复工作的一个目标，即使完全实现这个目标最终只是幻想也罢。

(德译中：陈钢林)

Vinzenz Brinkmann and Ulrike Koch-Brinkmann

Polychromy on Greek Sculpture: The Archer on the West-pediment of the Aphaia Temple, Aegina

Antique Greek sculpture was at all times polychrome. The sculptures were made of different materials, but their polychromy always lead to a homogenous aesthetical effect. An antique Greek clay figure would first of all be covered with a priming of white stucco, limestone sculptures with marble stucco, in order to create the illusion of a marble sculpture. Whereas abundant polychrome fragments and even intact paint layers are preserved not only on Greek terracottas[1] (Colour plate front cover) but also on early Greek limestone sculpture, there are few preserved traces on the works of art in marble.

In the last years the polychrome paint layer of Greek marble sculptures has been extensively examined in a research project, largely financed by the „Deutsche Forschungsgemeinschaft" using foremost scientific examination methods. With the help of technical photography, especially different shooting techniques in ultra-violet light, but also a special side-light technique many traces of earlier painting could be observed and documented. Chemical analysis of the pigments and binding agents as well as intensive microscopical analysis accompanied the documentation. For some of the figures it was possible to recover the almost complete form and polychromy of the paint layer. These findings led us to consider reconstructions of the sculptures using moulded stone copies.

The figure of the Archer on the West-pediment of the Aphaia Temple at Aegina, the kneeling Archer, dating from the early 5th century BC and created in Greece wears an oriental costume: a type of pullover, close-fitting leggings and a jacket (colour plate IX, fig. 4).

The surface of the figures on both pediments of the Aphaia Temple show only sparse traces of red, green and blue colouring. The use of gold-leaf on the pediment warriors has also been established. At the time of the excavation of the Archer in 1811, the discoverer Charles Cockerell and the architect Jakob Ignaz Hittorff, who was very interested in questions concerning polychomy, believed to have discovered the coloured shadow (ghost) of a costume of scales. More information has not been passed down by the excavators, whose account on the polychromy was otherwise very keen and correct. Adolf Furtwängler, who did further excavation work and research at the site of the sanctuary in 1901, devoted a lot of attention to questions concerning the polychromy of the pediment sculptures. He ventured a complete reconstruction of both pediments from the west and east side of the building[2] (colour plate IX, fig. 2). However, only the colours blue and red were used, because these were the only pigments which had at that time been discovered on the originals.

Due to the lack of any traces of colour on the Archer, he reconstructed this figure in close accordance to the so-called Persian Horseman (colour plate IX, fig. 5), a fragmented marble sculpture, which had been found on the Acropolis in Athens shortly before the turn of the century. This sculpture has an unusually well preserved paint layer[3] (colour plate IX, fig. 1). The horseman wears the same type of close-fitting leggings and jacket. A lozenge-shaped ornament is painted on the leggings; the jacket it decorated with slightly displaced lanes of scales.

The polychrome paint layer of the Persian Horseman is quite elaborate, but the coloured ornamentation of the Archer on the West-pediment of the Aphaia Temple exceeds all expectations. Photographs, shot in ultra-violet light and with raking light, made with the help of a number of colleagues[4] since the 1980´s, clearly show the splendor of the original sculpture.

On the ultra-violet-reflex shot of the leggings (colour plate IX, fig. 3), one can see a type of weathering, which most probably resulted from the different fastness of the pigments used. The complicated ornamentation, which originally decorated the complete leggings can be seen on this weather-worn area on the photograph: interlaced lozenge-stripes with lancet-shaped tips, which are again filled with small lozenges.

Using side-light, one can see a far more intense weathering on the sleeves, due to mechanical abrasion. This proves that leggings and upper garment were differentiated by their ornamentation. The sleeves of the „pullover" were covered with lozenges, with every second lozenge-strip again filled with small lozenges.

The findings on the jacket of the Archer are spectacular. The hem was trimmed with a sumptuous ribbon. Painted animal pairs, face to face in combat position covered the main areas of the jacket. Again using side-light, the rear region of a griffon can be cleary seen. The preparatory work that the artist did on the marble surface is of exquisite precision: using a metal graver each feather quil was individually grooved to form a tensioned swoop. Remarkable is that the lowest, that is the smallest feather quil is just 1 to 2 mm wide. This type of love to detail surprises, on account of the fact, that the figure is positioned at least 12 meters above the viewer.

Due to the different weathering of the individual coloured areas, which can be seen using raking-light as well as in ultra violet light, it is possible with high certainty to determine certain pigments. This procedure can be confirmed in the comparison with late archaic Greek sculptures, which show definite traces of polychromy. One of the best preserved examples to compare is the above mentioned Persian Horseman from the Acropolis in Athens. Here one can observe creative features in general, typical for Greek sculpture around 500 BC: colours are always applied with the greatest possible contrast. This enhances the recognisability of the elaborate ornamentation. The choice of pigments is also canonical: for blue and green the copper-carbonate azurite and malachite are used, for red a natural cinnabar or red ochre. The brown and yellow tones were produced by using ochre.

Our reconstruction, which was realised on a marble mould copy considers all observations and possibilities concerning the analogy (colour plate IX, fig. 6). Natural pigments, similar to those found in Antiquity were used.[5] For the outer side of the Archer's bow gold-leaf was applied. The naked skin was painted with haematite, a pigment, which was last discovered on the colossal kouros of Samos.[6]

Notes

1 Brinkmann, Vinzenz: Farbigkeit der Terrakotten, in: Hauch des Prometheus. Meisterwerke in Ton (Hrsg. F.W. Hamdorf, 1996) pp. 25 ff. See also Brinkmann, Vinzenz: La polychromie de la sculpture archaique en marbre, Pact 17 (1987) pp. 35 ff.
2 Furtwängler, Adolf: Aegina. Das Heiligtum der Aphaia (1906) p. 301.
3 Martini, W.: Die archaische Plastik der Griechen (1990), p. 53.
4 Special thanks to Mrs. Doris Lauenstein-Senff.
5 Red = cinnabar / blue = azurite / green = malachite / yellow ochre and brown ochre.
6 Kyrieleis, H. / Kienast, H. / Neumann, G.: Der grosse Kuros von Samos, Samos X (1996) pp. 23 ff, footnote 61.

布林克曼 科赫-布林克曼

古希腊雕塑彩绘－以埃吉那岛阿菲亚神庙西面三角板上的弓箭手为例

各个时期的古希腊雕塑的材料各异，但这些雕塑都有彩绘，每每上色，总能达到统一的审美效果。为了获得象大理石雕刻的表面肌理，一件古希腊的陶塑先用白石灰，而石灰岩雕刻甚至会使用仿大理石的石膏打底。迄今，我们还能在希腊的陶俑身上(彩图，见封二)[1]、包括希腊早期的石灰岩雕刻的表面，发现残留下来的丰富颜色，时不时甚至能看见完整的彩绘层，但大理石雕刻上的彩绘痕迹却不常见。

近几年，古希腊大理石雕刻的彩绘得到了立项研究，这个科研项目主要是由德国科学研究会赞助的。在项目中，自然科学的研究方法占有突出的地位。借助于科技摄影的手段，尤其是在紫外线下的各种摄像技术和一种专门的侧光技术，可以观察和记录许多当时施色的痕迹。记录的同时，对颜料和粘合剂进行了化学分析，并作了大量的显微分析。最后，在几座雕像上，几乎完整地重新获得了其彩绘的形和色。这些结果引起我们思考，通过人造石模型来复原彩绘。

埃吉那岛阿菲亚神庙西面三角板上的一个弓箭手像

这个跪射手像创作于公元前五世纪初的希腊，他看来穿着一件毛衣、一条贴身裤和一件夹克(彩图 IX, 4)。

阿菲亚神庙两面三角板上的雕像表面只留下不多而且很弱的红、绿和蓝色残迹。在三角板上的战士身上使用了金箔，在此之间也得到了证实。当弓箭手像于 1811 年发掘出来时，发现者查尔斯 · 科克雷尔和对彩绘问题极其关心的建筑师雅各布 · 伊格纳茨 · 希托夫都以为看到的是鳞甲的影子(ghost)。发掘者没有给我们提供更多的信息，尽管他们对彩绘作了十分认真和忠实的说明。[2]

阿道夫 ·富特文勒于 1901 年对神庙作了新的发掘和研究，对三角板上的雕刻彩绘问题，他重新予以关注。他大胆地复原了神庙西、东两面的两块整三角板(彩图 IX, 2)。但他把颜色局限在蓝和红色，因为当时在原作上还没有观察到其它的颜料。

由于弓箭手身上缺乏彩绘痕迹，在复原他时，富特文勒依据的是所谓的波斯骑士(彩图 IX, 5)，这是一件残破的大理石雕刻，它是在此之前没有几年在雅典卫城发现的，其彩绘保存状态甚佳(彩图 IX, 1)。[3] 这个骑士亦着贴身裤和夹克。裤子上画着菱形纹饰，夹克上装饰有稍微偏移的鳞片道。

波斯骑士的彩绘已经十分讲究，但是阿菲亚神庙西面三角板上弓箭手的彩绘装饰却超出了所有人的期望。紫外线照相和用 80 年代以来一些同事[4]研制的侧光灯所拍的照片，再现了这座雕像的华丽。

在裤腿的紫外线反光照片上(彩图 IX, 3)，可以观察到一种风化，这是由于不同颜料的牢固性各异所至。在这张风化图上可见曾经覆盖全裤的图案：交错的菱形带，柳叶刀般的菱尖，里面又布满小菱形。在雕像的袖子上，这一次通过侧光，可以看见极深的、受力造成的风化，这表明，裤子和上衣因装饰的不同而明显有别。"毛衣"的袖子有菱形纹饰，隔一排的每个菱形中又布满小菱形。

最轰动的最后还是在弓箭手的夹克上的发现。衣边由绚丽的带子作装饰。夹克的大块面上画着成对的动物，它们对视，摆着搏斗的架式，使画面活跃。侧光下，一只巨鸟的下半身清晰可辨。画家画在大理石表面上的羽茎，充满张力，艺术家再用金属雕刻刀把它们一丝不苟地刻出来。值得注意的是，最下面的、也是最小的羽茎仅有 1 至 2 毫米宽。这件摆在观者头上至少 12 米高处的雕像竟如此讲究细部，让人吃惊。基于不同的色面风化程度的不同，这在侧光下和紫外线下均能识别，便可相当有把握地将某些颜料鉴别出来。通过与彩绘痕迹较为明显的古风晚期的希腊雕塑进行比较，这种方法显得更有说服力。保存最好的、可以比较的例子之一，便是上面提到的雅典卫城的波斯骑士像。这里可以看到适用于公元前 500 年左右希腊雕塑的一般造型方式：设色时，相邻颜色的反差总是愈大愈佳。这使人们更易辨别精巧的纹饰。而且颜料的选择也是有规范的：蓝色和绿色多为碳酸铜石青和孔雀石，红色是天然朱砂或红赭石。褐色和黄褐色调当然是用赭石分解的。

在用人造大理石模型进行复原时，我们考虑到了类别的所有情况和可能性(彩图 IX, 6)。因此，我们用的是与古希腊使用的颜料相应的天然颜料。[5] 弓箭的外边的金色使用的是金箔。男子的皮肤系用赤铁矿作颜料画的，在此之前，萨摩斯岛的庞大少年雕像上也证实了这种颜料。[6]

注:

1. 参见英文文本注 1 。
2. 参见英文文本注 2 。
3. 参见英文文本注 3 。
4. 这里要特别感谢多丽丝 · 劳恩施泰因-森夫女士。
5. 红色=朱砂/蓝色=石青/绿色=孔雀石/金赭石和褐赭石。
6. 参见英文文本注 6 。

林春美

战国时代纺织工艺中的练染

中国服饰的颜色扮演很重要的角色，它不仅要区别场合，还要显示身份、地位。荀子(约公元前313-230)在书中提到"天子袾裷衣冕，诸侯玄裷衣冕，大夫裨冕，士皮弁服"[1]。不只服装颜色有别，其他佩饰、用品也有颜色上的差异，如"诸侯彤弓，大夫黑弓"[2]。这种区别贵贱、长幼和贫富的规定。古代称之为礼。

《周礼》《仪礼》等经书中详诉周代(公元前1027-前221)的服装制度，但是这些经书的内容已加入汉代(公元前206-公元后220)儒者的见解，可靠性受疑。有些子书，如《墨子》、《韩非子》、《管子》等也有后人或其弟子增述。因此，那些礼制的开端很难确定。尤其服制中五色配合五行、五方和季节等观念在战国(公元前475-前221)晚期才逐渐形成，吕布韦约于公元前241年才在《吕氏春秋》中完善相生相克的理念，试图说明秦国取代周朝是合理的。而《周礼》中又记载类似内容，导致先后难以厘清的困难。因此，本论文将以战国墓葬的发掘报告为主，整理出当时常用的颜色，配合汉代以前的文字资料，探讨当时的染色和精练方法。

从子书中许多与染色有关的语句，如"不曰白乎，涅而不缁"[3]，"白沙在涅，与之俱黑"、"青取之于蓝，而青于蓝"[4]和"染于苍则苍，染于黄则黄，所入者变，其色亦变"[5]等，可以想像当时染丝、染布之普遍，以及利用黑色泥土也有染不成黑的可能性已受到注意。这种织品染色的盛况也反映在几十年来所发掘的战国织品中。下面就以十个战国墓发掘报告为代表，将其中发掘出的织品颜色列成表1，以彰显当时的流行色。

从此表中得知青(蓝)和绿两色在战国时代最少用，最常用的颜色是黄色倾向棕色的系统[6]，以及赤(红)和玄、缁(黑)。红色系中的朱红据分析是矿物颜料朱砂。蓝、绿两色稀有的现象正与《诗经》中叙述蓝草和绿草不易采集的情况相符[7]。赤和玄、缁是祭服与礼服的颜色，出现频繁理所当然。黄色系统最多则与老化和染黄的染料多种有关。

当时织物施色的材料常用植物染料之外，还使用朱砂等矿物颜料。这些材料分别在下列各种颜色系统中介绍[8]。

一、红色系统

红色系统中有茜草、荼和朱砂。

1. 茜草(Rubia cordifolia，茜草科)茹藘、倩草、茅蒐

茜草是商周时期主要的红色染料，多年生攀援草本。根部主要色素是茜红素和茜黄素。春、秋两季皆可采收，但秋季挖出的根质量较佳。挖出后晒干后储藏，用时切成片，用热水抽提。茜素属媒染性染料，不加媒染剂只能染黄红色。古代用以精炼的椿木灰含铝盐，也成为茜素染红的媒染剂。用上述含有硫酸亚铁的黑土涅，可染成黑色(缁)。茜草染料染红(纁)和染黑(缁)的色光变化，在史书中，记载最详细，待说明染色部分时再叙述。守礼法的孔子也提醒君子，不以绀緅饰，也就是说不用纁和缁两种祭服、礼服之间的颜色来滚边，装饰衣领、袖、裾[9]。其他红色染料染草还有荼(Polygonum cuspidatum，蓼科)又名虎杖，多年生草本。

2. 朱砂(HgS)

朱砂色泽浓艳，光牢度好。中国境内利用朱砂的历史已很久。新石器时代中晚期(约公元前3000-前2000)青海乐都柳湾一具男尸下撒有朱砂[10]，安阳殷墟出土的甲骨文片上涂有红色硫化汞，妇好墓出土存有朱砂痕迹的玉杵臼，荀子(公元前313-前238)言及"珠玉满体，文绣充棺…，加之以丹矸(丹砂)"[11]。而秦始皇墓中以丹砂炼成的水银为百川的先例是齐桓公的陵墓(约去世于公元前642年)[12]。朱砂有天然的，也有炼成的。制作过程中随温度、浓度和时间的不同会出现多种红色，上层发黄，下层发暗，中间的朱红最好。西周強伯墓群中的朱砂呈朱红色(彩图X, 3)，可见已掌握技术[13]。另外，江陵马山一号白色素罗绣龙、凤、虎，其中老虎纹是用黑色绣线和浸渍过硫化汞的黑、灰色线绣成。硫化汞本身是种晶体结构，六方硫化汞是鲜艳的红色，四方硫化汞则呈深灰色[14](彩图X, 1,2)。

二、蓝色系统

1. 蓼蓝(Polygonum tinctorium，蓼科)葴、马蓝

自然界含靛蓝的植物很多，《诗经》描述妇女采集的蓼蓝是其中一种。蓼蓝为一年生草本，二、三月下种，六、七月草叶成熟，呈绿色，即可采叶。采后随发新叶，隔三个月又可收割，属靛系还原染料。靛蓝色泽浓艳，牢度非常好。马山一号墓的田猎纹中驾车狩猎人物的衣服和几只奔跑的动物就是靛蓝色[15]。此蓝色原称青，后来又称苍。青、苍之间的色光有无区别，是否因染料不同而引起尚待探讨。

三、绿色系统

1. 荩草(Arthraxon hispidus，禾本科)菉

荩草是一年生草本，茎杆细弱，茎叶中含黄色素，主要成分是荩草素，为黄酮类媒染染料，可直接染毛、丝纤维。以铜盐为媒染剂，可得鲜艳的绿色，这或许是其原名为绿的原因。

四、黄色系统

黄色系统的染料较多，有上面叙述过的茜草、荩草和栀子。其他黄色染料还有苄(地黄)，姜、孽和鬯等多种植物，是否已於战国时代运用仍待考究。另外还有石黄。

1. 茜草(参考一、1)可以直接染黄红

颜色	墓葬	江西贵溪崖墓	曾侯乙墓	信阳楚墓	长沙左家塘	江陵马山一号	江陵九店	望山沙家	包山楚墓	长沙烈士公园	长沙发掘报告
红	深红(缥)		*	*	*	*		*	*		
	浅红(赪)						*				
	朱红(祙)				*	*				*	
	桔红(縓)					*					
	紫红					*					
	清赤(绀)										
蓝	靛蓝(青)					*					
	浅蓝										
	蓝绿(苍艾)										
	绿						*				
	黄					*					
	绿黄					*					
黄	浅黄				*	*		*			
	深黄			*	*	*			*		*
	金黄			*	*	*					
	土黄	*			*	*	*	*	*		
	灰黄					*					
	棕				*	*	*	*			
	浅棕	*			*	*		*			
	深棕	*			*	*	*	*	*		
	红棕					*		*			
	紫褐		* 深						* 红		*
	褐				*	*			*		*
	黄褐	*									*
	藕色				*	*					
白	灰白					*					
	白			*					*		*
黑	灰黑									*	
	缁玄黑		*			*	*		*	*	*
	紫		*			*					

Tab. 1. Colour of textiles, excavation from tombs of the Warring States Period (206BC-220AD).

表 1. 十个战国时代墓葬所发掘出的织物颜色表。

2. 荩草(参考三、1)也可以直接染黄

3. 栀子(Gardenia Jasminedes Ellis, 茜草科栀子属)

栀子是常绿灌木，开白花。果实中含有栀子素、果胶、鞣质、藏红花素及藏红花酸等物质，主要的染色分为藏红花酸。用冷水浸泡栀子果实后，煮沸，呈深橙黄色染液，即可直接染得鲜艳的黄色。也可媒染成嫩黄(铜)、灰黄(铬)、暗黄(铁)等不同色光。

4. 石黄

据科学分析強伯墓群中沾有黄色残痕的泥土结果含砷 0.1 ~ 0.3 %，未发现铅、铬等金属，而确定为石黄。黄色的天然矿物颜料，分雌黄(AS_2S_3三硫化二砷)和雄黄(二硫化二砷、硫化砷)。腊光似的雌黄呈柠檬黄至桔黄色；脂肪油光的雄黄呈红色[16]。

五、黑色系统

黑色系中很多染料可以应用铁媒染剂染得，例如茜草染成的红可以媒染成黑。其他还有某些树的果实汁液，也可以媒染成黑。

1. 皂斗，柞树、麻栎(Quercus acutissima)的果实

柞树和麻栎的果实古代称皂斗，是当时主要的黑色植物染料。麻栎(栩、杼、柞)是落叶乔木，高达二十五米。其觳斗及树皮破碎后，用热水抽取，即可溶出其中的鞣质(丹宁)，以铁盐媒染得黑。

2. 除了茜草媒，其他可以染皂黑的还有荅(陵苕)，　(鼠尾)和欆(乌阶)等植物。当时表达黑色含义的尚有〖玄〗字，它常与玄冠，玄衮出现。之后又有玄堂、玄天等语词出现。缁则与衣一并出现，是下层贵族祀服。玄、缁色光的

区别同样有待探讨。

上述染草中染红的茜草，染绿的荩草和栀子、(地黄)等许多植物，都能直接染得黄色系的色光，加上素色织物老化泛黄、失去光泽，变成褐色，均为黄色系成为统计中最多的因素。

六、紫色系统

1. 紫草(Lithospermum erythrorhizon，紫草科)藐

紫草是多年生草本，八、九月茎叶枯萎时采掘紫草根。与椿木灰媒染得紫红色。齐桓公(在位于公元前 685-前 643)好紫，全国仿效，使紫色布的价钱五倍于素缟[17]。而招惹孔子恶紫夺朱。曾侯乙墓(约公元前 433)出土一具漆彩衣柜，上刻有紫锦之衣，或可反映当时时尚。

七、白色系统

1. 蜃灰

蜃灰是含有碳酸钙($CaCO_3$)的蛤蚧烧成的，可以当精炼剂、漂白剂之外，也是白色颜料。江西贵西崖出土印有深棕色苎麻布上的银白色颜料[18]即为此材料。

有关精练部分:

精练是漂白色染色之前的工序，纤维或布是否精练过会影响所染颜色的牢固度和光泽。所谓精练就是加入碱溶液，除去丝、麻等天然纤维在生长过程中混入的共生物和杂质，使纤维脱去其胶质而见柔软性。陕西省一春秋墓葬出土的苎麻布在显微镜观察下"表面光滑，没有胶块，碎屑等夹杂物"[19]，而越国生产的葛布能以"弱于罗兮轻霏霏"[20]的语句来形容。这两个例子均证明战国早期植物纤维经过精练。透过《仪礼》中的注疏得知当时已讲究精练，练过和未练的织物各有其名称，例如大功麻布和小功麻布都只用水沤渍、捶打。缌是先精练缕、使细如丝，再织成布。而锡正好相反：先织成布后，再加含碱的灰精练成柔软、松散的麻布[21]。精练可在丝、缕阶段，或在织成布、帛之后再处理，完全依实际使用的需要来决定。通常绢、纨、缟和衣缘的滚边条为未练织物。

麻皮剥下后要经过沤渍、捶打、除去麻纤维杂质，脱去其果胶，纤维也会变得柔软、纤细。这种利用发酵作用脱胶取得的麻纤维并未完全脱尽其果胶，因此，纤维乃成束联结在一起。要使纤维纤细均匀，还要将麻纤维束劈开分细，即所谓绩麻。

蚕丝是由两根外围包覆丝胶的丝纤并成的。在缫丝(用热水煮)时，一部分丝胶溶解在水里，但大部分还是保留下来，这就是未练的生丝。

这种只用水脱去胶质的丝、缕还要精练才能轻柔、富有光泽。按先秦史料有关练丝和练帛的精炼剂是含有碳酸钾的草木灰[22]和含有氧化钙的蛤壳灰[23]，两者均为碱性。练丝用较稀薄的温灰水浸渍七天之后，白天放在离地一尺的阳光中曝晒，晚上把丝悬挂在井水里，这样经过七天七夜，叫做水练[24]。

《考工记》中说明，练帛同样先用楝树灰汁浸渍(七天)，之后，再用蛤壳烧成的蜃灰涂、浸、漂洗，晒干，再浸、漂洗，反复再三浸、涂碱性溶液和晒干，夜里同样将帛悬挂在井水里，这样经过七天七夜，才完成练帛过程，也称水湅[25]。

至于染色的部分，除了上面提过与染有关的名言外，先秦古书中还有二段叙述织品施色的方法。一处在《尔雅》，说明多次浸染的过程:

"一染谓之縓，再染谓之赪，三染谓之纁"。[26]

从第一次染成黄红色的縓，再染一次成浅赤色的赪，到第三次染成赤色的纁。这个过程正是红色染料茜草多次浸染时染料色光的变化[27]。另一处叙述朱砂涂染羽毛和茜草染料媒染的过程:

"钟氏染羽，以朱湛丹秫，三月而炽之，淳而渍之。三入为纁，五入为緅，七入为缁。"[28]

这一段文字的诠释分歧多端。有学者以为〖朱〗是一种赤心木或茜素等植物染料[29]，三染成赤色，再染到第五次成青赤色的緅，染七次变成黑色称纁，他们强调矿物颜料不论涂布多少次，色光是不会变化的。这里从赤变化到黑，认为是描述植物染料媒染过程。有一派则以为〖朱〗是矿物颜料朱砂，朱砂和丹秫(红高粱)浸泡水三个月后，丹秫通过发酵分散成细颗粒的淀粉，用火炊蒸，即转化为绸粘的粘合剂糨糊。颜料颗粒朱砂即因粘合剂能粘在羽毛上，干后形成有色的淀粉膜，著色即成。因此，就有学者以为纁色是朱砂矿物颜料所形成的颜色[30]。陈维稷提出比较恰当的看法，他认为这一段文字叙述两种不同工艺法，前半段叙述矿物颜料施色法，即石染法，后半段说明媒染现象[31]。这种解释很合理地解决前后文互相矛盾的地方：〖朱〗若为植物染料不必与谷物浸泡、共煮，借以粘著。〖朱〗若为矿物颜料，是不该再次浸染时，色光起变化。

陈维稷说明古代以涅染缁的媒染过程时认为：涅是黑色泥土，含硫酸亚铁，在茜草染成的红色纁地上，交替媒染两次后，成青赤色的緅，再染两次便成带红的黑色缁。他又举近代海南岛黎族把浸过海南蒲桃树皮叶液的纤维品用黑泥土沤渍，染黑的例子。若没浸过树皮叶汁，则染不黑[32]。这染不黑的现象，正符合孔子(公元前 551-479)强调，意志坚定不受外界感染，"涅而不缁"的情况。

上述湅丝、湅帛和染羽是百工中五种设色工中的两种，另外还有画、缋和筐，后者内容失阙，无从考察。画缋之工在《周礼》中则放在一起说明，叙述五色与四方和天地的关系，以及两色相次产生的新色名，如，文是青、赤，章是赤、白，黼是白、黑和黻是黑等[33]，其意涵不属本文论述范围。同时，发掘出的帛画与服装功能没有直接关系，因此，画缋不加深入探讨。《周礼》还记载染人，掌以丝帛，夏天染纁、玄(黑而有赤)两色，秋天染五彩之色[34]。另外，还有掌染草，掌以春秋敛染草之物，在秋季染五色时颁给染人[35]。《吕氏春秋》中还更仔细区分夏为孟、仲、季三个月。规定仲夏盛暑不得割蓝草染色，不烧炭，不曝晒布等[36]，待凉风始吹的季夏才"命妇官染采，黼黻文章，必以法故，无或差忒，黑、黄、苍、赤莫不质良，勿敢伪诈[37]"。可见公元前第三世纪中页已掌握了练染时节。

丰富织品色彩的工艺:

战国时代以染料浸染丝、帛以及用颜料透过粘合剂浸渍丝缕、涂布施色的工艺之外，还透过织造工艺技术使染涂好的丝帛颜色更生动地呈现出来。从出土的织品观察到丰富织品色彩的工艺有并丝、织花、绣花和印花等。但印花资料不全，在此便不加详述。

一、并丝:

利用两种色泽相近的色丝并合后再织，外观上便产生出一种新的色彩。湖南省博物馆收藏的褐地矩纹锦是由黑色和红褐色两种经丝上下交替形成的花纹，其中红褐色的经丝是由一根豆沙色的经线和一根红色经丝并合而成的[38]。

二、织花

已利用分区布色和改变组织点两种方式来变化色彩。整经时分区布置不同色彩的经线，即能织成不同色彩的条纹。如彩图 X, 5 镜衣的边沿所饰黑、黄相间的条纹。条纹纹饰也曾出现在曾侯乙墓出土的编钟架上较大的铜人柱上。铜人所著的裳即黑红相间的细条纹。另外，运用两种以上的经线或纬线，以改变组织点的方式浮现花纹。例如马山一号出土的田猎纹锦(彩图 X, 4)，则由深棕经线和深棕、土黄、蓝和红棕四种颜色的纬线织成。深棕色的地上以蓝色、红棕和土黄显现花纹，如菱形纹的轮廓是黄蓝相间，中间穿插红棕色，车上的猎人著蓝色衣服，黄色腰带，身体的轮廓由红棕色显现。

三、 绣花:

用不同颜色的丝线以锁针绣满纹样。江陵马山一号白色素罗绣设计精美的龙、凤、虎纹(N9)袍，即或窥见色谱之丰富：朱红、金黄、银灰、黑。这里所见昂首张口的老虎，身上红、黑条纹相间的红颜色(彩图 X, 1)，即由矿物颜料硫化汞浸渍成的。其他金黄色为主绣的有饰花冠，张翅舞蹈的凤和其脚下踏的龙，均以银灰色点出中心单位，如眼睛，腹和花冠的花托。灰、黑虎的部分同样有四种绣线(彩图 X, 2)：金黄、红棕、黑和灰。最大的区别是老虎的腹部轮廓、扬起的后腿、眼睛、獠牙和鬃毛均锈金黄的明亮色强调出，其他部分的轮廓则以红棕色来表现其阴暗。弯长的尾巴以红棕、黑色两节为循环。

总而言之，战国时代已掌握运用碱性溶液精练丝缕和布帛，以及媒染的方法。同时，还持续使用矿物颜料粘涂法。除此基本的练染工艺技术之外，还更进一步利用分区布色和改变组织点的织造技术来丰富织品色彩，增加色彩变化，确立了染、织、绣的艺术基础。至于这些颜色名称的源流和染料的关系，以及其出现的先后，一一仍待实验和考究。

注:

1.《荀子逐字索引》(香港, 1996)，富国篇，页 43 。
2. 同上，大略篇，页 126 。
3. 钱穆:《论语新解》(香港, 1963)，阳货篇，第十七，页 597 。
4. 同注 1，劝学篇，页 1 。
5. 张纯一编著:《墨子集解》(成都, 1988),所染，页 14-15 。
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7. 诗经 · 小雅 · 采绿：终朝采绿不盈一匊，予发曲局，薄言归沐。终朝采蓝，不盈···，载:《毛诗逐字索引》(香港, 1995)，页 112 。
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12. 陈新谦编著:《中华药史纪年》(北京， 1994)，页 18 。
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15. 同上，页 36 。《江陵马山一号楚墓》发掘报告上报导为钴蓝，见湖北省荆州地区博物馆:《江陵马山一号楚墓》(北京， 1985)，页 104 、 106 。
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19. 同注 8, 页 76 。
20. 同注 18，页 31 。
21. 同注 6，页 33 。
22. 同注 8，页 71 。
23. 同注 6，页 32 。
24. 林尹:《周礼今注今译》(北京, 1985)，冬官 · 考工记第六，页 452-453 。
25. 同上。
26.《尔雅逐字索引》(香港， 1995)，释器第六，页 71 。
27. 上海市纺织科学研究院、丝绸工业司文物研究所:《马王堆一号汉墓出土纺织品的研究》(北京， 1980)，页 88 。
28. 同注 13，页 451-452 。

29. 同注 8，页 84，注 2。
30. 同注 6，页 35。
31. 同注 8，页 84，注 2。
32. 同上，页 88。
33. 同注 23，页 450-451。
34. 同上，天官 · 冢宰下，页 82。值得一提的是，这儿不用染纁缁，而以玄代纁。
35. 同上，地官 · 司徒下，页 175。
36. 何志华:《吕氏春秋逐字索引》(香港，1994)，仲夏第五，页 22。同样，这儿以黑代缁、玄，以苍代青，以赤代纁。
37. 同上，季下第六，页 28。
38. 同注 8，页 86。

Lin Chunmei

The Dyeing of Textiles in the Warring States' Time

The earliest find of textiles in China, dated around 2700 BC is from the Qianshanyang excavation site in the ZheJiang province. But the textile findings which are astonishing in both weaving technique and ornamentation were produced in the Warring States Period (475-221 BC). By this time figured gauges, self-patterned monochrome "damasks" and multi-coloured clothes in warp faced compound were highly specialised. From their rich colours and splendid ornaments we can imagine the fashion of clothes at the time. The dyeing of textiles was not popular in those days. Even the ancient philosophers, after observing the dyeing activity transferred the dyeing phenomenon from the material to an intellectual sphere, for example: "the textile is sturdy white, so it does not become black by dyeing with iron-bearing mud" of "dyeing with green, it becomes green, dyeing with yellow, it becomes yellow".

This paper will focus on the used colorants and the dyeing of textiles. The excavation reports from tombs of the Warring States Period and written sources before the Han-Dynasty (206 BC - 220 AD) are the base.

Before explaining degumming and dyeing, the fashionable colours for textiles will be listed together with their original traditional terms to give a survey of the then used colorants. The used methods for the colouring of the textiles will be discussed: the first one relates to the application of pigments on the textiles, the second is the dyeing with dyestuffs of plant origin and mordents which will also be described. Finally several arrangements of colours on textiles will be shown. *See colour plate X.*

高汉玉　金馥兰

古代织染绣品文物的保护技术

摘要

我国各地遗址和墓葬出土的织染绣品文物，品种繁多，色彩绚丽。由于长期湮埋在地下，保存条件的不同，大部分已呈破损的残片，有的已受到严重的污染，对于这批珍贵的文物，必须采取有效的保护方法，才能使它不再继续老化和褪色，保持纺织文物的质地、色彩和纹饰。

出土纺织文物首先要检验纺织纤维原料和染色状况，进行消毒灭菌处理和清洗表面的污垢物。对于植物纤维的麻、棉制品，要主要选用碱性的消毒液和清洗剂：动物纤维的蚕丝，羊毛制品，要选择酸性的药品制剂。高温消毒灭菌的温度可选用 50-60° C，低温处理的温度在 0° C- –5° C。根据出土织绣品的状况，采取干洗或湿洗的措施。清洗时，要制备尼龙网架和浴槽，选用清洗剂要做好小样试验。尽可能保护其质地和色彩原状。

经清理的纺织文物残片，要进行相同品种、类型的修整加固，可用丝网加固法、玻璃夹持法等措施。大件衣物采用隔离密封等方法保存。库房贮存丝绸的温度为 18-20° C，相对湿度在 65 %为宜。

织绣品色彩的保护，可用一定厚度的甲基丙烯酸甲脂类的有机玻璃遮拦紫外光侵入引起的褪色现象。同时，可选用有效的抗氧化紫外吸收剂，喷涂织绣品表面或陈列展示的玻璃上，达到保护色彩的效果。

中国古代织绣品和衣装，品种繁多，色彩绚丽。它是人类进入文明社会的重要标志，也是中华民族文化艺术发展的客观反映。郭沫若说：“衣裳是文化的表征，衣裳是思想的形象”。历年来，经考古工作者发掘各个遗址和墓葬出土的各式纺织品和衣物，对于民族的繁衍生息，保护自身，美化生活等方面，有着非常重要的作用和地位。它也是研究各民族传统纺织技术进步和精神文化发展的主要历史见证之一。普遍引起各国考古学家和纺织史家的高度重视，并组织大量人力物力进行研究。过去对于出土的纺织品在纺织原料种类、纺纱、织布、印染工艺、花纹图案等方面研究较多。而对于已出土的和传世的纺织品衣物，怎样进行长期保存，管理？如何防止它进一步霉变、老化和颜料色彩的褪色等保护技术和方法？各国学者均感到困难。还缺乏系统研究。

本文从出土纺织品衣物进行妥善保护技术的特殊要求出发，以不损坏或少损伤质地和保护色彩为原则，现就出土实物清理的消毒、清洗方法、入库后的保护技术、管理条件等几个主要方面叙述如下：

一、材质检验

古代纺织品衣物的纺织原料，一般是分植物纤维的麻(葛)，棉和动物纤维的蚕丝、羊毛两大类型。通过纺纱、织绣、染印后，制成衣冠带履等衣物。全国各地遗址和墓葬出土的各种纺织品实物，如浙江余姚河姆渡遗址(约 7000 年)出土的苘麻合股纱线，河南荥阳青台村新石器时代遗址(距今约 5500 年)出土的纨、纱、浅绛色罗和麻布，苏中吴县草鞋山遗址(距今约 5500 年)出土的花葛布，长期漂埋在地下几千年，由于各遗址墓葬的保存条件不同，周围环境因素的差异。先秦时期的大部分已老化损坏呈残片(迹)状态。春秋战国时期有的墓葬，如江陵马山一号楚墓出土的纺织品衣物，保存较好，但受到尸体腐朽的血渍、油脂、肪渍、锈渍、混色渍等污染，以及微生物细菌、病毒等的附着物的侵入，因此对于出土实物清理中的消毒、清洗的方法和液溶剂使用，必须根据纺织原料的材质性能和印染颜料的品种特点，选择确当的保护技术和方法，才能基本完善地保护它的质地不继续受到损伤和引起色彩褪色等影响。

植物纤维中最早使用的韧皮纤维是葛、苘麻、大麻、苎麻、亚麻等。棉纤维是木棉、草棉作为纺纱原料，其纤维素结构主要是碳水化合物的单基葡萄糖，以六元环排列有碳位羟基和葡萄糖甙键联结而成链式大分子，其分子量较高。如棉纤维分子量可达二百万左右(聚合度为 1000-15000)，苎麻和亚麻更大，分子量可达五百万左右(聚合度为 3000)，所以麻纤维单强比棉纤维高。由于麻棉纤维素结构上含有三个羟基，它在酸性水溶液中会发生水解，即引起纤维大分子的甙键断裂，聚合度下降，强度降低。这种纤维素耐碱不耐酸的特性，在选用消毒、清洗剂时，要注意不用酸性液剂处理。

动物纤维中蚕丝和羊毛亦是我国最早使用贵重的纺织印染原料，主要是由蛋白质分子组成，亦称蛋白纤维。蚕丝是由 17 种氨基酸组成，其中甘氨酸、丙氨酸、丝氨酸等约占 80 %，丝胶主要是丝氨酸和少量的硫，它是耐酸性物质。如果在碱液作用下，会使价键断裂，质地发脆，强度下降。羊毛亦是多种氨基酸组成。其中角质元素中以精氨酸、丁氨二酸、麸氨酸和胱氨酸的含量较多，还有少量的硫，同样它有耐酸性质，故用酸性染料染色。如果在碱液作用下，会使胱氨酸价键和盐式键水解而断裂，角质纤维表面迅速破坏，强度会明显编成降低。因此，在选用蚕丝和羊毛的洗涤剂，去除织物表面的污染物时，特别要注意它的酸碱度性质。使织物质地和色彩获得有效的保护。1972 年，湖南长沙马王堆一号汉墓出土大批完好的衣物，主要是深埋水封的条件，棺液呈中性状态，对丝麻织物降价小，它仍有一定的强度，就是妥善保护的例证[1]。

古代纺织品衣物在出土时，色彩比较鲜艳。如消毒清洗不当，就会发生较严重的色彩剥落和褪色现象。对于秦汉前出土的染色和印花丝织品，首先要判定它是哪种类型的颜料品种，是矿物粉末颜料，还是植物色素染料，若是朱砂、石黄、石青等色彩，由于它靠丝织物的予处理后，采用浸染或

涂染等染色工艺，还是粘接剂混和后敷彩、印花工艺。一般是将出土的印染品实物，放置于充满蒸馏水或无水酒精的容器内浸泡。先去除浮色和表面的污染物。如果是植物色素染料的织绣品衣物，要先取残片，做局部性的褪色试验，确定它是哪种染料品种(茜红、栀子黄、靛蓝等)。其予检的方法是在残片下面垫一块滤纸或石蕊试纸，在被试织物表面滴上氨水，看试纸上有无掉色反映。如有掉色出现，可用2-5％的醋酸或5％的食盐溶液进行予处理的固色试验。再用显微摄影或电子测色法，对比其色彩变化情况。但要注意区别它是浮色污染，还是受到某种物质作用下的褪色。这样可以初步确定出土印染品上的色泽，在清洗前是否需要进行固色的予处理。对于印金(泥金、描金、贴金等)和织金锦上的片金线，它们一般均使用胶粘剂混合金粉，或用金箔粘贴在丝绵纸的狭条上。由于长期埋葬在地下水中，本身的粘接力很差，有的已经脱落[2]。如经洗涤，将会造成印制的花纹，剥落殆尽，失去原有金色光彩。因此，出土印染织物的纺织原料、染化料和加工方法的予测检验，它是文物保护很重要的措施和先决条件。

二、除尘消毒

纺织品文物出土后，先要检查实物残片的情况和破损程度。对大块、大件的保存较好的衣物和地毯，可用毛刷等除去表面尘土，或用吸尘器吸附清除织品中的尘埃污垢物。由于墓葬中随葬的纺织品衣物，一般都带有细菌病毒，又受到地下各种微生物侵蚀，必须进行灭菌消毒处理，以防止危害人体健康。常用的消毒处理方法是化学药品消毒和高温消毒。

化学药品的消毒的方法，是将取出湿态的纺织文物，用丝绵纸或棉布衬垫包覆，放入复合塑料袋内，注入配置好的一定量消毒药品。已经使用的有乙醇、甲酚皂液、四氯化碳等，还有用环氧乙烷(C2H4O)和二氧化碳混合物，经密封后，放入密封性好的房间内，放置时间3-5天，以保证文物上残留的病毒、细菌、微生物等有害物质，彻底消除。

高温消毒灭菌方法有蒸汽法，远红外法和微波法等。蒸汽消毒是将文物包覆后放入蒸汽箱中，温度一般掌握在50-60° C。因为细菌、害虫致死温度在40° C时， 8小时内均可杀灭。如果温度过高，会使文物发脆、散裂、褪色，要注意其变质情况。远红外辐射和微波辐射是利用高温热源效应新的灭菌消毒方法。在印染企业中，有远红外烘干机新设备，可以将大件的文物放入远红外烘柜或烘房中进行，温度可控制在60° C左右，时间要短，亦可达到高温灭菌效果。微波炉加热消毒灭菌法是比远红外法更为快捷、效果更好的新方法。它可根据出土衣物的品种规格状况，利用电磁波产生的热效应，迅速定时温控灭菌消毒，不会损坏文物质地和色泽。

现在国外的现代化博物馆，按计划对馆藏的衣物定期进行处理。尤其是精品、珍品衣物的陈列展示，研究贮藏保管，非常安全可靠简便。此外，低温消毒法，可以因地制宜，是经济实用的无污染的常用消毒法。纺织衣物上附着的虫卵、细菌，一般在0- −15° C低温条件下，便会死亡。如我国东北地区，最低气温可达零下30° C以下，平均气温在零度以下的5-6个月，可直接将纺织品衣物置于低温冷冻的条件下，消毒和保管。在其它季节，亦可用冰库、冰箱进行冷冻处理。

阳离子灭消毒法是近年来研制的杀菌新方法。它的作用原理是根据细菌的细胞壁和细胞膜由磷脂质双分子膜组成，呈负电性的物质。按物理学中异性电荷相吸原理，只要加入阳离子杀菌剂，于是带负电荷的细胞壁会被阳离子的正电荷所吸引，从而束缚细菌的活动自由度，抑制其呼吸机能，并促使细胞壁和膜彻底变形破裂，细菌迅速死亡。

据研制的阳离子表面活性杀菌剂介绍，用1:1000浓度的水溶液，在半分钟内能杀死金黄色葡萄球菌、绿脓杆菌、大肠杆菌和霉菌等有害病菌[3]。它对于纺织品衣物，毛皮的保护，可以直接喷晒于文物表面，就能达到操作简便，保持原貌，且无污染的良好效果。

三、清洗方法

出土的纺织品衣物经消毒处理后，必须有针对性的进行清洁处理。出土的衣物，一部分是遗址墓地的随葬品，一部分是在棺内穿着在尸体身上的，受到较严重的污染。如衣物随葬品在沙漠干旱和高寒地区，不在棺内出土、表面无严重的渍斑污垢物。一般可用干洗处理，对于棺内湿态的衣袍、裙裤、鞋袜等直接受到血肉、油脂肪、病菌等腐烂物而造成较大块面的顽渍重斑，必须进行重点的清洗。要根据出土实物的情况，如能用干洗法除污的，就少用或不用湿洗法为原则。以达到清除污渍，保护文物的目的。

干洗法的采用，要根据出土衣物的污染程度和保存的条件而定。如厚重型织物(地毯、绒毯、重锦、织金刺绣等)表面的渍斑未渗入内部，且污染面积较小，或多彩复色印染品，可选用发挥性强的溶液状干洗剂，如丙酮、三氯乙烯、四氯乙烯、石油醚等。对于一般性的污渍(混色渍等)局部渍斑，可用乙醇、丙酮、乙酸、乙酸乙酯等溶液干洗剂。用毛笔或毛刷蘸取溶剂擦洗，再用吸污力强的棉布和棉纸擦拭，直到清除干净。最后用丝毛柔软剂1％和醋酸稀液5％配成混合剂喷洒保护。

湿洗法是用于棺中尸体上的纺织品表面侵入油渍、血渍等污染的顽渍重斑，面积较大，异味难闻，以及轻薄的纱罗织物，印染衣物等，要配置专用洗涤清洗。要准备好清洗浴槽(陶器、搪瓷器或不锈钢器皿)，还要配备一定规格的平幅尼龙丝网(不锈钢丝网)作载体，并配好边框。网框只数、大小、视被处理的品种、面积而定。如清洗厚重型织物，大件衣袍、裙、裤等，可选用30目-50目丝网。轻薄型织物，小面积和破损衣物，可用60-100目的丝网。在清洗时，使污染物可顺利通过网孔沉淀于槽底。

洗涤剂的选用，以不影响出土衣物变质和褪色为前题。过去曾用中性皂片，现在有去污力强的丝毛混合型洗涤剂。其组合成分有乙醇、醋酸、醋酸乙酯、三氯乙烯、丙酮等以及丝毛等柔软型洗涤剂和蒸馏水等混合。清洗处理的方法和步骤是：先将需清洗的污染衣物平展置于丝网上，放入

洗涤液中浸渍。对于污渍严重的，可在液中存放1-2小时，甚至更长时间，使洗涤液渗透到纱线内层，再用毛刷在表面衣物清洗干净，不留渍痕为止。最后用蒸馏水，多次冲洗，使衣物上无残留的洗涤液。取出后在室内干燥，如太阳光暴晒会引起衣物干裂和褪色。或用温湿度可调自控熨斗整理，去除洁净表面折皱叠痕。保持衣物原有的平正状态。

四、修复加固

出土的纺织品衣物，由于在遗址和墓葬的部位和条件的不同，有的已碳化破损为残片，有的粘结在青铜器表面，有的和泥土叠压在一起。经清理消毒、洗净后，大部分呈多块分离状的残片。先要辨别它的品种质地、色彩、花纹的特点，进行同件、同类品种组织花纹的归集拼接工作。用丝网在织物背面加固，以避免品名在编号造册时的差错。对于厚重织物的锦绣残片拼接修复，使用尼龙丝网加固法，轻薄纱罗，可用高目数的尼龙丝网，或用南京博物院研制的一粒茧单丝按经纬向粘结的蚕丝丝网加固，经加固后，仍保持原有柔软性和光泽。有利于研究分析和保存原貌。

喷涂浸渍树脂法，是丝织物残片和丝质老化发脆的衣物，已使用的增强加固的方法之一。在丝绸表面喷涂醋酸乙烯，或尼龙浆料增加强度。如1956年北京定陵明墓出土的丝织品和衣物，表面喷涂后，现在已完全失去了丝织物固有的丝绢光泽、柔软性和弹性，已经变成硬化发脆的丝绸标本了，丝绒翻动时会掉下粉末。在国外还有一种减少丝织品损伤的保存法是浸渍合树脂液，如毛利登[4]试用丙烯树脂和水溶性聚乙烯醇树脂，据说以这个方法处理古代文物残片，织物纤维的原有柔软特性不会丧失，色泽几乎没有变化，反而比原来的鲜洁(色泽的本质没有变化，由于树脂液渗入织物，原来织物内外粘附的尘埃脱落，实际上起了一种清洗作用)。然而，微妙的一点是丝的本质丧失了，例如丝的精练程度无法知道了。染色加工过程中附加的还原剂、媒染剂也分不清了，于是失去了探索加工方法的资料，丝绸的风格也变了。因而树脂加固的方法，还要继续进行研究。

玻璃夹持法是织品常用的保存方法。过去的固定方法是用两块平玻璃把残片夹起来，用胶带在四周粘起来。这个方法确能达到简易固定的目的。但是，几乎全部的残片在平玻璃中有水分凝结起来。这个方法确能达到简易固定的目的。但是，几乎全部的残片在平玻璃中有水分凝结出来，有时候，玻璃碎了，丝织物残片会粘在玻璃上拿不下来，不粘在玻璃上的残片会在玻璃之间滑动。水分凝结，可能是由于残片本身不干燥，也可能是后来收藏的环境温度变化引起的。如果密封的玻璃之间凝结了水汽，而一般的玻璃是石英玻璃，玻璃中的碱质就会溶解出来而毁损残片。

平玻璃夹残片时，要连带夹一块面纱网，这样有一面是与玻璃隔开的，剥离时会容易些。网对丝织品的磨擦系数大，因而残片不会在玻璃板之间滑动。美国纽约美德罗普利堂美术博物馆染织品保管部长谷宣子女士收藏的一系列染色织物中，用了两种不同的夹玻璃的方法[5]，过了四十年，再打开进行比较。用的埃及第十一王朝时代(公元前2500年左右)的麻布(长二米到三十米，宽一米半)，在布角上用单宁酸和铁的混合液写上字，做上制造的标记，或者用同样溶液染的麻纱织成的布，在1940年剪下十厘米见方的几块，分别夹在玻璃板里。那块麻布，不论是在展出过程中还是收藏室里，都是暴露在空气中的，特别是折叠(按出土时状态)的外侧，强度很弱，容易粉碎，而剪下来保存在玻璃板里的，状况就比较好，布的颜色和当时夹入玻璃中时一样的白净鲜洁，全没有碎成粉末的危险。丹宁酸和铁染色的那部分，在发掘时因氧化已发脆，但由于玻璃板的保护，发掘之后又经过了四十年，仍旧经得住镊取操作，并保持着纤维的较好状态。

五、贮存保护

在古墓葬保存条件较好的纺织品和衣物，由于长期浸泡在水里或棺液内，它的物理机械性能和弹性均好。一般用上法先除去杂质和气味，再使织物保持干燥，以防止湿度大而发霉变质。日本布目顺郎教授介绍朝鲜乐浪汉墓的办法是把丝织物放在水中保存[6]。当丝绸放在水中，溶于水中的氧气会和蚕丝起作用，但等到这部分氧气消耗完了，水便起了隔绝空气的作用，这和丝绸埋葬于地下浸泡在水里的条件相似。我国在南方的大墓里出土的丝织品，如湖北江陵马山一号楚墓，湖南长沙马王堆汉墓，江苏金坛周墓，福建福州黄升宋墓等，均因有上述良好的水封特点，所以丝织品和衣物就完整地保存下来。

古代丝织品最合适的保存条件是一个重要的探索课题。尤其是象长沙马王堆汉墓和福建黄升宋墓出土大批的丝织品和整件的服饰，所占面积大，不能用玻璃夹片法等来进行技术保护。这些珍贵的丝织品和大件的服饰，有的要供科学研究，有的常年展览，有的要长期收藏在库内，研究、展览和收藏往往是交替进行，保存技术条件也随情况而变化。因此，日本的学者为了保存正仓院和各寺庙内的唐宋丝织品，曾组织专门力量研究丝织品保存的主要条件，如温度、湿度、光线、气流和空气等，对收藏在库内的丝织品变化情况。他们采用的保护方法主要是密封，因此，正仓院的丝织口每年开放两次，组织展览和科学研究。他们发现日本弥生时代，密封的瓮棺内的丝织品的保存状态是很好的。他们将出土的丝织品密封起来，放在地底下温度变化不大的地方，保存效果则更好。根据我国马王堆一号汉墓出土的丝织品和服饰，在棺内保存完好的技术条件[7]，这个汉墓的尸体，随葬品保存的技术条件是深埋和完全密封。这墓的木椁四周和上部填充了三十到四十厘米的木炭，它的外面又封固了六十到一百二十厘米的白膏泥，水和气体都不能从外面侵入。棺椁又深埋离地面二十米，完全密封，不受地面温湿度的影响。虽然在埋葬时大气湿度可能很高，由于白膏泥的密封，墓室里的湿气被周围的大量木炭(约一万多斤)吸收到一定程度，使墓室内部的湿度、温度(是摄氏13-14度)始终保持不变。棺内放满随葬品，里面没有空隙，裹着尸体的丝麻织品又浸泡在棺液内。所以棺内丝麻织品的颜色都非常鲜艳，质地也很好。出土的丝织品就不可能造成这种密封的保

存条件。湖南博物馆将马王堆汉墓出土的丝织品，用塑料袋中抽真空充氮气，放入木箱内，再放入柜内。库内用空调装置，保持一定的温度、湿度，使丝织品和服饰的保存条件，在类似密封而不受外界温湿度条件的影响状态下，已经保存 20 余年了。福建博物馆对黄升宋墓出土的丝织品，用木箱装好，再放入木柜内，库房内控制温湿度，均收到良好的保存效果。

国外的博物馆和文物保护研究的学者，也都在探索合适的温度、湿度保存条件。如日本正仓院办事处阿部弘氏提供的资料[8]。在 1949 年-1959 年十年里，对正仓院的气候调查结果，考虑正仓院新宝库库房内气温夏天凉，冬天也不比室外冷多少，不设置特别的冷暖房，湿度常年调节在 65 %。每日大气温差和库房柜内的温差比值是十分之一以下，室外与柜内湿度日变化的比值为千分之八。日本专家的意见也不一致，登日健三认为温度尽可能低，相对湿度 50-60 %[9]；斋藤平藏等认为湿度为 23° C，相对湿度为 60 %以下为宜：永田四郎等则认为温度为 15° C，相对湿度 75 %[10]。说相对湿度以 60 %为宜的根据是：在 60 %以上空气中水分与氧气在光的作用下产生过氧化氢，它会促使丝纤维退化(结晶构造破坏)，染色品退色加快，还可能产生霉菌而损坏文物；另一说是 60 %以下太干，会使文物很快退化，故以 75 %为宜。

美国美德罗普利堂美术馆对染织品保存的相对湿度为 30 %，美模里亚博物馆采用的温度为 4.5-15.5 ℃，相对湿度为 50 %。这低温低湿的保存条件，可能与他们保存麻织品和丝绸残片的具体情况而异。目前，对于整件大块丝织品的保存条件还没有肯定的结论。

1970 年，为纪念日本万国博览会，也为了后代人知道现在人的生活，由每日新闻社和松下电器公司主办，用超硬不锈钢做了两个内径一米的球，里面放了介绍现代文化特点的物品和记录，把两个时代资料容器重叠地埋入地下 8-15 米处。容器收纳的物品涉及 2098 项，其中包括各种纤维制品，与丝有关的春蚕茧(日本、中国、欧洲杂交的现行指定品种)，生丝(15 厘米的丝绞)，日枝(天然染料染成蓝色)，大岛、结城、本陈织，博多织，黄八丈，盐泽召，本纱织，京都友禅等，这些质地相似的织物卷成一筒放入塑料袋，再用不锈钢板做成的小箱装起来，放在资料容器上面的一部分。资料容器在密封前先抽成真空，再灌入干燥的氩气，使它的内部为一个大气压的气体情况。深埋的两个重叠资料容器，在上面的那个(No2)是三十年后，即公元 2000 年开启，以后每一百年开启一次，每次检查一下收藏物品，经过若干年后发生的变化。下面那一个(No1)一定要到五千年后，即 6970 年才能启封考察。埋设的地底温度是摄氏 17.5° C，资料容器内大约也保持这样的温度。丝织品在纳入容器的操作是在空气洁净的室内进行，同时作充分的杀菌处理。但织物装入塑料袋内的湿度不清楚。丝织品通过这种密封深埋，按上述年代开启取样试验，可以比较科学地系统地掌握纺织品变化的情况，这对于出土纺织品文物的保护技术研究是有积极作用的。

这两个资料容器分别于 1971 年 1 月 20 日(No1)和 1 月 28 日(No2)埋在大阪城内本丸迹，到了 1971 年 3 月 15 日，EXPO' 70 开幕一周年纪念日举行竣工仪式，同时移交给日本文化部管理。根据日本布目顺郎的预测，资料容器内收藏的丝织品，包括染色的，五千年后大概不会有什么变化。

六、色彩保护

丝织品的染色、印花和刺绣品的鲜艳色泽的色问题，亦是纺织文物保护的重点课题之一。日本铃木三郎等研究认为，氨、氧、潮湿的空气对丝绸染料褪色影响比较大，受光的影响较显著是盐基染料，其次是酸性染料，对其它染料影响较小，而光线中紫外线的影响最大[11]。在染织品展出时，尽可能用防紫外线的有机玻璃，如果用照明亮度，登石键三希望用 100 勒克司的低度照明。古代织锦中的蓝色丝，从纤维断面来看，蓝色丝中心处色泽深，而四周的纤维却有相同程度的褪色。说明空气中的氧气和潮湿比光线影响更大[12,13]。

关于丝绸残片夹持材料和色彩保护方法，美国美德罗普利堂博物馆木谷设计的夹持片，是用丙烯系合成塑料板为面层，以抵抗紫外光引起的破坏作用。丙烯系合成塑料板的原料是甲基丙烯酸甲酯(俗称有机玻璃)。据试验，它能遮栏 92-99 %的紫外线。这是保护丝绸衣物质地和褪色的重要性能。该博物美术馆使用的紫外线吸收型有机玻璃是杜邦公司出品的 UF3 Acrylite，厚度为 1/ 8 寸，和罗姆汉斯公司出品的 UF4 Acrylite，正面看无色或颜色很淡，能很好地透视丝织物。同时能防止紫外线引起的褪色现象。据日本 JISK6714 航空用有机玻璃试验，当厚度为 6.35 毫米(0.250 寸)时，波长在 290-330nm 范围内紫外线，其透过率在 50 %以下。日本的浅见高研究认为，无色丙烯塑料如果不加紫外线防止剂，它在紫外线部分的分光透射率从 2500A 开始即能透过，加上通常的紫外线防止剂后，波长在 3500A 以上有光线才能透过。它不吸收可见光，可见光的透率约 93 %(表面反射率为 7 %)。3 毫米厚的有机玻璃 Acrylite，对于 2500A-3000A 的紫外线光透射率为 20 %。若用同样厚度的紫外线吸收型有机玻璃，却只有 0.5 %。紫外线波长范围是 130A-3970A 之间[14]。日本正仓院的丝织品残片的保存，是将防紫外线的有机玻璃夹片，做成大型的照相薄，装入密封的纸板箱或木箱里，放在空气不流通的冷暗处。用时随时都可翻阅，十分方便。但是这种保护方法不能看到反面。对于衣物，或缂丝、双面绣品，就带来研究观察的限止。

丝绸的老化变质，染料的褪色，主要是紫外光照和受热两个因素引起的降解过程。美国 S. P. Hersh 等研究认为：丝绸受紫外线光照氧化，引起染料分子结构的分解，导致了丝绸颜色发生变化，尤以深色的褪色现象最明显，而加热则使颜色变暗。紫外光比受热对染料变色的作用影响大得多，光氧化使纤维强度降低[15]。对于出土纺织品衣物的颜色保护，尤其在博物馆里陈列展览，研究保管，显得特别重要。于是，研究选用抗氧化化紫外光吸收剂，对衣物进行保护的实验，正在深入地开展。因为抗氧化紫外吸收剂，能有效的吸收紫外光，并将其光能量转变成无害的热能形式而释放。国外几种主要的抗紫外光吸收剂是：

UV-531, 即 2-羟基-4-正辛氧基二苯酮，为浅黄色结晶粉末，溶于乙醇、丙酮，挥发性低，低毒。它能吸收 300-375nm 的紫外线。6-二叔丁基对甲酚，简称 BHT，为白色或浅黄色粉末或片状物。溶于乙醇、丙酮、醋酸乙酯等溶剂，无毒，无味。它是应用较广的非活性抗氧剂。能够有效地抑制空气氧化和热降解等。苯并三氨唑，简称 BTA。为无色或淡黄絮状结晶物。可溶于水、乙醇等。其酸性溶液不够稳定，但碱性溶液安定性良好，在高温时能分解出苯胺、硝基苯等有毒化合物，味苦，有微刺激性。BTA 由瑞士 Ciba-Geigy 公司首创，是目前国际上比较好的抗氧化紫外吸收剂，可有效吸收 300-400nm 的紫外光，稳定性高。它已在青铜器、铁器保护方面应用效果较好。中国的张雪莲在研究丝绸的抗氧化紫外吸收剂保护作用对比试验时，也证明了 BTA 对丝绸防老有较好的效果。同时她首次提出用天然芦荟叶萃取为白色粉末状固体，它易溶于水及有机溶剂，无毒，无味，无污染，使用方便[16]。芦荟素主要是蒽醌衍生物和芦荟苷类的苦味配糖物及树脂，它有润湿、保湿、抗氧化的特点，是优良的光稳定剂。芦荟和苯并三氮唑(BTA)，UV-531 等抗氧剂，在出土的丝绸残片上作老化褪色测试，对比其白度变化证实芦荟和 BTA 具有同样的抗氧化吸收紫外光的作用，能将有害的紫外光能吸收，转变为无害的热能释放掉。因此，天然芦荟是较好的抗氧剂和热稳定剂，它对于抗丝绸老化和颜料色彩保护，具有明显的效果。为出土纺织品衣物的陈列展示、贮存保管，提供了新的途径。

结语

通过以上古代纺织品衣物几种处理方法和保护技术的叙述，对于中国历代织染绣品的质、色、纹的系统保护，在收藏、保管、展览时怎样防止其继续老化和变色等复杂问题的研究，已取得重要的进展。但纺织品文物保护技术和方法，有它的特殊性和艰巨性，必须接受较长时间的考验。它有待于各地文博部门和文物保护技术的学者们，不断总结已有的保护技术经验，积极研究行之有效的科学保护方法。才能使历代多姿多彩的纺织品文物长期地保存下去，流传于世。为光辉的古文化遗产的保存和展示、科学技术史、文化艺术史的研究和发展，提供最珍贵的可靠的物证。

注:

1. 湖南省博物馆:《长沙马王堆一号汉墓》上卷，文物出版社，1973 年；高汉玉等:《长沙马王堆一号汉墓出土纺织品研究》，文物出版社, 1980 年；注：棺液的酸碱度 pH 值略呈中性偏碱性，故丝纤维断裂强度降低 90.1 %，易破损：麻纤维断裂强度损失 31.2 %，在无光照，低温条件下，颜料色彩保护较好。
2. 福建省博物馆:《福州南宋黄升墓》,文物出版社, 1982 年。
3. 上海汇德丰申隆药业公司已研制阳离子表面活性杀菌剂－新洁尔灭，可供选用。
4. 毛利登:"染织品の保存法",《古文化财产の科学》，第 3 号，1952 年，第 21-26 页。
5. 布目顺郎:《养蚕の起源と古代绢》，附件，雄山阁，1979 年，第 437-454 页。
6. 布目顺郎:《养蚕の起源と古代绢》，附件，雄山阁，1979 年，第 437-454 页。
7. 顾铁符:《试论长沙汉墓的保存条件》，考古，1972 年第 6 期，第 53-58 页。
8. 日本正仓院事务所保存科科长阿部弘氏的信，1977 年 5 月 9 日：喜多村一男:"正仓院之气象"，大管区气象台，1960 年，第 23-25 页。
9. 登石健三:《古美术品保存の知识》, V, VII, 第一法规出版，1972 年。
10. 永田四郎: 1966 年，日本气象协会关西支部，大管区气象研究会上发表的论文。
11. 铃木三郎、林田朴:"在各单位浓度气象的湿润空气、干燥空气中，各种色素在日光曝晒下的褪色现象"。《蚕丝，科学研究汇报》，第 2 卷第 1 号，125-126 页，1948 年。
12. 登石健三:《古美术品保存の知识》, V, VII, 第一法规出版，1972 年：永田四郎: 1966 年，日本气象协会关西支部，大管区气象研究会上发表的论文。
13. 铃木三郎、林田朴:"在各单位浓度气象的湿润空气、干燥空气中，各种色素在日光曝晒下的褪色现象"。《蚕丝科学研究汇报》，第 2 卷第 1 号, 125-126 页, 1948 年；铃木三，森田朴:"染色绢とその褪色研究"(1),《蚕丝科学研究汇报》, 2 卷 1 号, 125 页, 1948 年。
14. 浅见高:《丙烯酸树脂、塑料讲座(12)》第 57 页, 157 页, 1978 年，日本工业新闻社。
15. S. P. Hersh: Advance in Chemistry, 212; American Chemical Society, Washington, DC, 1986, pp.111-127。
16. 张雪莲:"古代染料的剖析及丝绸的保护"(丝绸老化保护试剂的筛选), 1992 年，第 38-60 页。

Gao Hanyu and Kim Yinglan

Techniques to Protect Textile and Embroidery Relics

The textile and embroidered relics excavated from the ruins and tombs all over China are varied and often coloured. Most of them are broken fragments and some have been seriously damaged due to their long stay underground. Effective protective methods and techniques have to be adopted to protect these valuable relics from further decay, aging and fading and to maintain their texture, colour and patterns.

The first thing to do when conserving textiles is to examine the dyeing conditions of the raw textile fibre material, then sterilise the material and finally clean the surface to remove the dirt.

Alkaline disinfectant needs to be used to clean flax and cotton fabrics of plant fibres while acid disinfectant needs to be used to clean silk and wool of animal fibres. 50 - 60° C is the right temperature for high-temperature disinfection while 0 - 15° C is suggested for low-temperature treatment. Whether to use a dry-cleaning or wet-cleaning technique must be determined by the condition of the unearthed woven and embroidered fabrics. Before washing, nylon racks and washing grooves should be prepared and a small sample test should be made before deciding on the cleaning agent. A priority is to keep the texture and the colour intact.

The cleaned textile fragments should be repaired and reinforced by using measures such as silk-screen strengthening, glass clip holding, etc. Large pieces of clothings are to be kept separately and sealed off. The best temperature for silk and satin storage is 18 - 20° C and the suitable relative humidity is 65 %.

To protect the colour of textiles and embroideries an organic glass of methacrylate ester in the right thickness should be set up to keep out ultraviolet light, which causes fading. In the meantime, an effective anti-oxidisation ultraviolet absorbent may be sprayed on the fabrics or the protective glass to protect the colour of the exhibits.

高汉玉

中国先秦衣装颜料色彩与文化

中国是世界文明古国，礼仪之帮，衣冠带履，锦绣天下。我国地大物博，色彩资源极其丰富，色彩文化积淀厚淳。在古代对“彩色”、“采色”、“綵色”之称谓。“彩”是指矿物质料的天然颜色，“采”是指植物(动物)素质的原有采色，“綵”是丝帛染印的仕上色泽。这三者既有物素上的区别，又有应用上的统一。我国的上古先民从爱美、审美的原始色彩观念出发，是最早发现和使用矿物颜料制彩陶、染衣裳的民族之一。对于古代色彩名物的定义、分类以及光色和物体色的基本现象原理的认识，已有三千余年的历史。“未用谓之彩，已用谓之色”《尚书·正义》引注。未用之彩是自然固有之色；已用之色则是人化(制作)之彩。这就阐明了“色”与“彩”的内在联系和辨证关系。

中国色彩名物的起源与发展，大体上经历了原始社会的“三彩”(赤、黄、黑)，夏商周时期形成的“五色”(青、赤、黄、白、黑)，秦汉时期的“七綵”(赤、缥、黄、绿、青、蓝、紫)，唐宋以后的“九色”(赤、橙、黄、绿、青、蓝、紫、黑、白)四个阶段。本文根据考古发现的器物色彩实物为主线，结合典籍史料的记载，现试就先秦时期色彩的粉质颜料和色素染料的两大类型，使用彩绘、涂染、浸染、媒染、印花等工艺技术，彰施于衣物(器)上的萌芽，成长，壮大和拓展的系统发展过程作些探讨，并从彩陶文化、青铜文化和丝绸锦绣文化等方面，说明古代的色彩名物在中国文明发展史中的作用和地位。

一

色彩是存在于自然界天地万物中固有的素质。它是人类认识自然本质的直觉官感之一，也是最早用来表达原始审美意识观念的重要标志。远古先民们认识色彩，应用色彩历史悠久。在旧石器时代原始部落氏族已有了色彩的审美观念。北京周口店山顶洞人遗址(距今约二万年)中，考古学家发现遗骨下用一层红色粉末铺垫，经鉴定，它是赤矿的赭石(Fe_2O_3)，赭石粉末就是最早的赭红颜料实物。同时，山顶洞人用赭红粉末涂在穿空的小石珠，鲩鱼骨，兽牙，海蚶壳等空和沟漕内，并串缀在一起，象项链一样挂于胸前，手腕上，以示装饰美[1]。据此，可以推测串缀的线绳是被涂上赭红颜料。这种涂颜着色的行为，意味着原始染色技术的萌芽。它亦是原始先民们最早以色彩表达审美意识的物证。

在仰韶文化时期的新石器时代遗址发现的彩陶，最具彩陶文化的色彩性。如陕西西安半坡遗址(公元前4115±100 年)的彩陶上有用赭红，黄，黑三种颜色烧制的人首(戴帽)虫身，鱼网纹等图象。作为氏族的标志-图腾(totem)。青海省大通县上孙家寨新石器时期遗址(公元前3300 年)出土的三组“五女携手舞蹈”彩陶盆上亦有赭、黄、黑三种色彩。陕西宝鸡北首岭遗址(公元前5850-前5400年)发现随葬条状或小块的赭红、黄色颜料石和粉末。浙江余姚河姆渡遗址(公元前 5000 年)出土了涂朱红色的漆碗，双凤朝阳图象的蝶形器，似蚕纹雕刻的小盅等装饰品。湖北京山屈家岭文化遗址(公元前 3000 年)早期出土的整套彩陶纺塼(轮)，有其重要的纺织文化特征，先在陶纺轮两面涂石黄陶衣，再在单面绘赭红色的同心圆纹，漩涡纹，三角纹，弧线纹等。第一次发现的薄胎(黄泥质)晕染彩陶杯类器具，它是在灰、黑、红或橙黄色的陶衣上，用黑色彩绘出框格，网纹，绳条，垂幛等纹饰。富有无级层次的晕色效果。确是五千年前的色彩艺术精品[2]。河南郑州大河村遗址(公元前3790年)出土的彩陶以白衣(蜃灰)紫红彩陶以敷彩为特征，如用黑色、红色或赭红色彩绘，施淡黄色和白色陶衣，制成太阳纹、网状纹、钩叶纹、绳纹等纹饰。

色彩颜料的制备和彩绘工具，在新石器时代中期已有实物可证。如甘肃兰州东郊白道沟坪属马家窑文化期遗址的窑场，发现了5组12座陶窑，其中有一个备料坑，内有制造陶器的熟料和余料，并出土有研磨颜料的石板和杵棒，以及配色调料的陶碟，陶碟分格，中配紫红色颜料[3]。陕西临潼姜寨遗址(公元前 4600-前 4400 年)出土的彩陶上绘有黑、灰、蓝三色花纹，还有黑色颜料黑锰矿石(Mn_3O_4)数块和粉末。同时出土的一套彩绘工具计有石砚(臼)、砚盖板、磨棒、灰陶水杯、在砚凹和盖板上有残留的黑颜料共五件，它是我国发现最早的配套研磨颜料和彩绘着色的工具[4]。至于赭红颜料，在江苏邳县大墩子遗址(公元前4500 年±105 年)发现4块赤铁矿石小块表面有研磨痕迹，石杵、石板上附着朱红颜料粉末。山西夏县西阴村遗址(属仰韶文化期)中发现一个下凹石臼和破断石杵，表面上附有朱红颜料粉末。这一系列的考古发现的颜料，并非孤证，足以说明原始氏族先民已认识到利用赭石粉末、石黄的风化物，以及锰黑石粉粒，再经石臼、石杵等简单研磨工具，制备彩陶所需的矿物颜料细粒度的事实。

关于布帛织物上的着色，衣裳上的涂色的问题，曾有学者推测它是先民们用色料纹身(面、手)的延伸，逐步发展成为日常的美化装饰，为织物涂染色彩的起源获得了启示。即将原始纹身的审美习俗转移到织物(绳带)美化衣裳。这可能是原始织物上色的起源。1987 年，河南郑州荥阳青台村遗址(公元前 3500 年)发现了丝质的纱、纨和浅绛色罗残片，以及几块麻布片实物。这是我国第一次出土的染色丝织物的佐证，也是世界上最早的用赤色颜料涂染的实物[5](图1)。从浅绛色罗上折断下来的经纬线残断分析。其一，单丝表面丝胶残留较少；其二，单茧丝间呈分离半松散状态等特点，赭红色彩已渗入到纤维之间。这就说明罗织物在涂染上色前，先经过用灰水练或煮练的脱胶工序。它使丝织物具有丝光感和柔软性。同时增加了颜料色彩对丝纤维的着色率。至于赭红料的颗粒细度问题，粉末色料的微粒，在5微米以下，便可涂染上色。从这块浅绛色罗残片的色彩退色

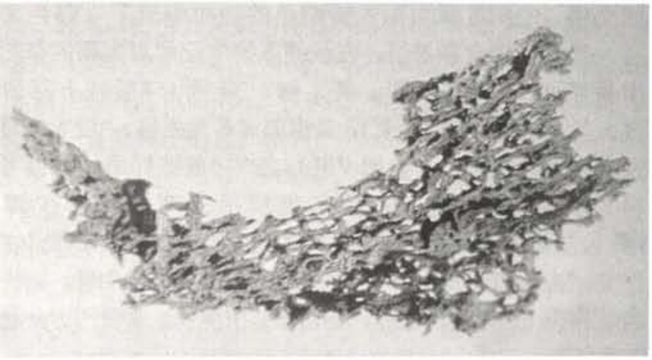


Fig. 1. Light dark red silk gauze, 1987 found in the ruins of Qingtai village (3500 BC), in Xingyang, Henan.
图 1. 河南青台村遗址的浅绛色罗。

程度来看，可能是长期湮没在地下，表面的粗粒子剥蚀，色彩就淡而浅了。但经纬丝之间附着明显的赭红色料，足以证明它是经过涂染加工的第一块染色织物。

夏代以前彩陶文化中的"三彩"赤、黄、黑原始色彩观念是怎样形成的？为什么红(赤色)又是人类最先使用的色彩呢？这可能是原始部落先民存在一元太神阳崇拜的信仰问题。在中国新石器时代的大量器物(彩陶、岩画等)上装饰刻划着"+、⊕、⊙、卐、[illegible]"等纹饰。这是日神(太阳神)符号的象征[6]。太阳代表着光明和生命。氏族先民首先见到的是朝夕的红太阳和"赤日炎炎"的自然现象；其次是鲜红色的血液象征生命不息，子孙繁衍；再次是红色能给人们温暖、醒目、刺激的感觉(如红太阳、火焰、鲜花等)，依据中外许多学家的调查考察，赭红色是首先用于图腾、纹身(面)的第一保护色，传说有祛兽、辟邪、护身的作用。因此，赤红色是上古氏族普遍崇敬的色彩。并采集易得的红土制红陶礼器和用具。并使用赤铁矿粉末涂染着色织物，纹身和保护美化生活。

二

夏商周时期，农牧业、手工业等有了相应的发展，手工业中的制陶、冶铜、织绣等生产技艺亦有较大的进步。用于器物敷彩着色的颜料品种不断扩大。颜色已从新石器时代的"三彩(赤、黄、黑)"扩展为"五色(青、赤、黄、白、黑)"，并应用于衣物上。《尚书 · 虞书》记载，传说帝舜令夏禹做衣裳的故事："予欲观古人之象，日、月、星辰、山、龙、华虫(彩雉)作会(画绘)；宗彝、藻、火、粉米、黼、黻絺绣。以五彩彰施于五色作服(衣裳)"。这种章服制规定前六章上衣花纹是用颜料敷彩画绘，后六章的下裳纹饰是用彩线刺绣加工的。《周礼 · 考工记》载："画绘之事，五彩备，谓之绣"。"画绣二工共其职也"。《礼记》"衣画而裳绣，奉五色"。这里的"五采"是指青、赤、黄、白、黑，"五色"是指布帛经彩绘、印绣的颜色。夏商时代，由于朝廷提倡耕织经济，蚕桑丝绸印染手工业得到较大发展。商代朝廷设"女桑"、"上丝"官吏，专职负责蚕桑，丝织印染品的征集和生产，珍贵的丝绸，绚丽的色彩，官府王室对衣裳和装饰品等需用量大增。据《管子 · 轻重篇》载："昔者桀(夏代帝王)之时，女乐三万人，端澡晨乐，闻于三衢，是无不服文采衣裳者。伊尹以薄之游女工文绣，纂组一纯，得粟百钟于桀之国"。《帝王世纪》载：商纣"多发美女，以充倾宫之室，妇女绫纨者三百余人"。(《帝王世纪辑存》，1964 年版)。《说苑 · 反质》引墨子对禽滑里说："纣为鹿台糟丘，酒池肉林，宫墙文画，锦绣被堂，金玉珍玮，妇女优唱，钟鼓管弦，流漫不禁，……非惟锦绣絺苎之用耶？"。可见，在夏商时代，色彩丰富的锦绣纂组丝织品，单是供王挥霍达到惊人的程度。另一方面说明了，颜料色彩品种增加、丝帛染色工艺技术得到了相应的发展。

商代对于青赤黄白黑五色现象的系统认识，"五色"观念的形成，已有三千余年的历史。在殷墟的甲骨文中发现青、赤、黄、白、黑的名称，导源于光的色泽。"五色"词汇，均以火字来组词。如熊熊燃烧的炎火发出赤色光，随着火势温度的变化，火的色光会变成黄色光、白色光、青白色光，最后残留炭黑色。这种火的光色现象与现代色度学中的光谱色相原理的加法混合律是基本一致的[7]。甲骨文中"五色"是：

赤色，大火之光色。赤的古字为"灻"。甲骨文中有"[illegible]"、"[illegible]"、"[illegible]"等象火燃烧的象形字。卜辞：赤为颜色之名，象炎火的色彩。《说文》：赤。南方之色，从大火。

黄色，火的光色之一。黄的古字为"[illegible]"。甲骨文中有"[illegible]"、"[illegible]"、"[illegible]"等象形字。《说文》："黄，地之色。从田从炗。炗，古文光"。《释名》：黄，晃也。犹晃晃，象日光色。盛夏，太阳黄金光色。

青色，火的光色之一。青的古字为"[illegible]"。甲骨文有"[illegible]"、"[illegible]"、"[illegible]"等象形字。《说文》："青，东方色，木生火，从生丹"。

白色，火的光色之一。白的古字为"[illegible]"、"[illegible]"，犹如火烛之光。甲骨文有"[illegible]"、"[illegible]"、"[illegible]"等象形字。《庄子 · 人间世》："白，日光所照也，太阳光色"。《说文》："白，西方色。阴用事，物色白。从入合二"。它和光色相加得白色的互补原理相吻合。

黑色，火熏之光色。黑的古字为"[illegible]"，表示火所熏烤之色。《说文》："黑，火所熏之色也"。《释名》："黑，晦也。如晦螟(夜)时色也"。

颜料色彩是自然界物质色料和光泽，对人体视觉的客观反映。矿物颜料"五色"中的青色和白色，是由于商代青铜文化的发展，在大量采集铜矿石料，冶炼青铜器时获得的副产品。而被发现和使用于器物的色泽。如青色颜料是石青，亦称大青、扁青，采自蓝铜矿石的共生物($2CuCO_3 \cdot Cu(OH)_2$)的粉末，色呈蓝青色。另一种青铜绿颜料，采自孔雀绿石($CuCO_3 \cdot Cu(OH)_2$)。它是一种结构疏松的碱式碳酸铜，犹如铜器表面生成的铜绿，色呈青绿色。孔雀石绿，亦称空青、青腰。《周礼 · 秋官》："职金，掌凡金玉锡石丹青之戒令"。郑玄注："青，空青"。这种青色颜料是商代开发的品种，它是衣裳和器物彩绘常用的色料。

白色颜料是锡石，亦称粉锡、铅白($Pb_2(OH)_2CO_3$)。它亦采自铜矿的共生物。也是青铜器冶铸的主要成分之一。《墨子佚文》："禹造粉"。张华《博物志》载："纣烧铅锡作粉"。世称"殷白"。这里的粉锡，是碱式碳酸铅，又名胡(糊)粉。它在使用时调成糊状，作白色颜料，故名胡粉。另

一种白色颜料是蜃灰(即贝壳灰粉)。《周礼·掌蜃》:“祭祀共蜃器之蜃”。汉郑司农注:“蜃可以白器，令色白。”周代设掌蜃的官吏，负责采集烧制的蜃灰作白色颜料，并在器物上描白敷色。

赤色颜料是朱砂，亦名丹砂(硫化汞 HgS)，色呈朱红色。在周代，由“职金”管理的重要赤色颜料。商代出土的丝织品中用赤色颜料朱砂涂染的织物较多。如北京故宫博物院收藏的商代玉戈，正反两面均留有丝绢和麻布痕迹。织物表面的纤维上渗有朱砂。河南安阳殷墟妇好墓出土的花绮和绣线实物，均是染过朱红色料的。陕西岐山贺家村西周早期墓出土的丝帛残片，有染着朱砂颜料的痕迹。陕西宝鸡茹家庄西周幕出土的卷草纹锁链绣残迹，绣线朱红色，仍非常浓艳[8]。关于赤色颜料中的朱砂颗粒的细度问题，是否已具备织物和绣线染色的条件呢？北京平谷刘家河商代墓出土的朱砂，使用显微镜观察了朱砂颗粒的大小如下表 1：

单位：微米(μ)

粒子长度	30μ 以上	10-30μ	5-10μ	3-5μ	3μ 以下
颗粒数	0	14	54	120	很多

Tab. 1. Particle size of cinnabarpigments.

注：此表引自《中国纺织科学技术史》古代部分，科学出版社，1984 年。

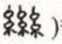
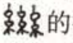
上表中所列朱砂微颗粒经研磨精制在 3-5 微米以下的超细粉末状态，就可用于丝帛、绣线的石染着色[9]。在古籍中记载的“朱殷”、“殷红”，可能是指用朱砂染的朱红色。又如商殷王朝占卜祭祀用的“祭红”，后世称为“霁红”，因色泽如朝霞霁红色而得名。它亦是用朱砂所染的大赤色丝织品。至于赭石粉末所染的赭红色，因其色泽较黯，以后渐被淘汰。《荀子·正论》：“赭衣而不纯”。后来，赭衣成了囚犯的标识衣裳了。

黄色颜料是石黄的粉末，石黄分雌黄(As_2S_3)和雄黄(AsS)两种，雌黄黄色纯正，雄黄是带红光的黄色。陕西宝鸡茹家庄在西周墓出土的刺绣残痕，有赤黄褐棕四种颜色，其中黄色绣迹是石黄所染。由于石黄色泽纯正，耐光性好，是常用的黄色颜料。

黑色颜料是黑石(锰黑)粉末，常用于陶器彩绘。在衣裳上的黑色是松烟，亦称炭黑色。由于“殷尚白，周尚赤”的习俗，周代另设有“掌碳”的官职，因松烟色牢度差，故一般在衣裳上很少使用黑色颜料。在春秋战国墓出土的丝织品上，使用黑色的实物是非常少的，有的黑色是用(植物)皂斗黑色素染成的黑色所替代。

商殷时代以青铜文化为特征，发展起来的青赤黄白黑五种色彩。已普遍用于织绣衣裳和彩陶漆器等器物的染色、敷彩，以供王室享用。但商王朝时尚的色彩，以“素白”为尊贵色。《礼记·檀弓上》:“夏后氏尚玄，殷人尚白，周人尚赤”。有些论著对于“殷人尚白”，多用“五行相克”的说法来解释。其实，“殷人尚白”，以白色为吉，白色为贵的色彩崇尚习俗，由来已久。首先，殷人尚白是由对太阳神崇拜而引起心理上的特征反映。殷人的祖先是东夷族支系，普遍存在对太阳神崇拜的习俗。太阳是光明的象征，给氏族带来幸福生活。先民直观太阳光是白色的进而形成了以白色为吉，为贵的观念和习俗。在殷墟卜辞中记载对太阳的祭祀名目繁多，有“宾、即、既、禘、御”等(《殷墟卜辞研究》，科技篇，第 3-4 页)。又据郭沫若先生称：“殷人于日之出人均有祭祀……盖朝夕礼拜之”(《殷墟粹编·粹编考释》，第 354 页)。相传东夷族祖先有太皞，少皞(昊)，“皞”、“昊”是取其光明之义，是先民对太阳崇拜在字义、字形上的体现。传说中的白帝少昊氏是光明神、阳光的管理神，后人称为白帝，穿白衣、白虎纹，掌管西方，秋天象征色。

其次，商殷以白色为吉祥，从事各种活动。传说成汤时，连续七年大旱，汤以身祷于桑林，雨。“汤之救旱也，乘素车白马，著布衣，婴白茅，以身为牲。”《尸子》的记载，留下了商殷“尚白为吉”的色彩倾向。故殷人作战时驾白马，“戎事乘翰，牡用白”。旗用白色，称为“殷之大白”(《礼记·明堂位》)。商殷的车辆用木料制成，不用色彩装饰，故称为“素车”(《礼记·礼器》)。商殷最贵重的器物是青铜器，除此之外是白陶，白陶是用高岭土烧制，色泽皎洁，素净细密，专供王室使用。商殷遗址墓地出土的白陶量少，显然只有贵族使用的遗物。还有出土许多白色玉人与玉石首饰器物陪葬品。这些都说明了“殷人以白为吉”的民俗文化。

再次，“殷人尚白”表现在庆典、祭祀等礼仪活动中，均以白色为贵。商殷王朝对轻软洁白的蚕丝生产，丝绸，当作是国计民生的大事。《史记·殷本记》载:“帝大戊立，伊陟为相，亳有祥，桑谷共生于朝，一暮大拱。”朝廷专设“女桑”、“上丝”等官职，从事管理蚕桑丝绸业生产。每年以隆重的庆典仪式，祭祀“蚕神”，祁求雪白蚕茧丰收。在殷墟出土的甲骨文卜辞中，祭祀蚕神有 11 块。如殷王武丁时占卜：“戊子卜，乎省于蚕，九。”(《甲骨续存补编》7402)说明朝廷呼人省察蚕事，占卜至少有九次之多。殷王祖庚、祖甲时卜辞说：“蚕示三宰。八月”。陈怀邦说：“蚕示”即蚕神，“宰”为一牡羊-牝羊之合称。这是说在八月祭蚕神，用三公三母的白羊六只。祭“蚕神”仪式，非常隆重。卜辞中还有“蚕王”之称。“蚕”和“王”，被臣民赋于最高的尊崇(《殷墟书契前编》六·六七)。殷人视蚕为天虫，是“蚕神”所赐洁白光亮的蚕茧丝帛，给人们带来最高贵的衣料。甲骨文卜辞中的“桑”字一般公认的 24 字，如果“桑”字表示方国名，地名(产地)，以及“丧”字的借假字计有二百余见(《甲骨文字释林》，上卷，第 75 页)。卜辞中的丝字(、、、)等，计从系的字形 81 个，从丝的字 16 个，从的字 3 个，总共有 100 字。如果将有“丝”旁有关的象形字数量在 150 个以上。可见，商殷王朝对于蚕桑丝绸生产的倡导，王室贵族们对丝绸贪婪的享用，达到了十分惊人的程度。它更增加了“殷人尚白”的崇敬心理。丝绸品种和生产技艺，均得到了较高的发展。

从商殷时期出土的丝织品残迹，如殷墟妇好墓，大司空墓，河北藁城台西村遗址，北京琉璃河商遗址等贵族墓葬中的实物品种，如纨、纱、缟、素、绢等均为白色(本色)丝织品、衣裳、巾、幔、旌、旗等物品，也是以白色为流。并有色彩(朱红、浅绛，土黄等)的绮、绣、组带，绳、缨作为装

饰。殷人以白色为高贵吉祥色，祭祀礼仪，庆典时用它；悼念亲人葬礼上的哀衣，孝服，也视白色为贵。这种缟衣(生丝织)缌布(洁白麻布)，披麻戴孝(白)的“殷人尚白”的习俗，一直流传于后世。

三

西周自周公姬旦辅佐成王后，朝廷对王室、官吏的冕弁，衮(九公)衣，规定了色彩、花纹、质料和绘绣工艺相结合的“九章衣制”。据《尚书·虞书》：“以五采彰施於五色作服(衣裳)”。《左传·昭公二十五年》：衣裳是“九文、六采、五章以奉五色”。《礼记·玉藻》：“非列采不入公门”。色彩已是周代“以别贵贱等级之度。”并作为衣装分主次、等级、尊卑等意识观念的政治色彩了。由于官府对色彩的重视和衣物的需求量激增，在石染色彩的基础上，又大力发展了“草木染”的色泽。周代朝廷设立了“掌染草”(掌以春秋敛染草之物，以权量受之，以待时而颁之)(《周礼·地官》)。“染人”掌染丝帛(《周礼·天官》)。“锺氏染羽”(《周礼·考工记》)。《周礼·月令》：“是月，命妇官(典妇功)染采黼黻文章”等官职。以保证色彩衣料的供应。又据《考工记》载：在衣物上的敷彩上色，有“设色之工五”，即“画、缋、钟、筐、㡛”五种专门工师来负责制作。就是按《周礼》中礼仪的规定，生产冕衮制的色彩衣料。这种以植物(草木)色素进行染色加工成“青、赤、黄、白、黑”五色的丝帛，无疑是周代染色技术发展的最大成就之一。而且在色彩的品种上，数量上已达到了相当规模。使周代的衣冠带履更加多姿多彩。它在世界的色彩与文化发展史上确立了十分重要的地位。现根据《诗经》、《周礼》、《礼记》、《考工记》、《尔雅》、《左传》等先秦著作，以及各地诸侯贵族(楚墓)等出土的丝织品与衣物上所反映的色彩实物，按植物染料的“五色”序列于下：

蓝草，染青蓝。它是一年生草本，六、七月间，蓝草叶呈绿色，即可采集。采后随发新叶，隔三个月又可收割。用鲜叶发酵，氧化缩合成靛蓝素($C_{16}H_{10}N_2O_3$)，是靛系还原染料。《诗经·小雅》：“终朝采蓝，不盈一襜”。《礼记·月令》：“仲夏令民毋刈蓝以染”。蓝草有数种，这里是指蓼蓝，为布帛普遍使用的青蓝色染料植物。天然靛蓝($C_{16}H_{12}N_2O_2$)，因其成分中含有20%的靛红素，尚有少量的靛棕素及黄色素存在，故色泽是带红光的蓝色。至于《易经·坤卦》中的“天玄而地黄”、《周礼》中的“玄衣纁裳”、“玄冕”等中的玄色，应是天空色或天青色。因这种玄色，当时还不能用蓝靛染得，“玄”色、是玄幻莫测之意。万里无云，见到的是幽远的天青色(玄)。直到战国时荀况《劝学篇》中有：“青取之于蓝而青于蓝”名句，才说明有了真青色。这就是在靛蓝染色中要抑红存青，染色时温度和碱还原的浓度不能过高，才能去除靛红素，得纯靛青素的青色效果。东汉《说文》中的“玄”是“黑而有赤色”。也不能误为黑色(《丝绸史研究》1994, 1期)。

茜草染绛。茜草，又名蒨草、茹藘、茅蒐。《诗经·郑风》，“缟衣茹藘”、“茹藘在阪”。《说文》：“茅蒐茹藘，可以染绛。”注：一名茜，今之蒨也，染绛。(《尔雅》注)。它是多年生攀援草本。春秋两季采挖其根，切碎，以热水提炼得茜赤素(深红)。其主要成分为茜红素($C_{14}H_8C_4$)和茜紫素($C_{14}H_8O_5$)。它是周代常用的赤色系染料。茜素是媒染性植物染料。使用媒染剂(铝盐、铬盐等)不同，所染的色泽有深浅。其中以铝媒染剂得色最鲜艳。《尔雅·释器》：“一染谓之縓(黄赤色)，再染谓之赪(浅赤色)、三染谓之纁(绛色)”。又《周礼·锺氏》：“三入为纁(绛色)，五入为緅(青赤色)、七入为缁(赤黑色)”。说明茜素是多色性染料。须经多次及复染得深色。《说文》：“绛，帛大赤色，即大红色(深红色)”。《说文》：“绛，帛纯赤色。”绛(朱红色)淡，为日中之色；大红浓，为日出之色。日中贵于日出，故天子朱市，诸侯赤市。绯色，即赤色。《说文》：绯，帛赤色，茜草染得。绯色，绯大红色、比绛色浅的赤色。这里的“赤”应与当时的间色红(粉红)予以区别。不能笼统的将朱、赤称为“红色”。(《流行色》，1988年，1期)。

栀子染黄。栀子实黄色素($C_{21}H_{22}O_9$)色泽鲜艳。在战国出土丝毛织物上已有应用。又菉草染黄。菉(绿)草，又名荩草、莀草、盭草。《诗经·小雅》：“终朝采菉(绿)，不盈一匊”。《诗经·邶风》：“绿衣黄裹”、“绿衣黄裳”。《尔雅·释草》：“菉，王刍”。《说文》：“莀，草也。可以染留黄”。荩草是越年生草本，茎杆细，分数枝，叶长披针形。其茎叶中含黄色素。主要成分是荩草素($C_{21}H_{16}O_{19}$)(《中草药成份化学》，第323页)，是黄酮类媒染染料，可直接染丝毛织物得黄色。《本草纲目》：“此草绿色，又名莀草或盭草。莀、盭乃北人呼绿字音转也，可染黄”。若用铜盐为媒染剂或放在铜器内染色，可得鲜艳的绿色。故而荩草原名为绿[10]。(《中国化学史稿》，1964年，第74页)。柘，又名柘木，奴柘，柘桑等，亦是黄色染料，《诗经·大雅》：“其檿其柘”。根皮煮汁液可染黄。还有鬯草，又名薑黄，郁草(金)等。《诗经·大雅》：“秬鬯一卣(有)”，是多年生草本，地下有卵形根茎及筒状块茎。用其根茎的黄色素酿酒及染帛，色黄如金。《本草纲目》：“郁金(俗名)生蜀地及西域，染色用其茎(浸泡沸煮液直接染丝帛)。染妇人衣最鲜明，惟不耐日炙，微有郁金(香)之气”。可以推测我国西周时已有郁金香味金黄色衣装了。

皂斗染黑。皂斗即栎属(包括栩，柞，麻栎等)树本的果实，是主要的黑色染料。《诗经·小雅》：“翩翩者，集于苞栩”。《诗经·秦风》：“山有苞栎”。《诗经·唐风》：“肃鸨羽，集于苞栩”。《周礼·职方志》：“山林宜皂物，柞栗之属”。汉郑从注：“今世间谓柞实为皂斗”。三国陆玑疏：“其子为皂，或言皂斗，其壳为汁，可以染皂”。栎属果实壳斗含有丰富的鞣质(丹宁)，经破碎后，用热水溶出鞣质，以铁盐媒染，得黑色色淀，具有染黑较好的耐光性和耐洗牢度。(《中药大辞典》1979年，附编41页)。

紫草染紫。紫草是多年生草本，八、九月茎叶枯萎时采掘紫草根，含乙酰紫草宁($C_{18}HI_8O_6$)，紫红色素。《管子·轻重丁》：“昔莱(山东莱州)人善染练，茈(紫草)之于莱纯缁”，“齐桓公好服紫，一国尽服紫。当是时也，五素不得一紫”。(《韩非子·外储说左上》，1974年，217页)。紫草宁需加媒染剂，才能染色。它与椿木灰、明矾媒染得紫红色。

周代布帛衣装的青、赤、黄、白、黑五种色彩，用矿物颜料的“石染”和植物色素的草木染色工艺均可获得。至于

“五色”和“五方”相结合的“五方正色”，最早见于《周礼·冬官·画缋》：“画缋之事，杂五色。东方谓之青，南方谓之赤，西方谓之白，北方谓之黑，天谓之玄，地谓之黄”。这些先秦史实的物体色，以齐国邹衍为代表的阴阳五行学家们的倡导。又将“五色”与五方、五行、四时、五帝、五神、五衣、五德等组合联系，构成了复杂的衣装制度上分等级，尊卑的色彩体系，使“五色”审美观念赋予了社会意识形态的内容。它对色彩名称的扩展，丝绸文化艺术系统化，均产生了深远的影响。

青色是东方、春天、草木萌发的象征色。青色是东方的方位色，又是天空色。表示着东方破晓时的黎明色，即鱼肚白色，又转为天蓝色，即青色中含赤色的蔚蓝色，天青色是秋晴时的天空色，又称空色、碧色。《释名·采帛》：青，生也。象物生时色也。春天，草木青青，绿意盎然，满园春色。相传五帝之一的青帝太(明亮之意)氏，着青衣(青龙纹)，掌管东方，春天。木神句芒辅佐春天的草木萌生。又夏代为木德，色尚青，或谓色尚“玄”。

赤色是南方、夏天、炎火的象征色。赤色是南方的方位色。表示着南方、夏天(季)、赤日炎炎，骄阳似火。它是典型的暖色调，相传炎帝神农氏(又称太阳神)，着朱衣(朱雀纹)，掌管南方、夏天。火神祝融辐佐，负责五谷繁殖，万紫千红。又周代为火德，色尚赤周灭商，火克金。

黄色是中央方，四时，黄土的象征色。土在“五行”中占有中心地位的方位色。《晋书·五行》：“土，中央，生万物者也。”相传五帝之首—黄帝轩辕氏聚居黄河流域的中心，土呈黄色。黄帝有四个面孔，领辖四方，四时。着黄色勾藤(似龙)纹衣。土神后土辅佐，负责稼穑万物，供衣食。黄帝为土德色尚黄。因此，古人将土地黄色视为帝王色。黄色是色相谱中明度最高的色，又称大黄色，明黄色。汉代以后，成为帝王衣的专用色泽。

白色是西方、秋天、金(金属)的象征色。《晋书·五行》：“金，西方，万物既成，杀气之始也”。西方是日落之方，秋天草木成熟、收割，给人以凋谢没落之感。金，表示镰刀和兵器，故有“杀气”的含义。相传白帝少昊氏，穿白衣(白虎纹)，掌管西方、秋天。金神蓐收辅佐，负责收割庄稼。《礼记·月令》：“孟秋之月，白露降，寒霜至，万物盖白霜”。以白色象征秋天，而称为素秋。白色是先秦表示哀悼的颜色，制白衣、素裳是祀祭、尽孝之用。

黑色是北方、冬天、水的象征色。北方、冬天意味着寒冷，黑夜漫长，黑色正是冷色调。《释名·采帛》：“黑晦也。如晦暝(夜)时色也。”相传黑帝颛顼氏，穿黑衣(玄武纹)，掌管北方、冬天。水神玄冥辅佐。但水并非“黑”色，常用白山(雪山)，“黑水”作对比形容词，可能与北方冬天长，水和雪映照着上去似乎变“黑”暗了。正如黑龙江是远看的色泽。又秦代为水德，色尚黑。秦灭周，统一六国，水克火。(《流行色》1988年，第1期)。

周代衣装制度有正色与间色的尊卑之分[11]。《礼记·玉藻》疏：“衣正色、裳间色”。天子、公侯、大夫、伯子在祭祀、上朝会客、外出等场合，衣装(冠履)的色彩均有严格规定：如玄冠朱组缨天子之冠也，缁布冠缋緌诸侯之冠也，缟冠玄武子姓之冠也。(《礼记·玉藻》)。西周青铜器铭文有：旅邑人譱(膳)夫易(锡)女(汝)玄衣，黹屯(纯)，赤市(韨)朱黄(衡)䜌(銮)旅(旂)。(“此鼎”，在陕西岐山董家村出土，1975年)。又《论语·乡党》：“君子不以绀緅饰，红紫不以为服”。绀、緅、红、紫都是间色，君子不取为衣色。否则就是违礼犯正!

五方间色是由五方正色中每两色拼配混合而成。即现代色彩学的“二次色”。正色和间色的关系可组成“五方色环”(或五角星形)分布图。图示中的配色系统是：青黄之间是绿。《礼记·玉藻》：“东方间色为绿，青黄色”。《说文》：“绿，帛青黄色。”《释名·采帛》：“绿，浏也。荆泉之水，于上视之，浏然绿色；赤白之间是红。南方间色为红，白赤色”。《说文》：“红，帛赤白色”。《释名·采帛》：“红，白绛色”。即浅赤色。按《考工记》染绛法，用茜草素，“二次染得赪色(白味赤色)，即浅色”。这里的红色，今俗称粉红色或桃红色。唐代前的赤、朱、绛、纁色与“红”应予区别；青白之间是碧。“西方间色为碧，白青色”。《说文》：“缥，帛青白色”。《释名·采帛》：“缥，浅青色”。用蓝草的靛青浸染丝帛，可得缥色，与碧色同；黑赤之间是紫。“北方间色为紫，黑赤色”。《说文》：“紫，帛青赤色”。“青”应正名为黑，因青赤为紫，是秦二世时的说法，民间从之。《释名·采帛》：“紫，疵也。非正色，以惑人者也。”《论语·阳货》：“恶紫之夺朱也”。(集解：“朱正色，紫间色之好者。恶其邪好而乱正色”)；黄黑之间是骝黄。“中央间色为骝黄(留黄、流黄)，黄黑色”。《说文》：“綟，帛莀草染色”。用莀草色素染色，可得骝黄色，骝是指赤马黑鬣尾色，其色黎黑而黄，故而用之。

以上五种间色各五方正色相对应，故绿、红、碧、紫、骝黄合称为五方间色[12]。图谱中余五种间色是绀、缃、缥、黛、灰，它虽不符合五行家们正色相克产生间色的说法，但同样可以从周代草本染色的浸染、套染、媒染技术中获得确切的色名，而载入史册。如绀色，青赤色。《说文》：“绀，帛深青而扬赤色”。《释名采帛》：“绀，含也，青而含赤色也。似天蓝色，又称红青。以缥入深青液，而赤见于表为绀；缥色，赤黄色”。《说文》：“缥，帛赤黄色。使用茜草素染，一染谓之缥”；缃色，黄白色。《释名·采帛》：“缃，桑也。如桑叶初生之色”。《周礼·礼记》：“鞠衣(王后衣)，黄桑服也。色如鞠尘，象桑叶始生”。缃色与鞠尘色同；黛色，青黑色。犹如远眺山林之色；灰色，白黑色。如草木灰烬色。如果将青、赤、黄、白、黑正色，列为光色，则和绿、红、碧、紫、骝黄、绀、缃、缥、黛、灰十种间色构成了“五光十色”图(图2)。这种色名分布规律的由来已久，它是以周代发达的印染技术为科学依据的。先秦时代对色彩和色名的认识深化，是完全符合现代色彩学中的中间混合律的原理的。

先秦时代自西周春秋战国至秦帝国的统一，以汉式衣装为代表的等级制、规范化的“上衣下裳”和“深衣制”的体系，已形成和发展。它是世界上首见的东方“衣冠王国”。周代的“礼治”所倡导的繁文褥节，在浩瀚的典籍中均有详细记载。但由于战国列强诸侯争霸，诸子百家力举评说，使中国衣装的色彩和丝绸文化达到了空前的繁荣和发展阶段。周秦

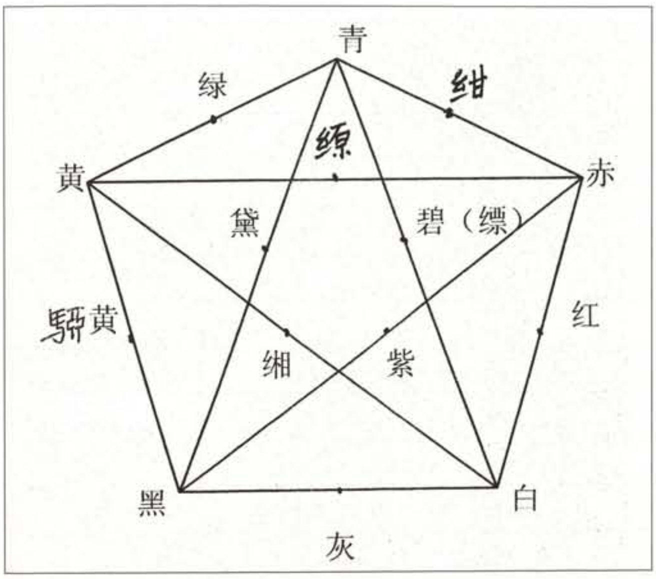


Fig. 2. Spectrum of five lights and ten colours.
图 2. 五光十色图谱。

名　称	在色谱中的位置		
	色名	纯度步度	所在明度级
棕色线	O_6	3	5
红棕色线	YR_3	5	2
深棕色线	YR_3	4	2
深红色线	YR_1	6	4
朱红色线	YR_3	6	4
桔红色线	RO_5	7	7
浅黄色线	YO_8	2	9
金黄色线	YO_8	4	9
土黄色线	YO_8	4	7
黄绿色线	YO_8	5	6
绿黄色线	GYl_3	4	6
钴蓝色线	PB_{24}	3	4

Tab. 2. Colours from the silk-yarns in the embroideries of the early Qin Dynasty.

表 2. 绣品用丝线色彩对照表。

时期衣装上的色彩，根据《周易》和《周礼》的记载，帝王、公侯、伯子等用以祭祀的衣色是“玄衣纁裳”。纁色，即绛色，帛大赤色。天子、公侯的上朝和日常衣色为白衣素裳。至于衣裳上绘绣的“九章纹”色彩是：上衣上配有山、龙，青色；华虫，黄色；宗彝，黑或白色五章色纹。下裳上绣有藻，白或苍(青)色；火，赤色；粉米，白色；黼，黑与白色；黻，黑与青色四章色纹(《尚书大传》注)。周代官府规定的“正色”，任何人不得潜越，即官府衣裳禁止用“间色”。到了春秋战国时期，“礼崩乐坏”，周制的禁用色也就成为民间流行色了。据《礼记 · 玉藻》：“玄冠紫緌，自鲁桓公始也”(春秋 12 诸侯国之一，公元前 711 年-前 694 年)。按周礼诸侯服“缁布冠缋緌”。而鲁桓公就不受礼制的束缚。而后，公元前 685 年，齐桓公问管仲：“寡人好服紫，紫贵甚，一国百姓好服紫不已，寡人奈何？”魏国人浑良夫著“紫衣狐裘”赴宴违礼，被太子所杀。(《左传》，哀公十七年)。可见，紫色已是春秋中期鲁、齐、魏三个诸侯国的流行色彩了。

根据《诗经》所记载的色彩统计表明，民间相当流行“非正色赤”的朱红系列色彩，赭、赫、赪、赤丹、炜、彤、赤裳、朱、瑞、茹藘、渥丹、䞓(红)灼灼，栗等 14 色占绝大多数。还有在《豳风 · 七月》：“我朱孔阳，为公子裳”。其次是绿衣，缁衣，素衣，朱襮、锦衣、绣裳、金舄(鞋)、朱英、绿縢等也是时尚的衣色。同时，从 1982 年，湖北江陵马山一号战国墓出土的衣物，有丝织品共 46 件[13]，其中有朱红、深红、棕红、深棕、浅棕、桔红、紫红、藕色等色泽的纱、绢、锦、绣、绦等品种 32 件(彩图 XI, 1, 2)，约占 70%。还有土黄、淡黄、深黄、全黄、黄绿、钴蓝、灰白、黑等色泽(《江陵马山一号楚墓》，附录一，丝织品色彩测定，文物出版社， 1985 年)。

四

秦始皇统一六国后，根据吕不韦的“五德相胜”说：秦灭周是水德胜火德。易服色制度，“衣服旄旌节旗皆上黑”。秦尚黑，黑色是“五正色”之尊，大礼服用之。但常服的色彩仍五彩缤纷。矿物颜料用于衣裳彩绘(包括兵马俑、宫廷装饰等)，和植物染料用于衣物的染色、印花、生产规模扩大，需用量多。印染技术发展很快。西汉初期朝廷专设“令史、织室、三服官”，有职工数以万计，为皇室和官吏衣装服务。《汉书地理志》：“齐三服官作工种数千人，一岁费数巨万”。“长安东西织室亦五千万”。官府投入丝织业人数多，耗资大，不惜工本、追求色彩艳丽的织锦、刺绣等高级工艺品，推动织绣印染技艺的全面发展。《史记 · 货殖列传》载：“千亩栀茜，其人与千户侯等”。丹朱砂等经营者，一年可获利二十万钱。汉代初期用于衣装的彩绘、染色、印花的矿物、植物颜料品种日益增加。矿物颜料有赭石、丹砂、石黄、石青、孔雀绿、胡粉、蜃白、绢云母、金、银等。植物染料种类繁多。有黄栀、黄栌、茜草、蓝草、紫草、郁金、皂斗、松烟等。丝织品的浸染、媒染、套染的色谱丰富，彩绘、套版印印花也相应发展。 1972 年湖南长沙马王堆一号汉墓出土的丝织品种衣物一百余幅件。保存完好的衣服有绵袍、夹袍、裙、手套、鞋、袜、组带等 58 件。丝织品有对鸟纹绮、杯形菱纹罗、几何纹锦、花卉纹锦、绒圈锦、千金条等。刺绣品有信期绣、长寿绣、乘云绣(彩图 XI, 3, 4)、茱萸云纹绣、方棋纹绣等。经分析鉴定，用植物染料的茜草、蓝草、栀子、紫草等色素，进行直接染、媒染、套染的原色、间色、复色、以及深浅、浓淡的不同明度和彩度的颜色有 20 余种。其中以赤色色谱为主有朱红、棕红、浅棕、深棕、深红、紫红、橙红等 10 余色。绣品的绣线色彩非常丰富，有朱红、棕红、深蓝、湖蓝、藏青、米黄、土黄、金黄、黑等。还有矿物颜料的朱砂、银灰等色泽。进行配色晕色，绚丽灿烂。

马王堆一号汉墓出土的彩绘“非衣”又称帛画

织物名称	经纬线	报告中的色名	在色谱中的位置		
			色名	纯度步度	所在明度级
塔形纹锦	经线	浅棕	YO_7	4	7
	经线	朱红	YR_3	7	6
	经线	土黄	YO_8	3	8
	经线	深棕	YO_7	4	5
	纬线	深棕	YO_7	4	5
凤鸟凫几何纹锦	经线	深棕	YR_3	4	2
	经线	红棕	YR_3	3	4
	经线	灰黄	YR_8	2	8
	经线	朱红	YR_3	7	5
	纬线	深棕	YR_3	4	2
凤鸟菱形纹锦	经线	朱红	YR_3	7	6
	经线	浅棕	RO_4	6	5
	纬线	浅棕	RO_4	6	5
小菱形纹锦	经线	土黄	YO_7	5	7
	经线	深棕	YR_3	4	2
	经线	深红	YR_3	6	5
	纬线	深棕	YR_3	4	2
十字菱形纹锦	经线	棕	RO_5	4	3
	经线	土黄	YO_8	5	7
	纬线	棕	RO_5	4	3
	纬线	朱红	RO_4	8	6
条纹锦	经线	土黄	YO_7	5	7
	经线	深棕	YR_3	4	2
	纬线	深棕	YR_3	4	2
A、B、C、D、E型大菱形纹锦	经线	深棕	YR_3	4	2
	经线	深红	YR_3	6	5
	经线	土黄	YR_7	5	7
	纬线	深棕	YR_3	4	2
几何纹锦	经线	深棕	YR_3	4	2
	经线	土黄	YR_7	5	7
	经线	深红	YR_3	6	5
	纬线	深棕	YR_3	4	2
舞人动物纹锦	经线	深红	YR_3	6	5
	经线	棕	RO_4	5	4

Tab. 3. Colours of the yarns.

表 3. 锦、绮的经纬线色彩对照表

以上大量出土的丝织品衣物的色彩，有力地佐证了周代的流行色是以朱红色调为主，此即史载“周人尚赤”的实物依据。它和各种黄色、蓝、灰黑色等彩色线相匹配、协调，织锦、刺绣成几何纹、花卉纹、龙凤虎纹、舞人动物纹等纹饰，制作的各式衣袍、帽、履，更显得多姿多彩，再现战国时期的色彩文化艺术风貌。

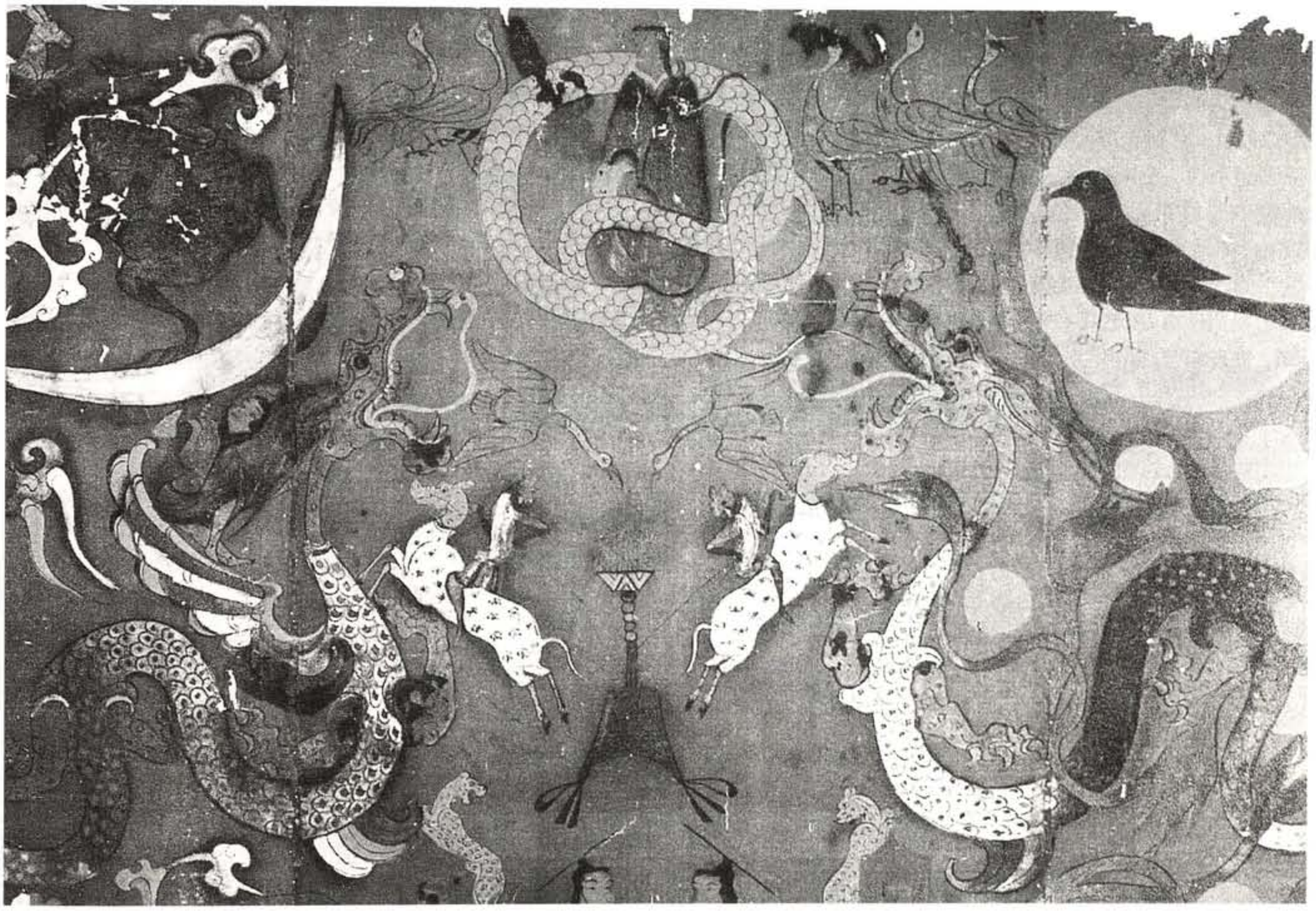
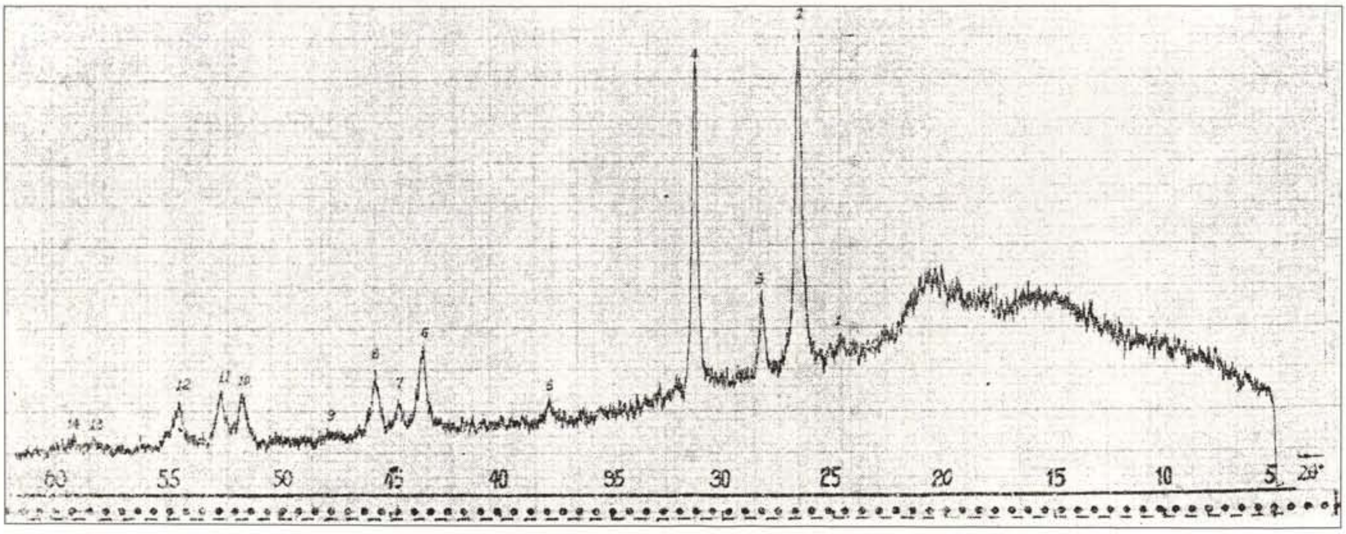


Fig. 3a, b. Silk painting (details), Western Han (206 BC-24 AD), 1972 excavated in grave No. 1 at Mawangdui near Changsha, Hunan
图 3a. 长沙马王堆一号汉墓出土彩绘非衣（帛画），上部； b. 中部。

▽ 3b

(图 3a., b.)和印花敷彩纱锦袍(彩图 XI, 5)、泥金银印花纱袍。它是矿物颜料应用的重要发现。彩绘“非衣”是覆盖在墓主人棺材盖上的一幅丁字形帛画。画面描绘了天上、人间、地下三个境界。扶桑、太阳鸟、蟾蜍、日月、奇龙异兽飞游翻腾。中间的墓主人的形象极为生动。充满浪漫主义情趣。彩绘帛画以矿物颜料为主体。朱红色为朱砂(硫化汞)，黄色是石黄，蓝色和绿色是石青(蓝铜矿)和孔雀绿，灰色是硫化铅和硫化汞的混合物。白色是绢云母 $[KAl_2(Si_3Al)O_{10}(OHF)_2]$。黑色是松烟等天然色彩，光亮华丽、世所罕见[14]。

印花敷彩纱锦袍，是首次发现的印花和敷彩相结合的产品。花纹是藤本植物的菱形纺样。整个印制分为七道工序。第一是印出藤蔓灰色底纹，即用阳纹版印单元纹样，高为 40 毫米，宽 22 毫米的菱形骨架；第二用朱红色绘出红花；第三、四、五、六是用灰色点花；黑灰绘叶(浪纹)；银灰勾绘蓓蕾；棕灰绘出苞片。第七是用粉白勾绘和加点。印花敷彩纱所用颜料、经实物取样用发射光谱仪。硫化根定性分析，X 射线衍射仪鉴定分析。朱红色是朱砂，白色是绢云母，灰色是硫化铅和硫化汞的混合物(图、表 4, 5, 6)。

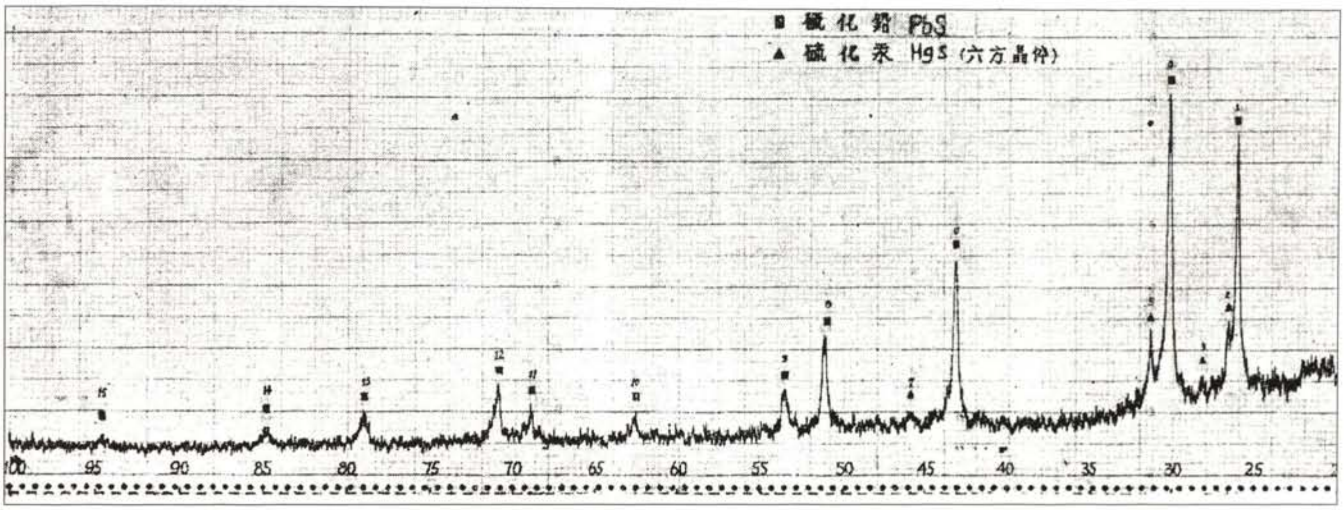


Tab. 4. Powder X-ray diffraction from cinnabar, silk No. 460-1.

图 4. 460 － 1 长寿绣袍上朱红绣线 X 射线衍射强度谱图。

表 4. 出土丝织品 460-1 上朱红颜料与硫化汞的 X 射线衍射强度比较表

试样种类	460-1 长寿绣袍上朱红色颜料		六方晶体标准硫化汞		备注
峰线序号	晶面间距 d(Å)	相对强度 (I/I。)	晶面间距 d(Å)	相对强度 (I/I。)	
1	3.62	5	3.59	5	试验电压: 40 千伏
2	3.36	100	3.359	100	试验电流: 20 毫安
3	3.16	26	3.165	28	扫描速度: 1/2°分
4	2.87	97	2.863	94	扫描范围: 5°-60°
5	2.37	6	2.375	9	(2θ°)
6	2.07	26	2.074	26	
7	2.03	9	2.026	12	
8	1.98	23	1.98	29	
9	1.90	4	1.90	3	
10	1.767	15	1.765	21	
11	1.735	15	1.735	27	
12	1.682	15	1.679	25	
13	1.586	5	1.583	5	
14	1.564	5	1.562	6	



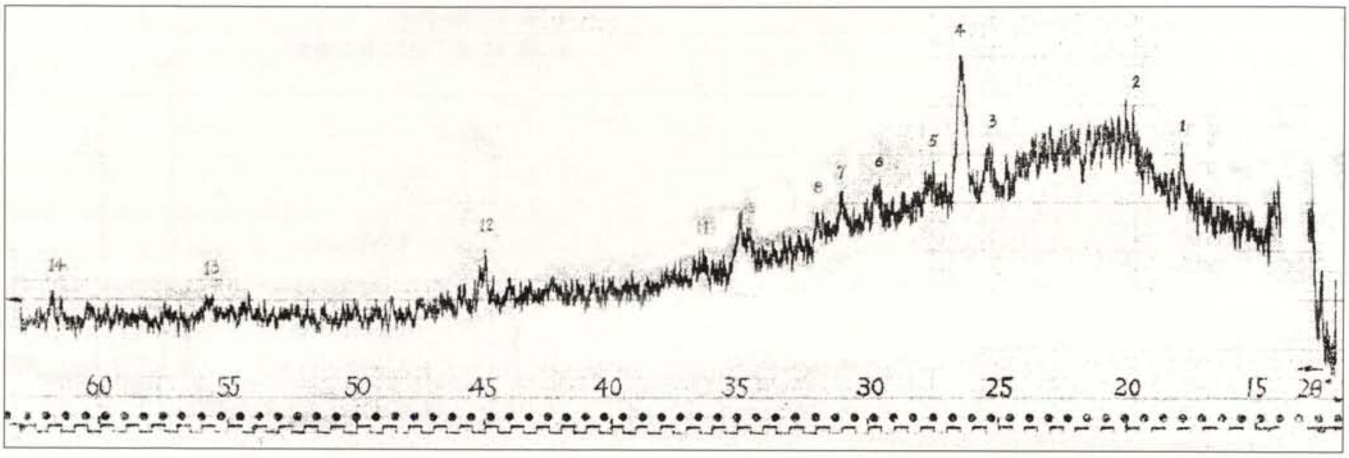
Tab. 5. Powder X-ray diffraction from Pbs and Hgs of silk-brocade No. 461.

图 5. 461 出土丝织品上的银灰色颜料的 X 射线衍射强度谱图。

表 5. 461 上银灰色颜料与硫化铅、硫化汞标准数据的衍射强度比较表

注：vss 最强　vs 极强　ms 次强　s 强　m 中　w 弱　mw 次弱　vw 极弱

峰线	461-银灰色涂料		硫化铅 (ASTM5-0592)		硫化汞 (ASTM 卡片 6-0256)	
序号	晶面间距 d(Å)	相对强度 (I / I 。)	晶面间距 d(Å)	相对强度 (I/I 。)	晶面间距 d(Å)	相对强度 (I/I 。)
1	3.43	vs	3.429	84		
2	3.35	m			3.359	100
3	3.16	w			3.165	28
4	2.95	vvs	2.969	100		
5	2.86	m			2.863	94
6	2.10	s	2.099	57	2.074	26
7	1.98	w			1.980	29
8	1.79	ms	1.790	35		
9	1.71	mw	1.714	16		
10	1.49	w	1.484	10		
11	1.36	w	1.362	10		
12	1.33	m	1.327	17		
13	1.21	w	1.212	10		
14	1.14	w	1.1424	6		
15	1.05	vw	1.0489	3		



Tab. 6. Powder X-ray diffraction of the white pigment from the silk-brocade No. 461.

图 6. 461 出土丝织品上的白色颜料的 X 射线衍射强度谱图。

表 6. 461 上白色颜料与白云母标准数据的衍射强度比较表

峰线	内 5-461 上白色涂料		白云母(ASTM 卡片 7-32)	
序号	晶面间距 d(Å)	相对强度 (I/I。)	晶面间距 d(Å)	相对强度 (I/I。)
1	4.98	m	5.02	55
2	4.46	s	4.48 4.46	55 65
3	3.51	m	3.500	44
4	3.36	vs	3.351	>100
5	3.23	m	3.208	47
6	3.01	m	2.999	47
7	2.88	m	2.871	35
8	2.80	w	2.803	22
9	2.59	w	2.589	50
10	2.56	m	2.562	90
11	2.46	w	2.458	19
12	2.01	m	2.010	75
13	1.65	w	1.653	17
14	1.50	w	1.499	40

由于硫化铅的含量多少，或是变色，就出现了棕灰、深灰、银灰、黑灰等不同的色泽。另一种是金银色印花纱是在深灰色的方孔纱底料上，彩用银灰色印分格定位纹(个字形)。套印黄色块面纹(六角形)再套印金色圆点纹(山形)。它是用三块型版，套印加工，开创了三套色印花方法的先河。

秦汉衣装所使用的矿物颜料和植物染料，品种繁多，色谱齐全。织绣染色、彩绘、印花的加工技艺，均达到了很高的水平。从秦始皇兵马俑上彩绘的颜料品种分析鉴定，以及长沙马王堆一号汉墓出土纺织品和衣物上色彩研究，完全证实了我国早在西汉初期(2100 年前)对于颜料色彩制备，已有完整的技术体系，和独立发展的客观事实。可以说，在西方学者的论著中认为"中国的颜料加工和印染技术，来自古印度、波斯以及地中海各国的输入"是完全缺乏依据的[15]。

中国是丝绸的发源地，曾以"丝国"闻名于世。绚丽璀灿的锦绣品，雕纹刻镂的印染品，多姿多彩的衣裳，早在公元前十世纪，通过陆上"丝绸之路"以长安为起点，向亚、欧、非各国传播。如埃及第 21 王朝(公元前 1070-945 年)法老的佣人墓中，一具女性木乃伊身上发现了丝绸实物。德国南部斯图加特的霍克杜夫村(Hochdorf)的克尔特(Celts)人的古墓(公元前 500 年)发现骨骼上附有丝绸刺绣纹残片。苏联南西伯利亚乌拉干河巴泽雷克 5 号古墓(公元前 440 年)出土了丝绸凤鸟花卉纹刺绣实物，得到了印证。中国美丽的丝绸印染，为各民族的繁荣兴旺，和文化艺术的交流。产生了深远的影响。

注:

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Gao Hanyu

The Dye Colours and Culture on Clothing in Early Qin

In the early Qin Dynasty woven and embroidered clothes were dyed by using such techniques as dye application, dip-dyeing, mordant dyeing, printing, etc. Great headway was made in the technology. The 5500-year-old light crimson silk gauze unearthed from the ruins of the Qingtai Village of Henan Province is a good example of the dyed fabrics in China. Of the three colours (red, yellow and black) in the Painted-Pottery Culture, the most individualistic colour used by the primitive tribes on their utensils was amber.

Over three thousand years ago in the Bronze Culture of the Xia and the Shang Dynasties, people began to recognise the 5 colours of mineral dyes (green, red, yellow, white, black). The 5 colours originate from the five colours, which are shown in the colour combination of the inscriptions on bones and tortoise shells at that time. Ground dye powders such as cinnabar, azurite, stone yellow, black stone, lead white etc. were used to dye fabrics into brilliant clothes. The fact that people of the Yin Dynasty cherished white shows that they worshipped the sun and regarded white as auspicious.

The Official Robes of the Zhou Dynasty stipulate that colour is one of the indications of rank and nobility. The court had 5 different craftsmen (Hua, Hui, Zhong, Kuang and Huang) in charge of making coloured silk robes. Plant dyes like madder, blue grass, jasmine, purple grass etc. developed quickly. The then used techniques such as dip-dyeing, resistdyeing and mordant dyeing expanded the spectrum. The five principal colours and their tints advocated by the scholars of Yin and Yang during the Warring States Period not only refer to the 5 colours (blue, red, yellow, white and black) but also refer to the 10 tints (green, crimson, blueish green, violet, Liu Yellow, yuan, reddish black, light yellow, grey and greenish black), hence the Chinese idiom "five colours and ten tints" which means brilliantly colourful. People in the Zhou Dynasty adored red colour and regarded "red" as noble, which is testified by lots of unearthed embroideries of the Spring and Autumn Period. *See colour plate XI.*

赵丰

汉魏云锦中的五色

汉晋杂记中多见五色云锦或五色锦之名。这里的五色或五彩究竟是指专门的五种色彩，还是仅仅泛指多种色彩？它与中国传统文化中的五行、五方和五星等是否有着直接的关系(彩图 XII, 1)？若有，能否用出土的与此同时期的丝绸文物进行验证？这是一个非常有趣的问题。

出土文物中的战国秦汉刺绣首数湖北江陵马山一号楚墓与湖南长沙马王堆一号汉墓。据发掘报告，两地出土的刺绣可分辨者一般为四色，如马山所出蟠龙飞凤绣所见绣线为棕、深红、土黄、浅黄色四种[1]，马王堆出所长寿绣所用绣线为深绿、紫灰、橄榄绿和淡棕红四种[2]。由于这批绣品在出土时受到墓葬环境的影响较大，色彩发生变化，有些不易辨认，给我们的研究带来一定的困难。但近百年来新疆地区所出大量的保存完好、色彩鲜艳的汉魏织锦却提供了大量的实物资料，其中绝大部分是云气动物纹锦，即汉代史料中所称的“云锦”，这使我们得以考察当时的五色云锦并了解当时的配色规律(彩图 XII, 3)。

一、文献中的五色云锦

目前所知汉魏关于五色锦的记载起码有两条。一是《飞燕外传》“遗女弟昭仪物有五色云锦帐”；二是《西京杂记》载武帝时得天马，“以绿地五色锦为蔽泥”，同一书也提及“五色绫文”和“五色文绶”等名。这两书均传为晋人所作，书中记载多有不确。但可以肯定的是书中提及的物名，一般者是当时存在的。因此，这两条记载还是汉魏时期织锦名目的客观反映。考之于出土织锦实物，可知所谓的云锦就是以云气动物纹样为主题的织锦。由于汉代统治者十分热衷于源于道家荆楚巫术的神仙学说，他们登泰山封禅，建仙阁灵宫，在各种艺术作品中画以云气，饰以云气。因此，在丝绸织绣中的具体表现则是大量的云气纹及与云气相伴的各种动物纹，正如山东嘉祥宋山汉画石铭文所说：交龙委蛇，猛虎延视，玄猿登高，狮熊嗥戏，众禽群骤，万兽云布。同时，在云气动物纹之间，还织入大量表示吉祥的词语，如“延年益寿大宜子孙”、“长寿明光”等，它们往往成为我们对某一织锦的称呼。

稍后的《邺中记》载后赵石虎织锦署中生产的织锦有：“大登高、小登高、大明光、小明光、大博山、小博山、大茱萸、小茱萸、大交龙、小交龙、蒲萄文锦、斑文锦、凤凰朱雀锦、韬文锦、桃核文锦，或青绨、或白绨、或黄绨、或绿绨、或紫绨、或蜀绨，工巧百数，不可记名。”书中提到的各种锦名也可以新疆出土之云气动物纹织锦相吻合，其中关于色彩的记载更是引人注目，共提及青、白、黄、绿、紫五种色名，色名之后的绨在此应作地解。也就是说，在公元三、四世纪，魏地织锦的常用地色一般有以上五种。

五色或五彩在先秦及汉代文献中十分常见。《礼记》礼运：“五色，六章，十二衣”；《周礼：冬官》考工记：“画绘之事杂五色。东方谓之青，南方谓之赤，西方谓之白，北方谓之黑。天谓之玄，地谓之黄。青与白相次也，赤与黑相次也，黄与玄相次也。青与赤谓之文，赤与白谓之章，白与黑谓之黼，黑与青谓之黻。五彩备谓之绣。”这里说明，标准的五色或五彩是赤、黄、青、白、黑，一般将其中国传统文化中的五行或五方相联系。五行或五星中的金、水、木、火、土分别与白、黑、青、红、黄相对应。而五方中的东、西、南、北则分别与青、赤、白、黑相对应，加上居中的天玄地黄，中间一方就算作黄。因此在汉代流行四方神的图案中有青龙、白虎、朱雀、玄武，以代表东、西、南、北四方。但是当时丝绸图案上所使用的五色是否真的也遵循了“画绘之事杂五色”和“五彩备谓之绣”的规则、采用标准的五色呢？

二、考古发现的五彩云气动物纹锦

汉魏时期的织锦无一例外地采用平纹经二重组织。所谓的平纹经二重组织是用夹纬将多种色彩的经线分成表里两层，表层的经线就是显示在织物正面的色彩，而其余的经线则沉在织物下层。当织物需要另一种色彩的经线时，则将此种经线提升到表面显示，而将其余的经线沉到下面。平纹则是明纬与经线的交织规律。

在这一种组织中，表层经线与沉在里层的经线数之比是一个重要的因素。并非经二重就是表里层各一种经线，表里各一是它在表里经比为 1:1 时的特例，但它也可以是 1:2 、1:3 、甚至是 1:4 。在某一特定的区域中，不同色彩的经线数应是表里层经线之和，也就是说，当组织表里层经线比为 1:2 时，色彩数应为 3 ，当表里层经线比为 1:3 时，色彩应为 4 。但必须指出的是，这里的色彩数只是局部区域中的色彩数，并不代表整件织物的色彩数。在汉锦中常见的现象是，将不同色彩的经线按不同区域排列，织物因此而呈现彩条效果。这样，尽管在某一局部区域中有着一定的色彩数，但在整个织锦中的色彩数总是等于或大于这一数。因此，在此文中，我们所称的五色织锦应是在整幅内色彩总数有五种的织锦，而将表示某一局部的色彩特征用比例来表示，如表里经线比为 1:1 的经二重组织为二经锦，以表示在同一组织中由二种色彩的经线为一组，表里经线比 1:2 的经二重为三经锦，1:3 的为四经锦，依次类推。

从新疆出土的汉魏时期织锦来看，色彩数少于五色的织锦不多，若有的话，一般都是二色锦。二色锦由于其正反面的组织相同，图案上恰恰是相反。如新疆楼兰遗址出土的续

世锦，以蓝黄两色显波纹和“续世锦”三字，一面是蓝地黄字，另一面则是黄地蓝字。最新从新疆尼雅遗址出土的风格相同、铭文不一的“世毋极锦宜二亲传子孙”锦用的也是蓝黄二色，效果与上相同。另两件楼兰出土的波纹锦用的则蓝、红两色和黄、褐两色。少量的云气动物纹锦如龙虎瑞兽纹锦也用二色锦织成，但图案较为简单，风格似乎偏晚。三色锦和四色锦均非常少，所知者如新疆尼雅出土的阳字锦和楼兰出土的斑纹锦、鱼纹锦，均不属云气动物纹。

事实上，绝大部分的云气动物纹织锦都是五色锦。但根据组织和用色的不同，可以将其分成几类。

1. 三经五色锦

三经锦在织物的任何区域都用三种经线为一组进行表里换层而显花。但在不同的区域中要用不同色彩的经线，这样的区域在一个幅宽中往往有十余个。在每一个区域中，三种色彩一般是地色、勾边色和主体色，不同色区间的地色和勾边色往往相同，只是更换主体色而已。极大部分的云气动物纹锦均用三种色彩进行交替更换，形成保二换三(保证两种色彩不变，另三种色彩进行替换)的规律。以下是一组实例：

a. 延年益寿大宜子孙锦：这类织锦出土最多，不仅在中国有出，而且在俄罗斯也有出土。但最为有名是新疆民丰尼雅古墓中所出的用此织锦制成的手套和袜子。从类型上看，它属于早期的穗状云，以红色为地，白色勾边，另一种色彩是用蓝、绿和橙(黄)交替更换[3]；

b. 万世如意锦：新疆民丰尼雅古墓出土，作为锦袍的主要面料。红色为地，白色勾边，深蓝、浅蓝和深红相互替换作为不同色区中的主体色。从纹样上看，同样也是早期的穗状云4。

此外还有不少的三经锦发现，如楼兰出土的“延年益寿”锦和“长葆子孙”锦(彩图 XII, 2)，从图案上分类均属于穗状云。由于它比较残破，在残片中只发现四种色彩，但我们推测它们在色彩总数上也应该是五色锦。

2. 四经五色锦

四经锦用四种色彩的经线为一组进行表里换层而显花。但在不同的区域中也用不同色彩的经线，四种色彩一般是地色、勾边色和两种主体色，各色区的地色和勾边色也往往相同，只是更换其中的一种主体色而已，但只用两种色彩交替更换，形成保三换二(保证三种色彩不变，另二种色彩进行替换)的规律。以下是一组实例：

a. 登高明望四海贵富寿为国庆锦：出自新疆楼兰，以深蓝作地，褐红勾边，三种色彩作为主体色，其中本色在各色区均相同，还有绿和黄两色交替出现[3]；

b. 永昌锦：同样出自新疆楼兰，以深蓝作地，白色勾边，红色为不变的主体色，另两种绿和浅黄交替作为主体色。织物上残留“永昌”两字[3]；

c. 鹿纹锦：出自新疆楼兰，已非常残破，但还可以看出完全的五色，深蓝作地，浅黄(白)色勾边，褐红为不变主体色，绿和浅橙(黄)为交替主体色[3]；

d. 王侯合昏千秋万岁宜子孙锦：新疆尼雅三号墓出土，以小单元的带有穗状特征的云气为主体纹样，并由左至右织人“王侯合昏千秋万岁宜子孙”铭文，织物为深蓝为地，红、白两色勾边，黄、绿两色作为变换出现的主体色[5]；

e. 茱萸锦：从图案上看，茱萸锦不属于云气动物纹锦，但其装饰风格则非常相似。现在发现有两种，一件出自新疆楼兰，以红色为地，白色勾边，鲜艳的蓝色为不变的主体色，另两种交替的主体色是绿色和黄色[3]；另一件出自最新发掘的尼雅古墓三号墓，以白色为地，深蓝勾边，红色为不变主体色，绿色和黄色交替[5]。

从图案上看，四经五色锦中的云气动物纹锦均属山状云式，理论上的出现年代较穗状云稍晚。特别是登高锦一件，从词意上就可知与登山有关，并与后赵石虎织锦署中生产的锦名“大登高”和“小登高”相吻合。

3. 五经五色锦

几乎所有的五经锦均属山状云式的云气动物纹锦。五经锦在每一区域中均有五种色彩的经线表里换层进行显花，本身就是五色。再查之于其色区，均无区别，整个幅宽内均为同一色区，也就是说，这些所发现的五经锦同时也是五色锦。其实例有：

a. 长乐明光锦：出自新疆楼兰，深蓝地，浅黄(白)勾边，褐红色、暗绿色和浅褐色(黄)为主体色，通体一致，不分色区，有“长乐明光”四字循环出现[3]；

b. 长寿明光锦：同样出自新疆楼兰，深蓝地，浅黄(白)勾边，褐红色、浅蓝色和黄色为主体色，通体还有纵向的浅褐色经线显露，形成条纹状，风格独特，有“长寿明光”四字循环出现[3]；

c. 金池凤锦：原物为一小袋状形，出自新疆尼雅一号墓，经研究其图案可以拼复成为对称的山状云为主的纹样，还可以看到树纹和奔鹿纹，残留“金池凤”三字。白色作地，蓝色为主勾边，其它为黄、绛(红)和绿三色[5]；

d. 五星出东方利中国锦：原物为一护膊，出自新疆尼雅八号墓，整个图案不分色彩区域，均以蓝、绿、红、黄、白五色织出，以蓝为地，白色作字，白色和红色在云纹的两侧勾边[5]。

三、云锦五色与五行的关系

从以上我们对新疆等地出土的汉魏时期云气动物锦色彩的考察来看，当时除一些不属于云气动物纹的织锦或是非常简单的二色锦之外，大部分云气动物锦的用色总数恰好都是五色。如三经锦在同一区域内只能用三种色彩的经线，织工就通过不同色彩的经线分区排列来增加二种色彩；四经锦只能用四种经线，织工就再增加一种；五经锦已达五色，也就不再分出色区。由我看来，这一现象决非偶然，它应与当时的阴阳五行学说相关。

五是中国古代一个非常特殊的数字，许多场合都对五有专门的定义，如上所说的五行金、木、水、火、土与五方东、西、南、北、中是其基本的含义，此外我们还可以看到有五音，宫、商、角、徵、羽；五伦或五常，君臣、父子、夫妇、兄弟、朋友；五戎指五种兵器，五礼指五种礼节，五谷指五种基本粮食，五金指五种金属，五脏指人体

内主要的五种器官，此外还有五岳、五水、五木等多种说法，甚至连刑罚，也有五刑之称。因此，有五种色彩被固定地用于织锦确实令人想到它会有特殊的意义。

为这一联想提供证据的可能是最新出土的“五星出东方利中国”锦(彩图 XII, 4)，铭文中的“五星出东方”则耐人寻味。此锦的基本情况已如前述，但同出另有一片上则有“诛南羌”三字铭文，根据我的研究可以将其图案基本拼复，但文字尚缺。在图案上除大小两鸟、独角兽与虎之外，还能看到三个圆点纹，由左至右为白、红、黄，其中黄点居中。由于图案对称，可以推测另外半幅必定还有两个圆点，其色彩也必定是青、绿两色。联系起来，这五个圆点就是金、火 、土、水、木五大行星。《史记: 天官书》:“五星分天之中，积于东方，中国大利，积于西方，外国用兵者利。”另据《汉书: 赵充国传》载: 汉宣帝神爵元年(公元前 61 年)时赵充国用兵羌地，宣帝赐书: “今五星出东方，中国大利，蛮夷大败”，通过天象星占预测军事行止。因此，此件织锦可以看成是这一军事行动的见证[6]。而此锦恰好用五色代表五星，可证当时云锦五色与五行学说的密切关系。

但是，值得注意的是织锦五色中的色相。几乎所有上述云气动物纹锦的五色均是赤、白、黄、蓝、绿，这说明织锦五色中的五色与记载中的五色稍有区别。与正式的五色的区别在于，织锦中用青色代替了黑，而用绿色代替蓝。这其中有两种可能。一是织锦以美为贵，采用喜欢采用较为漂亮的色彩，青色和绿色，就明显比黑色和蓝色好看。二是批织锦的主要年代是在东汉时期，发现在民间，这是传统五行在民间实用美术中的变形。

综上，汉魏织锦中五色云锦是非常重要的一种织物，其色彩的应用与当时的文化背景有着直接的关系。因此，除一些不是很重要的场合外，一般的云气动物纹锦都追求“五彩备”的效果。但由于织锦技术经历了由少经锦到多经锦的过程，多经锦的经密远远大于少经锦，因此非常难织。因此，在战国时期，我们只看到有二经锦或三经锦，到汉代早期，人们从技术上可能还无法达到五色，然后就用变换色区的方法来取得五色。逐渐地，随着织技的提高，人们已能织出五经锦，就直接用五经锦来制作五色锦了，不再分出色区。由于五星出东方锦的成型年代可以追溯到汉宣帝时期，我们推测，汉武帝所用的五色锦蔽泥及赵飞燕的五色云锦也极有可能是真正的五经五色锦。

注:

1. 荆州地区博物馆: 江陵马山一号楚墓，文物出版社， 1985 。
2. 湖南省博物馆: 长沙马王堆一号汉墓，文物出版社， 1972 。
3. 黄能馥、陈娟娟:《中国美术全集》印染织绣卷上，文物出版社， 1985 。
4. 高汉玉:《中国古代染织绣图录》，商务印书馆香港分馆，上海科学技术出版社， 1986 。
5. 新疆维吾尔自治区:《丝路考古珍品》，上海译文出版社， 1998 。
6. 于志勇: 尼雅遗址出土“五星出东方利中国”锦织文浅析，《鉴赏家》，上海译文出版社， No.8, 1998 。

Zhao Feng

The Five Colours in Polychrome Silks with Cloud Pattern from Han Dynasty to Wei Period

Based on the analysis of all available specimens of polychrome silks with cloud pattern from the Han dynasty to the Wei period (actually, from the 1st to the 4th century AD), an interesting phenomenon was found. Almost every piece of silk was composed of five colours, namely dark blue, green, yellow, red and white. This also applied to polychrome silks with 1:2, 1:3 and 1:4 warp-faced compound structure. In addition, Han dynasty documents contain references to wushe jin (silks with five colours) and wushe yunjin (silks with cloud pattern in five colours). This suggests that the five colours on polychrome silks have a special relationship to the wuxing (five materials, which are metal, wood, water, fire and earth) and wufang (five directions or locations, which are east, west, south, north and the centre) in Chinese philosophy because each direction and each kind of material is also associated with a special colour.

One important example which strongly supports this hypothesis is a polychrome silk recently discovered in Xinjiang. It bears an inscription of Chinese characters, wuxing chu dongfang li zhongguo zhu nanqiang (it is favouable time for the central country to conquer the southern Qiang tribe when the five planets appear together in the east). This piece consists of warps with five different colours, each symbolising one of the wuxing (five planets): jin (Venus), mu (Jupiter), shui (Mercury), huo (Mars), and tu (Saturn), which have the same names as the wuxing (five materials) in Chinese. *See colour plate XII.*

Birgitt Borkopp

Late Antique and Early Medieval Textiles and Costume and their Representations in Various Media

Whenever men and women are represented in the pictorial arts – especially whenever their official rank or function is emphasized – their clothes and accessories are an important part of the portrait. As comparatively few textiles and costumes are preserved from late antique and early medieval centuries, their reproductions in sculpture, paintings and other media may be considered as important documents, allowing us to visualize the richness of a material culture that would otherwise be lost. Not in all periods, however, do the pictorial documents mirror the decorative details of the reality, in which they were created, with the same degree of accuracy. Their testimony must, therefore, be checked against the evidence of surviving costume or textile fragments for a fair account of their credibility.

In a brief sketch – and more cannot be given here – it is not possible to give a detailed account of surviving documents and to follow closely the parallels and contrasts between textiles and their pictorial counterparts. Instead, several examples will be presented that demonstrate greater or lesser correspondence between textiles and their representations, indicating chances and risks of a method that might take the one as evidence for the other.

A recent study, published by Prof. Dr. Andreas Schmidt-Colinet[1], followed in detail the parallels between sculpture and textiles excavated in Palmyra and succeeded in proving that indeed the representations of costume and textiles have their foundation in the fabrics traded and used in the area.

The oasis of Palmyra was, from the 2[nd] century BC until the 3[rd] century AD, an important commercial centre trading silk and wool, spices, glass and ceramics between East and West. Remaining politically independent from Rome as well as from Iran, it entertained economically profitable relationships with both ruling powers and practically controlled the exchange of

Fig. 1. Lid of a sarcophagus, found in temple tomb no. 176, Palmyra (photo after A. Schmidt-Colinet, ed., Palmyra, Antike Welt 26/1995, fig. 50).
图 1. 棺盖，在巴尔米拉神庙发现，176号墓(取自A. 施密特-科利内编：巴尔米拉，载《古典世界》26/1995，图50)。

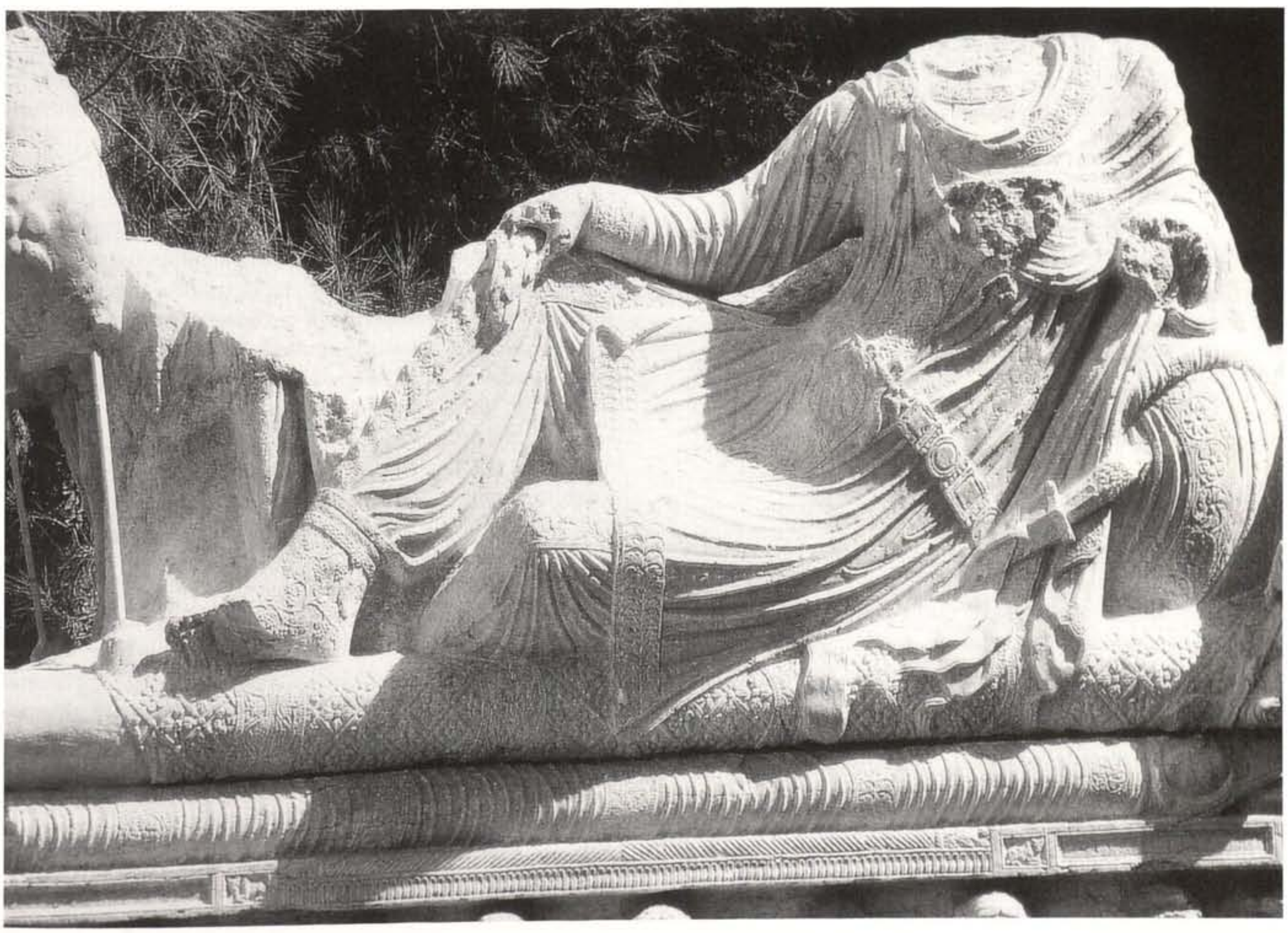

Fig. 2. Silver dish with simourgh, London, British Museum, inv.-no. BM 135913.

图 2. 神兽银盘，伦敦不列颠博物馆，编号 BM 135913 。

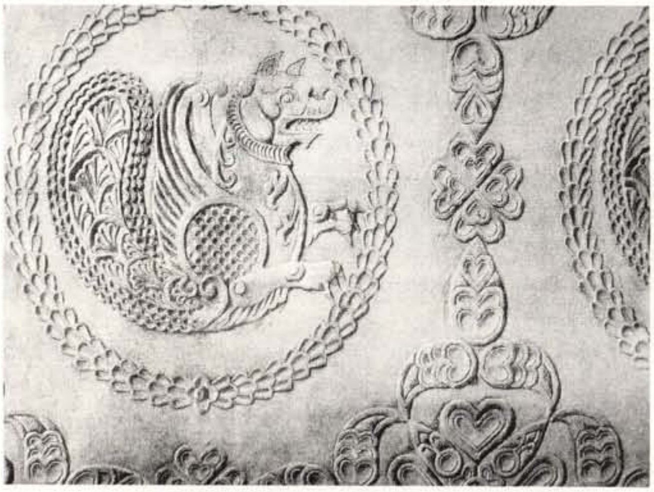

Fig. 3. Taq-i-Bostan, relief representing a horseman, detail of garment (photo after K. Erdmann, Die Kunst Irans zur Zeit der Sasaniden, Mainz 1969, fig. 97).

图 3. 园窟(Taq-i-Bostan)，浮雕表现一位骑手，衣着局部(取自 K. 埃德曼:《伊朗萨桑王朝艺术》，美因茨, 1969 年，图 97)。

luxury goods between the Mediterranean and the eastern centres of Persia, India and China. Its inhabitants acquired considerable wealth that allowed them to wear costly costumes and to indulge in lavish decorations of their houses and tombs. In the latter, a number of portraits have been preserved that represent their patrons dressed in sumptuous garments decorated with elaborate patterns and finished with ornamental bands[2]. Roman and oriental traditions, together with indications of rank and status, influenced the choice of dress; consequently the deceased might be clad in a Roman toga or in the Sasanian costume consisting of caftan and trousers respectively, in accordance with the image they wished to convey. Roman-style garments were decorated with clavi and ornamental borders, their patterns consisting of a variety of floriated tendrils or roundels filled with geometrically stylized flowers. The decoration of the oriental costume was more elaborate: Seams and hems seem to have been covered with braids showing intricate compositions of garlands and floral rosettes, or having geometrical motifs woven into the borders of the fabrics. Textiles used for mats and cushions were represented with a decorative grid system, the squares filled with star-shaped rosettes (fig. 1).

Silk and wool textiles found during excavations in Palmyra proved that these sculptures may indeed be considered as fairly exact representations of the actual textiles used: Woollen cloth with geometrical patterns in bold, contrasting colours (colour plate XIII, fig.1), tapestry-woven bands and roundels for the decoration of Roman-style tunics, intricate floral borders adorning the seams of the oriental caftans (colour plate XIII, fig. 2) and Chinese silks, probably used as decorative applications, were all identified in the necropolis of the oasis[3]. Their evidence allows the study of the sculpture as documentary material for the actual costume and decorative detail. It should be mentioned, however, that colour schemes and tactile qualities can be inferred only from the textile finds.

As a second example, textiles and their representations from Sasanian Persia are examined: Long after the art of silk weaving had been mastered in China, first efforts to follow its example were undertaken by its western neighbours in the 3rd and 4th centuries A.D., and by the 5th and 6th centuries there was quite an important silk production in what is now Iran, then the realm of the Parthians and their Sasanian successors. The Sasanians developed a very rich tradition in various arts and techniques (stone sculpture, metalwork and silk weaving featuring prominently among them) that were to have an enormous influence on their neighbours for centuries to come. And in these arts again we find remarkable parallels in the decorative elements, regardless of the material or technique used, and – more to our point – an exact rendering of textile patterns and ornaments in the pictorial representations of costumes.

Aligned pearl roundels enclosing animals or fabulous creatures belong to the staple motifs of Sasanian art, decorating architecture, sculpture, metalwork and textiles alike[4]. A particular composition, representing a simourgh (a fabulous beast made up of the head and body of a wolf, the claws of a lion, feathered wings and the tail of a peacock) is known from a stucco relief serving as an architectural decoration[5], a silver-gilt dish[6] (fig. 2), a jug of the same material[7], and from the decoration of the caftan worn by a horseman in the famous relief of Taq-i-Bostan[8] (fig. 3). The actual fabric of this garment has not been preserved, but there are quite a number of fragments surviving from silks woven in Sogdia in the 8th and the beginning of the 9th century closely following the Sasanian model[9] (colour plate XIII, fig. 3). In other garments represented in the Taq-i-Bostan reliefs we can identify textile patterns featuring pheasants, peacocks and ducks, some in roundels, some without such an individual frame[10]. All the motifs are known from existing Sasanian and Sogdian silk weavings[11]. Here again, we may take the pictorial representations as reliable sources for a study of the contemporary textile decoration.

We must realize, however, that the evidence of the pictures is not always as reliable as the examples given above seem to suggest. A closer look at medieval documents revealed that sculpture, painting and book illumination sometimes at best just hint at the textiles and costumes worn and cannot be trusted as an exact description of material, decoration or usage.

After its impressive beginnings in China and Persia, the art of silk weaving moved farther west, reaching a new climax in Byzantium. From the 8^{th} until the 11^{th} century, we can follow the development of large-scale medallion patterns, heraldic animals of huge proportions in solemn procession, smaller motifs in geometrical arrangement and monochrome incised patterns with floral motifs set into ogival grids (colour plate XIII, fig. 4) respectively[12]. In the contemporary representations of emperors and court officials, holy fathers or saints, we cannot identify any of these decorations. In costumes and furnishings, rendered with care in both wall painting and book illumination, fabrics are almost always given as unpatterned monochromes. If they do show a pattern, we cannot grasp more than an allusion to one of the compositions we know (fig. 8), and in the very rare cases where we recognize a known motif, the established dates for the actual textile and its representation are centuries apart[13]. For Byzantium, it would not be possible to develop a thesaurus of textile patterns from the evidence of their representations in the pictorial arts.

Together with the documents from Palmyra and Sasanian Persia, this last example should be kept in mind as a warning: the pictorial sources may have a life and style of their own, and they may not have been meant to serve as a thesaurus of a reality lost ever since.

Notes

1 Andreas Schmidt-Colinet (ed.), Palmyra. Kulturbegegnung im Grenzbereich (Antike Welt. Zeitschrift für Archäologie und Kulturgeschichte, Jg. 26, Sondernummer 1995) with detailed analyses of textiles and their representations by A. Schmidt-Colinet, Khaled al-Δs'ad and Annemarie Stauffer. Zu den Textilien seither auch: A. Schmidt-Colinet, A. Stauffer, Kh. Al-As'ad, Die Textilien aus Palmyra, Mainz 2000.

2 Schmidt-Colinet (ed.), Palmyra, op. cit., pp. 40-42 and figs. 48-51; pp. 44-52 and figs. 64-79.

3 Schmidt-Colinet (ed.), Palmyra, op. cit., pp. 57-71 and the resp. figs.

Fig. 4. Menologion Basileios´ II., Rome, Biblioteca Apostolica Vaticana, Cod. gr. 1613.

图 4. 巴西尔二世的圣徒节日历。罗马，梵蒂冈使徒图书馆， Cod. gr. 1613 。

4 Cf. Splendeur des Sassanides. L´empire perse entre Rome et la Chine (224-642). Catalogue de l´exposition aux Musées royaux d'Art et d´Histoire, Bruxelles 1993.
5 London, British Museum, inv.-no. BM 135913 (ill. in: Cat. Splendeur des Sassanides, op. cit., no. 11, with reference to related plaques).
6 London, British Museum, inv.-no. BM 124095 (ill. in: Cat. Splendeur des Sassanides, op. cit., no. 71).
7 St. Petersburg, Hermitage Museum, inv.-no. S-61 (ill. in: Cat. Splendeur des Sassanides, op. cit., no. 96).
8 Kurt Erdmann, Die Kunst Irans zur Zeit der Sasaniden, Mainz 1969, fig. 97.
9 The most prominent example is the fabric of the caftan from Moščevaja Balka (ill. in: Cat. Von China nach Byzanz, Munich 1996, no. 1).
10 Cf. Splendeur des Sassanides, op. cit., figs. 98-101.
11 Cf. Entlang der Seidenstrasse. Frühmittelalterliche Kunst zwischen Persien und China (Riggisberger Berichte 6), Riggisberg 1998.
12 Cf. Leonie von Wilckens, Die textilen Künste von der Spätantike bis um 1500, Munich 1991, pp. 50-63. – Rom & Byzanz. Schatzkammerstücke aus bayerischen Sammlungen. Katalog zur Ausstellung im Bayerischen Nationalmuseum, Munich 1998, nos. 65-73.
13 Cf. Birgitt Borkopp, Perlen, Rosetten und Blütenranken. Zur Ornamentik byzantinischer Seidengewebe, in: Lithostroton. Studien zur byzantinischen Kunst und Geschichte. Festschrift für Marcell Restle, Stuttgart 2000, p. 33.

博尔科普

古代晚期及中世纪早期的纺织品和服装以及它们在不同媒介中的表现

摘要

绘画艺术表现男女人物，尤其是要突出他们的地位和权势时，这些人物所着的服装和装饰品就构成肖像的一个重要部分。由于中世纪早期的纺织品和服饰保存下来的寥寥无几，它们在雕刻、绘画和其它媒介中的再现便成为重要的资料，使我们得见否则就会失去的这一部分物质文化。当然，这些资料必须根据残存下来的服饰和纺织品来查证，以对其可信程度有正确的认识。

我们先来看巴尔米拉的雕刻和纺织品。从公元前二世纪到公元三世纪，叙利亚的绿洲一直是东、西方之间经营丝绸、毛料、香料、玻璃器皿和陶器的贸易中心。其居民积攒下大量财富，其服饰华丽，房屋和陵墓装饰奢华。许多肖像雕刻得以在陵墓中保存下来，它们所表现的是死者的保护神。这些雕像衣着讲究，不仅装饰着复杂的图案，而且点缀着饰带。在巴尔米拉的考古发掘中发现的丝绸和羊毛织品表明，可能确实可以这样看这些雕像，即它们相当精确地表现了现实的纺织品。应当指出的是，它们的色彩只能通过纺织品文献来作出推断。

萨桑和早期波斯王朝的资料可拿来做对应的研究。萨桑王朝的统治者和军人的画像显示，他们的的衣着明显地具有地方特色。其式样和图案均有明确的规定。保存在教堂珍宝室的不全的纺织品和在考古发掘中发现的衣物(值得注意的是摩斯采瓦亚巴尔卡的考古发现，曾经于1996/97年在巴伐利亚州国家博物馆展出)表明，这些肖像可以作为创建了这一地区重要传统的萨桑王室人员豪华服饰的参考资料。

无论如何我们得承认，画像作证据并不总是象上面所引的、看来有提示作用的实例那么可靠。对中世纪的(更准确地说是拜占廷的)资料作一番仔细的审视表明，雕刻、绘画和古书细密画至多只暗示用过的纺织品和服饰，而不能看作是对材料和衣着习惯的准确描述。不管怎样，我们要想到这些实例，不把它们当作此后失去的现实的精确的类属词典。

(英译中：陈钢林)

△ 2　　3 ▽

1: Cracks and flacks of polychromed terracotta, arisen in open room after excavation. – 2: Polychromed face of a terracotta in pit No. 3. The polychrome was painted with brush. – 3: Polychromed robe of a terracotta in pit No. 2. The terracotta was at first undercoated with putty, then with lacquer. – 4: A few samples with polychromy, after treatment with PEG and eletronic-beam.

1: 彩绘出土后，在敞开环境下，出现的破裂、起翘情况。 2: 三号坑一俑面部彩绘涂层。从照片上可以清晰地看出：彩绘是用毛刷刷涂的。 3: 二号坑一俑袍部的彩绘涂层。从照片可见：该俑在涂生漆底层之前，先用腻子在陶上进行打底处理。 4: 用 PEG 法和电子束法保护处理后的一些彩绘陶片。

4

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1: 秦俑彩绘漆层干燥过程剧烈收缩, 从陶体上脱离。 2: 漆(底)层失水收缩, 导致整个彩绘层(漆底层, 颜料层)脱落。 3: 残片 F-003/96 经 PEG200 逐步处理, 两年以后的状态。 4: 残片 F-005a 经 PEG200 逐步处理, 两年以后的状态。 5: 残片 F-002/96 经保护处理, 两年以后的状态。 6: 陶片 F-006/96 经保护处理, 两年以后的状态。 7: 陶片 F-008/96 保护处理前。

△ 6

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△ 8

11 △

1: The lacquer layer with polychromy of the terracotta shrank drastically during the drying process and has peeled off from the terracotta. – 2: The lacquer undercoat shrank through loss of water, leading to the breaking off of the whole polychromed layers (lacquer undercoat and pigment layers). – 3: The phase of the sample F-003/96, two years after treatment with PEG200, step by step. – 4: The phase of the sample F-005a, two years after treatment with PEG200, step by step. – 5: The phase of the sample F-002/96, two years after conservation treatment. – 6: The phase of the sample F-006/96, two years after conservation treatment. – 7: Sample F-008/96, before conservation treatment. 8: Sample F-008/96, after conservation treatment. – 9: Sample F-007/98, four months after treatment. – 10: Sample F-003/98, four months after treatment, after optimised method. – 11: Sample F-012/98, four months after treatment, after optimised method. – 12: Sample F-013/98, four months after treatment, after optimised method. – 13: Polychromed samples of the terracotta army of Qin Shihuang, after treatment, soaked first with monomer, then consolidated with electronic-beam. The result was good.

8: 陶片 F-008/96 保护处理后。 9: 陶片 F-007/98 经保护处理，四个月后的状态。 10: 陶片 F-003/98 经优化后的保护方法处理，四个月后的状态。 11: 陶片 F-012/98 经优化后的保护方法处理，四个月后的状态。 12: 陶片 F-013/98 经优化后的保护方法处理，四个月后的状态。 13: 采用单体渗透、电子束辐射(EB)固化方法保护的秦俑带彩陶片。达到了理想的保护效果。

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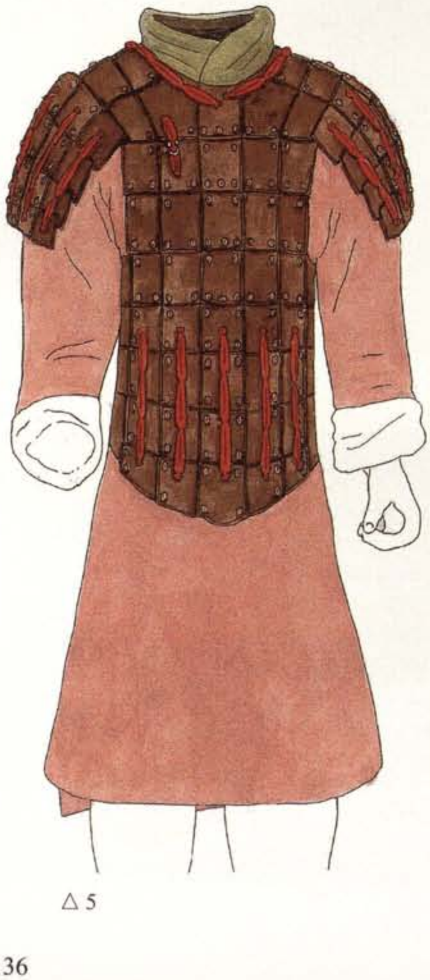
1: Lintong, pit No. 2, fragment 005/2000. Green collar with red ties; malachite and cinnabar. – 2: Lintong, pit No. 3, fragment 002/1996: malachite. – 3: Lintong, pit. No. 2, fragment 009/1998: Mixture of han-purple and azurite. – 4: Lintong, pit No. 2, fragment 009/1998, violet collar with red ties: han-purple and azurite, cinnabar. – 5-7: Lintong, Terracotta-museum, reconstruction of the original polychromy. 5, 7: Pink = mixture of caolin, cinnabar red and brown ironoxide; Red: cinnnabar; Green: malachite. – 6: Red-brown = cinnabar and red-brown ironoxide; Red: cinnabar. (Drawings: Bayerisches Landesamt für Denkmalpflege, Catharina Blänsdorf, 2000; Photos: Bayerisches Landesamt für Denkmalpflege, Catharina Blänsdorf and Cristina Thieme.)

1: 临潼(二号坑), 陶片 005/2000: 绿衣领, 红带: 孔雀石和朱砂; 2: 临潼(三号坑), 陶片 002/1996: 孔雀石; 3: 临潼(二号坑), 陶片 009/1998: 汉紫和石青的混合; 4: 临潼(二号坑), 陶片 009/1998: 紫衣领, 红带: 汉紫和石青, 朱砂(摄影: 巴州文保局, 布伦斯多福/蒂美); 5-7: 临潼秦俑馆; 原始彩绘复原。 5, 7: 粉色, 由高岭土、朱砂和红与褐色的氧化铁混合; 红色: 朱砂; 绿色: 孔雀石; 6: 红褐色: 朱砂和红褐色的氧化铁; 红色: 朱砂(绘图: 巴州文保局, 布伦斯多福, 2000)。



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△ 4b

1: Mural painting, Tang Dynasty; Mogao grotto, Dunhuang. – 2: Mural painting, Tang Dynasty; Mogao grotto, Dunhuang. – 3: Ming-Statue, Wofosi temple in Xiangshan, Beijing; azurite, with goldleaf, detail. – 4. a, b: Two Bodhisattvas, mural painting, Tang Dynasty; Mogao grotto, Dunhuang. – 5: Jiang Caiping, Old banana, traditional mineral pigment, 170 x 96 cm.

1: 敦煌莫高窟唐代壁画; 2: 敦煌莫高窟唐代壁画; 3: 北京香山卧佛寺明代塑像，石色，贴金箔，局部; 4. a. b.: 两菩萨，敦煌莫高窟唐代壁画; 5: 老芭蕉，传统矿石颜料, 170 x 96cm，蒋采蘋

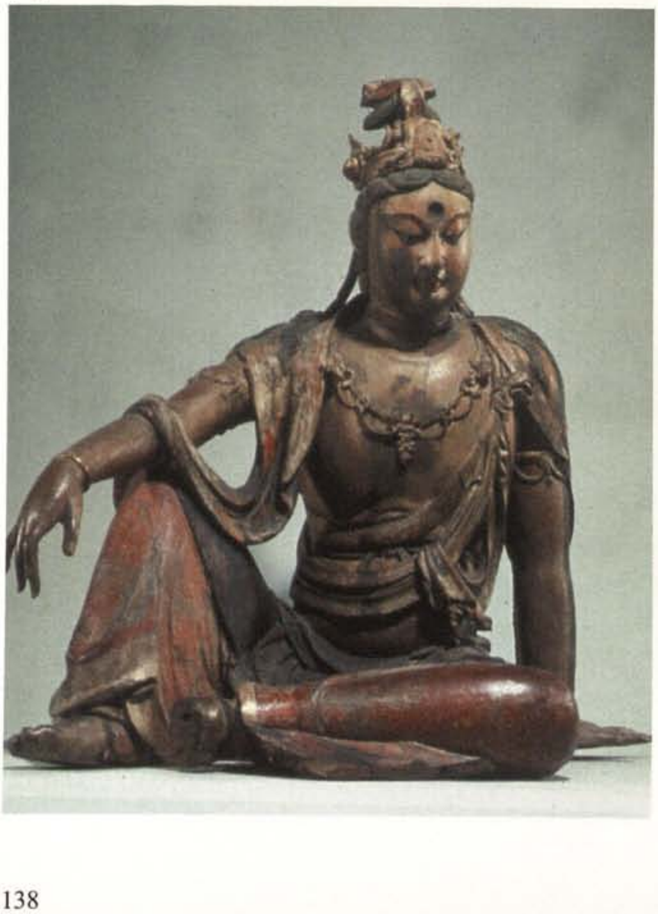
▽ 5

△ 1

1: Bishamonten, Kaidan'in, detail of trousers; Tôdaiji, Nara, 9th century (Repro from: YOSHITAKA). – 2: Guanyin, 11th-13th centruies, front; Amsterdam, Rijksmuseum. – 3: Weituo Tian, Southern Song dynasty (1127-1278), detail of the sleeve with hemp-leafdecoration; Chôryuji temple, Gifu province (Repro from: YOSHITAKA). – 4: Guanyin, detail of leg and skirt; Amsterdam, Rijksmuseum. – 5: Tôji Kannon, 1232, detail of upper garment, (Repro from: YOSHITAKA)

1: 毘沙门, 裤子局部; 东大寺, 奈良, 9 世纪(取自: 义孝有贺); 2: 观音, 11-13 世纪, 正面, 阿姆斯特丹皇家博物馆; 3: 韦驮天将, 南宋, 带大麻叶装饰的袖子局部; 岐阜县长涌寺(Choryuji)(取自: 义孝有贺); 4: 观音, 大腿和裙子局部; 阿姆斯特丹皇家博物馆; 5: 东寺观音, 1232, 下衣局部(Choryuji)(取自: 义孝有贺)。

▽ 2



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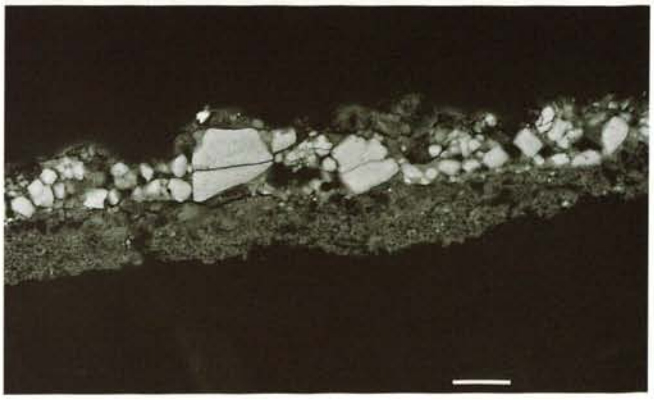
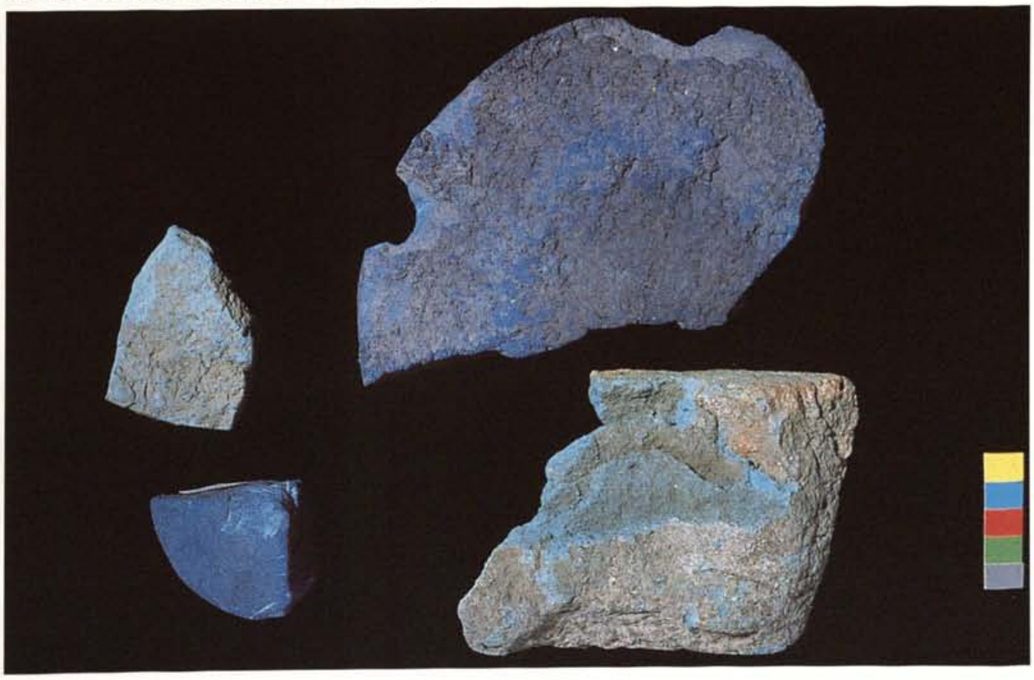
1: Inside of Henem's coffin: the yellow pattern is painted with pigments from the "jarosite minerals group" (Louvre AF 9757), © S. Joigneau, M. Louis.

2: Cross section of a woman's carnation sampled from the *Akhethetep's mastaba* (Louvre E 10958): 1-stone, 2-ground layer made of calcium sulphate, 3-yellow layer composed of pigments from the "jarosite minerals group", 4-copper chloride and calcium sulphate, © LRMF, S. Colinart.



3: Backscattered electron image of a part of the same cross section revealing the shapes and their heterogeneous size of the mineral grains, © LRMF, S. Colinart.

4: Pigments cakes stored in the Department of Egyptian Antiquities of the Louvre Museum. The turquoise colour belong to the Egyptian green. © LRMF, D. Vigears. 4 ▽



1: 赫尼姆棺的里面：黄色图案系用"黄钾铁矾矿物组"的颜料所绘(卢浮宫 AF 9757), ©S. 茹瓦尼奥, M. 路易；2: 阿克赫泰普的墓室中所取女子肉色的截面(卢浮宫 E 10958): 1-石头，2- 底层由硫酸钙组成，3- 黄色层由"黄钾铁矾矿物组"的颜料组成，4-氯化铜和硫酸钙, ©LRMF, S. 科利纳；3: 相同截面上一个部位的反向散射电子成像展现了其矿石晶粒的不同大小和形状, ©LRMF, S. 科利纳；4: 卢浮宫博物馆埃及古董店里的颜料块。绿松石色属于埃及绿。©LRMF, D. 维热拉。

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1: Attributed to Jacques-Louis David, *A. Ch. Quatremère de Quincy*, 1779; oil on canvas; private collection. – 2: Reconstruction of the Hera statue at Argos; coloured lithograph from A. Ch. Quatremère de Quincy, *Le Jupiter olympien*, Paris, 1815, plate XX; Bayerische Staatsbibliothek, Munich, Res. Arch. 218m. – 3: Reconstruction of the 'Olympic Jupiter'; coloured lithograph from A. Ch. Quatremère de Quincy, *Le Jupiter olympien*, Paris, 1815, endpaper; Bayerische Staatsbibliothek, Munich, Res. Arch. 218m. – 4: Reconstruction of the Temple of Empedocles at Selinunte; colour lithograph from Jacques-Ignace Hittorff, *Restitution du Temple d'Empédocle à Sélinonte*, Paris, 1851, plate II; Bayerische Staatsbibliothek, Munich, 2 Arch. 128°.

1: 被看作大卫所画: 卡特勒梅尔 · 德 · 坎西, 1779 年, 画布油画, 私人收藏。 2: / 3: 奥林匹斯的朱庇特的复原像 / 阿尔戈斯的赫拉的复原像, 卡特勒梅尔 · 德 · 坎西: 《奥林匹斯的朱庇特像》, 巴黎, 1815 年, 衬页 / 图版 XX, 彩色版画, 慕尼黑巴伐利亚州国家图书馆, Res.Arch.218m 。 4: 塞利农特的"恩培多克勒神庙的复原图", 希托夫: 《塞利农特的恩培多克勒神庙的复原》, 巴黎, 1851 年, 图版 II, 慕尼黑巴伐利亚州国家图书馆, 2 Arch. 128°。

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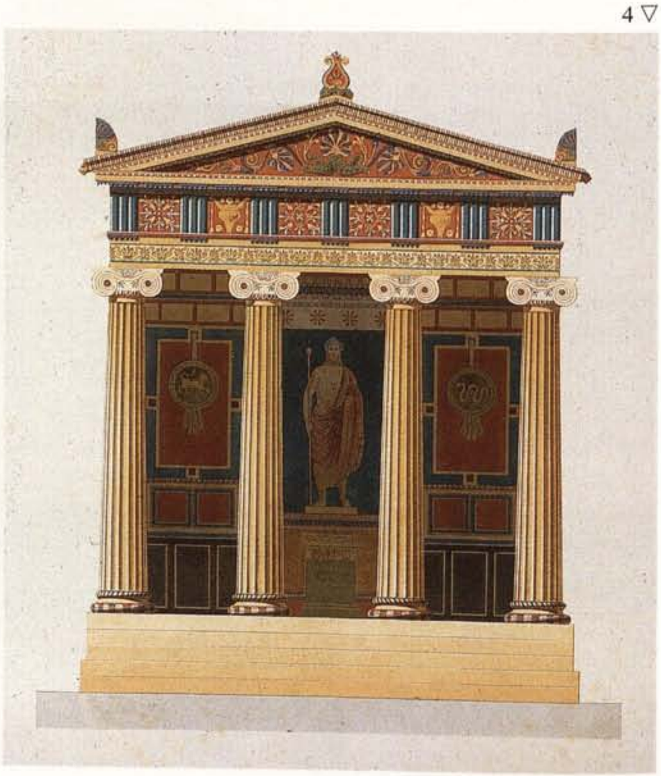

△ 1

1: Greek terracotta figure, height 19.4 cm, c. 260 BC, Staatliche Antikensammlungen Munich (NI 727). – 2: Colour reconstruction of the West pediment of the Aphaia Temple (from: A. Furtwängler, Aegina. Das Heiligtum der Aphaia [1906], plate 104). – 3: Archer from the West pediment of the Aphaia Temple (WXI), detail of the right hip and the right thigh, ultra-violet reflex shot. – 4: Marble figure of an Archer ("Paris") from the West pediment of the Aphaia Temple in Aegina (WXI), height 97 cm, c. 490 BC, Glyptothek Munich. – 5: Detail of fig. 3: Archer (WXI). – 6: Marble mould copy of the Archer from the West pediment of the Aphaia Temple (WXI), photo of the colour reconstruction (ochre tones not yet applied).

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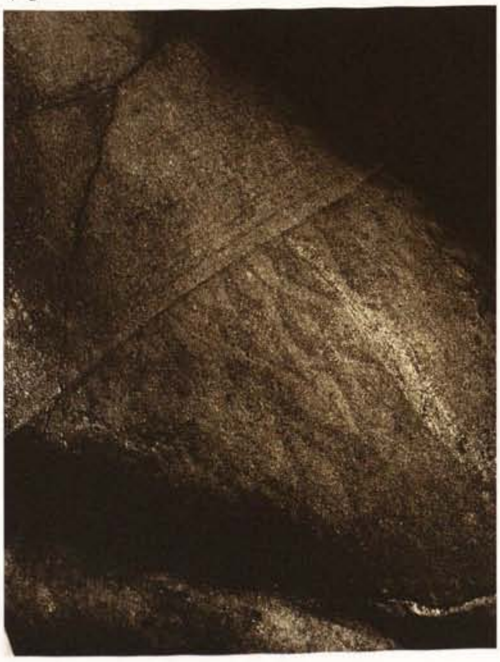
1: 希腊陶俑，高 19.4 厘米，约公元前 260 年，慕尼黑国立古希腊罗马艺术收藏馆(NI 727)。 2: 阿菲亚神庙西面三角板的彩色复原(取自 A. 富特文勒:《埃吉那岛。阿菲亚神庙》, 1906 年，图 104)。

▽ 3



3: 阿菲亚神庙西面三角板上弓箭手(WXI)，右髋和右上腿局部，紫外线反光照相。

4: 埃吉那岛阿菲亚神庙西面山墙弓箭手大理石像(巴黎)(WXI)，高 97 厘米，约公元前 490 年，慕尼黑古希腊罗马雕塑馆。

5: 彩图 2 的局部：弓箭手(WXI)。

6: 阿菲亚神庙西面山墙弓箭手的人造大理石铸像(WXI)，彩色复原的工作照。(尚缺赭石色调，待施)。

6 ▽

1: Tiger in black and red check, Warring States (475 BC-221 BC), embroidery with patterns of dragon, phoenix and tiger, excavated from grave No. 1 of Mashan in Jiangling, Hubei. – 2: Tiger in black and grey check, Warring States (475 BC-221 BC), embroidery with patterns of dragon, phoenix and tiger, excavated from grave No.1 of Mashan in Jiangling, Hubei. – 3: With cinnabar dyed clod, Western Zhou Dynasty (about 11th century BC-771 BC), excavated from graves of Earl Yu. – 4: A strip of silk with patters of hunting, Warring States (475 BC-221 BC), excavated from grave No. 1 of Mashan in Jiangling, Hubei. – 5: Mirror cloth, tough silk, with stripe in black and yellow check (brocade), Warring States (475 BC-221 BC), excavated from grave No. 1 of Mashan in Jiangling, Hubei.?

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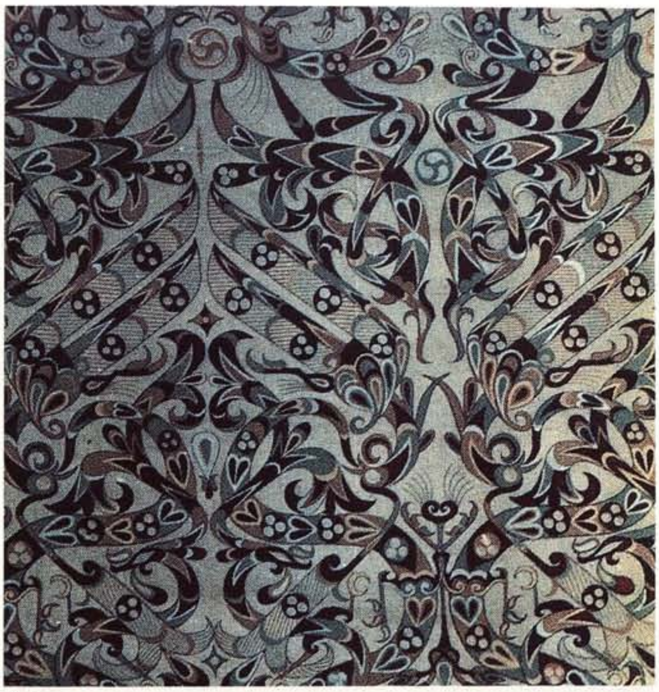
1: 江陵马山一号墓龙凤虎纹绣中黑、红相间的老虎； 2: 江陵马山一号墓龙凤虎纹绣中黑、灰相间的老虎； 3: 西周強伯墓群中染有朱砂的土块； 4: 江陵马山一号出土的田猎纹条； 5: 江陵马山一号墓出土的黑、黄相间的条纹锦镜衣。

5 ▽



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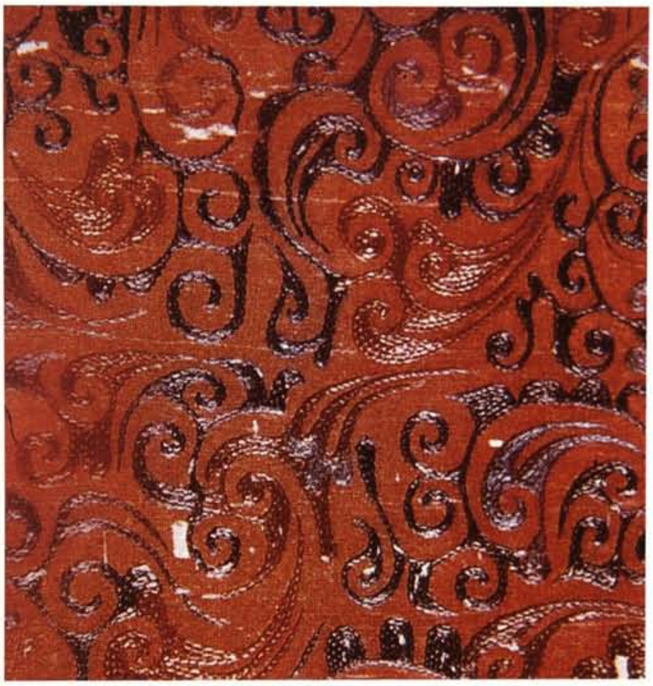
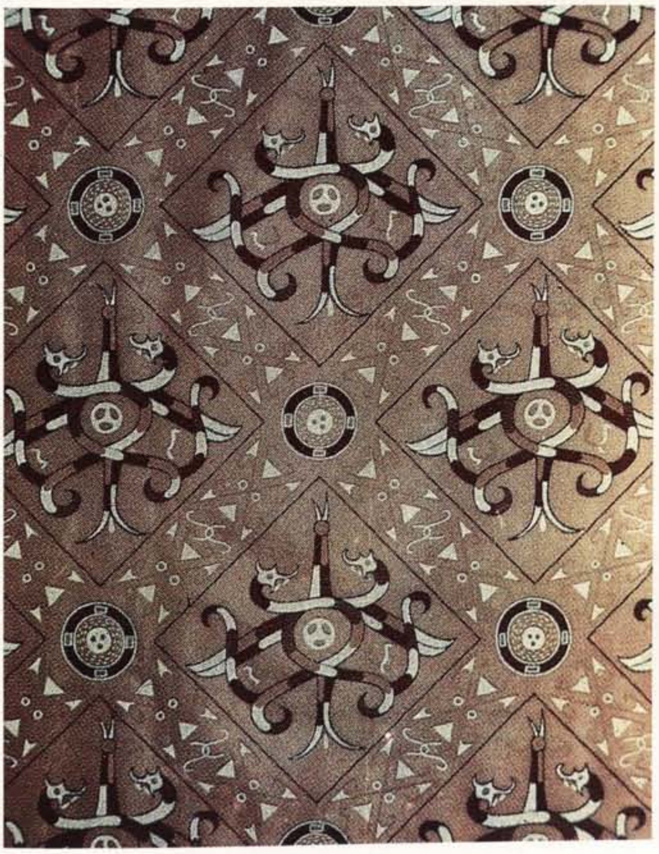


3 △

1: Embroidered silk quilt with pattern of coiling dragons and flying phoenix (detail), Warring States (475-221 BC); excavated in 1982 from grave No. 1 at Mashan in Jiangling, Hubei. – 2: Embroidered silk robe edge, with pattern of coiling phoenix and tow dragons (detail), Warring States (475-221 BC); excavated in 1982 from grave No. 1 at Mashan in Jiangling, Hubei. – 3: Embroidered silk robe (so called Longevity Embroidery, detail), Western Han (206 BC-24 AD); excavated in 1972 from grave No. 1 at Mawangdui, near Changsha, Hunan. – 4: Embroidered silk robe (so called Riding Clouds Embroidery, detail), Western Han (206 BC-24 AD); excavated in 1972 from grave No.1 at Mawangdui, near Changsha, Hunan. – 5: Silk gauze robe with printed and painted pattern (detail), Western Han (206 BC-24 AD); excavated in 1972 from grave No. 1 at Mawangdui, near Changsha, Hunan.

1: 江陵马山一号楚墓出土的蟠龙飞凤纹绣衾（局部）; 2: 江陵马山一号楚墓出土的一凤二龙相蟠纹绣锦袍缘（局部）; 3: 长沙马王堆一号汉墓出土长寿绣锦袍（局部）; 4: 长沙马王堆一号汉墓出土乘云绣锦袍（局部）; 5: 长沙马王堆一号汉墓出土印花敷彩纱锦袍（局部）。

▽ 2



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1: Five directions (wufang: north; south, east, west and middle). Five Elements (wuxing: metal, wood, water, fire and earth) and five colours (wucai: blue, yellow, red, white and black). – 2: Brocade with inscription „chang bao zi sun“ (Preserve a flourishing growth of descendants), Han Dynasty, excavated in Loulan, Xinjiang. – 3: Brocade, Han Dynasty. – 4: Brocade with inscription „wu xing chu dong fang li zhong guo“ (appearance of the Five Stars in the East is favourable to China), Wei and Jin Dynasty (220-420); excavated in Niya ruins, Minfeng county, Xinjiang.

1: 五方、五行及五色图示; 2: 新疆楼兰出土汉代《长葆子孙》铭文锦; 3: 汉代织锦; 4: 1995 年新疆民丰尼雅遗址出土魏晋《五星出东方利中国》铭文锦。

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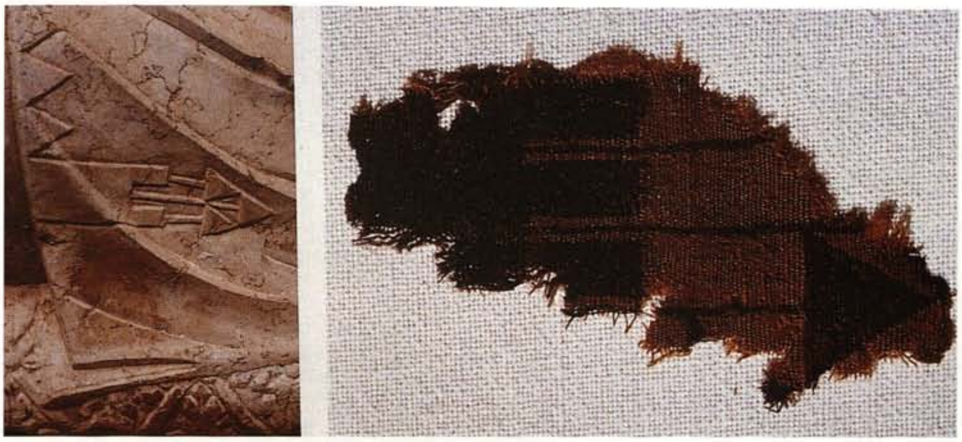

△ 1

1: Details of sculpture and woollen textile, found in tombs no. 186 and 46, Palmyra (photos after A. Schmidt-Colinet, ed., Palmyra, Antike Welt 26/1995, fig. 69 and 70).
2: Fragment of a tapestry-woven textile, found in the tomb of Kitot, Palmyra (photo after A. Schmidt-Colinet, ed., Palmyra, Antike Welt 26/1995, fig. 94).
3: Taq-i-Bostan, relief representing a horseman, detail of garment (photo after K. Erdmann, Die Kunst Irans zur Zeit der Sasaniden, Mainz 1969, fig. 97).
4: Caftan found in Moščevaja Balka, weft-faced compound twill with simourgh pattern, detail; St. Petersburg, State Hermitage, inv.-no. Kz 6584. Chasuble of the archbishop Willigis (reg. 975-1011), monochrome weft-faced compound twill, detail; Munich, Bayerisches Nationalmuseum, inv.-no. T 11/170.

▽ 2

1: 雕刻和毛织物的局部，在巴尔米拉 186 号和 46 号墓发现(取自 A. 施密特-科利内: 巴尔米拉，载《古典世界》 26/1995, 图 69 和 70); 2: 花毯织物的残部，在巴尔米拉基托墓发现(取自 A. 施密特-科利内: 巴尔米拉，载《古典世界》 26/1995, 图 94); 3: 在莫斯切瓦亚巴尔卡发现的土尔其长袍，带神兽图案的六股丝缎锦，局部; 4: 大主教维利基斯(975-1011 在位)的十字褡，单色六股丝缎锦，局部; 慕尼黑巴伐利亚州国家博物馆，藏品号: T11/170 。

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1: Lacquer box in the shape of a mandarin duck with scenes of dance and music. Warring States. Excavated from the grave of Marquis Yi of the Feudal State of Zeng in the district town of Suizhou, Province of Hubei. – 2: Bowl with two handles in the shape of a butterfly, painted. Warring States. Excavated from grave No. 2 in Wangshan near the district town of Jiangling, Province of Hubei. – 3: Decoration on the black ground of a lacquer coffin, detail. Han. Excavated from grave No. 1 in Mawangdui near Changsha, Province of Hunan. – 4: Lacquer ware with gold leaf or gold powder. Qing Dynasty.

△ 2

1. 鸳鸯形漆盒：彩绘乐舞图，战国，湖北随州曾侯乙墓出土；2. 彩绘蝶形漆耳杯，战国，湖北江陵望山 2 号墓出土； 3. 彩绘黑地漆棺漆画(局部)，汉，湖南长沙马王堆 1 号墓出土； 4. 描金漆器，清

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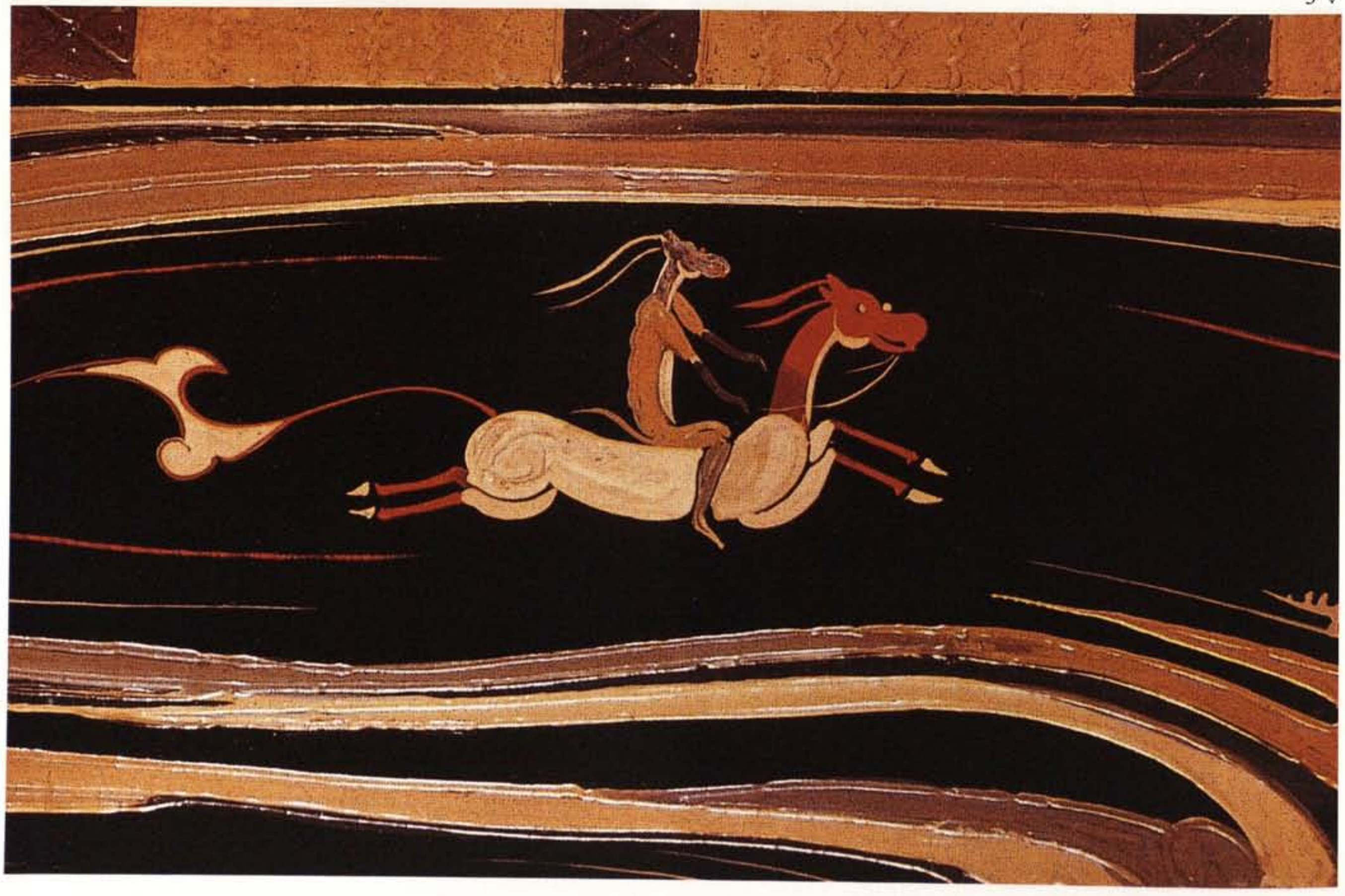

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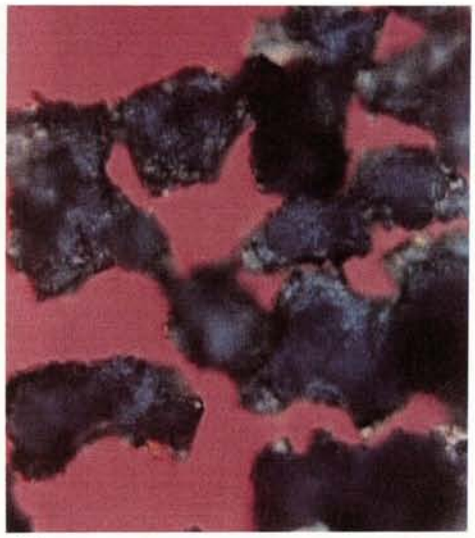

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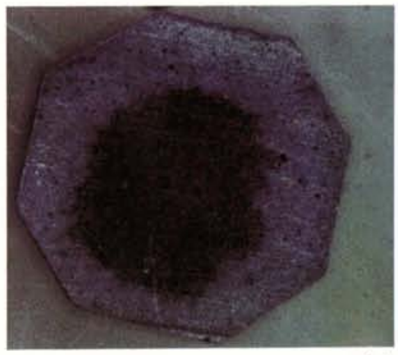
1:Amulet Bes (for description see text). – 2: The octagonal Freer Gallery stick (diameter 8.5 mm). – 3: Microscopic picture of single crystals of Chinese Blue, Ba-$CuSi_4O_{10}$. – 4: Microscopic photograph of the pigment layer of sample I of the Terracotta Army. These pigments are Chinese Purple and Cinnabar. Reprint with permission from Thieme, 1995. – 5: From left to right: Barium-Copper-Oxalate, $BaCu(C_2O_4)$; product of the reaction of Chinese Purple with oxalic acid; mixture of Chinese Blue and Purple; Chinese Purple. – 6: Photograph of the cylindrical seal (for description see text). – 7, 8: Growth of lichens. The central ring was mixed with Egyptian Blue (above) and Chinese Blue (below). No growth is seen in the central areas confirming the fungicidal effect of these pigments.



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1: Amulet Bes.照片(说明见报告); 2: 弗里尔画廊样品的八角形平板(直径为 8.5 mm); 3: 中国蓝的单晶体的显微镜照片, $BaCuSi_4O_{10}$; 4: 兵马俑一号样颜料层的显微镜照片。颜料为中国紫和朱砂。重印经蒂美允许, 1995; 5: 从左至右: 草酸铜钡, $BaCu(C_2O_4)_2$; 中国紫与草酸反应的产物; 中国蓝和紫的混合物; 中国蓝; 中国紫; 6: 圆柱形图章照片(说明见报告); 7, 8: 地衣的生长。中圈与埃及蓝(上图)和中国蓝(下图)混合。中心区未见生长, 证实这些颜料所具有的杀真菌功能。

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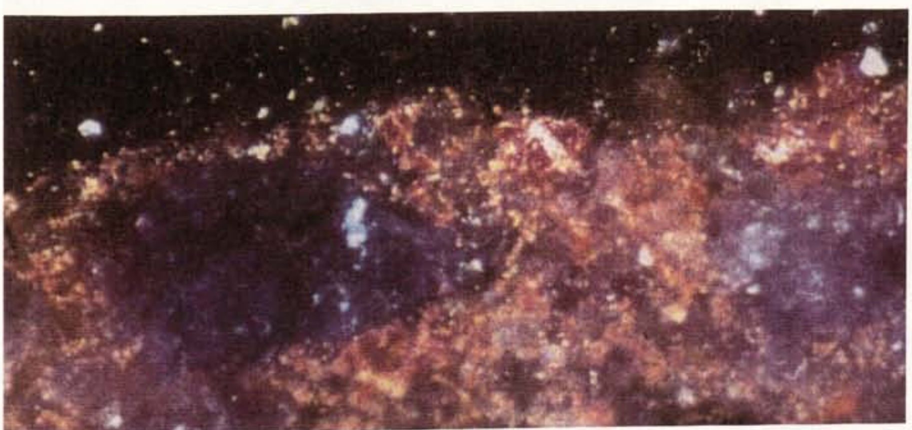

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1: Buddhist statues, polychromed clay, Tang Dynasty, Dunhuang, cave 460. The figure on the left was damaged, it shows its wood brace and splendid achnatherum. – 2: Buddha, polychromed clay, Northern Wei (386-534), Dunhuang, cave 254. The upper limbs are broken. You can see the inner stone body. – 3: Bodhisattva, polychromed clay, Dunhuang, cave 45 (Tang Dynasty). Rich polychromy and gilded parts on the dress. – 4: Buddha, polychromed clay, Northern Liang (397-439), Dunhuang, cave 275. Thrifty and simple polychrome. – 5: Bodhisattva, polychromed clay, Tang Dynasty, Dunhuang. On the altar in cave 205. The minium is changed. – 6: Buddhist statues, polychromed clay, Dunhuang, cave 335. The figures were painted in Qing Dynasty.

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1: 莫高窟第460窟唐代彩塑，左侧塑像已损坏，露出木骨架和芨芨草；

2: 莫高窟第254窟北魏彩绘佛像，上肢断裂，露出石胎岩体；

3: 莫高窟第45唐代洞窟中彩绘富丽并服饰上装金的菩萨塑像；

4: 莫高窟第275窟北凉洞窟中，彩绘简朴的佛像；

5: 莫高窟第205窟佛台上，铅丹已变色的唐代菩萨塑像；

6: 莫高窟第335窟中，被清代重塑和重绘的彩塑。

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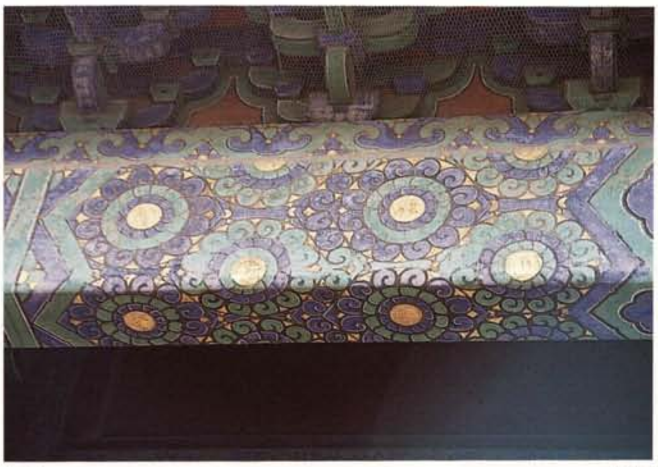

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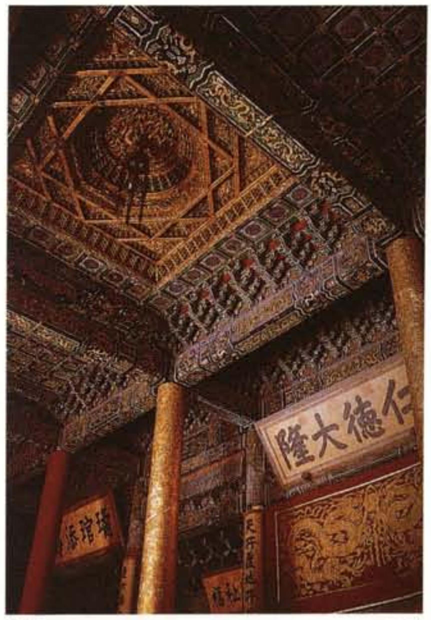
1: Painted decoration, Gate of Martial Spirit (Shenwumen), Forbidden City, Beijing. – 2: Painted decoration with dragon and phoenix pattern at ceiling, Palace of Longevity and Good Health (Shoukanggong), Forbidden City, Beijing. – 3: Painted decoration, two dragons playing with a pearl, Hall of Pleasurable Old Age (Leshougong), Forbidden City, Beijing. – 4: Painted decoration, Meridian Gate (Wumen), Forbidden City, Beijing. – 5: Caisson ceiling with golden dragon, Hall of Imperial Supremacy (Huangjidian), Forbidden City, Beijing. – 6: Painted ceiling with round cranes, Palace of Great Happiness (Jingfugong), Forbidden City, Beijing. – 7: Painted ceiling with frontal dragons, Hall of Preserving Harmony (Baohedian), Forbidden City, Beijing.

1: 神武门彩画; 2: 寿康宫龙凤天花; 3: 乐寿堂双龙戏珠彩画; 4: 午门彩画; 5: 皇极殿浑金蟠龙藻井; 6: 景福宫团鹤天花; 7: 保和殿正面龙天花。



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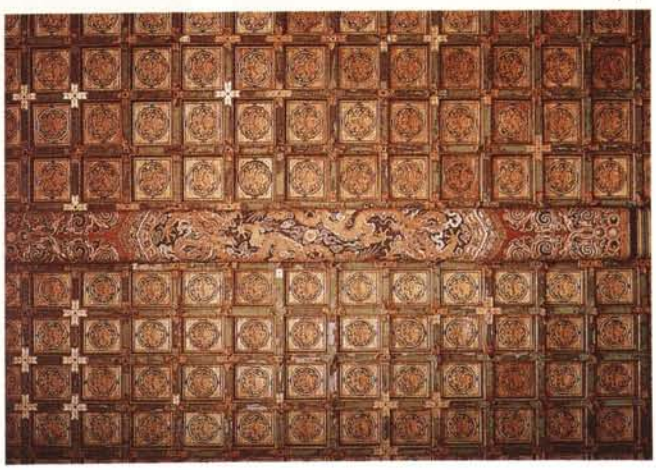

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8: Painted ceiling, mantra with six characters, Buddha niche, Hall of Comprehensive Correspondence (Xianruoguan), Forbidden City, Beijing. – 9: Painted decoration with haiman pattern (cloud, flowers and plants), Study of Jiangxue (Jiangxuexuan), Forbidden City, Beijing. – 10: Painted ceiling with haiman pattern (Chinese wistaria), Study of Tiredness with Diligence (Juanqinzhai), Forbidden City, Beijing. – 11: Painted decoration, Hall of Mental Cultivation (Yangxindian), Forbidden City, Beijing. – 12: Painted decoration, Palace of Gathering Excellence (Chuxiugong), Forbidden City, Beijing. – 13: Painted decoration, Study of rinsing of fragrant (Shufangzhai), Forbidden City, Beijing. 14: Painted decoration, Study of rinsing of fragrant (Shufangzhai), Forbidden City, Beijing.

8: 咸若馆佛龛六字真言天花; 9: 绛雪轩海墁彩画; 10: 倦勤斋彩绘藤萝海墁天花; 11: 养性殿彩画; 12: 储秀宫彩画; 13: 漱芳斋彩画; 14. 漱芳斋彩画。

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15: Vase, painted pottery, Neolithic Age. – 16: Guardian Warrior, painted earthenware, covered with gold leaf, Sui Dynasty. – 17: Court Maid, painted clay, Qing Dynasty. – 18: Avalokitesvara, wood, Ming Dynasty. – 19: Arhat, painted clay, Ming Dynasty. – 20: Buddha, painted clay, Tibet, Qing Dynasty. – 21: Avalokitesvara, stone, Eastern Wei (534-550), painted in Song Dynasty.

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15: 新石器时代彩陶罐; 16: 隋画彩贴金武士俑; 17: 清代彩塑仕女; 18: 明代木雕观音菩萨像; 19: 明代彩塑罗汉像; 20: 清代藏传佛教泥佛像; 21: 北魏石雕观音(宋加彩)。

乔十光

中国漆艺髹饰技法

漆艺，漆工艺、漆艺术之意。包含了实用的漆器、欣赏的漆画和漆塑，它是一门综合性的艺术。

漆艺之“漆”，又称大漆、生漆、土漆、天然漆……是从漆树干上经人为的割伤流出来的液汁。通过过滤、搅拌、晾晒等精制过程，方可应用。

其具有抗潮防腐、耐酸耐碱、耐热绝缘等性能，又有美丽柔和的光泽，因此它是很好的涂饰材料，素有“漆料之王”的美称，广泛地应用于工业、建筑和艺术。

我们的先人在数千年和漆打交道的过程中，创造了多种多样的髹饰技法。所谓“髹”，即用发刷刷涂之意，“饰”即通过绘、嵌、刻、磨、堆、塑……等手段进行纹样装饰之意。分述如下。

一. 髹涂。以漆(包括调进颜料的彩漆)平涂的方法，这是最基础的方法。以黑、红色为最多。黑即漆之本色(漆本为棕色，稍厚即近黑色)，因此，中国有“漆黑”的词汇。红色即天然硫化汞—朱砂人漆，它即鲜艳，又稳重，历久不变。中国古有“丹漆不文，白玉不雕”之说，以示对朱漆的赞美。自古至今，黑和红成为漆艺的主要色彩。以黑漆髹涂者为“黑髹”，以朱漆髹涂者为“朱髹”。此外还有“金髹”(通体贴金)、“彩髹”……。

二. 描绘。以漆或金银描绘纹饰的方法。可以分彩绘、描金、晕金等不同类型。

1. 彩绘：最常见的是单色彩绘，如楚汉时的漆器，多是在黑漆底上画朱纹，或者在朱漆底上画黑纹。也有多色并施者。

2. 描金：利用漆的粘性，在漆液半干不干之际粘贴金银箔或金银粉的方法。

3. 晕金：在将干未干的漆上敷擦金银粉，以金银粉之疏密来表现纹样浓淡变化方法。

以上三种方法可以相互结合运用。

三. 镶嵌。利用漆的粘性，把自然界中的美材，如金银、贝壳、玉石等镶嵌于漆物上的方法。

1. 嵌金银：将金箔片或银箔片刻成纹样贴于漆面，再涂漆磨显。唐代称此为金平脱或银平脱。日本称为“平文”。现代有以锡代银者。

2. 嵌螺钿。把贝壳加工成薄片粘贴于漆面，再涂漆磨显。有软螺钿和硬螺钿之别，前者螺钿片薄，又称薄螺钿，后者螺钿片厚，又称厚螺钿。

3. 嵌蛋壳。这是现代的镶嵌方法，蛋壳镶嵌不仅解决了漆艺的白色，同时又有美丽的龟裂肌理。不仅可以镶嵌成白文，还可以镶嵌成白地；不仅可以俯嵌，还可以仰嵌。

四. 刻填。在漆底上用刀、针刻划处纹样，可以刻点，也可以刻线，还可以刻面，然后再填金、银或彩。有戗金、雕填、刻漆三种类型。

1. 戗金。古也称“锥画”、“针刻”。多为线刻，也可以刻点，点分疏密。刻后填金者谓“戗金”；填银者谓“戗银”；填彩者谓“戗彩”。

2. 雕填：和戗金法基本相同。不同处在于刻后饱填彩漆，干后研磨，纹质齐平。缅甸多用此法。

3. 刻漆：又称“刻灰”，漆层较厚，多刻块面留阳纹，内填彩色，不必求平。古称“款彩”，多用来制作屏风大件作品，有版画风采。

五. 磨绘。漆液干后很坚硬，耐用石头、木炭、水砂纸研磨。磨绘即是在层层描绘涂漆之后再磨出纹样效果的方法。有以下几种类型。

1. 彩漆磨绘：先用彩漆描绘纹样，再通体涂漆，干后磨显。

2. 罩漆磨绘：利用漆的半透明特性，罩屠宰金银或彩漆上，再磨出浓淡效果。

3. 莳绘：用金、银粉(颗粒状)或干漆粉等根据纹样需要播洒成疏密浓淡，再罩漆磨显。日本精于此道。

4. 铝箔粉磨绘：这是当代的髹饰方法，即在铝箔粉上罩涂透明性漆再研磨出明暗层次的方法，透明性漆中加入透明颜料，常用来表现人物的肌肤。

六. 变涂。用某种工具(如漆刷、滚珠……)，或某中介物(如纸片、树叶、粟粒……)。或用汽油、樟脑油将漆稀释……以引起抽象纹理的方法，千变万化，古称“彰髹”，日本称为“变涂”。

七. 堆塑。用稠漆原描，或漆中拌进填充料(如瓦灰、木炭粉、石膏等)原堆纹样如浮雕的方法。

八. 雕漆。涂漆数十道、上百道、数百道……待达到所需的厚度时，再用刀雕刻的方法。根据漆的色彩不同，用剔红、剔黑、剔犀、剔彩之别。

1. 剔红：纯以朱漆雕刻者。

2. 剔黑：纯以黑漆雕刻者。

3. 剔犀：以黑、朱色漆相间者。

4. 剔彩：多彩者。

中国古代，如战国、秦、汉时期的漆器多用髹涂描绘技法，唐代出现了金银镶嵌，宋元又发展了雕漆，及至明清技法就更加多种多样了，中国当代的漆画，各种髹饰技法得到更加综合的运用。

多种多样的漆艺髹饰技法，开拓了丰富多彩的漆艺之美，创造了光辉灿烂的漆艺文化。中华漆艺不仅是一门历史悠久的传统艺术，同时也是一门富有广泛开发前景的现代艺术。

Qiao Shiguang

Qi-Lacquer – Technique and Art

The lacquering, the art of lacquer means the technology of applying lacquer. It is a traditional Chinese art.

The lacquer also called big lacquer, raw lacquer and rhus lacquer, is a natural paint derived from the varnish tree. It is not only water-proof and antiseptic but also lustrous. In China, it began to be used six or seven thousand years ago to protect and beautify articles and utensils, for example the wood raw lacquer bowl unearthed from the 3rd level of Mudu Culture in Yuyaohe of Zhejiang Province. The black lacquer mug and the black lacquer jar, both made of pottery and unearthed in Wujiang of Jiangsu Province, are relics from the Liangzhu Culture about 4 or 5 thousand years ago.

The liquid lacquer may be applied not only to wood and pottery but to metal, leather and bamboo as well. In addition, it can be combined with linen to form multi-layered patterns by taking advantage of the lacquer's adhesiveness and the linen's tensile force. Using this method, which was called "Jia" in ancient times and is used on lacquer sculpture works, any pattern you wish to have, can be formed.

The lacquering work falls into many varieties and the coating methods are also diversified including coating and painting, inlaying, carving and filling, polishing and painting, embossed sculpture, carved lacquering, etc.

(1) Coating and painting refers to the method in which lacquer is blended with pigments, gold or silver to then be applied by brush as a coating or as designs and pictures.
(2) Inlaying refers to the method of inlaying shells, jade or metal onto the surfaces by using the adhesiveness of the lacquer.
(3) Carving and filling refers to the methods by which decorative patterns are first carved by a needle or a knife on the surfaces and then filled in with gold , silver or colour lacquer.
(4) Polishing and painting refers to the method of first applying colour lacquer (including gold and silver) layer by layer, then polishing the surface and grinding patterns with water-proof abrasive paper or grinding stones.
(5) Embossed sculpture refers to the method of using lacquer or the mixture of lacquer and fillings to project the patterns.
(6) Carved lacquering refers to the method of carving which is done after dozens or even hundreds of lacquer coatings are completed.

The diversified coating and lacquering methods produce both lacquer wares of practical use and artistic works of painting and sculpture. It is a comprehensive art form, which uses various materials and combines practical art with pure art. It is not only traditional but also promising in its developing prospects. *See colour plate XIV.*

Hans-Georg Wiedemann* and Heinz Berke**

Chemical and Physical Investigations of Egyptian and Chinese Blue and Purple

* Mettler-Toledo GmbH, CH-8603 Schwerzenbach
** Anorganisch-chemisches Institut, Universität Zürich, Winterthurerstrasse 190, CH-8057 Zürich

Introduction

The production of Egyptian Blue can be traced back from earlier than 3000 B. C. up until approximately 300 A. D. One of the earliest documentation of Egyptian Blue is found on the Tablets of an olive oil container, which certifies the quality of the oil blessed by the Godess Iset (pre-dynastic). Another proof for the early use of Egyptian Blue is the Mastaba of the vesir of Mereruka (2300 B. C., Saqquara). This and other samples are shown in Table 1 and represent a selection of identified Egyptian Blue up to the Greek-Roman period.

A contemporary artist, E. Arpagaus, has studied mineral colours and pigments of Egypt and surrounding areas (Arpagaus, 1996) showing the variety of different colours, which were prevalent in nature. The presented blue pigment has however been artificially produced in the manner of the Egyptians.

In ancient times continents and countries were connected by famous trade routes; the link between the Western World and ancient China was established via the Silk Road. Aside from its economic function this adventurous and risky route played an outstanding role in the distribution and exchange of ideas and technologies between East and West. The relatively constant composition of Egyptian Blue over the period of the Old Kingdom up to the Ptolemaic and Greek-Roman time (Table 2) indicates that the information about the production of coloured pigments never got lost. For blue pigments this is attributed to the fact that they had a prominent role in religious rites and everyday life. States adjoining the Silk Road were challenged by the tradition of blue production and its use in manufactured Egyptian goods to either obtain it by trade or to produce it themselves. This background was apparently a major driving force for the expansion of artificial blue and even other pigments.

The change in location and the need for further improvements of artificial pigments induced new technological developments, which generated similar advanced materials such as strontium and barium copper silicates as in the Iraqi and Iranian samples of Brick Nimrud (British Museum London) the Sistrum Hasanlu and the Goblet Hasanlu, Iran (both Metropolitan Museum New York) and barium in Chinese artefacts represented by the blue and purple octahedral sticks and samples of the Terracotta Army, all compiled in Table 1.

The Chinese samples are attributed to the Warring States, Quin and Han period 600 B. C. till approximately 200 A. D.. As we will see in the later context they contain man-made blue and purple pigments called Chinese Blue and Purple, sometimes also denoted as Han Blue and Purple (Fitzhugh, 1992). They were used in colouring applications and they refer to destinct, but very related chemical compounds. Only Egyptian and Chinese Blue are found as minerals in nature (Cuprorivaite, Effenbergerite (Giester, 1994)). They are, however, so rare that any utilization of these minerals by ancient civilizations can be excluded. It should be mentioned at this point that the only mineral pigment used by earlier civilizations, which naturally appeared blue and did not demand chemical transformation or processing, was lapis lazuli (Reinen, 1999). Its scarcity in nature caused it to become highly esteemed, at least in the western hemisphere. Presumably as a consequence of the general scarceness, the blue has been attributed divine character in some civilizations, such as the Egyptian.

In general colour has played a major role in the development of civilizations and has acquired important cultural functions as one of the essential ways of human self-expression and affectation. Colours produce aesthetic stimulation, which is reflected in art forms. All this emphasizes the outstanding role of colour in human development, and colouring substances in the form of pigments have thus always been used by mankind as they became available.

Apparently motivated by the lack of natural blue minerals and mankind's intrinsic desire for colours, people were driven to invent blue pigments. It is may be worth mentioning that among those invented Blues there is also the Indigo based Maya Blue, which had wide-spread application within Indian cultures (José-Yacaman, 1996). Any of the mentioned man-made blue pigments but also Chinese Purple required sophisticated chemical and technological developments, which could only be mastered in a sound cultural and technological environment. In the following article we will see that the chemistry behind these man-made pigments is quite complicated. Ancient chemical achievements could not be based on atomic or molecular grounds. Therefore any progress was established by long and tedious processes of empirical probing.

Investigated Original Samples of Egyptian Blue, Chinese Blue and Purple

The investigated ancient samples of Egyptian Blue and Chinese Blue and Purple are summarized in Table 1. The Egyptian samples cover a span of almost 3000 years starting with Blue from the 6th Dynasty of the Old Kingdom to the Roman time.

The oldest sample stems from the Mastaba of Mereruka in Saqqara, Egypt. Mereruka was vesir to King Teti, reaching the Mastaba from his tomb through a fictive door to receive the daily sacrifice from his relatives, who prepared the altar (Wiedemann, 1997b). The second sample originates from the tomb of General Antef, Middle Kingdom, 11th Dynasty. General Intef reported to Mentuhotep II as the commander of the troops. He belonged to the most important courtiers, which is also expressed by the location of his tomb in close vicinity to the funeral temple of his King in Thebes. The next three samples studied came from the New Kingdom period. Blue from the crown of the famous bust of Nefertete (Ägyptisches Museum der Staatlichen Museen Berlin, Germany) and Blue of the Talatat Stones of the Temple of her husband Echnaton (Amarna, Egypt). The cylindrical seal, which is also dated to the New Kingdom and whose orgin falls into a very productive period for artisans,

Time	Name	Colour	PL	RS	X-Ray	EDX
2345-2181 B.C.	Mastaba of Mereruka	EB	+	+	+	+
2133-1991 B.C.	Tomb Intef	EB	-	+	+	-
1340 B.C.	Bust of Nofretete, blue of crown	EB	-	+	-	+
1353 B.C.	Echnaton temple, blue of Talatat	EB	-	+	-	+
1300 B.C.	HGW, Cylinder Seal, Thebes	EB		+	-	+
13th – 7th Century B.C.	Brick Nimrud, Iraq	EB	+	+	+	-
712-332 B.C.	HB, Amulet Bes	EB	+	+	-	+
500 B.C.	Ba-bird, Soul	EB	-	+	+	+
3rd Century B.C.	Mummy cartonage	EB	+	+	+	+
1st Century B.C.	Ptah Sokaris Osiris Fig., Munich	EB	-	+	+	+
Roman time	Mummy coffin, Cairo	EB	-	+	+	+
Han Dynasty	Stick Freer Gallery, Washington	CP	+	+	+	+
Han Dynasty	Stick Royal Ontario Museum	CP	-	+	-	-
Han Dynasty	Stick 4069 Oestas. Mus.,Sweden	CB/CP	+	+	+	+
Han Dynasty	Stick 4070 Oestas. Mus.,Sweden	CP	+	+	+	+
Qin Dynasty	Sample I, Terracotta Army	CP	-	+	-	+
Qin Dynasty	Sample II, Terracotta Army	CP	-	+	-	+

Appendix (substances not investigated by us)

Time	Name	Colour	PL	RS	X-Ray	EDX
9th Century B.C.	Sistrum Hasanlu, Iran*	EB ?	-	-	+	+
9th Century B.C.	Goblet Hasanlu, Iran*	EB ?	-	-	+	+

EB = Egyptian blue, CP = Chinese purple, EB? contains probably $SrCuSi_4O_{10}$
PL = Photoluminescence, RS = Raman Spectroscopy, *Metropolitan Museum of Arts, New York

Table 1. Egyptian, Mesopotamian and Chinese samples investigated by different physical methods.

表 1. 利用不同物理方法对埃及、美索不达米亚和中国的试样的研究。

is the property of one of the authors (fig. 1). It has been described in detail elsewhere (Wiedemann, 1997a). The sample of Brick Nimrud comes from Mesopotamia and is dated to the 13th – 7th century B. C. Today it is the property of the British Museum, London.

The Late Egyptian Period is documented by several other samples. Amulet Bes was protecting those who wore it by the powers of the dwarfish God Bes. It is dated to the 24th Dynasty and is the property of one of the authors (colour plate XV, fig. 1). The wooden falcon figure Ba-bird (Kestner Museum, Hannover, Germany) contains blue areas, from which a sample was studied. Ba-bird from approximately 500 B. C. symbolized a protection god at burial ceremonies (Wiedemann, 1997b). The figure Ptah-Sokaris-Osiris from the 1st century B. C. stems originally from Memphis, Egypt. It is now property of the Staatliche Sammlung Ägyptischer Kunst, Munich, Germany (ÄS 19). It served as a container for corpses. A sample of the Blue was taken (Wiedemann, 1997b). The samples of the mummy cartonage and the mummy coffin represent Egyptian Blue from Ptolemaic and Roman times. Their present locations are unknown.

Four of the six originally investigated samples of Chinese Blue and Purple (Table 1) were taken from original Blue or Purple sticks of octagonal shapes. It is thought that these sticks were trade items. They were used as pigment bases in paints and applied by grinding. The general phenomenology of the Freer Gallery sample has been described earlier by FitzHugh (FitzHugh, 1983; FitzHugh, 1992). The photograph of a slice of the Freer Gallery sample (colour plate XV, fig. 2) shows its purplish blue colour and the representative size of such sticks.

The Royal Ontario Museum Sample stick came from a blue octagonal stick said to have come from Jincun near Luoyang, China (FitzHugh, 1992). It is reported to be made of mainly blue particles with scattered purple ones. The two samples of sticks from the Museum of Far Eastern Antiquities in Stockholm, K 4069 (Blue) and K 4070 (Purple) are described as worn and porous materials (FitzHugh, 1992), from which powdery material was taken for investigation. The stick samples were recently discussed (Berke, 2000).

Distinct samples from different parts of the Terracotta Army (sample I and II), were investigated as cross sections of the pigment layer. Earlier investigation showed the presence of Chinese Purple and other pigment materials (Herm, 1995; Thieme, 1995). Application of Raman spectroscopy and electron microscopy with EDX were expected to confirm these results, but also to deliver further information on the nature of the pigment content. Colour plate XV, fig. 3 shows the microscopic photograph of one of the studied cross sections (sample I) containing a crystallite of Chinese Purple.

All the samples were compared to pure Egyptian Blue and Chinese Blue and Purple or their mixtures, obtained by contemporary independent synthesis (among others Bayer, 1991).

Chemistry of Egyptian and Chinese Blue and Chinese Purple

Compositions and Structures

Egyptian and Chinese Blue are calcium and barium copper silicates with the compositions $CaCuSi_4O_{10}$ and $BaCuSi_4O_{10}$, (Finger, 1989; Fitzhugh, 1983; Fitzhugh, 1992) respectively. They thus differ in the replacement of calcium with barium. Their chemical relationship is so close that crystals of both compounds adopt exactly the same habitus (Pabst, 1959; Chase, 1971; Bayer, 1976) and on the microscopic scale they are isostructural. Their structures consist of puckered infinite silicate layers composed of $(SiO)_4$ silicate squares, which are condensed together via oxygen bridges and thus form a two-dimensional network of connected $(SiO)_4$ and $(SiO)_8$ rings. Each silicon atom bears a terminal oxygen group, which can either contribute to binding of Cu^{2+} or Ca^{2+}/Ba^{2+}. As sketched in fig. 4 four oxygen atoms from a silicon atom of four adjacent $(SiO)_4$ rings accommodate a copper ion in square planar arrangement. The calcium or barium ions are employed in a similar fashion, however in an alternating way, with the coppers they twice pick four oxygens from two adjacent layers for binding and in this manner, they 'glue' the layers together.

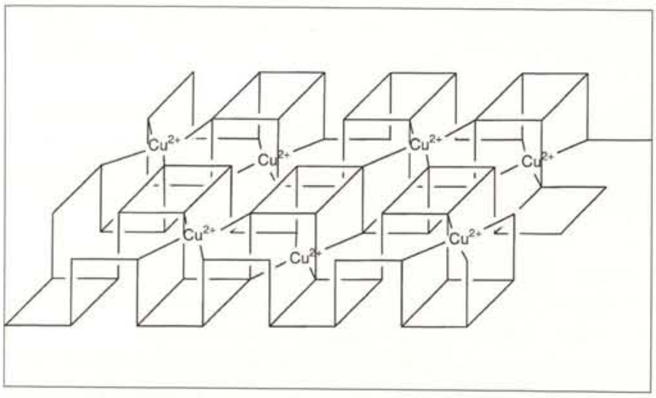


Fig. 1. Schematic representation of the puckering of a $Si_4O_{10}^{4-}$ layer in Ca, $BaCuSi_4O_{10}$ induced by Cu^{2+} coordination. Every other open square is filled by Cu^{2+}. The non-filled squares are occupied by Ca^{2+} or Ba^{2+} connecting the layers. The structure of Egyptian Blue was determined by Pabst (Pabst, 1959) and redetermined by Bensch (Bensch, 1995). The structure of Chinese Blue was studied by Finger (Finger, 1989).

图 1. 由 Cu^{2+}配位引起的 Ca, $BaCuSi_4O_{10}^{4-}$层皱褶的示意图。每隔一个敞口的方格由 Cu^{2+}填充，非填充的方格由连接层间的 Ca^{2+}或 Ba^{2+}占据。埃及蓝的结构由帕布斯特(Pabst, 1959)测定，本施(Bensch, 1995)重新测定。中国蓝的结构由芬格研究(Finger, 1989)。

In $CaCuSi_4O_{10}$ and $BaCuSi_4O_{10}$ the copper ions are thus in a very similar oxygen atom environment. Since the pigment properties, e. g. the blue colour, are merely related to the copper ions (chromophore), both compounds have almost the same colour properties. The structure of Egyptian Blue was first unraveled quite some time ago (Pabst, 1959; Bensch, 1995), while that of Chinese Blue has been elucidated more recently (Finger, 1989). It is a frequent observation, that layered structural frameworks with preferred spatial orientations of the chromophores give rise to pleo- or dichroism. Two or more different colours (dichroism or pleochroism) can be seen in different orientations of the crystal faces when irradiated with (white) light. Egyptian Blue does show pleochroism (Bayer, 1976) and due to the close structural resemblance of Egyptian and Chinese Blue, we can assume that Chinese Blue is also pleochroic. When grinding is applied to solid matter, particle size, crystal shape and crystal face distributions are changed and subsequently the overall colour appearance may concomitantly be altered. While large platelets of Egyptian or Chinese Blue appear light blue (colour plate XV, fig. 3), when grinding is applied, both pigments becomes more bluish. This is illustrated in photographs of powders of the Chinese pigments (colour plate XV, fig. 5).

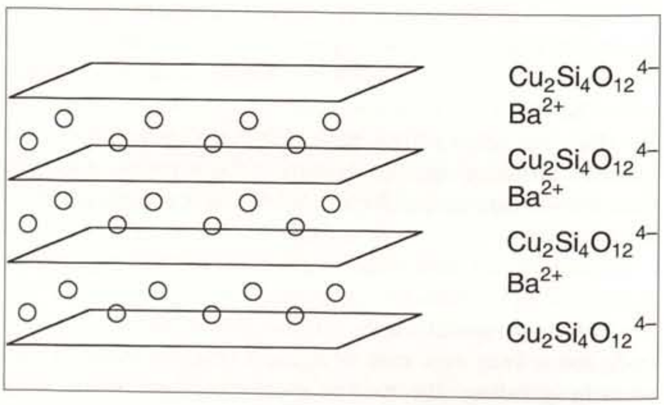
Chinese Purple's composition is $BaCuSi_2O_6$. It formally contains two equivalents of quartz (SiO_2) less than Chinese Blue. It should be mentioned at this point that an analogous 'Egyptian Purple' with the formula $CaCuSi_2O_6$ could to date not be prepared. Chinese Purple may be viewed as a reaction intermediate (so-called kinetic product) while producing Chinese Blue. Even though Chinese Purple also consists of layers in its microscopic structure (fig. 7a and 7b), these layers differ signifantly in their basic structural motifs from that of Egyptian and Chinese Blue.

There is no other extended silicate framework like that of the Blues. The silicate condensation process is stopped at the $(SiO)_4$ four ring stage generating a patchwork of isolated $Si_4O_{12}^{8-}$ four-ring units infinitely connected by Cu-Cu bonded moieties to build-up a $Cu_2Si_4O_{12}^{4-}$ layered structure (Janczak, 1992). Like in Chinese Blue the barium ions are located between the layers and hold these together by coordinative contacts. Figure 7b also shows a piece of a $[Cu_2Si_4O_{12}^{4-}]\sim$ layer as taken from a single-crystal X-ray structure of Chinese purple.

The extraordinary and very unique feature of this structure is tighed up to the copper-copper bond, which was overlooked in the earliest structural determination of Finger et al (Finger, 1989). This inner core of the structure of Chinese Purple is thus related to the dimer of prototypical copper acetate, $Cu_2(acetate)_4$, which also contains a bridged Cu-Cu unit, where the bridging functions are provided by the acetate ions. Early Chi-

Fig. 2a. Schematic representation of the structure of Chinese Purple with the principle arrangement in layers of Ba^{2+} and $Cu_2Si_4O_{12}^{4-}$.

图 2a. $Ba^{2+}Cu_2Si_4O_{12}^{4-}$层状规则排列的中国紫结构的示意图。



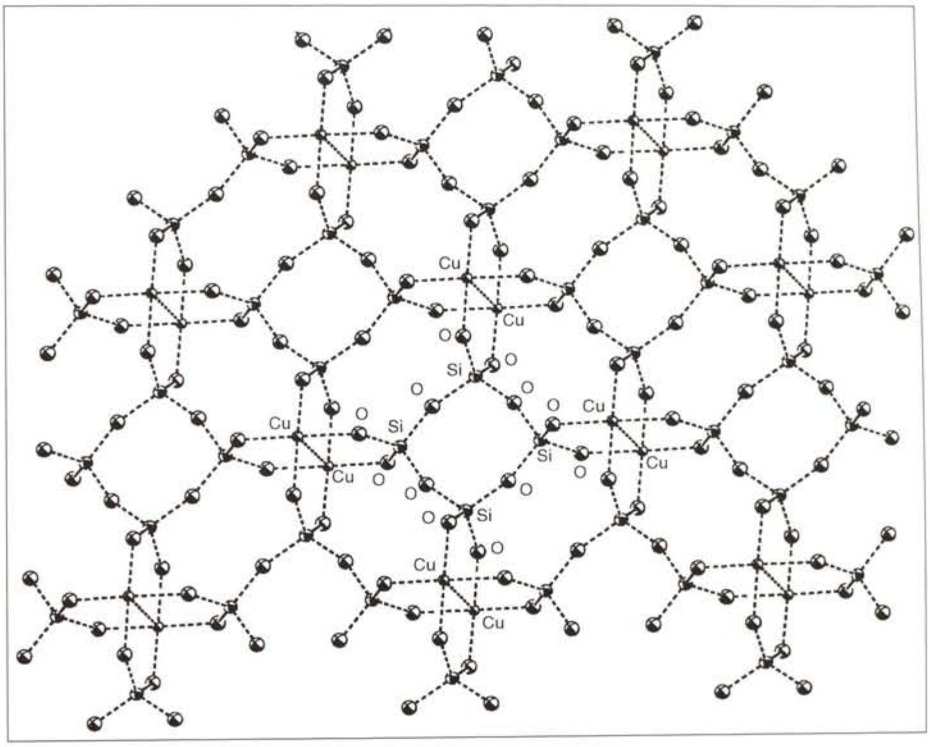


Fig. 2b. Sketch of the structure of Chinese Purple, $BaCuSi_2O_6$, as obtained from a single crystal X-ray diffraction study. Only the $[Cu_2Si_4O_{12}]^{4-}$ layer is presented. The Cu-Cu distance is 2.73 Å.

图 2b. 由单晶 X-射线衍射研究得到的中国紫 $BaCuSi_2O_6$ 结构简图。只显示$[Cu_2Si_4O_{12}]^{4-}$层的结构。 Cu-Cu 距离为 2.73Å。

nese chemists were thus, to our knowledge, the first humans to prepared a chemical compound containing a metal-metal bond. This peculiar finding is even more important in view of the chemical fact, that in compounds other than in metals, metal-metal bonds still have nowadays the flair of curiosities.

It is important to note that in Chinese Blue and Purple the copper ions are rigidly fixed in the structural framework. As a consequence of that, they can effectively absorb and emit light: the latter is effective, when excited by light with short wavelengths inducing fluorescence (Ajo, 2000). Layered structures such as Chinese Purple are also expected to display pleochroic features similar to those of Egyptian and Chinese Blue. On grinding, Chinese Purple changes it's colour tone from more bluish to more purplish (colour plate XV, fig. 5).

Stability Properties of Egyptian and Chinese Blue and Chinese Purple

The thermal and chemical stabilities of Egyptian and Chinese Blue on the one hand and Chinese Purple on the other are strikingly different. This can be related to two structural factors:

(a) contrary to Egyptian and Chinese Blue the silicate framework of Chinese Purple consists of relatively small $Si_4O_{12}^{8-}$ units connected by only weak coordinative bonds to copper and barium
(b) Chinese Purple contains a chemically labile Cu–Cu bond

The more silica-rich Egyptian and Chinese Blue are more SiO_2-like with a higher degree of condensation in the silicate framework. Melting, which requires breakage of the silicate layers into smaller molecular units, is thus only possible at elevated temperatures. This was confirmed by an isothermal heat treatment of corresponding Chinese samples at 1200 °C for four hours. Pure Chinese Purple melted to a viscous, black green glass, whereas Chinese Blue only showed increased sintering. X-ray investigation of these samples quenched from 1200 °C proved that the former was amorphous and vitreous, while the latter was unchanged $BaCuSi_4O_{10}$. $BaCuSi_4O_{10}$ actually starts to decompose at 1170 °C under loss of O_2. It can however be reoxidized completely at 1060 °C. (Wiedemann, 1997b; Bayer 1976). The thermal decomposition of Chinese Purple is expected to take place according to the following equation

$$3\ BaCuSi_2O_6 \rightarrow BaCuSi_4O_{10} + 2\ BaSiO_3 + 2\ CuO$$

Barium and copper meta-silicates are formed first, the former has even been detected in experiments under melt conditions (Bayer, 1991). At temperatures above approximately 1000 °C the potential decomposition product $CuSiO_3$ (dehydrated dioptase) is known not to be stable and to liberate tenorite and quartz (Kiseleva, 1993), the latter may subsequently be consumed by Chinese Purple to generate Chinese Blue. Under conditions of above 1050 °C the copper(II) oxide content of these compounds could furthermore turn into copper(I) oxide and oxygen:

$$2\ CuO \rightarrow Cu_2O + 1/2\ O_2$$

Prolonged firing of Chinese Purple thus results in additional formation of Chinese Blue, colourless barium meta silicate and red cuprite (Cu_2O). Powdered mixtures of these constituents would actually generate a more reddish appearance of the Chinese Purple, the more the higher the cuprite content is. All of these components have been identified in samples of Chinese Purple made by independent synthesis, and which underwent prolonged thermal treatment.

What both, the Egyptians and the Chinese could not know, was the reactivity of their pigments in the presence in chemical or biological agents. In acids a striking difference in the chemical stability of Chinese Purple and Chinese Blue was observed (Pabst 1959; FitzHugh 1983) and could be confirmed by our own experiments. Egyptian and Chinese Blue are stable in dilute acids, whereas Chinese purple, $BaCuSi_2O_6$, rapidly fades and decomposes. The same effect is observed when these pigments are exposed to an aqueous solution of oxalic acid. As products Ba- and Ca-oxalates could be identified by EDX, X-ray diffraction and simultaneous thermogravimetry / mass spectrometry investigations (Lamprecht, 1997). This is an important finding with respect to conservation procedures, since it demonstrates that in the deterioration of works of art, lichens, which excrete oxalates or even oxalic acid, may play a relevant role (Seaward, 1989).

In turn, it has been shown in previous investigations on coloured Egyptian papyri, that spores and fungi did not exist in areas where Egyptian Blue was used as a pigment. These findings were confirmed by further studies of different papyri. This can be explained by the fact that copper is a strong fungicide, which was proven by experiments with limestone covered by lichens. No further growth occurred in areas where the lichens were removed and which was subsequently painted with Egyptian Blue (Wiedemann, 1996; Lamprecht, 1997) (colour plate XV, fig. 7, 8)).

It is interesting to note that the production of blue bread is mentioned in documents of the 18th dynasty (1500 B.C.) in ancient Egypt (Sethe, 1961). Since the Egyptians produced air-dried bread for emergency situations, it may be that they had some knowledge about the conservation effect of Egyptian Blue. As shown in figure 8 Chinese Blue has similar fungicidal properties. Chinese Purple, however, deteriorates under the influence of oxalate producing lichens and leaves light blue residues behind. Chemical reactions of Chinese Purple with oxalic acid produced a double salt $BaCu(C_2O_4)_2$ of light blue colour (colour plate XV, fig. 7,8). It is therefore probable that the light blue colour of the trousers of some Terracotta Warriors (Ledderose, 1992) may not be the original colour, but rather the transformed Chinese Purple, which occured under the influence of oxalate excreting lichens.

Synthesis of Egyptian Blue

Preparation of Egyptian Blue has been carried out by our group and others. In our search for optimal conditions for the preparation, various techniques have been reported. The synthesis of Egyptian Blue was mostly in powdery form as a pigment, but also as a compact body. The effect of the firing temperature and of the atmosphere on its formation and stability has been demonstrated elsewhere (Bayer, 1976). The effect of various fluxes on the development of the tone of blue colour has been confirmed by microscopical light studies. Compact bodies were produced either directly from mixtures of the raw material or from presynthesized Egyptian Blue by heating the dry-pressed powders at 900 °C in air. This proved that, in the raw material samples, the flux (Na_2CO_3) migrates and is concentrated in the surface, whereas the flux-free interior remains greenish and practically does not react. On the other hand the compact bodies made from presynthesized Egyptian Blue powder are less intensively coloured, but blue throughout. The morphology of the surface of the compact bodies reveal $CaCuSi_4O_{10}$ crystals embedded in the flux materials. Single crystals of Egyptian blue could be prepared by long-time annealing (100 h, 880 °C) of a borax-flux containing mixtures of the raw materials. Based on the results of synthetic experiments, it seems probable that the fine-textured Egyptian blue objects, e.g. cylinder seals, were made by a two-stage firing cycle in oxidizing atmosphere. A single firing at 900 °C of bodies formed directly from the raw material mixture leads to fragile structures. This is due to the migration of alkali flux to the surface, forming a coarser-textured surface layer of Egyptian Blue, but leaving the bulk unreacted and greenish coloured. Therefore, the preferred method would be first to synthesize the Egyptian blue pigment, then the finely ground material can be used for forming the objects with addition of an organic binder (e.g. gelatine or wax) in order to get sufficient strength. For improved sintering at 900 – 950 °C it is of advantage to add some flux or even better to add glass powder. These additions form a grain boundary melt, which enhances the liquid phase sintering. The objects should not be heated higher than 1000 °C, since above this temperature Egyptian Blue decomposes irreversibly to tridymite and glass.

Synthesis of Chinese Blue and Purple

Detailed studies on the chemical composition, as well as of the phase diagram of this Ba-Cu silicate-system revealed that there exist – in contrary to the mentioned Egyptian Blue, $CaCuSi_4O_{10}$ – at least four stoichiometric ternary phases (Finger, 1989; Malinovskij, 1984; Tsukada, 1999):

$BaCuSi_4O_{10}$ (blue), $BaCuSi_2O_6$, (purple), $BaCu_2Si_2O_7$ (blue), $Ba_2CuSi_2O_7$ (lightblue).

This seems to be of considerable advantage for the Egyptian manufacturer, but certainly caused difficulties to those Chinese manufacturers trying to synthesize pure tones. On the other hand it was an advantage for those Chinese painters, who wished to vary their tone of colour from blue to purple in mixtures (colour plate XV, fig. 5).

The Chinese applied the Egyptian Blue analogue $BaCuSi_4O_{10}$ and the purple phase $BaCuSi_2O_6$. These phases differ in colour strength and tone, e. g. the Chinese painter was able to enlarge the spectrum of his blue colour palette by using or admixing one or the other purplish or bluish phase. Of course the choice was limited with respect to the skills in fabricating pure phases.

The synthesis of the pure phases is not direct: depending on the raw materials used, their ratio, the addition of fluxes and of course the temperature, atmosphere and reaction time different products, but usually a mixture of compounds is obtained. Since the Chinese civilization was very adept at functionalizing natural minerals, it seems of special interest, which resources for barium were used: Barite, $BaSO_4$, is found in a variety of deposits all over China, or Witherite, $BaCO_3$, which is much rarer and sometimes associated with barite. As will be shown the choice between these minerals can be quite relevant for the products obtained by the available techniques. It is very likely that copper-sulfides were used together with barite and silica sand or quartzite. Thus, one can assume that the copper minerals for the fabrication of the blue and purple BaCu-silicate pigments e.g. used in the Mogao Grottoes were collected in deposits of the Gansu province, e.g. near Lanzhou, Gulang or Jiayuguan (Gloria, 1985). Our experimental studies focused on the effect of the barium mineral used. As copper source tenorite, CuO, was used, since any copper sulfide is oxidized to CuO well below the temperature where the reaction starts (Bayer, 1992). The parent materials $BaSO_4$, $BaCO_3$, CuO, Cu_2S, SiO_2 were homogeneously mixed and slightly compacted. Heating times at the various temperatures were usually 20 hours. The identification of the crystalline reaction products was done by X-ray diffraction. The influence of fluxes such as NaCl, Na_2CO_3 and PbO (found in various pigments) were studied. Additional investigations were concerned with the thermochemical reactivity of the various pigment samples. Previous studies on $BaCuSi_4O_{10}$ blue confirmed that there is a distinct effect not only of the temperature used but also of the Ba-compound and of the fluxes added on the colour tone of this pigment (Bayer, 1976).

Mixtures of $BaCO_3$, CuO and quartz powder were prepared with different, stoichiometric ratios (1/1/2, 1/1/4, 1/2/2 and 2/1/2). The mixtures were filled in porcelain crucibles, slightly compacted and heated at 900, 1000 and 1100 °C in air. To some of these mixtures 3 % Na_2CO_3 or 5 % PbO or 10 % NaCl were added as a flux. TG/DTA runs of 1/1/2 and 1/1/4 mixtures showed that, owing to the presence of SiO_2, the decomposition of $BaCO_3$ already starts below its phase transition at around 800 °C (Wiedemann, 1986; Wiedemann, 1992). The decomposition to $BaO+CO_2$ proceeds faster above this temperature and is complete at about 950 °C. The solid state reaction to Ba-Cu-silicates probably starts around 900 °C. Depending on the BaO/CuO/SiO_2-ratio partial melting and reduction of Cu^{2+} to Cu^{1+} occurs at temperatures above 1050 °C. The purple compound $BaCuSi_2O_6$ is formed as the primary Ba-Cu-silicate, also in mixtures with the stoichiometry 1/1/4. It is thermally less stable than $BaCuSi_4O_{10}$ and melts with decomposition around 1100 °C.

As mentioned above, the addition of fluxes have a definite effect on the formation and the colour of the pigment. Pure $BaCuSi_4O_{10}$ can be synthesized by adding fluxes such as Na_2CO_3 or borax. The addition of more than 5 % Na_2CO_3 and heating above 1000 °C resulted in the melting of the purple $BaCuSi_2O_6$ compound to a glass. However, the fluxes may also cause side reactions. Addition of NaCl causes volatilisation of some copper as $CuCl_2$ and disproportionation to CuO in the cooler zone of the furnace. In starting mixtures where $BaCO_3$ is present as the barium source, the addition of Na_2SO_4 causes the intermediate formation of $BaSO_4$ due to the displacement reaction $BaCO_3 + Na_2SO_4 \rightarrow BaSO_4 + Na_2CO_3$ in the temperature range of 600 to 800 °C, (Bayer, 1987). Fluxes such as Na_2CO_3, PbO or borax did not cause problems. Since many original Chinese Purple pigments contained a high proportion of lead oxide, this oxide was also tried as a flux. It was found to be very effective in the formation of both Chinese Purple and Chinese Blue already at 900 °C. However, additions of more than 5% PbO led to partial melting and glass formation above 1000 °C (Wiedemann, 1997a and b).

In addition to their function as flux, lead additives can activate $BaSO_4$. In the presence of lead oxide (or carbonate) a dismutation reaction with barite can be envisaged, which leads to equilibrium formation of lead sulfate

$$PbO + BaSO_4 \leftrightharpoons BaO + PbSO_4$$

Since pure lead sulfate decomposes at around 1000 °C to $PbSO_4 \cdot 2\,PbO$ (Malinowski, 1996), much lower than $BaSO_4$, which decomposes at 1560 °C, it can be anticipated that the BaO will be withdrawn from the equilibrium by the Chinese Blue or Purple formation, while the PbO part will be reintroduced into the barite decomposition process. Thus, lead additives can also take over the function as a catalyst for the decomposition of $BaSO_4$ at comparatively low temperatures, which is a decisive circumstance especially for the preparation of the thermally less stable Chinese Purple.

When copper sulphide minerals are used as starting material, their oxidation leads to the evolution of SO_2, which reacts with $BaCO_3$ to $BaSO_4$. Compared to a parent mixture of identical stoichiometry where CuO is used instead of e.g. Cu_2S distinct changes of the colour tone of the product are observed. In both cases, however, Chinese Purple (1/1/2) and Chinese Blue (1/1/4), as well as mixtures of both can be identified by X-ray diffraction. Obviously the presence of $BaSO_4$ changes the synthesis pathway of the different phases: $BaSO_4$ has a higher thermal stability and starts to decompose under the reaction conditions only slowly above 950 °C. As thermogravimetric measurements proved a large amount of $BaSO_4$ dues not react even after heating for 20 hours at 1100 °C. Therefore the ratio between the reaction products $BaCuSi_2O_6$ and $BaCuSi_4O_{10}$ and hence also the colour tone differs from that of corresponding mixtures using $BaCO_3$ as barium source (Wiedemann, 1997b). The slower decomposition rate of $BaSO_4$ mobilising only small amounts of BaO obviously favours the primary formation of the silica-rich Chinese Blue, $BaCuSi_4O_{10}$. Even for 1/1/2 starting mixtures and at 1100 °C, $BaCuSi_4O_{10}$ continues to persist besides Chinese Purple, $BaCuSi_2O_6$. This is in contrast to the corresponding starting mixtures containing $BaCO_3$, where the formation of Chinese Purple is strongly favoured and where reactions generally start at lower temperatures.

The fact that we have the possibility to investigate blue copper pigments as testimonial on the technological skills of ancient Egyptian and Chinese manufacturers also accounts for the chemical stability of these synthetic and simultaneously aesthetic products. It could be shown that the silica-rich phases Egyptian Blue, $CaCuSi_4O_{10}$ and Chinese Blue, $BaCuSi_4O_{10}$ adopt analogous structural frameworks. As the X-ray diffraction confirms, there is also a $SrCuSi_4O_{10}$ analogue, which seems to be present in certain archeological samples (Sistrum and Goblet Hasanlu, Iran of Table 1).

Physical Investigations of Ancient Egyptian Blue, Chinese Blue and Purple Samples

Methods of Characterization for Ancient Pigments

Ancient pigment samples often appear as heterogeneous mixtures and due to this varying contents of the pigment are present in coloured materials. Apart from this, the pigments themselves may have differing compositions based on the fact that they might consist of more than one similar, but distinguishable chemical species. Quite often the origins of this are complicated phase diagrams of such materials, which make it difficult to define appropriate conditions in the synthesis of a peculiar species. Accurate analyses of multicomponent heterogeneous mixtures constitute challenging problems in chemistry, especially in view of the fact that the analyses are expected to be carried out in a nondestructive fashion applying samples in the milli- or microgram range.

In recent years however, physicists and chemists have developed an arsenal of very powerful, sophisticated methods for the detailed investigation of ancient materials. In particular miniaturization, utilization of new physical effects and advanced computerization have contributed to an enormously improved situation, which allows us to obtain satisfying information on the nature of such mixtures. Important applicable methods typical of the analysis of compact and powdery samples are:

A) Thermal analysis

Most widely used in this area are thermogravimetry (TG) and differential thermal analysis (DTA) with its frequently used branches of differential thermal gravimetry (DTG) or differential scaning calorimetry (DSC), which allow characterization of materials through thier physical and chemical behaviour under the influence of temperature.

B) Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray analysis (EDX)

Applied to ancient samples SEM is superior for their surface characterization and studies of their macroscopic fine structure (e. g. texture, surface appearence and composition etc.). EDX is used in combination with electron microscopy and provides reasonable estimates of elemental compositions in the surface regime of materials.

C) Powder X-ray diffraction

A useful method to determine and identify single components in heterogeneous mixtures by their characteristic powder X-ray diffraction patterns.

D) IR and Raman spectroscopy

Raman and IR spectroscopy are (sometimes complementary) vibrational spectroscopy methods. Dealing with solid samples Raman spectroscopy is superior to IR spectroscopy. Usually it is applied in combination with a microscope and allows easy identification of mixtures of phases according to the vibrational patterns of the atoms in the microscopic structures of unique components.

E) UV/Vis spectroscopy and laser induced photoluminescence (PL)

Both methods support the characterization of chromophores of pigments or dyes.

In the following section the described methods are applied to a selection of samples of Table 1.

A) Thermal analysis of Egyptian and Chinese Blue and Purple

In conjunction with Egyptian Blue and Chinese Blue and Purple preparations TG or DTA methods have been used for the pursuit of the solid state reaction courses. Figure 9 shows in an exemplary way the TG curve for the formation of Egyptian Blue from Malachite (Wiedemann, 1986).

First we see the decomposition of Malachite between 300 and 400 °C to produce CuO. At approximately 550 – 740 °C CaO and CuO react with SiO_2 in the presence of the flux to generate $CaCuSi_4O_{10}$, Egyptian Blue. Similarly, the solid state reaction between azurite, calcium carbonate and sand also leads to Egyptian Blue.

The synthesis of Chinese Blue was similarly studied by TG and DTG in fig. 10 starting from $BaCO_3$, quartz and CuO.

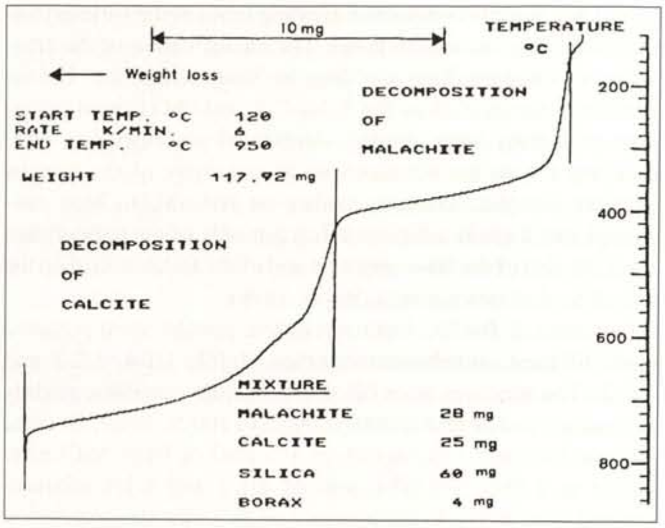


Fig. 3. TG curve for the reaction of Malachite, $CaCO_3$ and SiO_2 to form Egyptian Blue, $CaCuSi_4O_{10}$. The reaction starts with the decomposition of Malachite. With beginning decomposition of $CaCO_3$, the formation of $CaCuSi_4O_{10}$ sets on. This process is finished somewhat above 700 °C.

图 3. 孔雀石，$CaCO_3$ 和 SiO_2 生成埃及蓝 $CaCuS_{i4}O_{10}$ 的反应的热重曲线。反应从孔雀石分解开始。随着 $CaCO_3$ 开始分解，$CaCuSi_4O_{10}$ 开始形成，这个过程在超过 700°C 后结束。

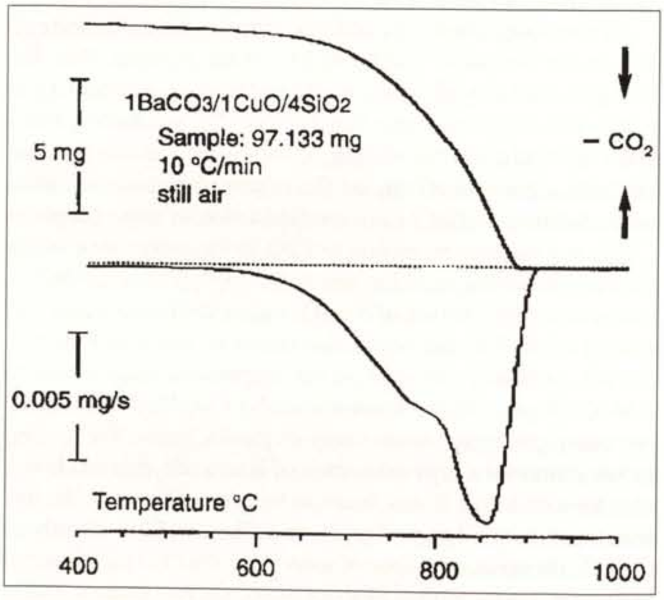


Fig. 4. TG (above) and DTG Curves (below) of the reaction of $BaCO_3$, CuO and 4 SiO_2 to afford $BaCuSi_4O_{10}$. The reaction starts at approximately 650 °C to form BaO. At around 800 °C the formation of $BaCuSi_4O_{10}$ sets in and is over at around 900 °C.

图 4. $BaCO_3$，CuO 和 $4SiO_2$ 生成 $BaCuSi_4O_{10}$ 的反应的热重(上图)和差示热重(下图)曲线。大约在 650°C 反应开始，BaO 形成。$BaCuSi_4O_{10}$ 的形成在 800°C 左右开始，900°C 左右结束。

DSC reveals that quartz ist the least reactive component in mixtures of starting materials. Therefore, the decrease of the quartz peak at 572 °C (phase transition α-quartz → β-quartz) may be used as a criterion for the completeness of such reactions.

Actually, very few of the ancient Egyptian Blue materials were completely free of residual quartz. Most of them contained varying amounts of unreacted quartz, in spite of their bright colour appearance. For example, in figure 11 DSC curves of a contemporary Egyptian Blue and ancient Egyptian Blues of Table 1 are shown, which demonstrate by their quartz peak (and partly by their calcium carbonate peak), residual contents of these starting materials, which would even allow quantification (Wiedemann, 2001).

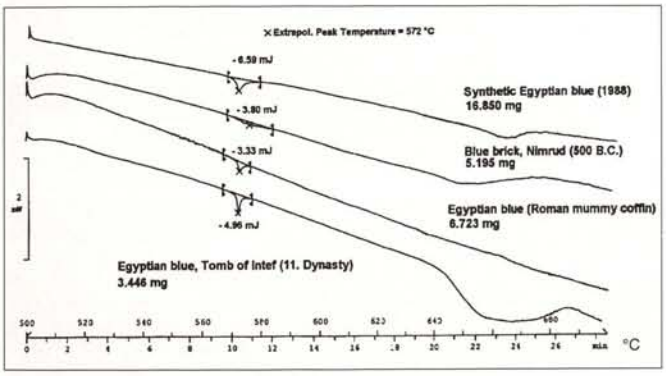


Fig. 5. DTA curves for selected Egyptian Blue samples as designated. The left peaks correspond to the quartz transitions (see text) and the right ones to the decompositions of $CaCO_3$.

图 5. 选定的埃及蓝样品的差热分析曲线。左边的峰对应于石英转变(见文章内容)，右边的峰对应于 $CaCO_3$ 分解。

Thermal analysis investigations of contemporary synthesized Chinese Blue lead to very similar conclusions as for Egyptian Blue (Wiedemann 1997 a and b), e. g. that residual quartz contents are expected to be traceable even in ancient samples. Whether this conclusion is valid for Chinese Purple, as well, is unclear. A respective study was attempted on the ancient Chinese Purple Freer Gallery stick which by Raman spectroscopy was claimed to contain some SiO_2. However, the assignment of the Raman band of quartz is ambiguous, since in the range of 460 cm^{-1} it may be obscured by the presence of a weak band of Chinese Purple appearing at approximately the same wave-number. DSC measurements did not reveal a quartz peak. This may be attributed to the possibility that there is indeed no quartz present. An alternative interpretation could be based on the relatively high reactivity of $BaCuSi_2O_6$: At the given temperature the excess quartz reacts further with Chinese Purple to give Chinese Blue in an almost thermoneutral fashion according to the equation:

$$BaCuSi_2O_6 + 2\ SiO_2 \rightarrow BaCuSi_4O_{10}$$

Thus, Egyptian and Chinese Blue samples may be analyzed by DSC for residual quartz contents (also for $CaCO_3$ and perhaps even for $BaCO_3$). However, when applying DSC for excess quartz studies of Chinese Purple, it is not clear yet, whether reliable conclusions can be drawn.

B) Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray analysis (EDX) of samples of Egyptian Blue and Chinese Blue and Purple

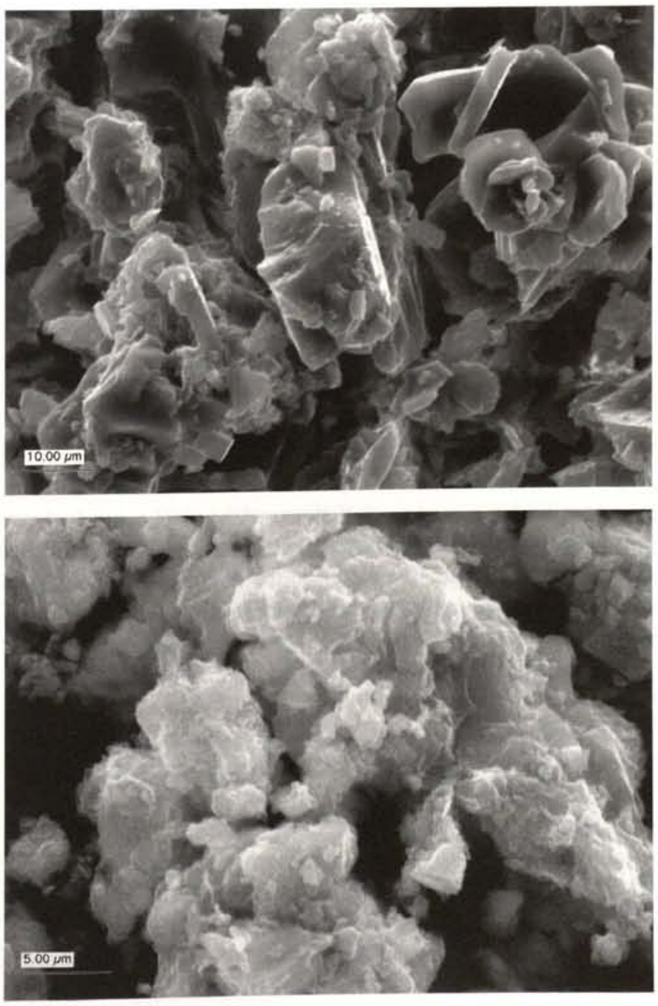
In this section it will be demonstrated that the combined techniques of SEM and EDX applied to the Egyptian and Chinese samples such as indicated in Table 1 are very benificial for the elucidation of surface structures of pigments and their elemental compositions. Figure 12 clearly shows two electron micrographs of two samples of the crown of Nefertete and of stick 4070, which reveal a platelet-like microcrystalline structure of the Egyptian Blue and the Chinese Purple content.

Table 2 and 3 contain valuable EDX microsonde type applications for the determination of the elemental composition of ancient pigment surfaces. A statistical approach was used with measurements at different surface locations in order to average local deviations. Interpretation of these values lead to the following conclusions:

The investigated Egyptian Blue samples show grossly constant composition over time, which is surprising, especially in view of the great period of time which their origins span. Regarding the average values of all samples, in comparison with the theoretical composition of Egyptian Blue $CaCuSi_4O_{10}$, the ideal values for calcium and copper were usually underscored by the Egyptian producers, while the amounts of silicon were always too high. This is confirmed by the results of the thermoanalytical studies (vide supra) and of the Raman investigations

Fig. 6. SEM photographs of sample crown of Nefertete (above) and Stick 4070 (below) revealing crystallinity and the platelet-like structure of both samples.

图 6. Crown of Nefertete 样(上图)和 Stick4070 样(下图)的扫描电镜图。该图显示了两个样品的结晶性及其类片状结构。



Time	Period	Composition, [%] weight			Objects
		Ca	Cu	Si	
2575-2134 B.C.	Old Kingdom	15.2	21.3	63.0	Mereruka, Saqq. Egypt
2040-1640 B.C.	Middle Kingdom	14.9	21.5	63.8	Tomb Intef, Egypt
1340 B.C.	New Kingdom	17.4	30.2	52.3	Nefertete, Berlin, Germany
1353 B.C.	New Kingdom	24.0	22.5	53.5	Echnaton Temple, Blue of Talatat
712-332 B.C.	Late Period	13.6	28.1	58.3	Bes Amulet, Egypt
332 B.C. – 395 A.D.	Greek-Roman	18.4	22.5	59.2	Mummy Coffin
13th-7th Cent. B.C.	Mesopotamia	8.2	13.0	73.0	Brick Nimrud, Iraq
		16.0	22.7	60.4	Average of all samples
		18.6	29.4	52.0	Egyptian Blue, theoretical

Table 2. Composition of Egyptian Blue samples from different periods.

表 2. 不同时期埃及蓝试样的成分。

Sample	Ca	Ba	Cu	Si	Pb	S
Freer Gallery	2.5 (3.5)	35.3 (13.0)	5.6 (4.7)	37.7 (64.8)	11.4 (3.4)	2.0 (2.3)
Stick 4069	3.1 (6.2)	31.6 (18.2)	13.2 (16.6)	15.8 (44.5)	35.4 (13.7)	–[a]
Stick 4070	1.0 (1.7)	36.5 (17.0)	15.6 (15.7)	25.9 (58.9)	20.7 (6.4)	–

a Not analyzed due to a too high amount of lead

Table 3. Compositions of chinese stick samples with respect to major constituents [weight or atom % (in brackets)] from EDX. Other elements of minor amounts add up to 100 %.

表 3. 能量分散 X 光射线荧光下的中国颜料棒试样的成分，涉及主要组分[重量比或原子百分比(括号内)]。加其余的微量元素，合计为 100 %。

(vide infra), which in several samples show the presence of residual quartz. The "cleanest" Egyptian Blue is contained in the sample of the Nefertete bust, which is in all constituents quite close to the theoretical values. The greatest deflection is given by the Mesopotamian Brick Nimrud, which deviates by more than 10 % in calcium and more than 16 % in copper. Intrestingly it shows a high amount of quartz. An interpretation of this observation would be that the brick presumably was designed as a sophisticated construction material, which required specialized material properties and consequently a different chemical composition.

Deviations from the ideal compositions of Egyptian Blue may in general arise from inclusions of the flux material, starting materials or furthermore from influences of the matrix, in which the pigments were embedded. Quite often this is seen by the appearance of additional elements in the compositional analysis. For instance the samples of the Nefertete bust contains the metal ions of Na, K, Mg, Al, Fe and Ti and the non-metal elements S and Cl as minor constituents. Similarly, the Talatat and the Bes samples have traces of K, Mg, Al, Fe and S, Cl and Al, Fe and S, Cl. The Ptah Sokaris sample consists additionally of zinc, besides traces of K, Ti, Fe and Cl. The zinc content is also found in certain Raman bands not identified in other Egyptian Blue samples. Zinc is therefore a unique companion of ancient Egyptian Blue samples. Its origin and possible function is yet unclear. It should be noted in this context that tin has been frequently found in original samples of Egyptian Blue (Jaksch, 1983).

The ancient Chinese samples analysed by EDX do not show clear-cut atomic ratios with respect to $BaCuSi_4O_{10}$ or $BaCuSi_2O_6$ (Table 3). The Ba/Cu atomic ratios are however approximately 1:1. Quite counterintuitively, stick 4069, which consists of an approximate 1:1 mixture of Chinese Blue and Purple with silica-rich Chinese Blue (see also powder X-ray studies) possesses less Si atomic content than stick 4070. This contradiction can only be reconciled with the assumption that stick 4070 additionally contains quartz or other quartz-rich compounds.

The sticks also contain non-Purple or Blue constituents in greater quantities. As already noted in earlier research (FitzHugh, 1992), they are often mixtures of compounds and also consist of calcium in quantities > 1 % and great amounts of lead. While calcium with its relatively low content can safely be identified as an unintended ingredient accompanying starting materials from sand, Barytes or Witherite, the lead content is of chemical relevance and was added as an essential ingredient to all the ancient Chinese pigment preparations (vide supra). The amount of lead in stick 4069 is especially high, even exceeding 30 % in weight (Table 3).

Minor constituents of the sticks are: Freer Gallery stick: Na, K, Al, Fe, Cd and S, Cl; stick 4069: Al, Fe, Cd; stick 4070: Al, Fe. It should be noted that stick 4069 presumably also contains sulphur, which could not be analyzed by EDX due to overlap with a too intense lead X-ray emission. Quite remarkable are the cadmium contents of the Freer Gallery stick and of stick 4069. Because of the uniqueness of this element in the blue and purple pigment content, its presence may point to a common mineral or even synthetic origin. The nature and function of the chloride content of the Freer Gallery stick is still puzzling. It was supposedly introduced as NaCl or KCl. The accompanying amounts

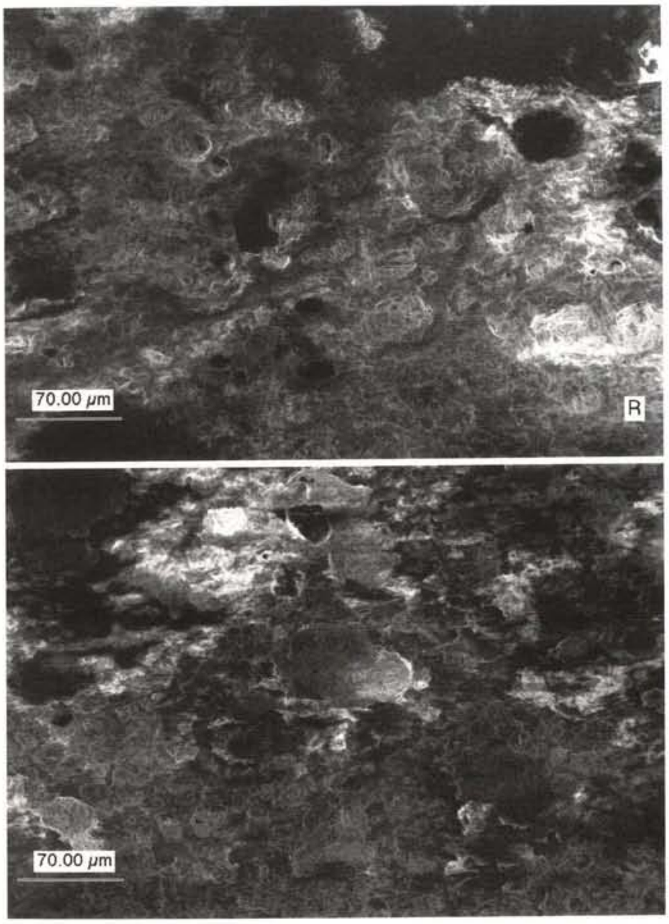
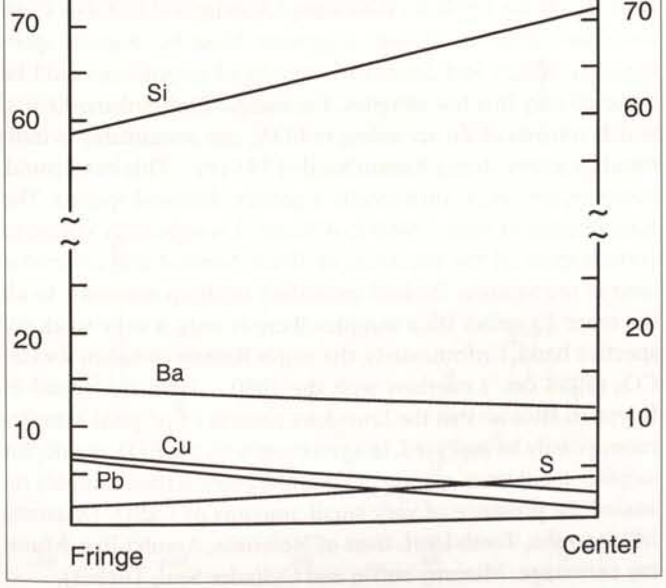


Fig. 7. SEM of the Freer Gallery stick comparing the surface morphologies of the fringe (above) and the centre area (below).

图 7. 弗里尔画廊样品边缘(上图)和中心区域(下图)表面形态的扫描电镜图。

Fig. 8. Schematic plot of the profile of the atomic content of Ba, Cu, Pb, S and Si in the slice of the Freer Gallery stick.

图 8. 弗里尔画廊样品切片中 Ba, Cu, Pb, S 和 Si 原子含量分布示意图。



of aluminium are presumably in all samples of impure quartz as a starting material, which was very likely used in the synthesis as crude sand.

From the Freer Gallery stick the octagonal plate, shown in colour plate XV, fig. 2, was investigated in greater detail. It reveals a porous but otherwise hard and compact surface. It can be divided into a darker central core and a lighter fringe section. Magnifications of these areas by SEM show qualitatively no difference in the heterogeneous microcrystalline surface morphology of the core and the fringe areas. Both sections have obviously darker pigment areas and lighter inclusions (fig. 13).

Based on the areal dependent EDX analysis a schematic profile of the major elemental constituents can be established (fig. 14).

In absolute measures the silicon content is very high, it even increases drastically from the outside to the inside of the sample. Similarly, but to a much lower extent the amount of sulphur increases, while the other elements of significance like Ba, Cu and Pb conversely decrease in this direction. Lead even reaches almost zero atomic content in the center. From the DSC measurements (vide supra) it seemed likely that there is no free SiO_2 in this sample. The high silicon value can thus only be interpreted in terms of the presence of silicates (presumably mainly glassy Ba-silicates). Furthermore, it can safely be anticipated that sulphur appears as sulphates. Lead and barium sulfate should thus meet to a noticable extent on the transition of the outer to the inner part ($PbSO_4$) and in the center area ($BaSO_4$). The "outside" lead is assumed to appear primarily as PbO (as confirmed by Raman spectroscopy). Finally it should be noted that the atomic copper content of this sample is quite low. In ideal Chinese Purple it is expected to be 25 % considering the cationic ingredients alone. Thus, in total copper not even half of the Ba content is reached. Nevertheless, as we will later see, only Chinese Purple was definitely identified by Raman spectroscopy, so that the "excess" barium is not expected to be engaged in the formation of other barium-copper-silicate phases, such as $Ba_2CuSi_2O_7$.

The amount of lead decreasing from outside to inside may be interpreted in terms of a specific preparation process for this stick. It may be assumed that, before reaction, the lead (as PbO or $PbCO_3$) covered the reactants as a crust. (See also FitzHugh, 1992). At higher reaction temperatures the lead starts to penetrate the inner parts of the stick by diffusion. However, the lead did not apparently fully reach the center to the extent required for completion of the chemical processes. In the presence of lead, the described catalytic decomposition (vide supra) of the presumed major starting constituent $BaSO_4$ is expected to be promoted producing Chinese Purple and volatile sulphur compounds. With this in mind the lead gradient would then also explain the sulfur profile increasing from outside to inside (see fig. 14). Not shown in the diagram is the minor constituent chloride, which appears only in the central area to a detectable extent. All the given observations make it reasonable to assume that the inner section consists more of non-purple compounds, while the fringe area shows more of Chinese Purple. Contrary to the generally lighter appearance of the fringe section, Chinese Purple is apparently to a greater extent associated with the lead.

Judging from EDX studies, the Terracotta Army, samples I and II, indeed consists of the Chinese Blue and Purple constituents Ba, Cu and Si. As in the earlier investigations (Herm, 1995; Thieme, 1995) a relatively high Pb content was noticed (fig. 15). This could be related to its function as a synthetic additive, but could also point to its role as a pigment component in form of PbO or $PbCO_3$ in mixture with Chinese Purple. Sample II contains, besides Chinese Purple, cinnabar, phosphorite or apatite and ilmenite, $FeTiO_3$, representing red, white and brown colouring tones. The ilmenite and the phosphorus compounds were found as isolated pieces on the mm scale and could therefore be studied separately by EDX without a disturbing background. The EDX analysis revealed almost exactly the atomic ratios expected for $FeTiO_3$ and $Ca_3(PO_4)_2$.

In particular, it is worth mentioning that the EDX analysis of sample II demonstrated that it apparently not only possesses a 'spread out' lead content, but also consists in significant amounts of lead in areas where Chinese Purple is located. This may allow us to conclude that lead compounds were also added in the preparations of Chinese Purple samples.

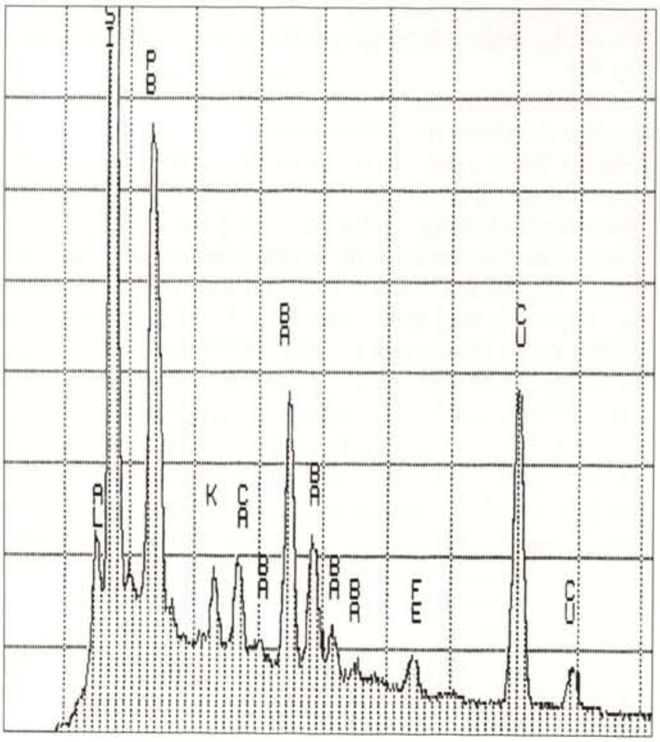


Fig. 9. EDX of sample I of the Terracotta Army displaying the major constituents Ba, Cu, Si and Pb and minor quantities of other elements as impurities.

图 9. 兵马俑样品 I 的能量色散 X-射线分析。结果显示样品主要成份为 Ba, Cu, Si 和 Pb 并含微量的其它元素杂质。

C) X-ray powder diffraction studies on original samples containing Egyptian and Chinese Blue and Chinese Purple

X-ray powder diffraction studies have been commonly used to identify major microcrystalline components in heterogenous mixtures. In original pigment samples this normally holds for the pigment content. Figure 16 shows powder diffraction patterns of Egyptian Blue (Cuprorivaite), Chinese Blue (Effenbergerite) and synthetic Chinese Purple drawn out of the Blues schematically as stick diagrammes. To some extent the patterns of the Blues resemble each other because of their structural relationships.

Several Egyptian Blue samples in Table 1 have been analysed and consist of prevailingly $CaCuSi_4O_{10}$ according to the presence of the respective major Egyptian Blue reflections of Figure 16. Impurities could only be identified properly when they were contained as major constituents. This was the case for the strong quartz content of Brick Nimrud.

The Chinese samples, the Freer Gallery stick, stick 4069 and stick 4070 were analyzed by X-ray powder diffraction, as well. The pigment component of the Freer Gallery stick and of stick 4070 was Chinese Purple. Chinese Blue was not found to be present within detection limit. However, from the powder diffraction analysis of stick 4069, it could be derived that it consists of an approximately 1:1 mixture of Chinese Blue and Purple. The Freer Gallery stick shows the greatest amounts of impurities. They were identified as $BaSO_4$, $PbSO_4$ and $BaCO_3$. Several remaining reflections of this quite heterogeneous mixture could not be assigned, but are assumed to belong to certain crystalline areas of silicates.

The powder diffractogramme of stick 4069 contained minor reflections for $BaSO_4$ and $PbSO_4$, while that of stick 4070 displayed additional reflections for $PbCO_3$ (see fig. 17). A few reflections in each of the samples could not be designated.

D) Micro-Raman spectroscopy of original samples containing Egyptian and Chinese Blue and Chinese Purple

Micro-Raman spectroscopy can advantageously be used for the identification of pigments in heterogeneous mixtures like paints and paint applications. Concerning Barium-copper-silicates it previously has been applied only in the case of Chinese Purple (Finger 1989, see also McKeown, 1997). Our Raman studies on various ancient samples (indicated in Table 1) and reference samples brought about well-defined conclusions. In the spectral range of 1200 – 100 cm^{-1} Egyptian Blue and Chinese Blue samples show two very strong Raman emissions between 1080 and 1090 cm^{-1} and 1100 cm^{-1}, respectively, and around 430 cm^{-1} for both types of species. In an exemplary way the Raman spectra of the Crown of Nefertete and the Amulet Bes are shown in figure 18.

The Chinese Blue bands at around 1100 cm^{-1} are thus of little higher energy than the corresponding ones of Egyptian Blue, a fact which could be used for their distinction. The two major bands of the corresponding strontium blue $SrCuSi_4O_{10}$ would appear at 1090 and 425 cm^{-1} very close to those of Egyptian Blue. In all the Egyptian Blue samples indicated in Table 1, we were thus able to identify Egyptian Blue by Raman spectroscopy. Major and dominant contents of impurities could be detected only in a few samples. For sample Ptah-Sokaris-Osiris, which consists of Zn according to EDX, this presumably is indicated by a very strong Raman band at 745 cm^{-1}. This band could, however, not yet be attributed to a certain chemical species. The Raman band of quartz (460 to 470 cm^{-1}) is especially strong in certain spots of the spectrum of Brick Nimrud and otherwise seen in the samples Ba-bird indicating medium amounts. In all the other Egyptian Blue samples there is only a very weak respective band. Unfortunately, the major Raman emission for $CaCO_3$ (1088 cm^{-1}) overlaps with the 1080 – 1090 cm^{-1} band of Egyptian Blue so that the limestone content of original samples cannot easily be analysed. In agreement with the EDX results for sulphur, the Raman spectra of several Egyptian Blue samples revealed the presence of very small amounts of $CaSO_4$ (Mastaba of Mereruka, Tomb Intef, Bust of Nefertete, Amulet Bes, Mummy cartonage, Mummy coffin and Cylinder Seal, Thebes).

Fig. 10. Stick representations of the Powder X-ray Diffractogrammes of Egyptian Blue, $CaCuSi_4O_{10}$ (Cuprorivaite), Chinese Blue, $BaCuSi_4O_{10}$ (Effenbergerite) and Chinese Purple, $BaCuSi_2O_6$. Only the more intense reflections are given.

图 10. 埃及蓝 $CaCuSi_4O_{10}$ (Cuprorivaite),中国蓝 $BaCuSi_4O_{10}$ (Effenbergerite)和中国紫 $BaCuSi_2O_6$ 的粉末 X-射线衍射图。图中只给出较强的反射峰。

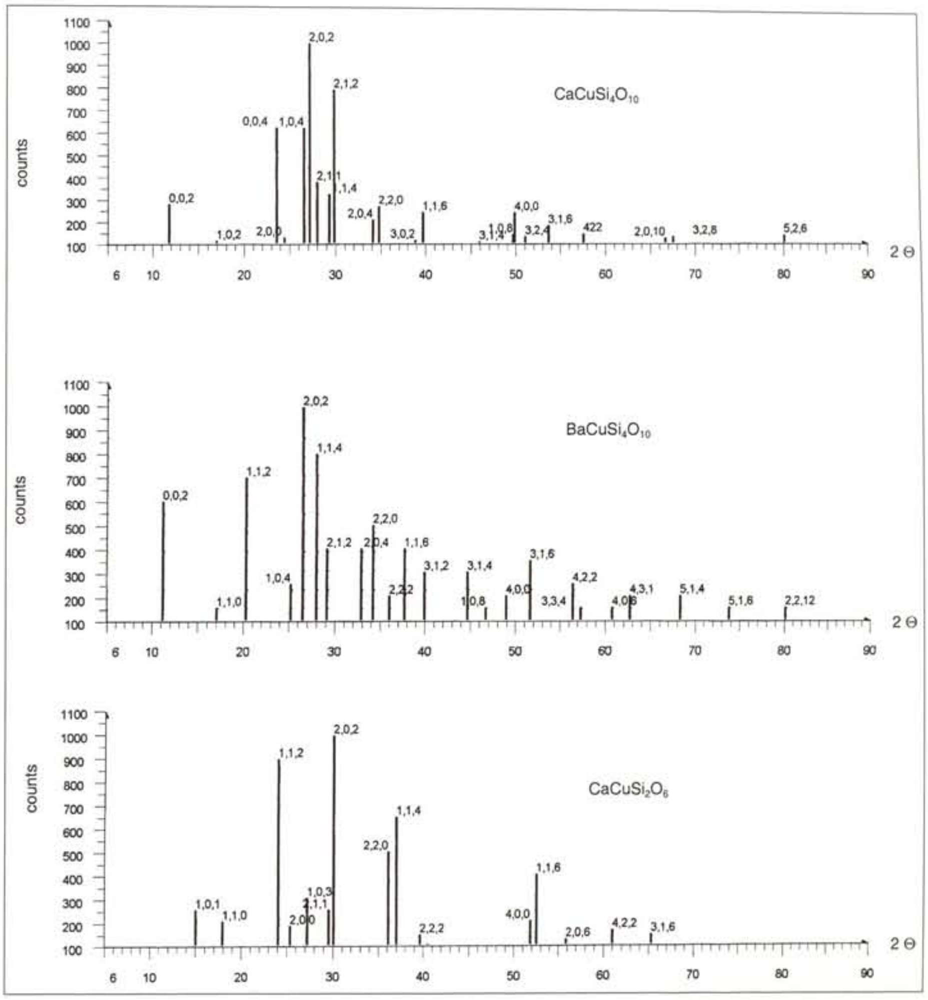


Fig. 11. Stick representation of the Powder X-ray Diffractogramme of Stick 4070. Lines not designated belong to Chinese Purple. o refers to major lines of $PbCO_3$. *Not assigned.

图 11. Stick4070 样品的粉末 X-射线衍射图。未标识的峰属于中国紫。°表示 PbCO3 的主要峰。*未归属。

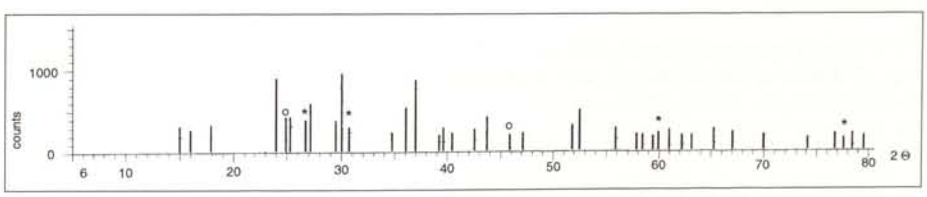
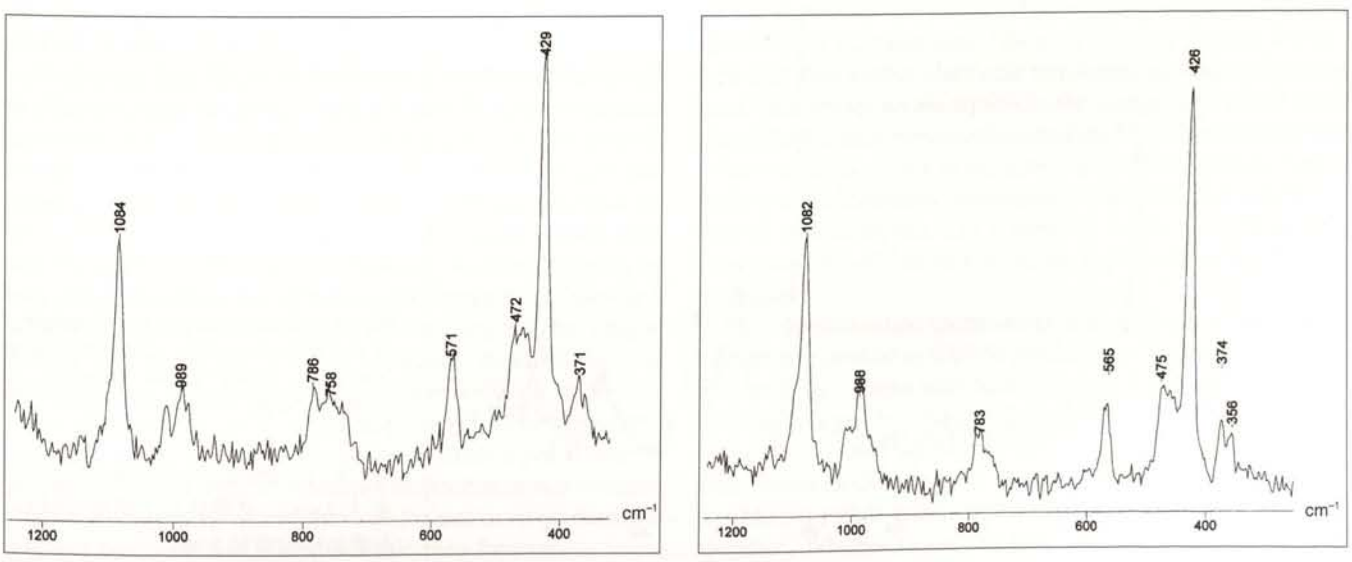


Fig. 12. Raman spectra of original samples of Egyptian Blue (Excitation Laser 514 nm). Left the spectrum of the blue from the crown of Nefertete. Right the spectrum of the Amulet Bes. Both samples display primarily Egyptian Blue.

图 12. 埃及蓝原样的拉曼光谱(激发光 514nm)。左图为 Crown of Nefertete 样的光谱，右图为 Amulet Bes 样的光谱。两个样品都



From the Chinese samples, stick 4069 contains Chinese Blue, which however is is mixed with Chinese Purple (see fig. 19). This confirms the result of the powder X-ray studies.

Spectra of Chinese Purple samples revealed, as finger-print patterns, two strong bands at around 590 cm^{-1} and 514 cm^{-1}. A band at 990 cm^{-1} could also be identified, but in contrast to the blue pigments this band at higher wave-numbers is only of medium intensity. Chinese Blue and Chinese Purple are thus easily distinguishable by Raman spectroscopy.

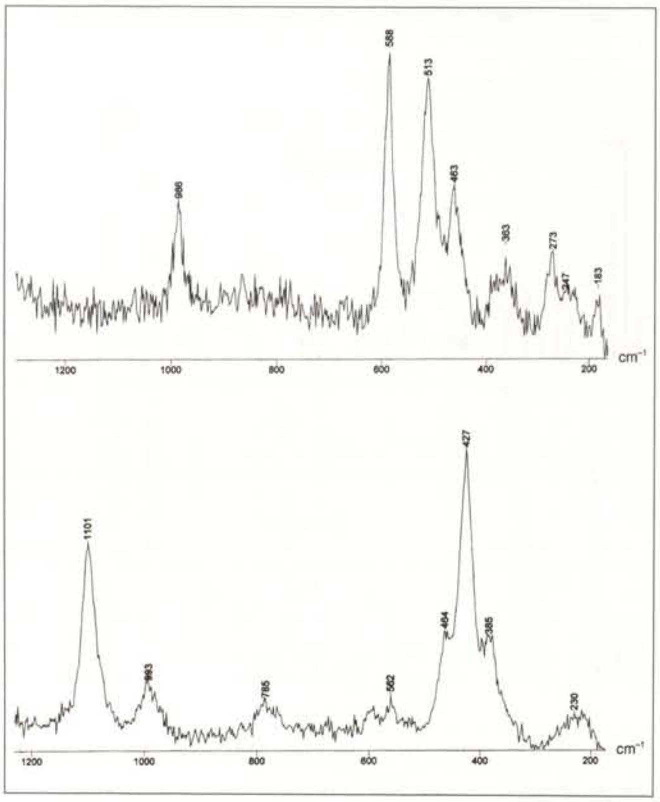


Fig. 13. Raman spectra of stick K 4069 at two different spots (Excitation Laser 514 nm). The spectrum above corresponds to Chinese Purple, the spectrum below to Chinese Blue with some impurity of quartz (464 cm^{-1}).

图 13. K4069 样品两个不同位置的拉曼光谱(激发光514nm)。上图对应于中国紫，下图对应于混有石英杂质(464cm-1)的中国蓝。

In all Chinese samples the following potential impurities were checked, which might originate from the minerals used, the added flux or chemical transformations occuring during synthesis: CuO, Cu_2O, azurite, $BaCO_3$, $BaSO_4$, $PbCO_3$, $PbCO_3 \cdot 2\,PbO$, $PbSO_4$, CdO and SiO_2. Several Chinese samples presumably show a Raman emission for quartz, which varies in relative intensity from sample to sample. However, identification of the Raman band of minor amounts of quartz in mixtures with Chinese Purple is obscured by the fact that Chinese Purple also possesses an emission of medium to weak intensity in this region. In the Raman spectrum of the Chinese sample, the Royal Ontario Museum stick, no definite conclusions on impurities could be drawn due to the low quality of the spectrum caused by an insufficient amount of sample. Stick 4069 showed quartz, however no spectrum of isolated spots showing $BaSO_4$ and $BaCO_3$ expected from the powder X-ray results could be found. Stick 4070 unambigously showed the presence of $PbCO_3$.

As in the case of the EDX analysis, the slice of the Freer Gallery stick was investigated in greater detail by Raman spectroscopy. Table 4 shows the results of the Raman study at 12 different spots following an approximate order from outside to inside. In general the given collection of spectra makes clear that this stick is a very heterogeneous mixture, since several other components have been detected besides Chinese Purple.

Several bands were assigned to crystalline or glassy silicate phases. Other attributable phases were $CaCO_3$, $BaCO_3$, $BaSO_4$, $PbSO_4$, PbO and perhaps SiO_2. They are in full agreement with the elemental contents analyzed by EDX. Apparently due to some arbitrariness in the choice of the measured spots and the heterogeneity of the sample, an accurate areal dependence like that of the EDX analysis could not be established.

It is however clear that, due to the various residual constituents, it can be concluded that the stoichiometry of the starting materials did not match that of Chinese Purple. An insufficient copper content leads to production of several non purple constituents. Presumably the bands around 940 and 421 cm^{-1} account for glassy phases with polysilicate (SiO_3^{2-}) units and the bands at 914 cm^{-1} for disilicate ($Si_2O_7^{6-}$) (Frantz, 1995). Due to

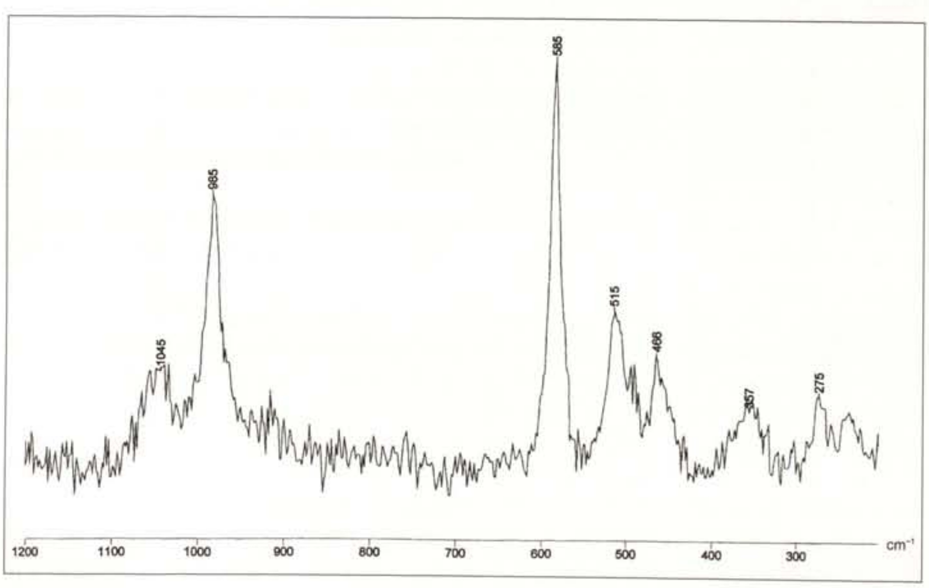


Fig. 14. Raman spectrum of sample I of the Terracotta Army (Excitation Laser 514 nm) displaying the spectrum of Chinese Purple with some impurity of $PbCO_3$.

图 14. 兵马俑样品I的拉曼光谱(激发光 514 nm)。谱图显示了带有 $PbCO_3$ 杂质的中国紫的光谱。

	1085											$CaCO_3$
			1059	(1059)	1057	1060	1060	1060	1057	1056		$BaCO_3$
986	988	984			985				985			CP/$BaSO_4$
	965	966	965			967	966	966	967	966	966	$PbSO_4$
			939	945			941		939		941	SiO_3^{2-} (glass)
			915	(915)			914	914				$Si_2O_7^{6-}$
		757	754	754	754	757	753	754	750		752	$PbSO_4$
	637											$CaCO_3$
588	587	588	586	586	587	588	587	587		588	586	CP
516	514	518	515	514	516	516	516	518		516	516	CP
469	466	466	(466)	(466)	466	468	465			464	466	CP/SiO_2
			418	421			419	421			421	SiO_3^{2-} (glass)
	391											$CaCO_3$
356		356	351	352	353	353	354	351	356	351		CP
276	278	280			274		274		274		275	CP/PbO
									243			?
185		185	184	198		187	191				186	CP
148	142	148										PbO

Table 4. Raman data of various spots (column) of sample Freer Gallery stick with assignments. CP = Chinese Purple. Weak bands in brackets; ? = not assigned.

表 4. 确定了的弗里尔画廊颜料棒试样的不同点的拉曼数据。 CP = 中国紫。括号中为弱谱带; ? = 没有确定。

the great stoichiometric excess of SiO_2 (see also EDX analysis) glass formation seems to be very plausible and indeed the relatively hard general nature of the disc speaks for a relatively high amount of glassy phases. It is maybe quite amusing to see that an early German patent from 1900 describes the preparation of glassy highly coloured barium-copper-silicates for use as pigments (Le Chatelier, 1900). This historic discovery was certainly made without knowledge of the existence of Chinese Blue and Purple and may simply reflect need for artificial colouring matter.

The Terracotta Army samples I and II consist of Chinese Purple as indicated by the appearences of the major Raman bands for this compound (fig. 20).

A relatively high $PbCO_3$ or PbO content was noted. This could be related to their function as synthetic additives, but could also point to their role as colouring components. For sample I and II cinnabar could be traced as indicated also by EDX. I and II also showed substantial quantities of matrix constituents, such as quartz. This is assumed to be a natural circumstance associated with their use in paints. It should, however, be noted that none of both samples showed the presence of Chinese Blue. Sample I possessed considerable amounts azurite crystallites (major Raman band at 402 cm^{-1}), which apparently stood for the blue colouring tone in the pigment layer. In contrast to the sticks, the Terracotta Army samples represent mixtures of actual paints, which are naturally more heterogeneous. Their a priori heterogeneity, however, makes it sometimes difficult to decide whether a specific component is to be attributed to a mineral or chemical origin or whether it was related to a colouring function.

E) UV/Vis and Photoluminescence spectroscopy (PL) of Egyptian Blue and Chinese Blue and Purple

As mentioned before, Chinese Blue and Purple contain copper(+II) ions as effective chromophores. The electronic structures of chromophore models of Chinese Blue and Purple have been calculated by us in order to trace any difference in the absorption spectra expected for Chinese Blue and Purple (Density Functional Calculations). In an ideal square planar silicate ligand environment as in Chinese Blue, the copper ion should give rise to only one visible absorption in the orange, which is seen as the complementary blue colour (compare with the UV/vis spectrum of Egyptian Blue (Ford, 1979)). For Chinese Purple, however, two visible electronic transitions are expected to appear. One causes an absorption in the orange with a blue complementary colour very much as predicted for Chinese Blue. The other transition occurs in the green, which then appears purple with its complementary counterpart. Both electronic transitions indeed arise from the Cu-Cu bonding in this compound. The experimental verifications of these predictions are yet to be established.

Photoluminescence spectroscopy is to a certain extent a complementary method to UV/Vis spectroscopy. For instance, when irradiated by a green laser beam Chinese Blue and Purple very effectively transform this light into fluorescent infrared light between 800 – 1100 nm (Ajo, 2000). This means that when sun light shines on Chinese Blue and Purple, they not only give rise to a blue or purple colour perception, but additionally emit heat radiation. Whether or not this latter circumstance may have an effect on human perception is not clear, and has to our knowledge not yet been investigated. The luminescence spectra of synthetic samples of Chinese Blue and Purple reveal that the fluorescent light of both is emitted as a characteristic double band pattern, where the shorter wavelength band appears as a less intense shoulder for Chinese Purple, while for Chinese Blue they have about the same intensity. The emission maxima of both compounds appear at somewhat different wavelength: 945 and 995 nm for Chinese Purple and 930 and 970 nm for Chinese Blue. The similarity of these emission bands with respect to their positions, and, to a certain degree, also to their intensities indicate that it is the copper(+II) ions that gives rise to luminescence. Unfortunately, this observation makes it impossible to use luminescence to identify and distinguish Chinese Blue and Purple in complex mixtures of both components.

Conclusions Drawn from the Chemical and Physical Investigations of Egyptian Blue and Chinese Blue and Purple

Our investigations gave clear evidence that the ancient Egyptian samples of Table 1 are all based on the chemical compound $CaCuSi_4O_{10}$, which is commonly denoted as Egyptian Blue. The samples of Table 2, investigated for their compositions normally deviate from the theoretical values. They show mixtures originating from their production process or from the fact that they were paint applications. A gross trend of constant compositions of the blue pigments can be recognized over a period of approximately 3000 years. This naturally required a stable route of transmission, that is, a reliable mechanism for the handing-down of the manufacturing recipe, which apparently could only be provided in the environment of a highly developed civilization.

Egyptian Blue was produced from quite abundant minerals. Only the copper component needed to be made available from mining sites. Copper mining was quite common at the time. It played a major role in the Egyptian civilization and also in previous human developments. The general situation of the resources did not impose restrictions on the spread of the use of Egyptian Blue. However, because of difficulties connected to the sintering-type solid state synthesis and the fact that Egyptian Blue cannot be processed by casting, technological restrictions emerged. Besides the general requirement that the minerals used for Egyptian Blue preparation required pretreatments like grinding and compacting, the production of compact blue bodies demanded specific sophisticated developments involving multistage processes. The physical and chemical conditions for successful production of Egyptian Blue were not too difficult and could usually be established with ease, such as the optimal temperature for the reaction, the temperature control and the maintainance of the reaction temperature over a longer period of time. Based on these circumstances the Egyptian pigment could be produced with satisfying quality over a great span of time.

For the Chinese pigments the general situation seems somewhat different. First of all it seems quite plausible that the production of Chinese Blue and Purple was based on the knowledge of the production of Egyptian Blue. Chemically the blue compounds resemble each other quite closely, and differ in the chemically minor variation of the replacement of calcium with barium. Such a variation is be anticipated for ancient craftsmen, who were involved in purely empirical testing and did not have knowledge of atomic views and the Periodic Table of Elements. Nevertheless, it cannot be ruled out that the chemical developments for Chinese Blue and Purple occured independently without any relationship to those of Egyptian Blue. This has to be stressed especially in view of the fact that there is no historical documentation concerning the ancient production methods of Chinese Blue and Purple in China. However, there are the two ancient artefacts, the Goblet and the Sistrum Hasanlu from Iran, which prove the spreading of the man-made Blue into regions considerably east of Egypt. Secondly, it is indicated by these artefacts that chemical variations of Egyptian Blue occured by modifying $CaCuSi_4O_{10}$ into at least partly the strontium derivative $SrCuSi_4O_{10}$. Both these facts provide further support for the hypothesis that the preparation of Egyptian Blue may have also become the basis for the development of ancient Chinese blue and purple pigments. The transmission of knowledge along the Silk Road, which also passed through Iran and which is anticipated to have been used as a trade route as early as least 1000 B. C. To the present date we have to assume that Chinese Blue and Purple appeared no earlier than the Warring States period and that for this reason, these Chinese pigments are 'younger' than Egyptian Blue. They emereged in historic times when the Silk Road was in full operation as a trade path and concomitant with this as a potential path for the exchange of ideas.

Even if they were based on the knowledge of Egyptian Blue, development of Chinese Blue and Purple faced several difficulties. Firstly there was the mineral problem, that barium minerals are much rarer than those of calcium. Barite ($BaSO_4$) or Witherite ($BaCO_3$) display the prominent property of being heavy, which makes them recognizable in nature and perhaps because of this characteristic they caught the interest of eager human beings. In China barium minerals are not rare and thus it seems plausible that they were utilized. The other necessary ingredients for Chinese Blue and Purple production were abundant; SiO_2 used as quartzite or sand and copper as copper sulphide, malachite or azurite. Therefore, we can hypothesize about the actual synthetic procedure. The use of barite demanded the addition of lead salts, such as lead carbonate or lead oxides. As we have seen, lead salts promote the decomposition of the quite stable barite and can also act as a flux additive. With the given combination of ingredients Chinese Blue and Purple could then have been obtained by a sintering-type process at temperatures between 900 and 1000 °C. It should be noted that this temperature is about 150 – 200 °C higher than that required for the production of Egyptian Blue. In the technically highly developed China of the Qin and Han time the achievement of such temperatures seemed to be no principal problem (Wagner; 1996). However, the severer synthetic conditions with respect to Egyptian Blue required more intense provisions concerning the construction of firing devices etc. Applying appropriate temperature conditions would have permitted a typical batch of Chinese Purple to have been finished within 10 – 24 hours, while the production of Chinese Blue presumably must have taken twice as long. It seems to be somewhat of a technological problem how these relatively high temperatures could have been maintained for a longer period of time within narrow limits. In order to obtain acceptable product results, the temperature control had to be quite accurate, presumably + –50 °C for Chinese Purple. Efficient temperature controlling devices were to our knowledge not known in the Qin and Han period or earlier. Therefore, the accomplishment of a steady temperature level had to be a matter of empirical testing and the production had to be supervised by experienced personnel. Manufacturing of the thermally less sensitive Chinese Blue would not have required such strict control. This compound could even have been brought to melt at least for a short period of time.

For Chinese Purple it was not possible to obtain a homogeneous melt and it therefore had to be produced by a sintering or pseudo-sintering process. By doing so, relatively dense compact bodies like the described sticks were efficiently obtainable, since the sintering temperature is only about 100 – 150 °C from the potential melting point of the pure compound.

As previously indicated, Chinese Blue and Chinese Purple could have been produced as unique components or as mixtures controlled by the addition of appropriate amounts of SiO_2 and by applying appropriate temperatures and reaction times. If mixtures of both were the desired product, this could however have been achieved easiest by grinding the pure components together. In this way it was possible for Chinese painters to have all tones from blue to purple available. It is evident that the sticks of Purple and Blue were essential components of coloration mixtures of paintings and sculptures, as the Purple was used in the case of the analysed samples of the Terracotta Army. As mentioned before it is probable that the sticks were trade items. Their use thus required that pigment particles were ground from the sticks and added to the paint or colouring mixtures.

Relating back to the physical studies of the original Chinese samples, these made clear that, except for stick 4070, all of them contained considerable amounts of impurities. Highly contaminated is the Freer Gallery stick which witnesses incomplete chemical reaction and by a Cu:Ba ratio even considerably below 1, the additional formation of presumably glassy silicate components. These observations point out that the sticks were not of optimum pigment quality. Nevertheless, the overall appearance of the sticks seemed to be satisfactory with regard to their colouration properties.

In view of the fact that the preparation of Chinese Blue and Purple are still nowadays sometimes not easy to tackle, the invention of Chinese Blue and Purple may be considered a fine chemical and technological achievement. It is indeed an outstanding example of how the level of science and technology, which is well-described for ancient China by Joseph Needham and his collaborators (Needham, 1976) may positively influence civilizations. For early Chinese Culture we thus may recognize a steady unbiased impetus for improvements accompanied by high civilization standards.

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维德曼 贝尔克

埃及与中国的蓝色及紫色的化学和物理研究

本文叙述11个古代埃及蓝($CaCuSi_4O_{10}$)颜料样品和6个含中国蓝($BaCuSi_2O_6$)的中国颜料原样品的物理-化学研究。所有这些古代颜料都对应于固定的化学物质并通过化学合成方法得到。文章对这些化合物的化学进行了广泛的综述，尤其是对它们的化学结构进行了讨论。其结构表现为无限连接的$Si_4O_{12}^{4-}$单位的层状结构或含有孤立硅酸根环的$[Cu2Si_4O_{12}^{4-}]$ ∞层的层状结构。异构的埃及紫和中国紫含有作为发色体的正方平面的Cu^{2+}离子。中国紫表现很特别的 Cu-Cu 键合的现象。这些化合物的稳定性依赖于它们的化学结构。埃及蓝和中国蓝很稳定，而中国紫化学和物理性质都易变。这一点归因于孤立硅酸盐环和 Cu-Cu 键的存在。

文章详细叙述了这些化合物的现代及古代的制备方法，包括合成的物理及化学条件。着重阐述了在制备中国蓝和中国紫中铅化合物添加剂的作用。

用热分析、扫描电镜、粉末 X-射线衍射、拉曼光谱、光致发光光谱对原样进行了表征，明确了样品的元素及物相组成，从而确定了制备这些颜料的原料、添加剂及制备条件。

跨越 3000 多年的不同源地的埃及蓝具有相对稳定的路线。中国颜料的合成需要更严格的物理和化学条件，这些条件更加难以满足。在这种情况下，中国蓝和中国紫的制备方法被假设为是建立在更古老的化学相关的埃及蓝的制备方法的基础上。不管怎样，中国颜料的精细化学品的成就需要进一步发展。

尚宗燕 张继祖 李汝娟

中国漆树及应用

一. 源远流长的中国生漆

漆本作桼，其字象汁自木出自而滴下之形也(东汉许慎《说文解字》)。依此推测，可能在象形文字之前，也就是大约远在 4000 年前，我们中华民族对漆树和生漆就有了一定认识和应用，例如远在舜禹时代就用生漆涂饰食具和祭器，西周时用生漆涂饰车辆，并征收过漆林税(《周礼》)。

《韩非子 · 十过》："尧禅天下，虞舜受之，作为食器，斩山木而财之，销锯修其迹，流漆墨其上，输之于宫，以为食器。……舜禅天下，而传于禹，禹作为祭器，墨漆其外，而朱画其内。"

《诗经 · 唐风》："山有枢、山有漆、隰有栗。"

《尚书 · 禹贡》："兖州(今山东兖州)厥贡漆丝，豫州(今河南)厥贡漆……"

《史记 · 庄子传》："庄子者，蒙(即中牟，今河北邯郸附近，非今河南中牟)人也，名周，周尝为蒙漆园吏。"

《史记 · 货殖传》："陈夏千亩漆，此其人与知户侯等。漆千斗(言满千斗，即今千桶也)，此亦为千乘之家，千乘之家，即千户之君也。"

《周礼》："载师(官职名)掌任土之法，近郊十一，远郊廿而三，甸、县、都(井田制：四邱为甸，四甸为县，四县为都，四都为同)皆无过十二，惟漆林之征，廿而五。"

以上文字材料足见中国古代对漆的认识和应用历史悠久，下面的考古发掘更能说明我国应用漆的历史的辉煌；四川成都羊马山 172 号战国中期墓；陕西省长安县普渡村西周墓；河南陕县上岭村虢国墓(西周晚期到东周早期)；河南省洛阳邙山庞家沟西周墓；江苏省吴江县梅堰的新石器时代遗址；山东省临淄郎家庄东周墓；湖北省江陵县望山、李家台、雨台山等地相继出土一批战国时代的漆器；河北省藁城县台西村商代遗址；辽宁省敖汉旗大甸子古墓，距今 3400-3600 年；山西省襄汾县陶寺遗址；北京房山县琉璃河；安徽省屯溪；浙江省余姚县河姆渡村遗址及在秦兵马俑二号坑发现彩绘兵俑有生漆涂层等等；上述十余省(市)在对秦以前的考古发掘中均见有与漆有关的葬品。

二. 中国漆树及其分布

全世界漆树属植物约 25 种，分布于亚洲东部和北美到中美。中国产 15 种，主要分布于长江以南各省(区)，中国用来采割生漆的仅 1 个种，即漆树(及 1 个变种(系三倍体漆树)和漆树农家栽培品种，根据全国的调查近 100 个)。迄今未发现用漆树属其他种进行割漆生产。在越南有野漆树(ToXicodendron Succedaneum)。漆液也可作涂料。被称为安南漆类。在柬埔寨、泰国、缅甸也割漆，植物为柬埔寨漆树 Melanorrhoea laccifera，缅甸漆树 M. usitata。鸡腰果 Anacarodium Occidentale 的果壳中提取的果液，用于合成漆涂料，中国海南、广东也把它用作涂料，应该说不属生漆的范畴。肖育檀对中国现代漆树的地理分布进行研究的结果认为：大体符合于中国植被区划中的暖温带落叶阔叶林到中亚热带常绿阔叶林地区(见图)。这个分布范围相当于北纬 25° - 41°46′，东经 95°30′ - 125°20′，东西约 1500 公里，南北约 900 公里。按我国行政区划来说，包括了 22 个省(区)的 500 多个县。其中以陕西、湖北、四川、重庆、贵州、云南、甘肃、河南漆树资源最多。全国主要产漆县(产量在 100 担以上)如下：

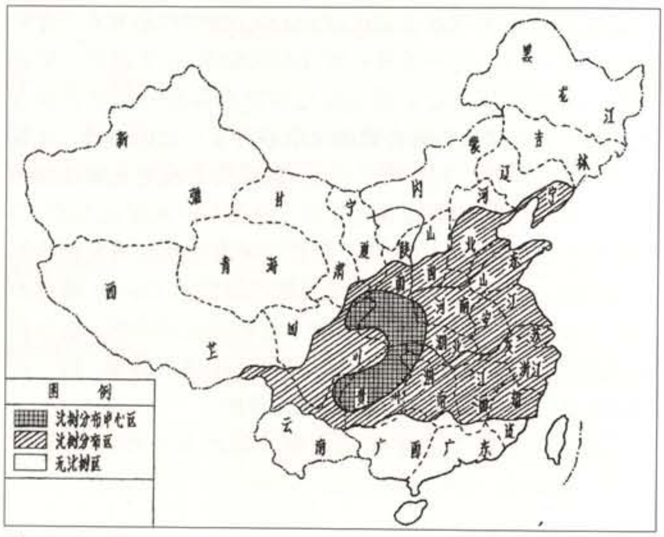


Fig. 1. The distribution of lacquer trees in China.
图 1. 中国漆树分布图。

省份	产量 100-500 担	产量 501-1000 担	产量 1000 担以上
陕西	留坝、商南、周至、南郑、凤县、太白、柞水、安康、旬阳、汉阴、镇安	紫阳、镇巴、镇坪、宁陕	岚皋、平利
湖北	房县、竹山、巴东、宣恩、鹤峰、神农架	利川、恩施、建始、咸丰	竹丰
四川含重庆	酉阳、平武、南江、彭水、武隆、叙永、古蔺、开县	巫溪、北川	城口
贵州	赫章、纳雍、黔溪、织金、桐梓、清镇、德江、务川	大方、毕节、金沙	
云南	奕良、大关、威信	镇雄	
甘肃	天水、康县		
河南	西峡、卢氏		

上述重点产漆县共 58 个，陕西占近 1/3 ，其中产 1000 担以上的县 4 个，陕西占 2 个，我们发现的三倍体漆树产自安康(大巴山)，这种分化是长期利用与选择的结果，李时珍云：漆树人多种之，以金漆(今安康)者为佳，故世称金漆。

陕西漆质优，古有记载。

Shang Zongyan, Zhang Jizu and Li Rujuan

The Chinese Lacquer Tree and its Use

China is a country with the greatest lacquer tree population in the world and its output of raw lacquer accounts for over 80 % of world production. The raw lacquer, a quality natural paint, has been eulogised as "the king of paints". The history of using lacquer in China may date back to very ancient times. The legend goes that when the monarch Yao in the Patriarchal Clan Society was in power, he had wood cut, shaped and lacquer applied to its surface to make cooking utensils. Later Yao abdicated and handed over the crown to Shun, who inherited the lacquer wares and used them as sacrificial utensils. As Han Feizi (a philosopher in the Warring States Period) wrote in his book Shiguo, the utensils were "lacquer black outside and decorated with pictures inside". There have been many records in the classics about lacquer trees as to their place of origin, the plantation and management, the collection of lacquer, the taxation, etc. Lacquer trees are to be found approximately between 25° to 41°46' North Latitude and 95°30' to 125°20' East Longitude, covering 21 provinces (cities and autonomous regions) such as Shaanxi, Sichuan, Hubei, Guizhou, Yunnan, Hunan, Henan, etc. Of these places, Shaanxi is number one in the output of raw lacquer and its output of raw lacquer is one third of the total in China.

李最雄

敦煌莫高窟的彩绘泥塑及其保护

前言

敦煌莫高窟的492个洞窟中，保存着从北凉(公元4世纪)到元代(公元14世纪)十一个朝代、延续一千多年的2000多身彩绘泥塑。

这些彩绘泥塑其制作工艺大体分两类，其中小型彩塑，先以木料制做骨架，再做泥塑，大型彩塑以石胎为骨架。

莫高窟的泥塑全部敷彩。泥塑敷彩在各个时代都具有不同的特征，十六国、北魏等早期的敷彩比较简朴沉着，颜料主要用土红、石绿、石青、白、黑等。隋唐时代，莫高窟的泥塑敷彩发展到了光辉灿烂的时期，敷彩富丽堂皇，许多部位装金。特别是盛唐时期，彩塑的肤色大量应用了铅丹(Pb_3O_4)，由于铅丹的严重变色，这个时期彩塑的肤色全已变成深棕色或深咖啡色。五代、宋代等时期，彩塑的敷彩比较清雅。到了清代，将早期的彩塑进行了重塑和重绘，敷彩的白色颜料大部分采用石膏，兰色颜料为群青，红色颜料为朱砂。

千百年来，由于受温、湿度的变化，降水、岩体渗水、岩体和泥层中可溶盐的活动等环境因素的影响，莫高窟的彩绘泥塑不同程度的产生了各种病害。主要有彩绘颜料的变色、褪色；彩绘颜料层的龟裂起甲；彩绘层的酥碱粉化；木骨架遭朽而引起的塑像肢体断裂或塑像倾倒；石胎岩体风化而造成的泥层剥离等。

对彩绘泥塑的保护修复采取了如下的方法和措施，倾倒彩塑的扶正、定位、加固；遭朽木骨架脱胎换骨修复；风化石胎岩体加固；酥碱、起甲颜料层加固修复；以及洞窟环境的治理，如薄顶洞窟窟顶加固及岩体裂隙灌浆以防渗漏雨水。进行观众参观时对壁画、彩塑造成影响的环境监测和分析研究，控制每个洞窟参观人数，以免洞窟中CO_2和水份的剧增造成对彩绘颜料的影响。

1. 莫高窟彩塑的制做工艺

莫高窟的彩塑有的高达30多米，小的只有10多公分。其中小型彩塑，先以木料制做骨架，然后在木骨架上捆扎芨芨草或芦苇草做成人像的大体结构形像(彩图XVI, 1)，再敷粗草泥，最后在表面塑以细质薄泥。而大型塑像，不做木骨架，而是在开凿洞窟时，预留塑像石胎，将石胎凿成塑像的大体形状，然后在石胎上凿孔插椿，再在上面敷粗草泥，最后在表面塑以细质薄泥(彩图XVI, 2)。

莫高窟塑像的木骨架是用本地的胡扬、杨木或柳木做成的，因为这是本地最普遍的几种树种，木质较坚硬。塑造用的粘土是附近河床的沉积粘土或山洪暴发后在低洼地沉积的粘土。这种粘土细腻，大部分的可溶盐已被漂流，吸缩性小。粗泥中掺加的草主要是麦草，细泥中掺加的纤维主要是麻或棉。

2. 泥塑的彩绘

莫高窟的泥塑全部敷彩。泥塑敷彩在各个朝代都具有不同的特征，特别是敷彩所用的红色颜料，更具有鲜明的时代特征。十六国、北魏、西魏及北周等早期的敷彩比较简朴沉着，红色颜料主要以土红(Fe_2O_3)为主(彩图XVI, 4)。土红在红色颜料中是最稳定的一种，千百年来，这些彩塑的土红颜料没有发生变色，只是处于不同环境中的彩绘层中因含水不同，或者由于掺加在颜料中的胶结物老化程度不同，而颜料的亮度、彩度有所差异。

早期彩绘所用的兰色颜料主要是石青($2CuCO_3Cu(OH)_2$)和青金石($(Na,Ca)_8\ (AlSiO_4)\ _6\ (SO_4,\ S,\ Cl)_2$)；绿色颜料主要是石绿($CuCO_3Cu(OH)_2$)和氯铜矿($Cu_2(OH)_3Cl$)。这些兰色颜料和绿色颜料其化学性能较稳定，和上述相同的原因，其亮度和彩度有差异。彩绘的白色颜料主要是方解石($CaCO_3$)，高岭土($Al_2Si_2O_5(OH)_4$)、滑石($Mg_3Si_4O_{10}(OH)_2$)。

隋唐时代，莫高窟泥塑的彩绘发展到了光辉灿烂的时期，敷彩富丽堂皇。彩绘所用的红色颜料主要是朱砂(HgS)和铅丹(Pb_3O_4)，土红颜料明显减少。

朱砂是一种较稳定的红色颜料，由于长期受光照的的作用，朱砂的结晶状态产生了变化，部分由原来鲜红色的朱砂变成暗红色的黑晨砂。这仅仅是一种物理状态的变色，色相没有变化，亮度和彩度却发生非常明显的变化。但是，由于受湿度的影响，特别是开挖洞窟的初期，以及塑像刚做成后高湿度的环境作用，彩绘的铅丹基本已变成棕黑色的二氧化铅(图1)。因此，这个时期的彩塑，凡用铅丹的部位，主要是肤色，基本已变成棕红色或棕黑色的二氧化铅(彩图XVI, 3,5)，很难找到未变色的铅丹。这个时期彩绘所用的兰色颜料，绿色颜料以及白色颜料和早期彩绘所用的兰、绿、白颜料基本相同。另外，这个时期彩塑的服饰、菩萨项链等部位装金，以显富丽。

五代，宋代等晚期，莫高窟泥塑的彩绘比较清雅，这个时期彩绘所用的红色颜料除土红外，大量采用了土红与铅丹、或朱砂与铅丹等的混合红色颜料。铅丹与土红、或铅丹与朱砂混合后具有较稳定的化学性质。混合红色颜料中的铅丹基本未变色，其原因不清楚，正进行化学机理的研究(图2)。这个时期彩绘所用的兰色颜料、绿色颜料和白色颜料基本与早期和隋唐时期所用的兰、绿、白色颜料相同。

清代，莫高窟的彩塑大部分被重塑和重绘。重塑的泥塑十分粗糙，重绘的颜料也是对比非常强烈的大片红色、兰色、白色，完全破坏了早期彩塑的优美形象和艺术性(彩图XVI, 6)。

彩绘所用的红色颜料主要是人造朱砂、朱砂与铅丹、或土红与铅丹的混合红色颜料。所用的白色颜料主要是石膏。

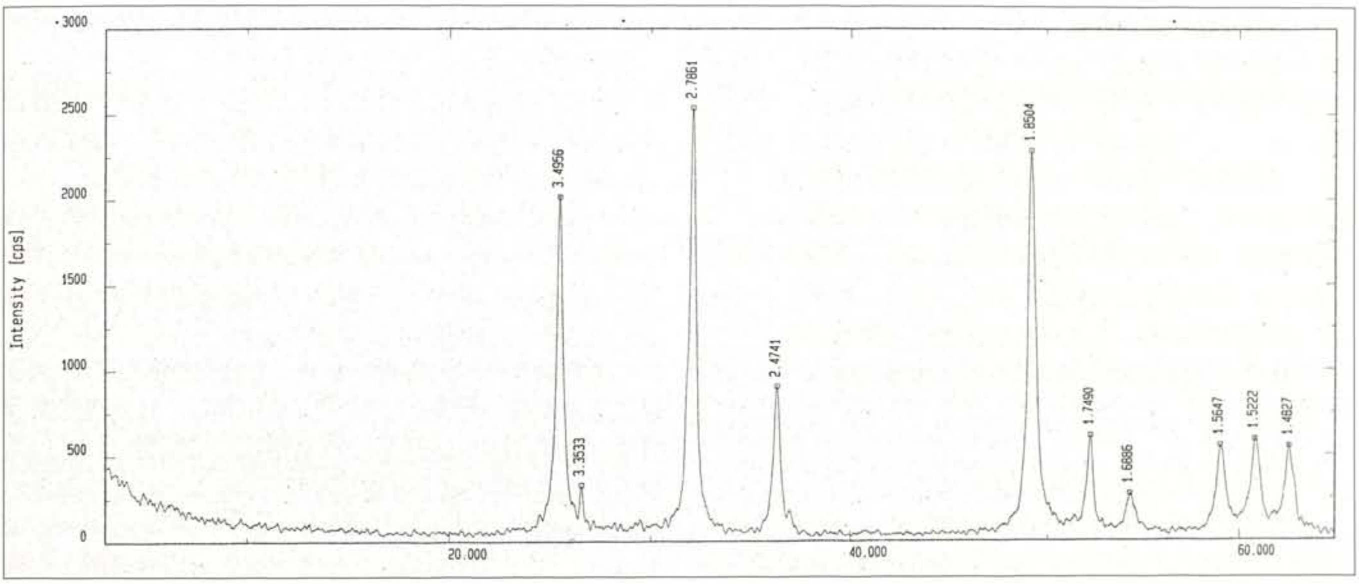


Fig. 1. The altar, left side, Funhuang, cave 205, a Bodhisattva, Tang Dynastyy, its polychromo was changed. X-ray diffraction spectrum of the brown black pigment sample (from the right armpit of the Bodhisattva), mainly PbO_2.

图 1. 莫高窟第205窟佛台左侧，唐代已变色菩萨塑像右腋下，棕黑色颜料试样的X衍射谱图，主要是PbO_2。

3. 彩塑的主要病害

3.1. 彩绘颜料的变色、褪色

由于莫高窟的彩塑，敷彩大量应用了红色颜料中的铅丹，特别隋唐时期，不论是彩塑还是壁画，铅丹是应用量最大，最普遍的红色颜料。由于铅丹在高湿度环境中，当遇到碱性条件，是很容易变色的，由桔红色的Pb_3O_4变成棕黑色的PbO_2。经调查研究证明，新开挖的洞窟湿度很大，又由于砾岩中有许多碎石，岩面凹凸不平，以石胎为骨架的泥塑上面要敷很厚的泥层。木骨架的泥塑泥层也很厚。这样厚的泥层在通风不良的洞窟中不容易干透，加上新开挖的洞窟本身湿度也很大。许多彩塑、壁画的地仗又涂刷一层石灰，然后再进行彩绘。因此，彩塑上的铅丹是塑像完成不长的时间已经变色。 彩绘应用的另一种红色颜料朱砂，长期受光照的影响，也已变暗。由于莫高窟的洞窟开凿在南北走向的崖面上，过去没有门，早晨太阳直射洞窟，这样的环境朱砂的变暗也很快。另外，由于莫高窟的彩绘颜料是矿物颜料，矿物颜料敷彩时必须掺加适量的植物胶或动物胶。这些有机胶结物，千百年来基本已老化失去胶结作用，使彩绘颜料层粉化掉落，颜料的密度大大降低，因而颜料彩度变淡，这就叫彩绘颜料的褪色。

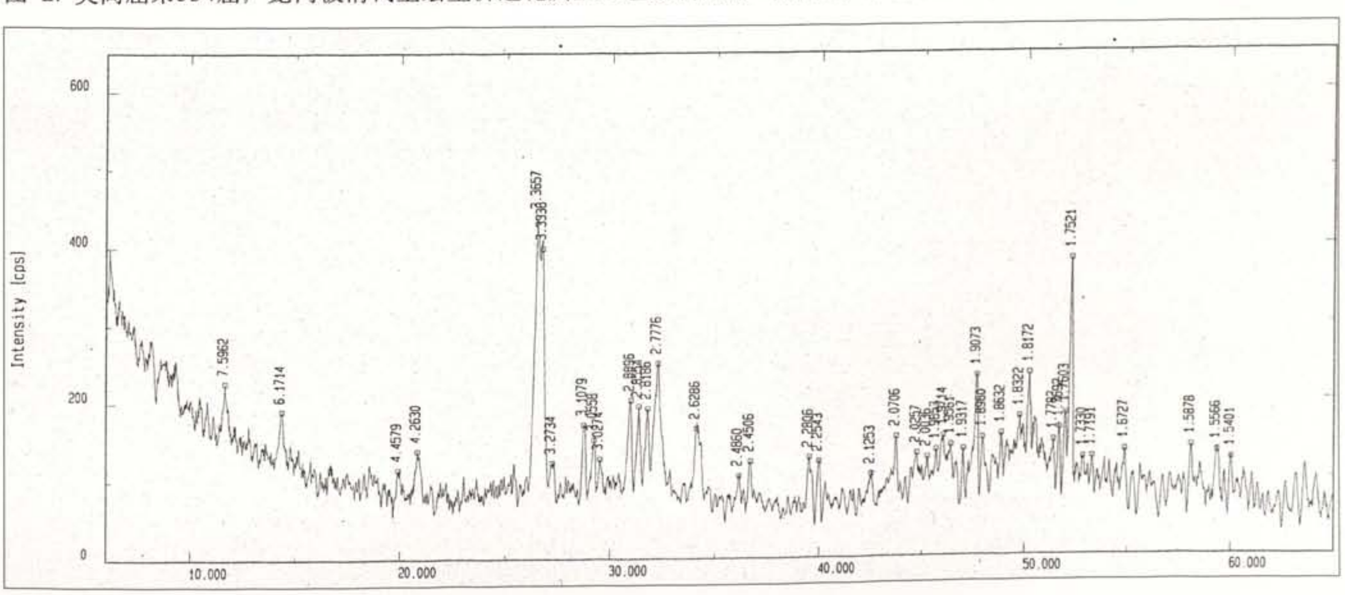
3.2. 彩绘层龟裂起甲

由于彩绘颜料中加胶过量，或胶的浓度过大，使颜料层强度过高、结壳、龟裂、甚至起甲剥离。

与壁画的起甲相比，莫高窟彩塑颜料层的起甲没有那么严重。

Fig. 2. Cave 334, Dunhuang, X-ray diffraction spectrum of the red pigment (from the lotus petal of the chief Buddha which in the Qing Dynasty was painted again), the main composition is Pb_3O_4+HgS.

图 2. 莫高窟第334窟，龛内被清代重绘主佛莲花瓣上红色颜料的的X衍射谱图，主要成份是Pb_3O_4+HgS。



3.3. 彩塑表面的泥层酥碱

莫高窟的彩塑虽然应用了河床或洪水沉积的粘土，但这种粘土中还是含有少量的可溶盐，主要是芒硝(Na_2SO_4)和石盐(NaCl)。大型塑像的石胎岩体中，可溶盐的含量就更高。当湿度急剧变化时，这些可溶盐时而吸水膨胀，又时而失水收缩。这样反复的胀缩使彩塑表面的泥层风化，严重者酥碱，使颜料层受到严重破坏。另外，莫高窟的岩体为松散、孔隙率很大的砾岩，过去，部分上层洞窟窟顶很薄，常有雨水渗漏。也有相当一部分下层洞窟被潮湿的沙子埋在里面，这些上层渗漏雨水和下层埋在潮湿沙子中的彩塑早已酥碱。

3.4. 彩塑泥层剥离肢体断裂及倾倒

以石胎为骨架的大型塑像，由于受水的作用所引起的可溶盐活动的影响，岩体风化，造成彩塑的泥层大块剥离。以木料做骨架的小型塑像，长期受潮湿环境的影响，捆扎在木骨架上的芨芨草和芦苇草遭朽，而导致彩塑泥层剥离。

彩塑的肢体断裂，主要是由于木骨架遭朽断裂所引起的。塑像的倾倒主要是由于塑像本身承重大，受地震等因素的影响，塑像的重心外移而造成的。另外，立像都是在地面上凿孔，将塑像的骨架固定在地面的岩体中，依墙的立像将塑像腰中的木骨架固定在墙面岩体中预埋的木楔上。当固定的木骨架遭朽断裂，或固定的岩体风化而固定点松动，都会造成塑像倾倒而遭受严重破坏。

4. 彩塑的修复保护

对于起甲、酥碱彩塑的修复，采用与起甲、酥碱壁画基本相同的修复材料和方法。由于莫高窟环境比较干燥，多年来用聚醋酸乙烯乳液和聚乙烯醇修复壁画、彩塑起甲颜料层，取得了很好的修复效果。其工艺方法是，将2~3 %的聚醋酸乙烯乳液，或2.5 % 聚乙烯醇: 1 % 聚醋酸乙烯乳液=4:1的混合胶结剂，用注射器注入颜料层下的地仗层和起甲的颜料层。待起甲颜料层稍软化具有一定柔性后，用丝绸包扎棉花做成的纱包将起甲颜料层微微按下，粘复在地仗上。近年来，我们对丙烯酸乳液和ParaloidB-72修复起甲壁画、彩塑进行了实验。从观察短期效果还比较好，但最终的效果有待进一步观察和监测。

目前，酥碱壁画、彩塑的修复还是一个难题。过去也用修复起甲壁画的材料修过部分酥碱壁画，但过几年后，修复过的部位又开始酥碱，修复效果不佳。5年前，我们采用日产化学工业公司生产的7.5的硅酸锂(商品名称：(スノ—テゥス)在榆林窟进行过酥碱壁画的修复试验。从目前初步观察，这种材料对酥碱壁画修复效果较理想，但有待做进一步的深入研究。

对于泥层剥离的彩塑的修复，分两种类型进行。以石胎做骨架的大型彩塑，首先加固风化岩层。对莫高窟这种环境较干燥的风化砂砾岩，以高模数的硅酸钾(即PS)加固风化岩体，其效果比较理想。待岩体加固好后，将剥离的泥层用稍加胶合剂的泥浆粘合复原。如果剥离的泥层体量较大，或在立面上承重较大，再用适当的锚杆锚固，当然锚杆要做的隐蔽，最后进行裂隙灌浆和修复。以木制骨架的小型彩塑，要更换遭朽的木骨架，或捆扎在木骨架上的芨芨草和芦苇草，这就是进行脱胎换骨的修复。对倾倒的塑像进行扶正，定位和重新固定加固。

对酥碱和颜料变色的防止，我们正通过环境监测和变色机理的研究，采用工程措施进行预防性保护，如对薄顶洞窟的窟顶加固，岩体裂隙进行化学灌浆，以防雨水渗入洞窟内。对地下渗水的部位进行帷幕灌浆等工程措施，切断渗水。另外适度的通风，对防止壁画彩塑颜料层变色、酥碱也有较好的效果。

大量的游人进入洞窟，所排出的CO_2和水汽也是引起壁画、彩塑地仗酥碱和颜料变色的因素之一。过去我们和美国Getty保护研究所合作，做过这样的试验，40个人进入空间为141m^3的洞窟中37分钟，结果是洞窟中的CO_2比原来升高6倍，温度和相对湿度也急剧升高，但CO_2排出却非常缓慢。可以想象，如果在一个中等大小的洞窟中，成天大量观众不断进人，窟内的CO_2和湿度就会叠加升高，真是一个令人担忧的问题。虽然这个研究有必要进一步进行，但对中、小型洞窟的开放进行适当的控制，对防止壁画、彩塑地仗酥碱和颜料变色肯定会有好的作用。

Li Zuixiong

Coloured Clay Sculptures and their Protection at Mo Kao Grotto at Dunhuang

In the 492 caves of the Mo Kao Grotto at Dunhuang more than 2,500 clay sculptures, from Beiliang (4th century AD) to the Yuan Dynasty (14th century AD), covering 11 dynasties in all are kept.

The technology of making these coloured clay sculptures falls into two categories. The first kind of technology is for those medium-sized and small sculptures. One ties elders and reeds around the complete wooden framework to form man-like structures, whose height reaches 20-30 meters. Instead of wooden frames, stone bases are left when caves are dug. On the bases holes are cut to put in stakes on which rough and coarse grass clay is applied. The application of fine clay completes the sculptures.

All the clay sculptures of Mo Kao Grotto are coloured, but their colours vary from dynasty to dynasty. In the Sixteen States Period and the Northern Wei Dynasty, the colours were simple, ranging from earth red, mineral green, azurite, white to black. In the Sui and Tang Dynasties, the colours became bright and brilliant with many sculptures inlayed with gold. Especially at the zenith of Tang Dynasty, minium (Pb_30_4) was used extensively. The skin colour of the sculptures became dark brown or dark coffee due to the big change of minium. In the Five Dynasties Period and the Song Dynasty the colours tended to be light and elegant. In the Qing Dynasty, the sculptures were remoulded and repainted with gypsum as the white pigment, ultramarine as the blue pigment and cinnabar as the red pigment.

Due to centuries of dampness, changes of temperature, rainfall, rock percolation, the activity of soluble salt in the rock body and between rock layers, and other natural factors, the coloured sculptures have extensively suffered showing fading, colour change, cracking of the pigment layer, alkaline pulverisation, broken limbs and collapse caused by the decaying wooden frames, the dropping of clay caused by the weathering of stone bases, etc.

To protect and repair the sculptures we have taken measures such as setting up and reinforcing the collapsed figures, replacing or repairing the wooden frames , strengthening the weathered stone bases, repairing the pulverised pigment layers, thickening the cave roofs to prevent leakage and other environmental improvements. With the environmental monitor and analysis, we have control over the number of visitors in the caves so as to avoid the impact of CO_2 and moisture on the sculptures. *See colour plate XVI.*

陆寿麟

故宫博物院的彩绘艺术品
—兼谈保护问题

Fig. 1. Female Attendant with Tall Coil, painted earthenware, Tang Dynasty.

图 1. 唐画彩高髻女陶俑。

故宫博物院收藏的带有彩绘的艺术品涉及范围相当广泛，主要有四大类型：建筑装饰彩绘、壁画、彩速和器物彩绘(在这里不包括书画、陶瓷彩釉、油漆制品和印染品等等)。其中建筑装饰彩绘是故宫彩绘艺术品中数量最大、内容丰富、品种繁多、形式多样的一类。

中国古建筑主要是木架构，其建筑装饰彩绘是宫廷建筑的一大特色。有房梁上的彩画及天花、藻井、屏门、隔扇、罩上的彩绘。主要是做在木构件、木版、墙体上的彩绘，也有画在纸、布、绢上的彩绘。就宫廷建筑而言，不同的时代，根据不同的功能，有不同的风格。在制作材料及工艺上也有区别。旋子彩画，也有点缀金之说，是古老的品种。现在能尖刀的元代还有，故宫神武门莱花就属于这一类(彩图XVII, 1)。和玺类，以金箔为主，在明末清初就比较成熟了。主要用在皇帝的政治和社会活动场所。例如三大殿等。内檐梁枋采用浑金做法。图案通体贴金与天花、藻井的龙纹彩画相呼应，共同装点出庄严肃穆的环境气氛(彩图XVII, 2, 3, 5, 7)。宝珠吉祥类彩画风格粗放、色调炙烈，带有满民族的风格(彩图XVII, 6)，也有的带有典型的宗教色彩(彩图XVIII, 8)。在康熙以后，可能同康熙南巡有关，在宫廷彩画中吸取了江南比较自由休闲的风格，主要用在后妃生活和皇帝休息的地方。内容上出现了山水、花鸟、人物、戏文、西译画(彩图XVIII, 13, 14)。根据绘画需要，颜料也改变过去用单一颜料的做法为采用两种或两种以上的混合颜料。另外还有一类称之为海墁彩画或海墁天花，比较灵活，像绛雪轩的彩画(彩图XVIII, 9)。特别是倦勤斋，顾名思义，倦于勤政了，是乾隆皇帝为自已退位后用做休息准备的地方。室内装饰十分清丽雅致。其天花(彩图XVIII, 10)满绘藤萝、花朵漫垂、枝叶丰茂与墙壁所绘园林景致映嵌呼应，栩栩如生。平添几分情趣。其中也反映出自觉不自觉的吸收了西方绘画的技法。在彩画颜料方面在清初雍正年间(约18世纪早期)已经逐渐引进了西方颜料，到十九世纪中晚期的同治年间，中国的建筑彩画已经大量采用泽青、佛青、泽银珠等西方颜料。

故宫博物院内壁画不多。有山西稷山县兴化寺元代壁画—七佛说法图，为典型的寺庙建筑的宗教壁画。有长春宫的清代壁画，吸收了西方绘画透视学原理，在绘画风格及技法上都融合了西方绘画，是中西方文化交流的产物。院内另外还有不太多的装饰性壁画。

故宫博物院收藏的彩塑，包括彩绘陶塑、彩绘泥塑。由汉魏，经隋、唐、宋、元、明、清及至近代都有。同时还藏有彩绘木雕，彩绘石雕(图1; 彩图XIX, 16-21)。

器物彩绘，除了具有较高考古学价值的新石器时期的

彩陶和汉代彩陶(图2; 彩图XIX, 15)以外，每种古代工艺品、日用品、钟表机械、玩具、仪仗，都带有彩绘装饰艺术，品种繁多。

彩绘艺术品在各种文物材质中最为脆弱，较难保存，特别是在室外部分，湿度、温度、光照、风、雨、虫、雷、火灾、环境污染……等等因素都能侵害彩绘彩画，造成龟裂、起瘕、酥碱、剥离、褪色、变色……等等现象。历来都有采取保护措施，给予保护。

故宫博物院的彩绘艺术品，除了藏品以外，作为主体的宫廷建筑群，在1911年辛亥革命以前，还是实用建筑。辛亥革命以后随着封建王朝的消灭，作为宫廷使用建筑完成了它的历史使命，开始成为历史的遗迹，遗物，成为凝固的艺术品，把它作为文物来保护和保存。二十世纪的上半叶，对它的保护和修缮，基本上还是延续了传统的工程做法。在古建筑修缮过程中，对其彩绘艺术品采取原封不动，保持现状的做法，或者采用原材料、原工艺，保持原来的风格进行修缮。近四十年来，随着文物意识的不断增加，特别是制定了“不改变文物原状”的原则。随着科学技术的发展及社会工业化水平的提高对彩绘艺术品的保护技术有了很大的发展。

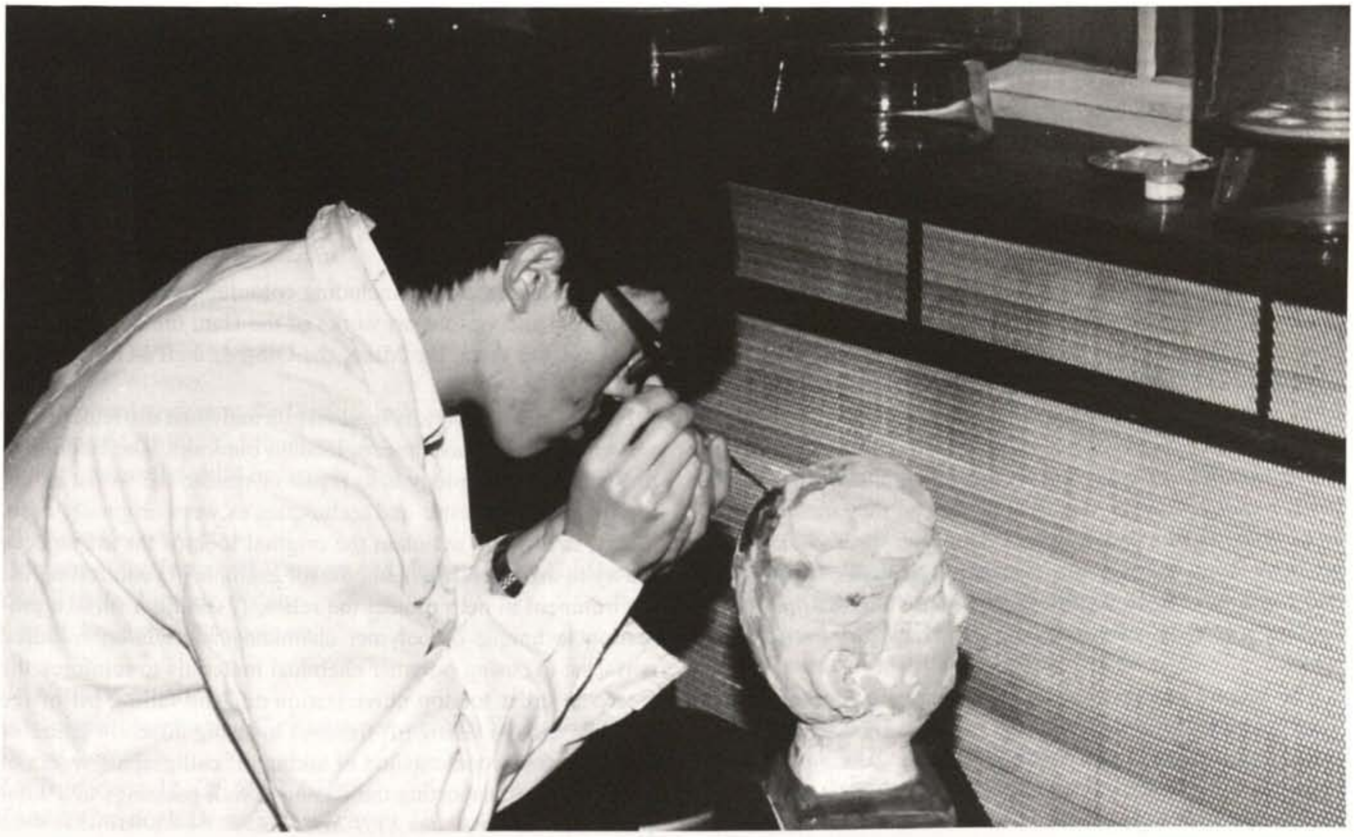
我们坚持“保护为主，抢救第一”的方针。文物是一旦受损不可再生的历史遗存物，都具有一定的历史、艺术、科学价值，保留有历史信息。文物保护的原则，首先是保护文物本身的存在。更重要的是最大限度的保存它所固有的价值的科学性和完整性。任何一种对文物本身的技术处理方法，很难对文物本身不产生任何后遗症和对文物本身价值不产生任何的影响。所以除了对濒临破坏的文物进行抢救，做必要的技术处理以外，对绝大多数文物来

Fig. 2. Vase, painted pottery, Western Han.

图 2. 西汉彩绘陶壶。

Fig. 3. Consolidation of a painted clay head, Tang Dynasty, with infiltration.

图 3. 唐代彩塑头像渗透加固操作。



讲，不在迫不得已的情况下，尽量少对文物本身做技术处理，尽量少在文物上添加新材料，应该采取"保护措施"。我们的办法是研究影响文物保护的环境因素，制定保护文物的环境质量标准，改善环境条件，适应文物保护的需要。

对于已经出现了表面粉化剥落、地仗或泥胎酥碱、颜料(涂料)层龟裂、颜色褪色、变色等现象的彩绘艺术品，就不得不进行必要的技术处理。我们曾经筛选合适的高分子化学材料配合必要的紫外线吸收剂、防老剂进行渗透加固和表面封护处理。甲基丙烯酸甲酯、甲基丙烯酸丁酯和甲基丙烯酸的三元共聚物、聚醋酸乙烯酯、聚乙烯醇缩丁醛……等高分子材料都可以作为渗透加固的材料(图3)。故宫博物院也曾经研究采用聚酰胺和有机硅的共聚体作为彩画和彩绘表面封护材料。

对地仗损坏的壁画、版画，用粘布揭取或用中国传统书画揭裱的办法揭取转移保存。曾经有一墓室壁画，砖室墓，非常潮湿，在墓砖砌的墙上，刷上一层白灰， 随即作画，没有地仗，画面在潮湿情况下，呈泥浆状。风干后，一有风吹就要掉片、脱落。又没有条件在现场采取措施给予保护。对这种墓室壁画，我们研究了采用高分子化学材料粘布揭取转移的办法：先将画面用红外线烘干，用聚甲基丙烯酸甲酯溶液喷雾加固画面，再用醇溶性的聚乙烯醇缩丁醛溶液粘贴棉纱布覆盖画面。利用砖墙内部水分向外蒸发的过程，促使画面与砖墙面剥离、然后将画面层从砖墙上揭取下来。回到室内后，利用画面加固材料与贴金材料不同的溶解性能，可以揭去表面覆盖的棉纱布，而不伤及画面。最后，将壁画复原后放置在室内合适的环境中保存。

总之，对彩绘艺术品的保护，在坚持"保护为主，抢救第一"的方针，在"不改变文物原状"原则指导下，可以根据不同的情况，采取现场加固、封存保护、揭取转移保存。最好还是尽量少做技术处理，采用改善环境条件，使彩绘艺术品得以长期的保存。

Lu Shoulin

The Polychrome Works in the Palace Museum and their Preservation

The polychrome art works in the Imperial Palace of Beijing cover a wide range of exhibits and fall into four categories: i.e. painting on architectural elements, wall paintings, polychrome sculptures and colouring on utensils. They do not include calligraphy, porcelain or lacquer ware or painted and dyed articles.

The examples of colouring on architectural elements are extensive, rich in content and great in variety; they include painted ceilings, sunken panels, screen doors and spear shields. They are to be found not only on construction elements, wood boards and walls but also on paper, silk and gauze and their pigments, coating, materials, technology and functions vary over the centuries.

The second category of wall paintings are few in number. They include a religious fresco of the Yuan Dynasty brought to Beijing from Xinghua Temple in Jishan County of Shanxi Province and a fresco of the Qing Dynasty, which is a product of the cultural exchange between China and the West. The last two categories are extensive, including coloured pottery of the New Stone Age and various art works of the Han, the Sui, the Tang, the Song, the Yuan, the Ming, the Qing as well as modern examples.

Polychrome art work is most fragile and most difficult to preserve, especially those pieces located outdoors. The traditional preservation technology is to repair or restore the works by using the same materials and techniques as were originally used. Today, in order to maintain the original look of the art objects, we try to use scientific methods: for example (1) controlling the environment to help protect the relics; (2) using a surface protection technique of polymer chemical materials on coloured surfaces; (3) using polymer chemical materials to reinforce the fresco in order to stop pulverisation and the falling off of the paint layers; (4) taking off frescoes by using adhesive gauze or using the traditional method of taking off calligraphic works of art and then transporting the damaged wall paintings to a safer place. *See colour plates XVII-XIX.*

Authors

Prof. Dr. Heinz Berke
Anorganisch-chemisches Institut der Universität Zürich
Winterthurerstr. 190, CH 8057 Zürich
E-mail: hberke@aci.unizh.ch

Dr. Birgitt Borkopp
Bayerisches Nationalmuseum München/ Bavarian National Museum Munich
Prinzregentenstr. 3, D 80538 München
E-mail: bay.nationalmuseum.@extern.lrz-muenchen.de

Dr. Vinzenz Brinkmann
Staatl. Antikensammlungen und Glyptothek
Meiserstr. 10, D 80333 München
E.mail: brinkmann@antike-am-koenigsplatz.mwn.de

Prof. Derun Cheng
Liberal Arts College, Northwest University
PRC 710069 Xi'an

Dr. Sylvie Colinart
Centre de Recherche et de Restauration des musées de France
6, rue des Pyramides, F 75041 Paris Cedex 01
E-mail: sylvie.colinart@culture

Prof. Erwin Emmerling
Lehrstuhl für Restaurierung, Kunsttechnologie und Konservierungswissenschaft
Technische Universität München
Oettingenstr. 15, D 80538 München
E-mail: e.emmerling.@rkk.arch.tu-muenchen.de

Prof. Dr. Hans van Ess
Institut für Ostasienkunde – Sinologie –
Ludwig-Maximilians-Universität München
Kaulbachstr. 51a, D 80539 München
E-mail: vanEss@ostasien.fak12.uni-muenchen.de

Prof. Hanyu Gao
China Textile University
Zhanwulu Road
PRC 200092 Shanghai

Dr. Egon Johannes Greipl
Generalkonservator
Bayerisches Landesamt für Denkmalpflege
Hofgraben 4, D 80539 München
E.mail: poststelle@blfd.bayern.de

Direktor Baofa Guo
Museum of the Terracotta Warriors and Horses of Qin Shi Huang
PRC 710600 Lintong, Xi'an
E-mail: bmybwg@ihw.com.cn

Dr. Christoph Herm
Schweizerisches Institut für Kunstwissenschaft/Swiss Institute for Art Research
Zollikerstrasse 32, CH 8032 Zurich
E-mail: Christoph.Herm@sikart.ch

Prof. Caipin Jiang
Central Academy of Fine Arts
PRC 100005 Beijing

Dr. Ulrike Koch-Brinkmann
Staatl. Antikensammlungen und Glyptothek
Meiserstr. 10, D 80333 München

Dr. Yinglan Kim
China Textile University
1882 Yuan'an Xilu Road
Building for International Students
PRC 200051 Shanghai

Dr. Detlef Knipping
Bayerisches Landesamt für Denkmalpflege
Hofgraben 4, D 80539 München
E-mail: Detlef.Knipping@blfd.bayern.de

Prof. Rujuan Li
Botanical Garden
Cuihua Nanlu Road
PRC 710061 Xi'an

Prof. Dr. Zuixiong Li
Dunhuang Research Institute
PRC Gansu

Prof. Dr. Chunmei Lin
Tainan National College of the Arts
66 Ta-chi Village, Kuan-tien, 720 Tainan County, R.O.C. Taiwan
E-mail: lincm@mail.tnca.edu.tw

Direktor Shoulin Lu
Science & Technology Department
Palace Museum
PRC 100000 Beijing

Dr. Sandrine Pagès-Camagna
Centre de Recherche et de Restauration des musées de France
6, rue des Pyramides, F 75041 Paris Cedex 01

Prof. Shiguang Qiao
Beijing Central Handicrafts and Fine Art Institute
6-3-602 Hongmiao Beili
Chaoyang District
PRC 100025 Beijing

Dr. Petra Rösch
Kunsthistorisches Institut
Ruprecht-Karls-Universität, Ostasiatische Abteilung
Seminarstr. 4, D 89117 Heidelberg
E-mail: proesch@gw.sino.uni-heidelberg.de

Dr. Ingo Rogner
c/o Lehrstuhl für Restaurierung, Kunsttechnologie und Konservierungswissenschaft
Technische Universität München

Oettingenstr. 15, D 80538 München
E-mail: rogner@rkk.arch.tu-muenchen.de

Prof. Zongyan Shang
Botanical Garden
Cuihua Nanlu Road
PRC 710061 Xi'an

Dipl.-Restauratorin Cristina Thieme
Lehrstuhl für Restaurierung, Kunsttechnologie
und Konservierungswissenschaft
Technische Universität München
Oettingenstr. 15, D 80538 München
E-mail: thieme@rkk.arch.tu-muenchen.de

Prof. Dr. Michael Petzet
Präsident ICOMOS
Geschäftsstelle c/o Bayerisches Landesamt für Denkmalpflege
Hofgraben 4, D 80539 München
E-mail: michael.petzet@blfd.bayern.de

Dr. Hans-Georg Wiedemann
Trinkbachstr. 17
CH 8712 Stäfa bei Zürich
E-mail: wiedarchta@goldnet.ch

Direktor Yongqi Wu
Museum of the Terracotta Warriors and Horses of Qin Shi Huang
PRC 710600 Lintong, Xi'an

Prof. Zhongyi Yuan
Museum of the Terracotta Warriors and Horses of Qin Shi Huang
PRC 710600 Lintong, Xi'an

Prof. Jizu Zhang
Botanical Garden
Cuihua Nanlu Road
PRC 710061 Xi'an

Minister Tinghao Zhang
Ministerium für Kulturgüterschutz der Provinz Shaanxi

Prof. Zhijun Zhang
Museum of the Terracotta Warriors and Horses of Qin Shi Huang
PRC 710600 Lintong, Xi'an

Prof. Feng Zhao
China Silk Museum
PRC Hangzhou

Prof. Tie Zhou
Museum of the Terracotta Warriors and Horses of Qin Shi Huang
PRC 710600 Lintong, Xi'an

作者

埃尔温·艾默林 (Erwin Emmerling)，教授，慕尼黑科技大学修复、艺术工艺和文物保护科学专业
海因茨·贝尔克 (Heinz Berke)，博士，教授，苏黎士大学无机化学学院
比尔吉特·博尔科普 (Birgitt Borkopp)，博士，慕尼黑巴伐利亚州国家博物馆
文岑茨·布林克曼 (Vinzenz Brinkmann)，博士，慕尼黑古希腊罗马艺术收藏及雕塑馆
程德润，教授，西安西北大学文学院 (邮编: 710069)
克里斯蒂娜·蒂美 (Cristina Thieme)，修复师，慕尼黑科技大学修复、艺术工艺和文物保护科学专业
汉斯·凡·埃斯 (Hans van Ess)，博士，教授，慕尼黑大学东亚及汉学学院
高汉玉，教授，上海纺织大学 (邮编: 200092)
埃贡·约翰内斯·格莱佩尔 (Egon Johannes Greipl)，博士，教授，慕尼黑巴伐利亚州文物保护局局长
郭宝发，副研究员，陕西临潼秦始皇兵马俑博物馆 (邮编: 710600)
克里斯托夫·赫尔姆 (Christoph Herm)，博士，瑞士艺术科学研究所
蒋采蘋，教授，画家，中央美术学院 (邮编: 100005)
金龑兰 (Kim Yinglan)，博士，上海纺织大学留学生楼
乌尔利克·科赫-布林克曼 (Ulrike Koch-Brinkmann)，博士，慕尼黑古希腊罗马艺术收藏及雕塑馆
西尔维·科利纳 (Sylvie Colinart)，博士，法国博物馆研究和修复中心
德特勒夫·克尼平 (Detlef Knipping)，博士，慕尼黑巴伐利亚州文物保护局
彼德拉·勒施 (Petra Rösch)，博士，海德堡大学艺术学院东亚部
李汝娟，研究员，陕西科学院西安植物园 (邮编: 710061)
李最雄，博士、研究员，甘肃敦煌研究院
林春美，博士，副教授，台南艺术学院博物馆学研究所，台南县大崎村 66 号
陆寿麟，教授，北京故宫博物院 (邮编: 100000)
罗格纳 (Ingo Rogner)，博士，通讯处: 慕尼黑科技大学修复、艺术工艺和文物保护科学专业
桑德尼·帕热斯-卡玛纳 (Sandrine Pagès-Camagna)，博士，法国博物馆研究和修复中心
米夏埃尔·佩策特 (Michael Petzet)，教授，国际古迹遗址协会主席，通讯处: 慕尼黑巴伐利亚州文物保护局
乔十光，教授，北京中央工艺美术学院
尚宗燕，研究员，陕西科学院西安植物园
汉斯-格奥尔格·维德曼 (Hans-Georg Wiedemann)，博士，瑞士施未尔岑巴赫 Mettler-Toledo 有限公司
吴永琪，陕西临潼秦始皇兵马俑博物馆馆长
袁仲一，教授，陕西临潼秦始皇兵马俑博物馆
张继祖，教授，陕西科学院西安植物园
张廷皓，研究员，陕西省文物事业管理局局长
张志军，副研究员，陕西临潼秦始皇兵马俑博物馆
赵丰，教授，杭州中国丝绸博物馆
周铁，副研究员，陕西临潼秦始皇兵马俑博物馆

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