The Matter of Chinese Painting, Case studies of 8th century murals

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Chapter 4

The technique of the murals

The Samples

My search for a fixed marker of painting technique naturally led me to the tomb paintings of the Tang dynasty, since they have the special characteristics of being of an undisputed age and of having some pieces left in situ and relatively undisturbed. In order to carry out a technical study of these works of art, the taking of samples was unavoidable. I looked for the least beautiful, most damaged, and specifically most broken up areas of the murals from which to take my samples. I sampled the paint layer and the underlying structure (to which I refer as the ground layer) and brought them into the laboratory for further analysis.

I collected basic visual information by using magnifying glasses to study the painted surface of those murals now in the Shaanxi History Museum. The cracks and crevices on some of the paintings allow an even closer look at the underlying structure, but to fully understand the nature of the technique more information is essential.
In October 2000, with the much appreciated help of Mr. Liu Xiangyang of the Qianling museum, we took an expedition to the tombs of the tombs of the Prince Yide, Prince Zhanghuai and the Princess Yongtai. Our group consisted of Mrs. Shen Qinyan, Mr. Zhang Qunxi, Mrs. Yang Xiaojun, the Chinese painter Mr. Li Guoxuan, a Japanese painter Mr. Hayashi Tsutomu (who at that time went by the Chinese pronunciation of his name, Mr. Lin Gong) and myself (Chinese name: Fan Lüxian). Mrs. Shen, Mr. Zhang and I collected numerous samples in the three tombs; in total I was allowed to collect 13 samples in the three tombs.

The pieces of mural that remain are for the most part not of great iconographical value, and for that reason might be considered to be of less importance or interest.. Nonetheless, they still represent the material evidence of the painting technique, and are therefore of the greatest value for my research. As the samples I required were very small, and were taken for the most part from areas where the surface was crumbling anyway, I do not believe that any great harm was done by their collection. The samples are taken from the paint layers on the walls of the tombs of Prince Yide, Princess Yongtai, and Prince Zhanghuai. The murals in the three tombs were all painted in or around the year 706. The tomb of Yongtai was excavated in 1959, and the tombs of Yide and Zhanghuai in 1971. As previously mentioned, their dating is unchallenged, and all three are from the same period, the early Tang dynasty. As it turns out, there is also a typical feature to their layer structure to confirm this dating: this will be discussed further.

The purpose of sampling

Samples are taken in order to be able to analyse and identify the structure and material of the ground layers and the nature and composition of the paint. The results of the analysis of my samples have been shared with the staff of the Shaanxi History Museum, Shaanxi Lishi Bowuguan, Mrs. Shen Qinyan and Dr. Zhang Qunxi. I hope very much that the results of this analysis can be used to improve and develop techniques for the conservation and restoration of the remaining parts of the murals. Working together with the museum staff served both our interests and makes it possible for me to use my research for the benefit of the works of art themselves.

The extent of our knowledge about the painting materials

The manufacturing process of the Tang murals as discribed in the *Wenwu* and *Kaogu* excavation reports, Wang Renbo, et al, Wenbo, 1984, 1, p 39-54, [Wang 1]:
It is remarkable that by 1984, a first analysis of samples (*yuanhao* 原号) from the tomb of Yide had already been done by Wang Renbo, which provides us with the following list[89]:

> Shaanxi Tangmu Bihua uses mainly mineral colours, like those in the Yide tomb samples.
> The analysis:

Yuanhao 1: earth red,	$HFeO_2$, Fe_2O_3
Yuanhao 2: mineral blue,	$Cu_3(OH)_2(CO_3)_2$
Yuanhao 3: mineral green,	$Cu_2(OH)_2CO_3$
Yuanhao 4: mineral yellow,	PbO, $HFeO_2$-nH_2O
Yuanhao 5: *zhubiao* [A]	Pb_3O_4

[89] The chemical notation of the original Chinese text is followed, although it differs from the western custom.

Yuanhao 6: *yinzhu*/ quicksilver [B]		PbO, Fe_2O_3
Yuanhao 7: purple/	#1	$HFeO_2$-nH_2O,
		MnO_2-$Mn(OH)_2$
	#2	$HFeO_2$-MnO_2-$Mn(HO)_2$
	#3	$FeTiO_3$, TiO_2

The list of minerals given in the article comprises the following:

Chitiekuang	red iron ore	hematite	Fe_2O_3
Hetiekuang	brown iron ore	limonite	$HFeO_2$-nH_2O
Zhentiekuang	needle iron ore		$HFeO_2$
Lantongkuang	blue copper ore		$Cu_3(OH)_2(CO_3)_2$
Kongqueshi	malachite		$Cu_2(OH)_2CO_3$
Shuimengkuang	manganite		MnO_2-$Mn(OH)_2$
Taitiekuang	ilminite	titanic iron ore	$FeTiO_3$
Jinhongshi	rutile		TiO_2
Mituoseng	litharge	lead monoxide	PbO
Qiandan	red lead		Pb_3O_4

Here we see that in the first column of chemical terms, *zhubiao* [marked A] is considered to be lead, instead of cinnabar, which is the common modern term for *zhubiao* in translation. Another example: *yinzhu* [marked B], a term that would normally be translated as vermilion, is in this case seen to be a mixture of lead and iron oxide.

The method of analysis is only mentioned briefly as 'spectral semi quantative analysis', and so it is possible that the method might account for the strange result. The authors do indicate that this is by no means a complete analysis of the samples, and that it is only the first inventory of minerals.

The partly translated text in Chapter 2, originally written in 847 by Zhang Yanyuan in the *Lidai minghuaji,* is quoted in Wang Renbo's article as a source of information on whence the minerals originated. As this list is quoted in so many later works, it is included again here – the full translation is found in Chapter 2 of this study**:**

> The *dan* from the Wu-lin water-source [Yutang Hunan], the *sha* from Mocuo, the *kongqing* from Yuesui [Sichuan], the *cengqing* from Wei [Shanxi], the *pianqing* from Wuchang [Hubei], the *qianhua* from Shu [Sichuan], the *jieyi* from Shixing [Guangdong], all need to be broken, grinded, filtered and washed......
> Then there is *huang* from Linyi Kunlun, the *xie/jie/xi* from Nanhai [Guangdong], *lujiao* from Yün [Shanxi], *biaojiao* from Wu [Jiangsu], *niujiao* and *qi* from Dong'e [Shandong], and all must be taken into account.[Wang 1, p 39-54]

More recently, in 2002, the book *Mural Paintings in the Mausoleum of Prince Yide* (*Yide Taizi Mubihua*) by the director of the Shaanxi Lishi Bowuguan, Mr. Zhou Tianyou, and the head of the division for study and conservation of the Murals, Mrs. Shen Qinyan gives only a very limited summary of painting pigments in the English translation of the text:

> Colours used in the mural paintings in the mausoleum of Prince Yide include purple, red, green, yellow, blue, black, gold and silver. All pigments are made of minerals. The colouring method consists of flat colouring, diffusion, tracing over lines or painting in gold. [Zhou 1, p 3]

The Chinese version of the text in the same book does include the chemical formula of each of the colours, and for that reason is more accurate and precise. When comparing the Chinese and the English texts, it becomes clear that the Chinese names of the colours are much more than just 'red' or 'yellow'. In my experience, this is a problem that often arises in translation. To show the difference from the English text cited above, I here include my translation from the Chinese version of the same text in *Yide Taizi Mubihua*:

> The paint in Yi De’s tomb has colours such as: purple, red, green, yellow, blue and black. We know from spectral semi quantitative analysis results all of the colours that are used; they are:
> *chitiekuang* 赤铁矿, Fe_2O_3, light red
> *hetiekuang* 褐铁矿, $HFeO_2•nH_2O$, yellow, light brown
> *zhentiekuang* 针铁矿, $HFeO_2$, red
> *lantongkuang* 蓝铜矿， $Cu_3(OH)_2•(CO_3)_2$, blue
> *kongqueshi* 孔雀矿， $Cu_2(OH)_2•(CO_3)$, green
> *shuimengkuang* 水锰矿， $MnO_2•Mn(OH)_2$, brown
> *taitiekuang* 钛铁矿， $FeTiO_3$, black

jintiekuang 金红石， TiO_2, yellow, light brown

mituosheng 密陀僧， PbO, yellow

qiandan 铅丹, Pb_3O_4, red

All of these are mineral colours. Aside from these minerals, gold and silver are also used. The most important methods of applying the colours are: flat colouring, faint dye, coloured line drawings, mud gold etc.. [Zhou 1, p 7][90]

The technique of painting and the structure of the ground-layers

It must first be stated that the walls in the three tombs of the Tang dynasty and many if not all other tombs in China are not executed in the *fresco* technique, meaning that the paint is laid on a dry surface. I must emphasize here that this chinese technique and the *fresco* technique are very different.

'Fresco', the Italian method

Fresco is a technique of painting with wet minerals onto, or rather into, a wet freshly-plastered surface, which leads to a chemical binding between the ground-layer and paint-layer. One of the most famous examples of *fresco* painting is the Sistine Chapel in Rome by Michelangelo. [91] He started in 1508, and it took him 4 years to complete the ceiling. 24 years later, he painted the end wall using the same *fresco* technique. By the time he died in 1564, some damage to the ceiling had already been recorded. In recent years, the restoration of this magnificent work has revealed the technique of Michelangelo: A smooth thin layer of wet plaster, called *intonato,* is put on top of a rougher layer of dry plaster, called *arriccio*. A drawing of the subject is made and small holes are punched along the drawing's most important outlines: this is then put in place on the wall and charcoal dust is applied to it with a pouch, resulting in an outlined sketch. Some of the dots can still be seen in the finished *fresco*. While the plaster is wet, the water-based paint is applied: as in dries, the paint binds with the plaster layer. Due to this chemical binding process, the colours lighten and the paint

[90] Note that the results are the same as the list previously cited from Wang Renbo's article directly above.

[91] This section is based on the report of the restoration of the wall in: Jefferey, David, A Renaissance for Michelangelo, *National Geographic*, December 1989, Vol. 176, no 6, p 688-713

and plaster form an inseparable layer. This technique limits the painter's daily work to a freshly-prepared section of the bigger composition. Every part of the composition must be finished before the plaster is dry, making it almost impossible to use a freehand method of sketching.

The Chinese method

The Tang murals were created by painting on the plastered surface of a wall after it is completely dry, allowing a freer hand of painting. In order for the paint to adhere, all the mineral and vegetable colours have to be mixed with glue. This Chinese form of glue painting can not be compared to the *fresco* technique. For this purely technical reason I prefer to call these works of art murals and not *frescoes*. The difference will be all the more clear when we look at the test results of the samples from these murals.

Today, in bookstores in China, I have seen many examples of printed outline drawings on paper that can be used as a model for re-creating ancient Tang images.
The method described above in the fresco technique can be used in order to transfer these drawings onto a wall: punching holes in the paper and dusting the holes with a powder bag. If this method is used, the difference lies only in the execution of the painting, not in the development of the imagery. I found no trace of this transferral method on any of the murals I examined: on the contrary, in many places freehand sketching is visible proof of a different technique.

Photograph 4-01

A sketch used for a painting after a traditional Tang painting.

The chemical binding is the most significant difference in the technique between the chinese method and the *fresco* method. A second important factor is the time factor. Wet painting requires careful and precise planning, and does not lend itself to freehand sketching. The Chinese method of glue painting on a dry wall, however, allows free improvisation both during the initial sketching and during the process of painting.

Layers for testing

After I had taken the samples in China, they accompanied me in small containers that I put in a lunch box and guarded with my life. I could not but be aware of the unique value of this cargo resting safely in my hand luggage while travelling. Once back in in the Netherlands, I took the samples to the laboratory of the Netherlands Institute of Cultural Heritage [ICN] in Amsterdam. There I prepared to examine the samples and to analyse the composition of the paint layers. As I had 13 samples from the three tombs and 5 more samples from other sources, the empirical side of my research could be expanded to include the stratification of the ground layers.
Under the guidance of and in cooperation with Dr Karin Groen, the research on the layers of paint and the ground layers was begun. Firstly, using the microscope, I divided the 18 samples, taking a small part from each separate layer for further analysis. At that point I also prepared a part of each sample for a a cross section to be embedded in polyester for further examination.

Photograph 4-02
A cross section of sample ZQX1.

Secondly, I chemically analysed each of the separated layers of these minute samples from the tomb sites, in order to establish their composition.

At the ICN, every scientist has his or her own field of research, and I would like to give a short summary of the specialists involved in my research, and of the methods used so far:

HPLC (High Performance Liquid Chromatography) was used by Dr Maarten van Bommel to analyse organic components such as glue and organic colour.
X-ray diffraction was used by Dr Peter Hallebeek for identification of minerals.
Further identification of individual components was performed using a SEM, (Scanning Electron Microscope), with the help of Ir. Kees Mensch of Shell Research, and Dr Ineke Joosten of ICN.

An exhaustive description of these methods goes beyond my expertise, and I must therefore refer the reader to the bibliography of technical books for the specifics of the various methods. However, a short description follows, based on the explanation in the magazine ‘Art Matters’, vol 1, 2002, p 59:

> Light Microscopy
>
> Light microscopy on paint cross sections gives information about the layer build-up, as well as limited information on the pigments and binding media. Samples were imbedded in polyester resin and after grinding with SiC-paper examined under a Zeiss Axioplan 2 microscope under normal and UV light.
>
> PLM
>
> Polarized Light Microscopy gives information on separate particles from a paint sample. The samples were imbedded in Permount medium.
>
> SEM-EDX
>
> Scanning Electron Microscope- Energy-Dispersive X-Ray spectroscopy tells us about the elemental composition of pigments in paint cross sections.
> Analyses were performed at the Shell Research and Technology Centre, Amsterdam using a Jeol JSM 5900 LV scanning electron microscope and a Noran Vantage EDX-system with a pioneer Novar detector. Electron beam 25 kV. The samples were coated with carbon before analysis.
> Analyses performed at the ICN, Amsterdam were carried out as at SRTCA but with a JAOL JSM 5910 LV SEM, and electron beam 20 kV. No carbon coating was used.

XRD

X-Ray diffraction is used for the elucidation of crystalline materials (mostly anisotropic pigments). A sample of solid material, 0,05 mm^2 in size, is attached to the tip of a glass fibre with a small amount of cedar oil. X-ray camera; Debeye-Scherer powder camera; 2r=57,3 mm. Philips PW 1024, X-ray generator: Philips PW 1830 X-ray film: double coated CEA REFLEX 25. Exposure conditions: 40kV, 30mA, time 300 min., Copper tube.

HPLC

High Performance Liquid Chromatography was performed for the analysis of organic components.

250 μ 3 N hydrochloric acid is added to the samples (in vials). The hydrochloric acid causes the samples to dissolve completely. This produces carbon dioxide, which points to the presence of calcium carbonate. Subsequently the vials are sealed and the samples are hydrolysed at 105 ° C for 16 hours. This causes the protein to decompose into amino acids. After evaporation of the samples, phenyl isothiocyanate is added to react with the amino acids. This reagent is necessary to detect amino acids with UV absorption. After the reaction, the samples are dried again and dissolved in the HPLC buffer and analysed. At an earlier stage the retention times of every individual amino acid is determined for identification. The proportion of the amino acid content indicates that a specific protein is present in the sample.

For many chemical tests and chemical spot tests I used the tests recommended by Joyce Plesters[92] and by J.R.J. van Asperen de Boer[93]. The reader provided by Drs Karin Groen and Dr Arie Wallert for their course ‘Microscopy and Micro Chemical Analysis’ which I took in 1999 was also essential for my investigations.

The build up of ground layers

The first layer, *maicaoni*

To prepare the wall for painting, several ground layers must first be applied.

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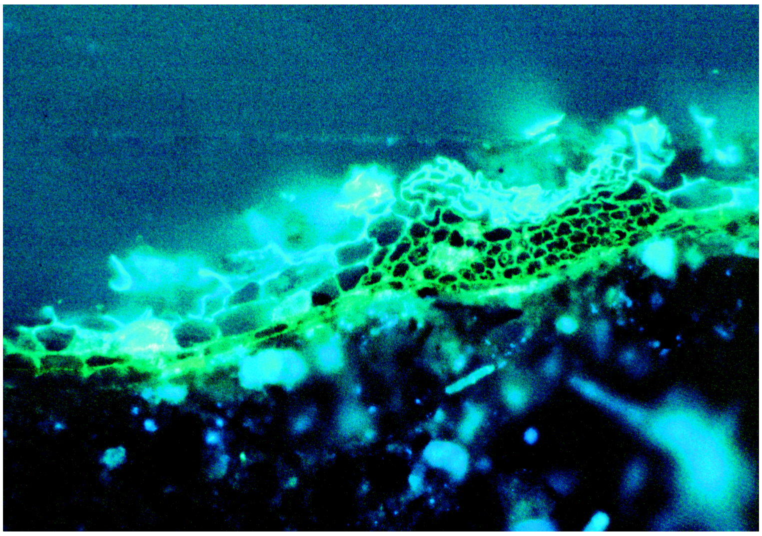
92 Joyce Plesters; ‘Cross-sections and Chemical Analysis of Paint Samples’ in *Studies in Conservation*, vol II, nr 3, 1956

93 J.R.J. van Asperen de Boer, “Some Practical Aspects of the preparation and study of cross-sections”, ICOM Committee for Conservation Preprints, Copenhagen 1984.

The first layer consists of mud to prepare the wall, and is about 1 to 2 cm thick. The main component is loess or yellow earth (*huangtu* 黄土) containing iron, sand and some quartz. In the case of these three tombs, I learned from private communication with Dr Zhang Qunxi of the Shaanxi History Museum that this first layer is a mixture of *huangtu* and wheat straw (*maicao* 麦草). These are both readily-available locally, and are still used for plastering walls. Present-day samples taken for reasons of comparison are exactly the same as the samples from the 8th century.



Photograph 4-03

Microscope photograph: with UV light we see the structure of a straw fibre in the ground layers of the wall in the Yongtai tomb; magnification 200x.

Glue

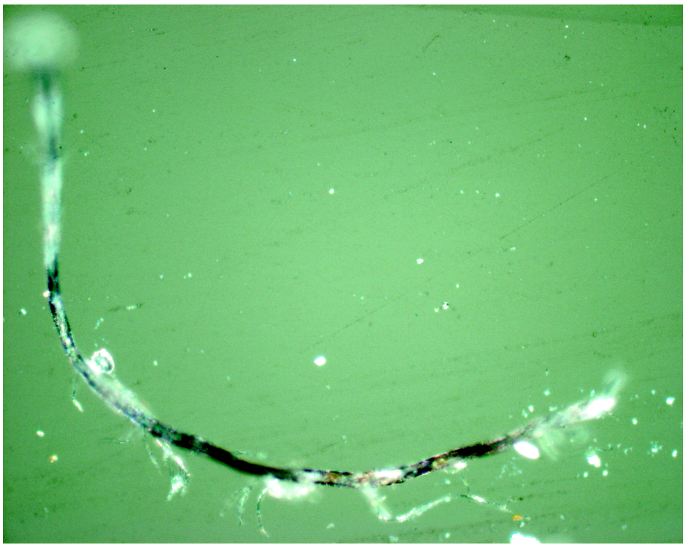
To my surprise, the HPLC test-results prove that in this basic first layer glue is added.
In some samples, the *huangtu*, yellow earth, layer contains an animal glue; other samples contain a protein that has yet to be identified. It has been suggested to me by a Danish conservator that this animal component might stem from animal remains thrown into a lime pit. However, firstly we are dealing not with lime but with chalk, and secondly, even if this was a contamination by a discarded carcass, it still has the same effect as a glue component in the layer. The difference between lime and chalk is clarified by the presence of coccoliths in the chalk layer: were this lime, these coccoliths would be absent.[94]
So far, we have been unable to identify the specific animal or to differentiate between the various parts of the animal. This unfortunately makes it impossible to tell whether it was bone or skin that was used for the preparation of the glue. It might also have been a

[94] Private communication with Catharina Blänsdorf.

combination of all available parts, as we can derive from the description of one of the glue-making methods in the farmers handbook (*Qimin yaoshu*) [see the entry on glue in Chapter 3, p 116].

An unexpected second layer

While examining the samples of ground layers under the microscope, I found that two of the three tombs had a surprise in store: an unexpected layer.
As mentioned above, *maicao,* wheat straw, is mixed with yellow-earth to form the *maicaoni*-layer 麦草泥, and this combination of components is what I expected to find. However, under the microscope I could see that many of the samples of yellow-earth ground layer contained other fibres in addition to the wheat straw. At first sight these fibres look black and curly, and in all samples from the Yong Tai tomb these same black fibres are present.



Photograph 4-04

Microscope photograph of a fibre of mumian, cotton. Magnification 200x.

Furthermore, in the Yi De tomb all first-layer samples (that is to say, all *maicaoni* samples) contain these same fibres. So, what kind of fibres are they?
Under the microscope, they appear more bluish than black, with a twisted appearance, which identifies them as *mumian* 木棉, cotton fibres. This 'extra' layer is a mixture of *huangtu* yellow earth and *mumian* cotton fibres, together forming what is called a *mianhua* cotton mix layer.
The composition of this layer could be similar to *mianhua* layers from the same era found in

Dunhuang.[95] During a relatively short period of the early Tang dynasty the ground layers have this extra layer between the courser layer of *maicaoni* and the white-plaster top layer, making them distinctly different from the ground layers of the other periods.
As it turns out, in the Yongtai tomb, the same kind of fibres are present in some samples of the next layer, the white plaster-layer.

Mumian, 木棉, *cotton fibres*

In early China, cotton came from the tree *Ciba pentandra,* which provided the cotton lining for winter cloth. At a later date, according to Schafer[96] probably during the Tang dynasty, the cotton plant as we know it in the West was introduced. In some translations there is confusion about the nature of 'cotton' because of this, and it is hard to differentiate in written sources between the indigenous *mumian* cotton fibres and the later imported variety.

The third layer, whitewash

The next layer is a much finer white ground, used to smooth the surface for the final painting. Calcium carbonate is found in all samples, but there are slight variations in the composition. X-ray diffraction results indicated the mineral component of calcium carbonate for most samples, which confirm the chemical test results,which also indicated chalk. The chemical test was negative for gypsum.
However, as was mentioned earlier, some samples are different: for example, the result of X-ray diffraction for Sample YD2 shows 50% chalk + 50% aragonite, of which the aragonite component is again confirmed by the sulphur that earlier showed up in chemical testing.
The aragonite must originate from a maritime source, either an ancient cretaceous deposit or a contemporary shell component.
In the Shuilu'an a temple in the Xi'an area some of the samples of white intaglio lines under gilding show a 100% aragonite content.[97] This is now identified as pure clam white: for a description of the calcites and of clam white see Chapter 3 (p. 95).
Particles in the samples show various other elements such as Silicon, Potassium, Calcium,

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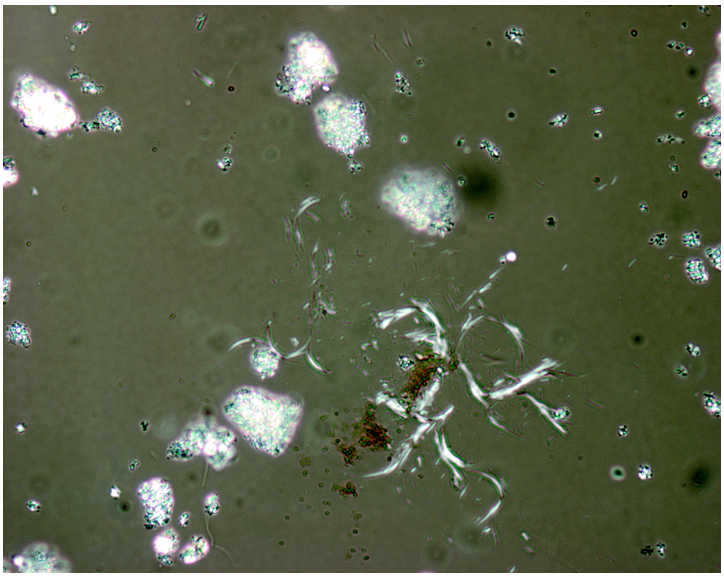
[95] See Table between page 64 and 65 of *Wenwu Baohu Jishu 5*, 1987; The same table also in *Dun Huang Yanjiu Wenjiao Shiku Baohubian xia*, 1997, page 249 and 250.
[96] N.B. Schafer, E, 'The Golden Peaches of Samarkand', University of California Press, Berkeley, 1963 [Schafer 1, p 204-206]: ".......cotton is a novelty in the mid-Tang period."
[97] Private communication with Catharina Blänsdorf.

Sulfur, Aluminum, Iron and traces of Magnesium and Titanium, which indicate a clay component or a mica component.

One fact stands out in this layer: no matter what the different components are of these white ground layers, all the white-layer samples from the tombs I have examined (samples ZH2, YT5, YD2, YD2, YD3 and YD4) are mixed with an animal glue, proven by the HPLC-test. This is very important, because testing has enabled this to now be firmly established. The SEM results show also that several of the white layer samples are a mixture of chalk and china clay *gaoling*.



Photograph 4-05

The feathery structure is Gaoling and the round forms are chalk coccoliths in sample ZH3. Magnification 500x.

I must also point out that in the white layer of some samples other, finer fibres are present; these are probably hemp, but this question has yet to be further examined.

Verification

For a verification of my findings I turn to modern publications on the history of mural painting. The next historical overview of the early period to the end of the Sui dynasty (roughly from 221 BCE - 618 CE) is a compilation of the relevant parts of the Chinese publication by Chu Qi'en[98] [Chu]:

[98] Chu Qi'en, *Zhongguo bihuashi, The History of Chinese Wall Painting*, Beijing gongyi meishu chubanshi, Beijing, 2000

The technique of Wall painting; A historical survey of the early period: Qin, Han, Gui, Qin, Northern and Southern dynasties

China has a rich history of wall painting, which stretches from at least the *Guhuangdi*[99], when they served to decorate the buildings, to the present day, where they are used for more or less the same purpose. [Chu, intr p 1]
Chinese wall painting is, as far as we know now, always done on a dry surface and never on a wet surface.
The build-up of the wall and ground layers varies, as does the colouring. Walls can be made of brick or, for example, the flat loess surface of the a newly dug tomb entrance corridor.
Most commonly, the first layer is a mixture of *huangtu* with *maicao*, meaning yellow earth with coarse wheat straw, which creates a strong, stable basis. For the second layer, whitewash is used, for example, *baitufen* or *gaoling* is mixed with the much finer fibre *ma*, which is hemp. *Gaoling* is the white earth that is normally used for the production of porcelain. This layer smooths the surface and provides a clear white ground on which to paint.

In the Qin, there must have been an abundance of wall painting in the palaces and possibly in other buildings, though few traces of it can be seen today. The remains of the palace building recovered in Shaanxi Xianyang Gucheng pit no 6 have paintings of subjects such as palace ladies and flower-patterns [Chu, intr. p 2] depicted using red, blue, yellow and black.
The biggest piece of the over 440 pieces found in pit 1 measures 37x25 cm and contains the colours: *hei*, black, *zhu*, red earth, *huang*, yellow, *da hong*, red, *zhu hong*, cinnabar, *shi qing*, azurite, *shilü*, malachite etc, of which black is most used, together with the red and yellow. The minerals used are *zhu hong*, cinnabar, *taitiekuang*, ilminite and *chitiekuang*, haematite.[Chu, p 24] The walls were first prepared with a layer of *caonimashuai,* a mixture of huangtu and coarse fibres of plants, and then secondly with a layer of whitewash. [Chu, p25] The lines are painted flat on the surface and are not carved into it; this is called ‘boneless’.

[99] *Guhuangdi*: the ancient period of the mythical Emporers whom are seen as the ancesters of Chinese civilisation.

Han wall paintings from palaces have not survived the ages and were lost with the buildings. However, although no buildings with painted wall have yet been discovered, written evidence of their existence is recorded in the *Hanguangdianzhi*[100]: 'In the *Shangshu*[101] in the memorial to the throne about the Mingguan Hall: in the district all use *hufen*, (*dabaifen*, oisterwhite) to smear the walls, and use *zi*, purple and *qing*, blue to mark them, (*qigao*, to make a draft), and paint old martyrs, with written odes and praise.’

Painted tomb walls are mostly eastern Han, and only a few western Han examples have so far been found: in Henan in Luoyang, Gansu in Wuwei's Wudashan, and Shaanxi in the Jiaotong University in Xi'an.[Chu, p 39]
The paintings were done with black outlines and than filled in with mineral colours such as *zhu*, cinnabar, *qing*, azurite and *huang*, orpiment. With few exceptions, the walls are constructed of hollow brick and than whitewashed with *baifen*, white powder [Chu, p 39]; after drying a drawing is made using red or black lines. Mineral colours are applied afterwards, such as *shiqing*, azurite, *shilü*, malachite, and *hongtu*, red earth, *qunqing*, ultramarine, *baise*, white, and *heise*, black [Chu, p 260].

In the first and second century CE, Buddhism entered China through Xinjiang and Gansu, adding new vigour to the tradition of wall painting. From then on, not only palaces and tombs were decorated and their walls painted, but also the newly erected temple buildings in honor of the Buddha. As early as 67 CE, the White Horse Temple in Luoyang had painted walls [Chu, intr. p 2].

During the Gui, Jin and Northern and Southern dynasties, the walls of the caves in Dun Huang were whitewashed and painted. Through the use of *shuajiangfen,* a mixture of white powder and glue, the walls were prepared for painting.
The Dunhuang specialist Xiang Di says:
Layer 1 *tuni*, earth mud with *majin*, hemp needle or *maicao*, wheat straw
Layer 2 add layers for reinforcement
Layer 3 *jiaoshui*, glue water or *mitang*, rice soup is used; and *xinijiang*, thin mud gruel is smeared on the *biaoceng*, surface

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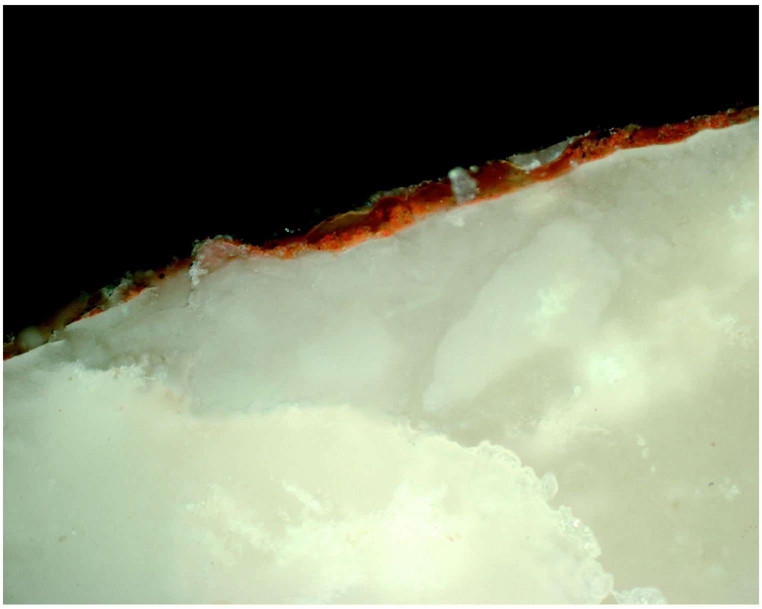
[100] Han official code of duty.
[101] *Shangshu*: ‘Venerated Document’, one of the ancient Chinese texts.

Layer 4 *jiaofenjiang*, glue-powder gruel (in the *jiang*, gruel can be used a grounding colour) [Chu, p 261]

The Dunhuang specialist of the first group Lu Di says:
In Gui and Jin times the technique of wall painting used in most cases was:
Layer 1: coarse mud with *mai,* wheat straw, pressed in, and when it is half dry pound hard and press flat,
Layer 2 after that use the local *bai e tu*, (a sort of sticky strong earth) mixed with *mitang*, rice soup (fine rice soup) or *jiaoshui*, glue water
Layer 3 another *baijiaofan shuijiang*, 'white-glue alum water gruel'
after drying it is ready for painting.

Tang period

By the time the Tang emperors ruled the heartland of China, a great tradition of painting on walls had already been firmly established. From the short overview of earlier periods above that is based on the work of Chu Qi'en, we arrive in the Tang dynasty, the period that forms the main focus of the research. The result of the testing as described in detail in this chapter and in chapter 5 form solid evidence for the technical methods used in Tang mural painting in tombs. Different tombs show a slight variation in techniques, but the basic structure of layers on the painted wall surface remains more or less the same. In some Tang tombs, according to Dr. Zhang Qunxi, more than one paint layer is used; sometimes mixed paint is used, and some single-layered walls are painted on.

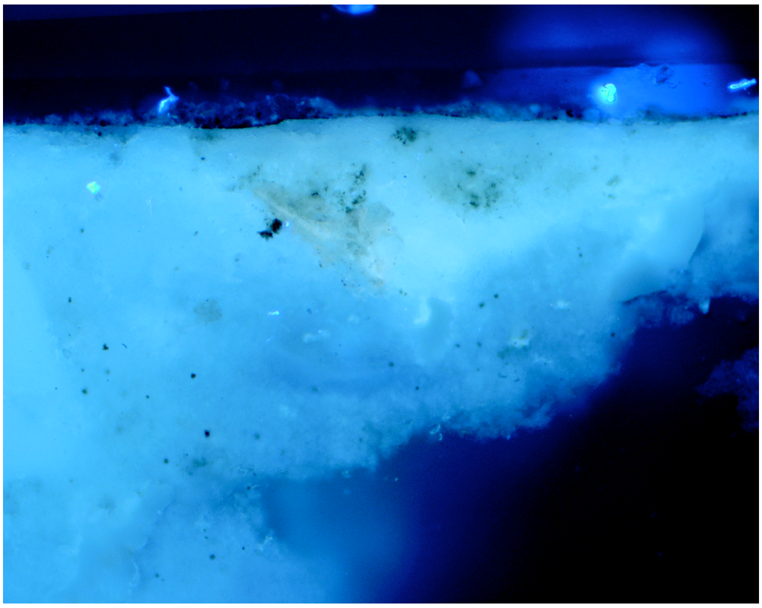


Photograph 4-06

In the ground layer of sample YT5 we found fish glue. Magnification 500x.

Fish glue

One sample is special in several aspects: YT5. In this sample, an animal glue of another kind is found: possibly fish glue. This is a chalk sample and the majority of samples are of a similar composition. The choice of this glue, therefore, seems to be unrelated to the chalk factor and must be for another reason. It could be related to the colour layer above it, making this a key issue for further research.



Photograph 4-07

UV photograph of a cross section of sample YT5; Magnification 200x.

Red minerals in the top paint layer

The remaining parts of the murals were examined in situ. These parts are more or les undisturbed and can be seen as representative of the other sections. However, for some of the other sections I can only speculate about the minerals that were used. The best parts of the murals are now in the Shaanxi History Museum, where the conservation department is studying them in their own laboratory, and their results will hopefully be published soon. Red is the most used colour in all three tombs and all red samples seem at first sight to be some form of iron oxide, like haematite or red ochre. The red pigment samples of the three tombs were examined using several of the methods mentioned before. Some of these tests produced unexpected results, which are described below.

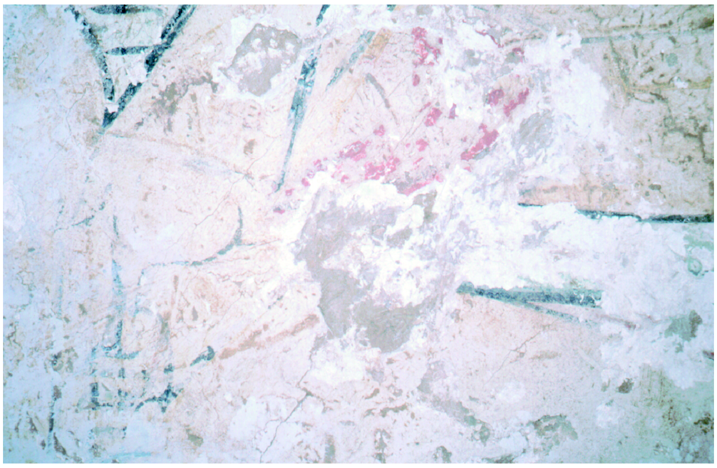
Iron oxide/haematite

Iron oxide is by far the most frequently present mineral in the samples I have analysed. However, contrary to what was expected, in some samples this red is not the only component of the paint layer. In several cases the paint is a mixture, containing other components in addition to the glue component, which is essential to attach the colour to the white surface.

Photograph 4-08

Cross section of sample YT5; Magnification 500x.

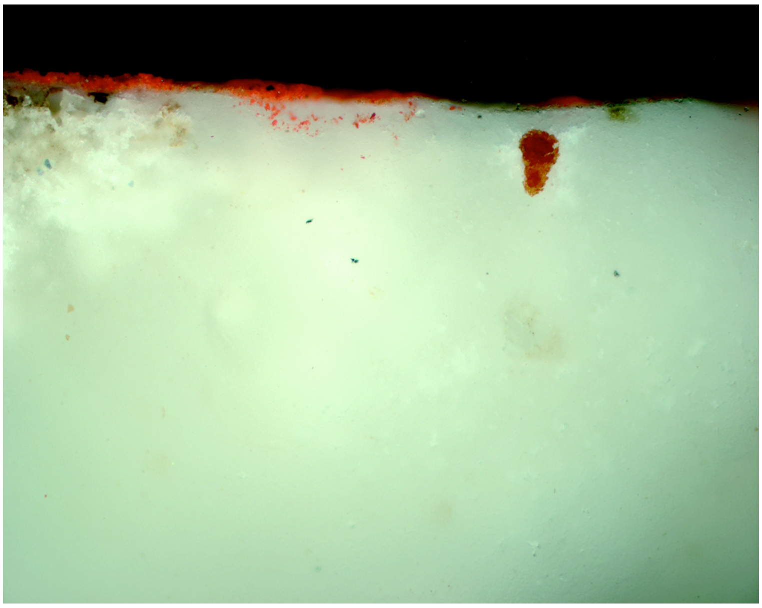
For example, this is the case in the afore-mentioned sample YT5 from the Yongtai tomb. This is a sample of a red paint layer from the curved ceiling of one of the corridors in the Yong Tai tomb. In Photograph 4-08 we can see that the red layer is very thin, only 30 μm, [micron]. Cinnabar or vermilion is the dominant pigment, but iron oxide, clay and chalk are also present, and the paint mixture further contains glue and possibly alum. When I looked at the top of this paint layer in the cross section under the microscope, the top layer shows an almost transparent, very thin surface layer. I expected this to be glue that had come to the surface over the long period since the mural's creation. However, the Scanning Electron Microscope enabled this layer to be identified as a chalk. The chalk is only visible in the cross section and does not influence the red colour when viewed normally. As stated earlier, the white layer in this sample contains a mixture of chalk, clay and glue.



Photograph 4-09

The location from which sample YD3 was taken.

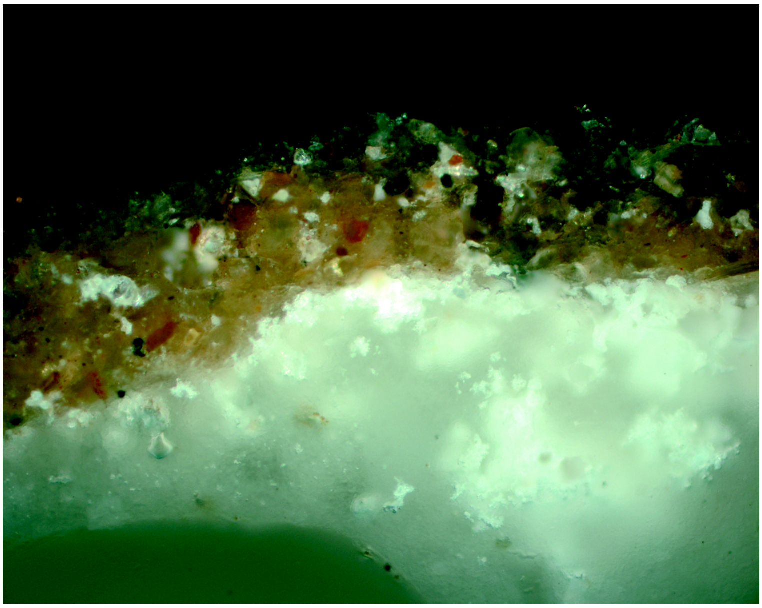
In another sample from the Yide tomb, YD3, the red paint layer proved to be a mixture of vermilion with some iron oxide and chalk.



Photograph 4-10

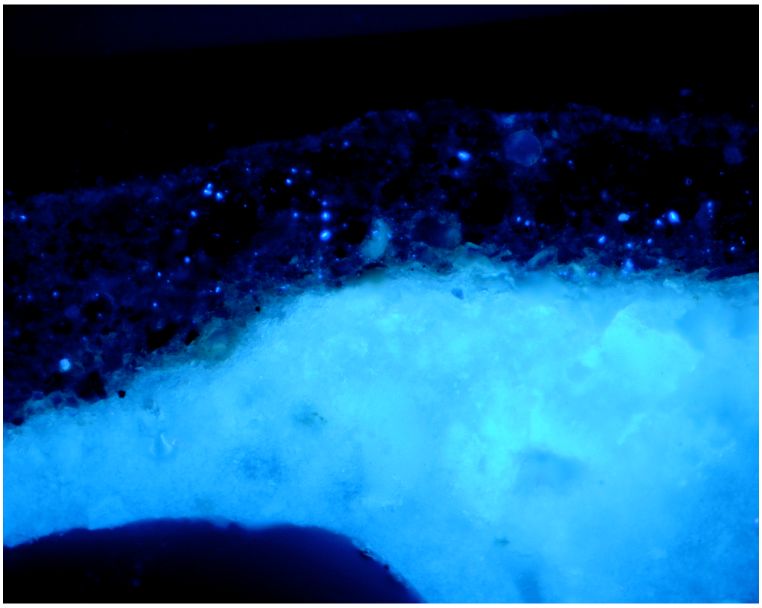
Cross section of sample YD3, showing a remarkable, small spot of lead in the chalk layer: no other traces of lead in any form are present in the samples of the three Tang tombs.

In the sample YD3 was found, curiously enough, the only trace of lead that I encountered during the analysis. The lead was in the form of a small brown spot in the white layer. This means also that lead is significantly absent in all other samples. All red paint samples were also subjected to chemical spot test for lead and all came out negative. The paint layer of YD3 is only 50µm [microns] thick, which is again a very thin layer of paint, similar to all the paint layers in my samples.



Photograph 4-11

Layers of a huangtu, yellow earth mixed with mumian, cotton fibre in the ground layer of a cross section of sample YD3; Magnification 200x.



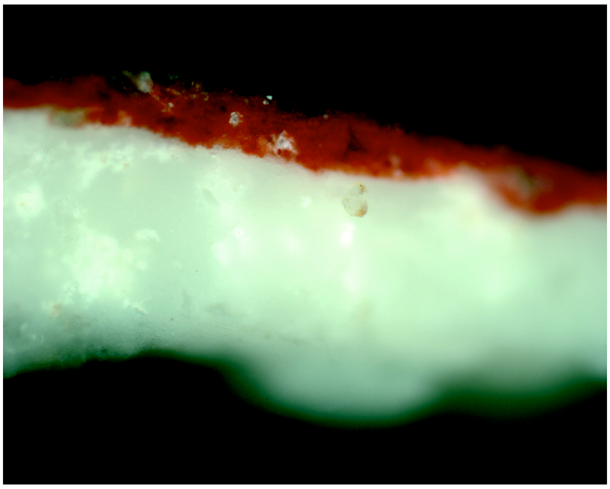
Photograph 4-12

Under UV light the fibres are clearly visable in the layer of huangtu, yellow earth mixed with mumian, cotton fibre in this ground layer of the cross section of sample YD3; Magnification 200x.

Other mixtures

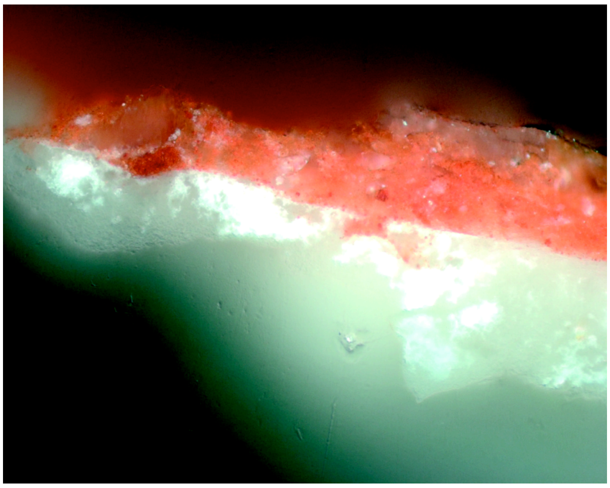
Yet another mixture is found in the Zhang Huai tomb, of which at least one sample [ZH2] contains traces of an organic dye in the paint layer.

There was a problem with sample ZH 2, and it took a while to discover the nature of this problem. The sample disappeared without trace when it was prepared in a cross-section for microscopic examination. The second attempt to make a cross section was handled with even more caution. When the sample was polished, it vanished completely once again. This highly frustrating moment illuminated the cause of the problem: this sample was much more water soluble than the other samples, which could be due to its organic dye component. The sample is a mixture of an as yet not identified organic red with chalk, iron oxide, and glue. Possible candidates for the red organic dye may be safflower, dragon blood, or stick lac.



Photograph 4-13

The troublesome sample ZH2: which vanished more than once during the preparation of a cross section, due to its disolving components; Magnification 200x.



Photograph 4-14

Cross section of sample ZH2; Magnification 500x.

Iron oxide is also found in the other samples from the Zhang Huai tomb, ZH3. The thickness of these paint layers, at between 40 μm and 50 μm, is similar to the thickness of the paint layers in the cross sections of the Yide and Yongtai tombs.

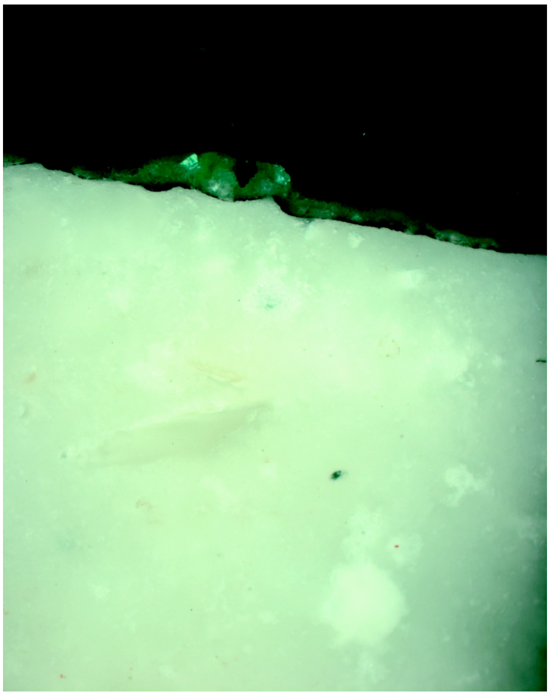
Green

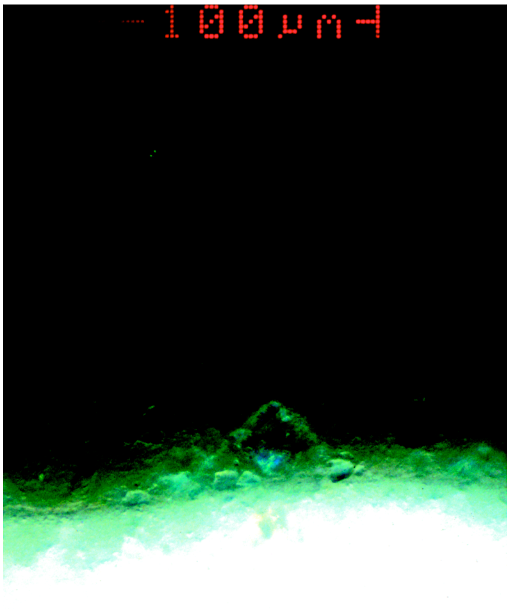
One sample from the Yide tomb, YD2, was tested with the micro chemical Ferro cyanide test advised by Gettens and Fitzhugh[102] which identified it as a malachite paint layer. This was further confirmed by the X-Ray diffraction test done by Peter Hallebeek, which showed 10% silicon and 90% para-atacamite $Cu_2\,Cl\,(OH)_3$.

Photograph 4-15, left: The location from which sample YD2 was taken.

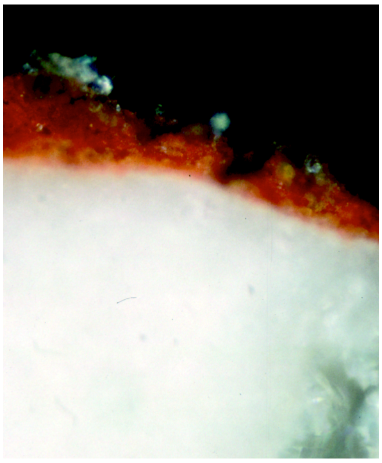
Photograph 4-16, bottom left: Cross section of sample YD2; Magnification 200x.

Photograph 4-17, bottom right: UV photograph of the cross section of sample YD2, Magnification 500x; measure strip of 100 µm.





[102] *'Artist' Pigments, Volume 2'*, Ashok Roy, Oxford University Press, Oxford, 1986, p 28.



Photograph 4-18:

The cross section of sample sample WM1; Magnification 500 x.

White

In X-Ray diffraction testing the following three samples ZH2a, WM1/6, YT5a, gave a result of 100% chalk-calcite. YD2b differs from the others in containing 50% chalk-calcite and 50% aragonite-calcite. Another variation is ZQX1a, which gave a result of 90% chalk-calcite and 10% quartz. When using the micro chemical testing, the samples YT1a, YT2a, and YT3b left a kaolin residue that does not dissolve with the applied acids.

Black

With SEM-EDX one sample, YT4b, was shown to contain carbon black that can be identified by the typical structure of its particles as graphite.

Photograph 4-19: The location from which sample YT4 was taken.