Plaster- and Wall painting technology in the tomb houses of the Petosiris Necropolis

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1. Introduction

The extensive preserved plasters and wall paintings of the tomb houses of Tuna el-Gebel span from the Ptolemaic period towards roman times.

To differentiate and assess the manifold technological features characteristic for various plaster- and wall painting techniques within the Petosiris Necropolis, detailed conservation and natural scientific investigations were implemented at field campaigns on site between 2009-2015[1]. More than 25 tomb houses were examined. By visual-phenomenological investigations the diverse ancient techniques as well as production processes, that were applied at the tomb houses during the time of occupation, could be identified. In addition, scientific material analysis of plasters and paint layers in a portable laboratory provided significant material technological information.

The complementary results furthermore allowed to answer questions on plaster- and paint layer compositions. Various techniques and material choices for diverse technological functions within the mud brick- and stone-based tomb architecture as well as approaches on raw material processing and technology transfer could be defined. They were applied in different times and building phases.

2. Applied conservation and natural scientific methods

To determine the chemical-mineralogical composition of the original plasters and wall paintings, selected plaster-, paint layer- and pigment samples were analysed. All analysis was implemented in a portable field laboratory according to the export ban of samples from Egypt and restrictions to transport samples from site within the country[2]. Before the detailed material analysis could begin, the preserved archaeological architecture was object of a detailed visual-phenomenological study. Based on these investigations the preserved mortars, plasters and wall paintings as well as important technological features could be generally differentiated, and representative areas for sampling

[1] The presented results are a summary of investigations made in Tuna el-Gebel by the conservators Prof Dr. Nicole Riedl and Alexandra Winkels in 2010 and 2012 and include the results of analysis done in 2009 by Prof. Dr. Henrik Schulz and Dr. Martina Schulz (laboratory for archaeometry, HAWK Hildesheim). Further they are part of an ongoing research project and PhD thesis by A. Winkels on: "Mortars and plasters in ancient Egyptian wall painting and architecture. A comparative study of the materials and technology using Conservation and natural scientific methods" at the Conservation Department of the Academy of Fine Arts Dresden, Germany.

[2] Winkels and Riedl 2015: Alexandra Winkels – Nicole Riedl, Entwicklung von Putz- und Maltechnik in der Petosiris-Nekropole von Tuna el-Gebel. Erste Untersuchungsergebnisse zu Akkulturationsprozessen in der Region Mittelägypten, in: K. Lembke – S. Prell (eds.), Die Petosiris-Nekropole von Tuna el-Gebel Vol. 1, Tuna el-Gebel 6 (Vaterstetten 2015) 260–303. Paint layer and pigment analysis: Schulz and Schulz 2009: M. Schulz, H. Schulz: Analysenbericht [011209]; unveröffentlichter naturwissenschaftlicher Untersuchungsbericht v.a. von Pigmentproben aus der Petosiris-Nekropole, Hildesheim 2009. Winkels 2010, Alexandra Winkels: Konservierungsbericht der Grabungskampagne 2009. Dokumentation der durchgeführten Maßnahmen an Fundobjekten und der Konservierung der Grabstele des Hermokrates, GB 20, S. 1-28 und Anhang, unveröffentlichter Konservierungsbericht, Freiburg 2010. Simon et al. 2009 Stefan Simon, Marisa Pamplona, Sabine Schwerdtfeger, Regine-Ricarda Pausewein: Untersuchungsbericht 47-58_052005, 12 Stuckfragmente aus Tuna el-Gebel, S. 1-74; unveröffentlichter Untersuchungsbericht, Rathgen Forschungslabor, Berlin 2009.

selected. The following scientific methods were then implemented on site and in the field laboratory at Tuna el-Gebel.[3]

- Visual-phenomenological investigations on site with magnifying glasses and digital Microscope (including condition assessment and damage analysis)
- Photographic documentation (macro- and micro-photography) of technological features on site as well as of samples and analytic procedure
- Multispectral imaging (e.g. digital Ultraviolet-fluorescence or Infrared-reflectography and VIL (Visible Induced Luminescence Imaging)[4] (figs. 1, 2)
- Stereomicroscopy of Cyclododecane[5] mortar- and plaster cross sections
- Stereomicroscopy of paint layer cross sections
- Polarised-light microscopy of pigment samples
- Wet chemical staining methods for the identification and localisation of inorganic and organic binding media and mineral components
- Measurement of calcium carbonate content in plasters with calcimeter device[6]
- Wet chemical analysis to determine the binder-aggregate ratio of the mortars
- Micro chemical analysis
- Sieve analysis to show the grain and particle sizes and -distribution of aggregates within mortars
- Determination of the mortar- and matrix-colour with the Munsell® rock- and soil colour charts
- Digital image analysis for the semi quantitative analysis of components.

[3] For a detailed description of the methods see Winkels-Riedl 2015 and Winkels 2007.

[4] With this imaging technique it was investigated if- and proven that- Egyptian blue was used in the wall paintings of the necropolis even after the Ptolemaic period. – Although weathered and not clearly detectable anymore in visible light, the method made it possible to show even smallest remaining grains of the pigment in single wall paintings (see Verri 2008). This proves that the artificially produced Ancient pigment Egyptian Blue was included in the colour spectrum of the roman period in the Necropolis. This could also be observed in wall paintings from other roman provinces like in Palmyra, Syria (Winkels 2013, 264) or the province Belgica in Europe (Riedl 2010, 125-131) Winkels-Riedl 2015, and Winkels 2013, 264).

[5] Vgl. Hangleiter 1998, 468-473.

[6] Müller-Gastner 1971, 466-469.

Fig. 1 and 2: Image in visible light (l.) and visible induced luminescence imaging showing that Egyptian blue was used in the wall painting with birds in GB 25 (M 9a/SE). Remaining traces of Egyptian Blue colour that are not visible any more in visible light, can be detected in the VIL image (r.). The Egyptian Blue pigment grains are visible shining bright-white by this characteristic reflected luminescence.

3. Preliminary results

The collected results revealed that quite a variety of different mortars and -plasters was processed for the building of the tomb houses and the plastering of their architectural surfaces. Individual material choices were made by the ancient workmen for different technological functions within the architecture (e.g. setting mortars, floor, ceiling and wall plasters). This reflects a sophisticated understanding of the properties and efficient uses of the available raw materials and their processing.

Overall nine development stages within the ancient plaster- and wall painting technology could be distinguished in the investigated tomb houses. These technical stages show differences in stratigraphy and technological application of plasters and wall paintings. In some tomb houses such variations could be observed even on the architectural surfaces of one room or between rooms and storeys in different building phases.

The analysis of the selected plaster samples proved a combined use of clay plasters with high contents of quartz sand and plant fibres as organic fillers and reinforcement with thin lime plaster washes with white washes on top could be observed (technology stage 2 and 3) in the earliest tomb houses from Ptolemaic times (figs. 4-7). This application of lime-based plasters and washes proves the knowledge and practice to produce burnt lime as binder for mortars, plasters and white washes before roman times.

Towards the beginning of the roman period, a development to the predominant use of lime plaster in thicker layers is obvious. These also contain characteristic plant fibres as organic fillers in most tomb houses. Within this period the tomb houses were decorated using roman plaster- and wall painting techniques and styles[7]. The walls were structured in two painted zones, a lower and an upper wall zone. Within these, varying plaster stratigraphies and painting techniques were implemented according to the planned decoration. Besides secco painting on stone or dried plaster with a lime based white wash as painting support, it was also apparently intended to apply the fresco technique: in areas of incrustation paintings in lower wall zones of certain tomb houses, lime plaster was applied in two layers and the wall paintings were carried out directly on the plaster surface (figs. 10-12, 14).

It was found that the composition of the different plaster types- clay plasters as well as lime plasters and plaster washes is generally similar within the technological stages. It merely differs slightly in varying contents of included mineral aggregates and organic plant fibre fillers.[8]

The results of the scientific investigations served as important basis for the development of adequate conservation materials and methods applied in the field schools for the consolidation of the tomb houses' ancient plasters and wall paintings (see chapter "conservation concept").

An overview of the differentiated technical stages and their technological characteristics is given in the following table 1.[9] The list is based on a relative chronology according to the stratigraphy observed in the investigated tomb houses. An absolute chronology is not possible at the current state of investigation.

Technology/ Characteristic features	Material/ Stratigraphy	Surface treatment	Plaster type/ mortar composition	Analysed Pigments	Examples of tomb houses
1st technological stage					
Polychrome painting on limestone (fig. 3)	Limestone surface, evenly sanded, polychrome painting directly on stone	Even, finely sanded limestone surface as functions as painting support	-	Yellow ochre, red ochre, Egyptian blue	GB-50-Petosiris GB-54-Padjkam
2nd technological stage					
Wall painting on thin white-washed lime plaster above clay plaster (figs. 4-7)	0-Adobe mudbrick masonry; 1-Clay plaster layer 5-7 mm strong; 2-3-4mm thin lime plaster wash applied fluidly indicated by many run-down drips; 3-Thin whitewash layer on top showing brush stroke impressions 4-Polychrome wall painting, linear, white wash serves as background colour in large areas, only partially other monochrome local colour; predominant colours are: black, red, green, less yellow	Thin lime plaster layer and white wash applied with broad coating brush, surface showing brush stroke impressions, no trowel traces visible	Clay plaster with organic plant fibres; lime plaster; calcium carbonate with secondary gypsum content	Calcite, chalk, yellow ochre, limonite, red ochre, Hematite, green earth, glauconite, Egyptian blue plant black	GB33-M20 (1st phase), GB29-M21 GB4-M12 SS (1st phase) GB 24-M9/SE
Revision/ revised decoration of 2nd technological stage					
Wall painting on white washed lime plaster (figs. 8,9)	Stratigraphy continues from 2nd technology stage (see above)- revised design phase of first wall painting phase of GB4 in same design and similar technological performance. 0- 3-4mm thin lime plaster wash 1- White wash layer 2- Polychrome wall painting, linear	Thin lime plaster wash applied with broad coating brush (not compacted) as well as white wash; visible brush strokes	Lime plaster; calcium carbonate with secondary gypsum content	Green earth, glauconite	GB4-M12 SS (2nd phase)
3rd technological stage					

[7] See: Riedl 2010: Provinzialrömische Wandmalerei in Deutschland, Geschichte- Historische Werkstoffe- Technologie- Restaurierungsgeschichte im Kontext der Denkmalpflege dargestellt an ausgewählten Beispielen. Dissertation Otto-Friedrich-Universität-Bamberg, Fulda 2007. Online-Publikation, 12.05.2010.

8 For details on plaster composition and analytic results of mortar analysis see Winkels-Riedl 2015, p.302ff., table 2.

[9] More detailed descriptions are provided in Winkels-Riedl 2015, 300-303. Also, further results will be published in the future publication of the mentioned PhD thesis.

Wall painting on thin lime plaster layer without white wash above clay plaster	0- Adobe mudbrick masonry; 1- Clay plaster layer 2- Lime plaster wash, millimetre thin, that received no extra whitewash 3-Linear polychrome wall painting, the lime plaster wash surface serves as background colour	Surface of thin lime plaster wash shows many brush stroke impressions from broad coating brush used for application	Clay plaster with organic plant fibres; lime plaster; calcium carbonate with secondary gypsum content	Green earth, glauconite	GB33-M20 (2nd phase) (compare GB33-M20 (1st phase: 2nd techno-logical stage)
4th technological stage					
Wall painting on single lime plaster layer with white wash as painting base; single plaster layer on adobe masonry on middle and bottom wall zone	0- Adobe mudbrick masonry 1- Lime plaster with higher content of plant fibres as organic fillers; pressed also in joints of masonry; division of wall in zones with red underdrawings 2- Lime based whitewash that serves as painting support 3- Polychrome wall painting	Lime plaster surface was evenly smoothed but not strongly compacted. The white wash on top shows streaky brush stroke impressions.	Lime plaster; calcium carbonate with secondary gypsum content; small plant fibre content as organic fillers	-	GB13-M5/SS (Wall fragment adjacent on eastern outside wall of tomb house)
5th technological stage					
Two layered lime plaster without whitewash on base of wall; one lime plaster layer with white wash on upper wall; one layered painted plaster on columns (fig. 12, 14)	Wall structured in two painted zones; technological differentiation between lower wall zone and upper wall zone. The middle and upper wall zones are plastered with one lime plaster layer painted monochrome white. The lower wall zone shows a two-layered lime plaster application. The polychrome wall painting of stone imitations and -incrustations on the top layer is carried out directly on the lime plaster surface without intermediate white wash. Two columns of a baldachin construction, built from burnt bricks, carry one lime plaster layer also directly painted.	Lime plasters evenly smoothed but not strongly compacted. The surfaces show very fine ridges and smoothing structures from flattening with plastering tools The white wash on the upper wall parts shows streaky brush stroke impressions.	Lime plaster; calcium carbonate binder with secondary gypsum content; plant fibres as organic fillers	Calcite as white wash with secondary gypsum content, yellow ochre, limonite, red ochre, haematite, green earth, Egyptian blue charcoal black	GB13-M5/SS GB 1-M13/SS GB25-M9a/SE
6th technological stage					
Wall painting on two layered lime plaster on white wash in lower wall zone; one layered lime plaster with monochrome white wash on upper wall	1- Adobe mudbrick masonry 2- First lime plaster layer, pressed also in joints of masonry; division of wall in zones with red underdrawings 3- Second lime plaster layer on lower wall with red underdrawings, string cord lines or circle line incisions as construction aids 4- Lime based whitewash that serves as painting support 5- Polychrome wall painting on lower wall zone	Lime plasters evenly smoothed but not strongly compacted. The surfaces show very fine ridges and smoothing structures from flattening with plastering tools The white wash shows streaky brush stroke impressions.	Lime plaster; calcium carbonate binder with secondary gypsum content; plant fibres as organic fillers; higher content in lower plaster layer	Calcite as white wash with secondary gypsum content, yellow ochre, limonite, red ochre, haematite, green earth, Egyptian blue, charcoal black, bone black, green earth with little additions of Egyptian blue to green paint	GB35-M4/SE GB16-M6/SS
7th technological stage					
Two layered lime plaster with wall painting on lower wall zone; partly also one layered lime plaster on base of wall and on upper wall zone; white washed with partial wall painting (figs. 10, 11)	Lower wall zone differs in plaster stratigraphy according to painting technique: 1- Adobe mudbrick masonry 2- First lime plaster layer, pressed also in joints of masonry; 3- Lime based whitewash on that serves as monochrome background colour and partially painting support 4- Second lime plaster layer on lower wall zone with red underdrawings or string cord lines as construction aids; application only in areas of polychrome incrustation painting; 5- Polychrome wall painting of stone incrustations directly on plaster surface.	Lime plasters evenly smoothed but not strongly compacted; very fine ridges and smoothing structures on surfaces from flattening with plastering tools; The white wash shows streaky brush stroke impressions and fine lime pats.	Lime plaster; calcium carbonate binder with secondary gypsum content; plant fibres as organic fillers; higher content in lower plaster layer	red ochre, haematite, calcite with secondary gypsum content as whitewash, charcoal black, grey colour-calcium carbonate white wash with addition of charcoal black	GB26-M9d/SE GB33-M20 (3rd phase, upper storey)
8th technological stage					
Two layered lime plaster with white wash on whole wall with partial wall painting	Upper and lower wall zones show the same stratigraphy: 1- Adobe mudbrick masonry 2- First lime plaster layer, pressed also in joints of masonry; 3- Second lime plaster layer 4- Lime based whitewash that serves as monochrome background colour and painting support 5- Polychrome partial wall painting.	Lime plasters evenly smoothed but not strongly compacted; very fine ridges and smoothing structures on surfaces from flattening with plastering tools; The white wash shows streaky brush stroke impressions and fine lime pats.	Lime plaster; calcium carbonate binder with secondary gypsum content; plant fibres as organic fillers	-	GB 5

9th Technology stage					
Tomb pillar; two layered lime plaster with white wash on whole wall with partial wall painting (figs. 13, 15)	Tomb pillar construction shows the following stratigraphy: 1- Core made of adobe mudbrick masonry 2- First lime plaster layer, pressed also in joints of masonry; 3- Second lime plaster layer- only in parts that needed a stronger application to create the pillar form 4- Lime based whitewash that serves as monochrome background colour and support for partial painting 5- Polychrome wall painting of stone incrustations.	Lime plasters evenly smoothed but not strongly compacted; partially plaster surface shows brush stroke impressions where appasrently smoothed with broad coating brush; streaky brush stroke impressions also in white wash	Lime plaster; calcium carbonate binder with secondary gypsum content; plant fibres as organic fillers	-	GB 20
Table 1) Characteristics of identifiable technological stages of stone polychrome and wall painting in the Petosiris-Necropolis of Tuna el-Gebel[10].					

Fig. 3: Naos of GB 50, east wall, tomb of Petosiris; the carved stone surface indicates fine chisel traces and included nummulites. The polychrome painting shows differentiated colouring and finely drawn details.

[10] Compare Winkels-Riedl 2015, tab. 1 and 2, p.300ff.

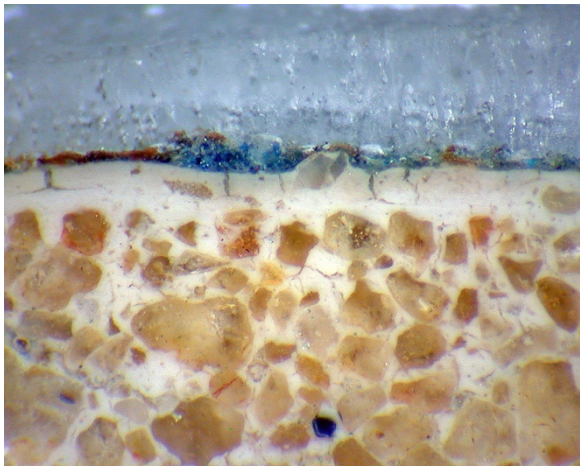

Fig. 4: Cross section of upper thin lime plaster with white wash and Egyptian Blue paint layer applied on top of clay plaster. GB 29 (M21/SE); width 2,6mm.

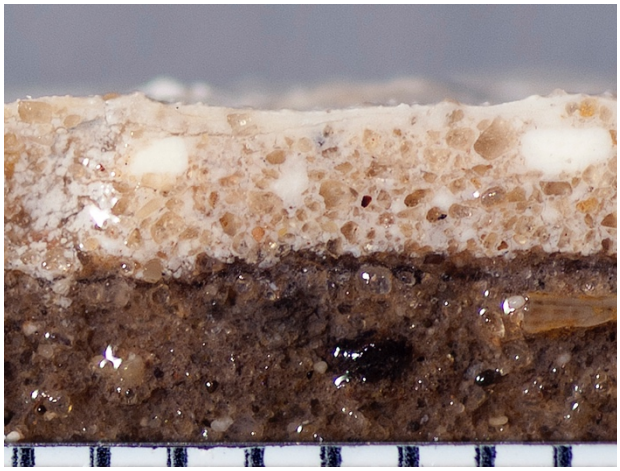

Fig. 5: Cross section of clay plaster with fine lime plaster on top. The plaster surface was additionally white washed. Sample from GB33 (M20/SE); scale: 1mm.

Fig. 6: Detail from east wall of GB33 (M20/SE). The falcon was painted on a thin lime plaster layer. A white wash serves as white background colour. Fine brush stroke impressions in the surface show that the plaster was not evenly smoothed. Like the white wash was applied with a broad coating brush. Width ca. 8 cm.

Fig. 7: second technological stage, example from first wall painting phase in tomb GB 4 (M12/SS), north wall, southern room. The first clay plaster layer is covered with a thin lime plaster wash. An additional white wash carries the painting.

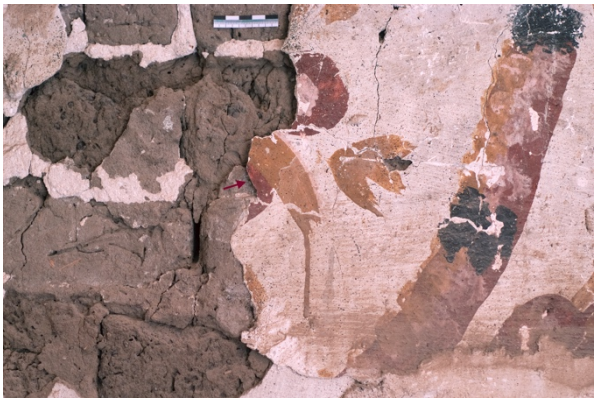

Fig. 8: Detail of second, wall painting phase in GB 4 (M12/SS), revised decoration of 2nd technological stage. The decoration is similar than the first painting phase and was carried out on a slightly thicker lime plaster layer with white washed surface.

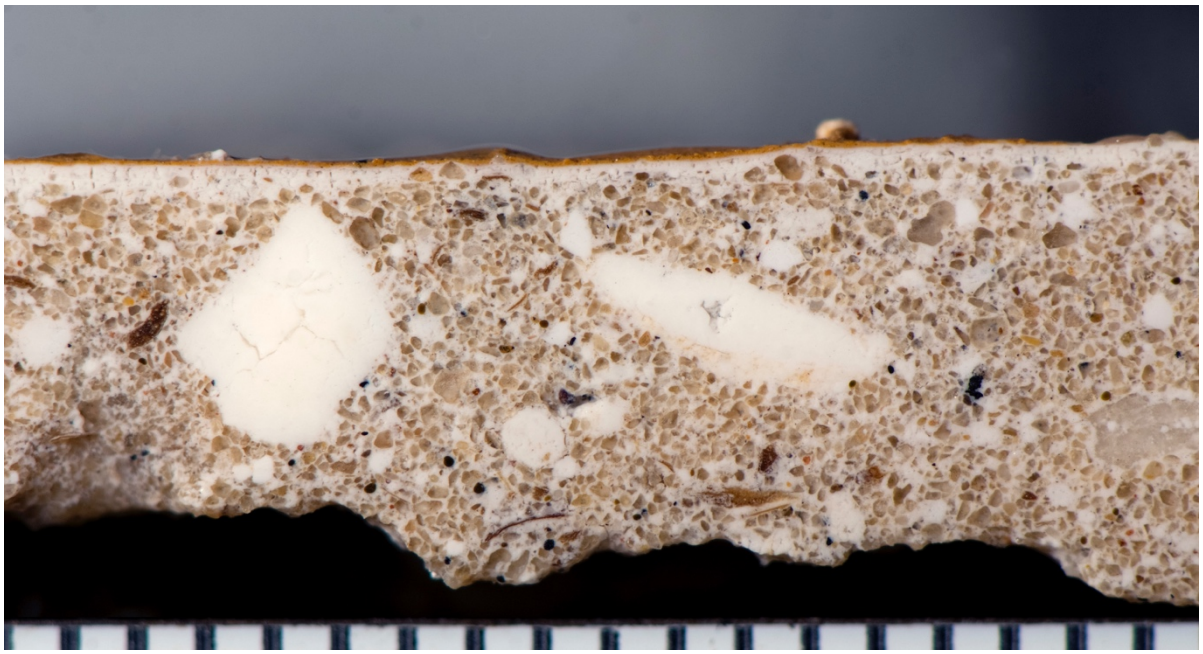

Fig. 9: Cross section of plaster fragment from GB 4 (M12/SS), revised decoration of 2nd technological phase (fig. 8); the fine plaster shows characteristic lime pats and organic plant fibres as organic fillers within the mortar matrix. The plaster surface is covered by a white wash that functions as painting support for a yellow ochre paint layer.

Fig. 10, 11) North wall of GB 26 (M 9d/SE), seventh technological state; plaster stratigraphy differs according to the applied painting technique. The upper- and parts of the lower wall are covered with one lime plaster layer that was white washed and partly painted. The detail (r.) the shows the transition to a two layered plaster stratigraphy in the lower wall zone. The second plaster was only applied in the area of the painted polychrome stone incrustation. The painting being carried out directly on the finely smoothed plaster surface, apparently intended as fresco technique.

Fig. 12: North wall in GB 13 (M 5/SS), fifth technological stage; two layered plaster in lower wall zone with polychrome stone incrustation wall painting directly on

Fig. 13: Tomb pillar of Hermokrates, GB20, lower part of western side, 9th technological stage; one, in parts two-layered lime plaster on mudbrick

surface. One layered plaster on upper wall with white wash. All plasters are lime plasters.

core. The red joints and inscriptions are painted on a lime based white wash.

Fig. 14: Cross section of plaster sample from North wall of GB 13 (M 5/SS) showing the two plaster layers of the lower walls painted stone incrustation. Both layers consist of lime plaster with a high content of desert sand as mineral aggregate and characteristic lime pats in the mortar matrix. The lower plaster layer contains a slightly higher content of plant fibres as organic fillers. The red line marks the two layers.

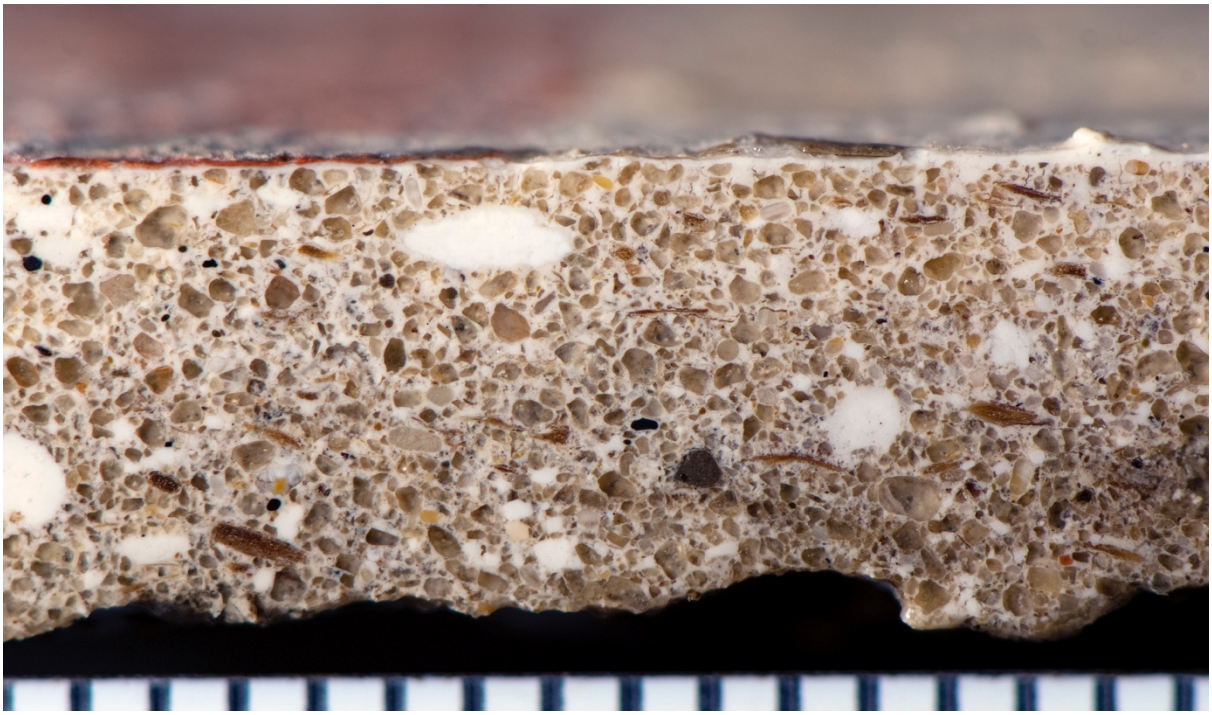

Fig. 15: Cross section of plaster from tomb pillar GB 20; the one layered lime plaster layer contains a high content of fine to middle grained quartz sand and lime pats in the binder matrix; the white wash on the plaster surface is also lime based and carries the red paint layer of painted joints on the pillar.

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