DEVELOPING APPROACHES FOR CONSERVING PAINTED PLASTERS IN THE ROYAL TOMBS OF THE VALLEY OF THE QUEENS

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Abstract
The Theban Necropolis on the West Bank of Luxor, Egypt preserves one of the world’s richest repositories of ancient painted tombs, including those in the Valley of the Kings and the Valley of the Queens. Over three millennia, many tombs have been subjected to flooding, causing severe rock collapse and loss of surface decoration. How best to conserve and repair vulnerable wall painting in the tombs is an urgent issue.

Understanding the nature and composition of original materials is necessary in the selection of appropriate treatments for stabilizing fragile painted plasters. As a result, investigation of Egyptian plasters became a focus of study as part of the ongoing Queens Valley collaborative project between Egypt’s Supreme Council of Antiquities (SCA) and the Getty Conservation Institute (GCI). Based on a review of the literature, it was clear that the binder and aggregate composition of Egyptian plasters is not well understood. Despite a generally accepted belief that plasters were bound with gypsum and clay, past and current treatment approaches have relied primarily on lime-based repairs, poorly matched to the properties of original plasters. During recent episodes of flooding, the presence of such repairs has caused more harm to wall paintings, where differential stress reactions have led to cracking and loss in the weaker ancient plasters.

This study allowed for characterization, investigation and analysis of a wide range of New Kingdom period tomb plasters from the Valley of the Queens in order to clarify many unresolved issues concerning binder and aggregate types and ratios. Findings indicated that the ancient craftsmen had an empirically informed understanding of the properties and uses of gypsum and
clay binders in mortars and plasters. In particular, the role of clay as a binder appears to be far more widespread and nuanced than previously recognized, and the stabilizing role of calcite in plasters has been largely overlooked. These results have fundamental implications for improving the formulation of repair plasters for stabilizing wall paintings. The development of compatible repair plasters is therefore a key outcome of this project.

Fig.1 – The Valley of the Queens (credits: Getty Conservation Institute, 2008).

1. INTRODUCTION

The Valley of the Queens, on the West Bank of Luxor, Egypt, and a key component of the World Heritage site of Ancient Thebes, served as the royal necropolis for the wives, daughters and sons of the pharaohs during the New Kingdom period (c. 1570-1070 BCE) (Fig 1). Its most celebrated tomb, that of Queen Nefertari, constructed during the reign of Rameses II (1290-1224 BCE), preserves wall paintings of unparalleled beauty and sophistication (Corzo and Afshar, 1993). However, some twenty-two other tombs in the valley also contain surviving plaster and decoration, many of which are in very poor condition.

These tombs have been subjected to a wide range of threats over the past three millennia, including flood damage, salt deterioration, and exposure to fire, that have altered the tombs’ wall paintings in various ways. Of these, periodic flash floods have proved to be the most devastating and recurrent threat, causing catastrophic rock collapse and loss of surface decoration, and weakening the overall strength and cohesiveness of remaining painted plasters. Many of the tombs now require rock stabilization and interventions to secure fragile areas of surviving wall painting (Fig 2).
Fig. 2 – Flooding has caused serious cracking and loss of rock and painted plasters. Many of the tombs in Queens Valley now require urgent stabilization treatments (credits: Getty Conservation Institute, 2008).

The current treatment approach for conserving Egyptian wall paintings relies on lime-based repairs, poorly matched to the properties of the original plasters. These repairs have caused damages to the original decoration during recent periods of flooding as differential stress reactions in the rock have led to cracking and loss in the weaker ancient plasters (Fig 3).

Fig.3 – Lime-based repairs (the white-colored plaster visible along the crack) are typically used for conserving Egyptian wall paintings but are poorly matched to the properties of the original plaster. They have caused new cracking and loss in the weaker ancient plasters (credits: Getty Conservation Institute, 2008).

The development of more compatible repair plasters requires an understanding of the properties of the original materials, yet a review of more than sixty articles and books on ancient Egyptian technology found few specific references with detailed information on the composition of mortars and plasters. This area of study has, to date, been inadequate and requires further investigation (Borrelli and Laurenzi Tabasso, 1996, p.1451).

This lack is currently being addressed in an ongoing collaborative project between Egypt’s Supreme Council of Antiquities (SCA) and the Getty Conservation Institute (GCI), to develop and implement a conservation and management plan for the Valley of the Queens (Agnew and Demas, 2008). One component of this project has been the detailed study of a wide range of plasters from Nineteenth and Twentieth Dynasty (1292-1070 BCE) chamber tombs in the Queens Valley, undertaken as a basis for formulating appropriate repair materials.

2. THE NATURE OF EGYPTIAN PLASTERS AND MORTARS

Data on Egyptian mortars and plasters and their constituent materials, in terms of their origins, preparation and refinement, and binder and aggregate types and ratios, is limited. Partly as a result, reports in the literature have tended to be highly reductive.

Gypsum is generally believed to be the most common binder (Lucas, 1906, p.5; Lucas and Harris, 1989, p.76; Le Fur, 1994, p.88), and its use is attested in Egypt since the Early Dynastic
Period (3100-2700 BCE) (Lucas, 1989, p.76). Earthen plasters, with clay as the primary binder, were used since the Predynastic Period (5550-3100 BCE) (Quibell and Green, 1902, p.21 quoted in Lucas and Harris, 1989, p.76). The use of lime as a binder is more controversial and has been the subject of much debate since the first decades of the twentieth century (Lucas, 1906, p.6; Lucas, 1924, p.128; Borrelli and Laurenzi Tabasso, 1996; Capriotti, 2008, p.65). Though it is generally agreed that lime mortars and plasters were not used at Egyptian sites before the Ptolemaic Period (305-30 BCE), a number of authors have claimed to have found lime used much earlier (Gourdin and Kingery, 1975, p.148; Weatherhead, 2007, p.365-66; Winkels, 2007, p.280). However, analytical evidence in some examples is not conclusive and can sometimes be misinterpreted due to the difficulty in distinguishing calcium carbonate (limestone) present as an aggregate from calcium hydroxide (lime) used as a binder.

Generally, therefore, Egyptian plasters have been previously broadly categorized as being either gypsum plasters or earthen plasters.

The empirical physical evidence, however, points to a much more complicated situation. Plasters in the Queens Valley tombs vary greatly in terms of their color, aggregate composition (type, size and amount), density, hardness and overall cohesion (Fig 4). Plaster types also differ from tomb to tomb, as well as within individual tombs, from walls to ceilings, and between upper and lower plaster layers. The sheer variation of observable plaster types suggests that the binder need not be simplistically restricted to single reactive components, but could instead be a combination of different binder materials; and similarly, that binder to aggregate ratios could also vary considerably.

Fig.4 – Visual observations of the ceiling plasters in tomb QV 36 show a thickly-applied, brown, straw-containing lower plaster and a thinner, lighter in color, upper plaster (credits: Getty Conservation Institute, 2006).

Within this varied context some plaster layers—typically observed as lower plasters—are characterized by their darker earthen appearance and which may be empirically identified as being clay-bound. Lucas describes Nile alluvium (riverbed mud) as a clay source for plasters, and although there is now no way of verifying this (as ancient alluvium cannot be equated with its modern, much altered counterpart) there is little reason to doubt this assertion (Lucas and Harris, 1989, p.76). Lucas’s observation on Nile alluvium as being varied and generally of poor quality, “containing a considerable proportion of carbonate of lime as a natural impurity in the clay (Lucas, 1924, p.129)” is also evidenced by the decohesive and cracked nature of many of these plasters in the Queens Valley tombs. The plasters also display significant variations in color and composition, suggesting that they were, in some cases, modified by admixture with other materials.
Other plasters that are buff to pinkish-beige in color predominate in the Queens Valley tombs. Observed similarities in color and material composition suggests a close relationship to the local geology. In the literature these plasters are referred to as *hib* (Arabic: حيبة, *hiba*) from the clay-containing calcitic soil deposits found at the foot of the Theban Mountains (Lucas, 1989, p.76; Rickerby, 1993, p.45; Hassan, 2000, p.136) (Fig 5).

Fig.5 – Hib deposit in Queens Valley formed from the chemical and physical weathering of the clay-containing marl layers of the Theban Mountains (credits: Getty Conservation Institute, 2006).

Hib has historically been used in plasters in the Theban area, and while precise source locations for the raw materials of ancient plasters is difficult to determine after the passage of 3000 or more years, analytical and empirical evidence suggests that local sourcing was usually practiced. The diversity seen in these hib-type plasters in the Queens Valley tombs can be therefore partially explained by this geological context.

Finally, a third category of plasters exists which relies on gypsum as the primary binder. Gypsum rock or alabaster would be heated to produce calcium sulfate hemihydrate (CaSO₄·0.5H₂O) which could then be used as a binder in plasters. Lucas describes gypsum plasters as varying considerably in color, “may be white or practically white, different shades of gray or very light brown (Lucas, 1924, p.130).” Black particles sometimes seen in gypsum plasters are thought to be traces of burnt fuel used during the calcination process (Lucas and Harris, 1989, p.77). The plasters, typically white to gray in color, may have also contained hib, added as a locally available filler and may therefore also contain small amounts of clay.

### 2.2 Geological context and the sourcing of raw materials
The local geology of the Valley of the Queens is dominated by the Theban Mountains. These are composed of four distinct stratigraphic limestone members (I-IV of the Thebes Formation), which sit atop the Esna Shale Formation (Saïd, 1960; Curtis, 1979; Wüst and McLane, 2000). Entrances to the Queens Valley tombs are excavated into the lowest limestone formation (Member I), which is characterized by its high clay content. Indeed, much of this limestone member is classified as marl (35-65% CaCO₃). The clays contained in the marl have been identified as sepiolite and palygorskite, as well as the swelling clay smectite, which is the primary clay responsible for the destructive action seen in tombs affected by flooding. In addition to calcite and clays, varying amounts of dolomite and/or ankerite, possibly anhydrite and/or gypsum, quartz and sometimes halite have also been found in marl samples (Huggett, 2011; Mahmoud, 2010, p.154; Hamza Associates, 2009; Moussa, 2008; Wüst and McLane, 2000; Wüst and Schlüchter, 2000).

The relevance of this richly varied geology to the nature of the hib-type plasters in the Queens Valley tombs is critical. As a geological deposit created by chemical and physical weathering of the rock, hib composition is intimately associated with and influenced by the complex and multi-varied limestone/clay geology within Member I of the Thebes Formation. Varying processes of breakdown, aided by periodic flash floods, would also greatly affect its component ratios, particle-size distribution, etc. Over the 200 or more years that the Queens Valley tombs were excavated and plastered, locations of hib sources must have shifted, as favored deposits became exhausted and new ones were exploited, further adding to the compositional diversity. Thus, although hib composition is broadly defined by the local geology, this also incorporates both considerable and subtle variations.

In this context, significant questions arise regarding binders and aggregates in the plasters, and the ability to distinguish one from the other. As a readily available natural deposit, hib incorporates both binder and aggregate components. Potential binding reactions include contributions from clay, calcium sulfate and calcium (1); but it is also simultaneously possible for calcium sulfate, calcium and even agglomerated clay-containing particles to be present as aggregates or fillers.

### 3. PROBLEMS IN THE ANALYTICAL CHARACTERIZATION OF EGYPTIAN PLASTERS

Soil texture characterization and identification of binder components are key to understanding the properties, composition, and source materials of earthen plasters. However, this is notoriously difficult to determine in the case of Egyptian plasters due to their heterogeneity and composition.

Friable and water-sensitive particles in source materials can be broken down at the time of plaster preparation and application or during preparation for analysis. Obtaining precise data on the nature of the binder is therefore complicated by the common presence of particles composed of clays, calcium carbonate, and calcium sulfate that may have originally been present as part of the aggregate. Conversely, particles may not have fully broken down during sample preparation or larger clay minerals, such as sepiolite and palygorskite, may be present in the >2µm fraction but may nevertheless still contribute to the binder. Because these components are also often well-graded and occur in all fractions, it is also difficult to determine if these plasters rely principally on hib or have been adapted by the intentional addition of other materials.

Furthermore, reconstructing the initial state of reactivity of these components is problematic, for example, where calcium sulfate states of hydration and calcium carbonate morphology may have changed over time. Particular difficulties in interpretation relate to the presence of gypsum in Egyptian plasters. Because of the semi-arid climate of the Theban area, gypsum is known to dehydrate to anhydrite (CaSO₄) (Wüst and Schlüchter, 2000, p.1167; Hamza Associates, 2009). As a result, many plasters, thought to be gypsum-bound, when analyzed are found only to contain anhydrite (Garcia-Guinea et al., 2008; Smeaton and Burns, 1988, p.301). Calcium sulfate may, therefore, be present from the intentional addition of calcined gypsum as a binder, which has subsequently converted through dehydration to anhydrite, or can be present as naturally-occurring anhydrite, in which case its contribution as a binder is arguably minimal.
Such problems of mineralogical interpretation have been major obstacles to achieving a fuller understanding of ancient Egyptian plasters. A crucially important factor in trying to address this situation is determining the most appropriate analytical approach for investigating the original plasters and their local source materials, and being aware of analytical limitations.

4. ANALYSIS OF QUEENS VALLEY PLASTERS
For the present study, twenty samples of original plasters from eight tombs in the Valley of the Queens, and three raw materials, were analyzed (2). The latter included hib and crushed limestone both from Queens Valley, and a locally available alluvial soil sample. Where sample size permitted, X-Ray Diffraction analysis (XRD) was conducted on each entire sample to indicate broad mineralogical composition, and of the <2µm fraction, to provide data on the clay composition of the finer fraction, including partial information on binder components (as calcite, calcium sulfate, and clays present in the >2µm fraction are also likely to have contributed to the binder) (3). The relatively small size of the samples precluded the use of sieving and sedimentation particle size analysis methods, so Laser Particle Size Analysis (LPSA) was undertaken to obtain a broad picture of soil texture (4). Unavoidable distortion owing to the removal of the >2000µm fraction and the possible incomplete separation of the <2µm fraction was considered in the interpretation of results. Thin-section analysis was used for detailed qualitative, quantitative and morphological examination of mineral and fiber content and distribution, and to balance LPSA results (5).

5. RESULTS AND DISCUSSION
The results of analysis have been tabulated and are presented in Table 1, which are referred to in relation to the discussion.
### Table 1 – Summary of XRD results (credits: Getty Conservation Institute, 2011).

| ID | Tomb | Layer Description | Clay minerals in Bulk XRD | Clay minerals in Clay XRD | Bulk | Clay | Bulk | Clay | Bulk | Clay | Bulk | Bulk |
|----|------|-------------------|---------------------------|---------------------------|------|------|------|------|------|------|------|------|------|
| 1  | QV 31| lower plaster     | 8% sepilolite, 3% polygorskite, 1% smectite, 1% illite/mica (Total: 13%) | 42% sepilolite, 37% smectite, 19% polygorskite, 2% kaolinite | 74*** | 7* | 0 | 0 | 0 | 0 |
| 2A | QV 31| ceiling upper plaster | 16% sepilolite, 4% polygorskite, 2% smectite, trace kaolinite (Total: 22%) | Trace sepilolite, smectite and polygorskite | 26** | 10** | 33*** | 7 | 0 |
| 2B | QV 31| ceiling lower plaster | 21% sepilolite, 4% polygorskite, trace smectite and kaolinite (Total: 25%) | not enough sample | 36 | 15 | 11 | 4 | 0 |
| 3  | QV 33| lower plaster     | 35% polygorskite, 29% smectite, 1% kaolinite (Total: 65%) | 55% smectite, 44% polygorskite, 1% kaolinite | 22** | 6** | 2* | tr | 0 |
| 4  | QV 33| upper plaster     | 16% sepilolite, 14% polygorskite, 4% smectite, 2% kaolinite (Total: 36%) | 60% polygorskite, 28% smectite, 13% sepiolite, 2% kaolinite | 44* | 13* | 0* | 0 | 0 |
| 5  | QV 36| lower plaster     | 20% sepilolite, 14% polygorskite, 9% smectite (Total: 43%) | 47% smectite, 29% polygorskite, 22% sepiolite, 2% kaolinite | 40** | 7** | 4* | 1 | 0 |
| 6  | QV 36| upper plaster     | 6% sepilolite, 1% polygorskite (Total: 7%) | 92% sepiolite, 7% polygorskite, 1% kaolinite | 86*** | 4* | 0 | 0 | 0 | 0 |
| 7  | QV 42| upper plaster     | 11% sepiolite, 10% polygorskite (Total: 21%) | 12% sepiolite, 27% smectite, 15% kaolinite, 13% polygorskite, 13% illite | 54** | 13** | 1* | tr | tr |
| 8  | QV 60| upper plaster     | 16% sepilolite, 3% polygorskite (Total: 19%) | 73% sepiolite, 25% smectite, 2% kaolinite | 51* | 15** | 7* | 0 | tr |
| 9A | QV 60| ceiling lower plaster | 12% polygorskite, 7% smectite, 3% kaolinite, 1% sepiolite (Total: 23%) | 61% sepiolite, 18% kaolinite, 12% illite, 9% polygorskite, trace sepiolite | 27* | 42* | 0* | 0 | 0 |
| 9B | QV 60| ceiling upper plaster | 6% smectite, 5% polygorskite, 3% sepiolite, 3% kaolinite, 2% illite and mica (Total: 19%) | 57% smectite, 18% illite, 15% kaolinite, 10% polygorskite, trace sepiolite | 29* | 41* | 0* | 0 | 1 |
| 11 | QV 66| lower plaster     | 14% sepiolite, 1% illite and mica, trace kaolinite and polygorskite (Total: 15%) | 52% smectite, 32% sepiolite, 9% kaolinite, 9% polygorskite | 29* | 35* | 3* | 0 | tr |
| 12 | QV 66| upper plaster     | 14% sepiolite, 1% illite and mica, trace kaolinite and polygorskite (Total: 15%) | not enough sample | 24 | 9 | 52 | tr | 0 |
| 14 | QV 66| unknown           | 33% sepiolite, trace kaolinite (Total: 33%) | 91% sepiolite, 8% smectite, 1% kaolinite | 48** | 5** | 5* | 0 | 1 |
| 16 | QV 66| lower plaster     | 24% sepiolite, 3% polygorskite (Total: 27%) | 80% sepiolite, 11% smectite, 7% kaolinite, 2% polygorskite | 48** | 9** | 10** | 1 | tr |
| 18 | QV 66| lower plaster     | 17% sepiolite, 4% polygorskite, 2% smectite (Total: 23%) | 45% smectite, 42% sepiolite, 12% polygorskite | 53** | 12** | 3* | 0 | tr |
| 19 | QV 66| upper plaster     | 14% sepiolite, 4% polygorskite, 2% smectite (Total: 20%) | not enough sample | 54 | 11 | 5 | 3 | 0 |
| 20 | QV 71| lower plaster     | 27% sepiolite, 4% polygorskite, 2% smectite, 1% kaolinite (Total: 34%) | 56% smectite, 27% sepiolite, 17% illite | 31* | 22* | 6* | 1 | tr |
| 21 | QV 71| upper plaster     | all 0% | trace kaolinite | 20* | 5* | 75*** | tr | 0 |
| 22 | QV 75| upper plaster     | 19% sepiolite, 1% kaolinite (Total: 20%) | 50% sepiolite, 41% sepiolite, 9% kaolinite | 48** | 17** | 6* | 0 | tr |
| 23  | QV hib| limestone crushed | 8% polygorskite, 7% sepiolite, 1% illite and mica (Total: 16%) | 49% polygorskite, 36% smectite, 13% sepiolite, 2% kaolinite | 65** | 8** | 5* | 0 | 0 |
| 24  | QV limestone crushed | 27% sepiolite, 5% polygorskite, 4% smectite (Total: 36%) | 64% sepiolite, 18% smectite, 12% polygorskite, 4% illite, 1% kaolinite | 39** | 15** | 0* | 0 | 0 |
| 26  | local dark earth | 66% smectite, 5% illite and mica, 4% sepiolite, 2% kaolinite (Total: 77%) | 93% smectite, 7% kaolinite, trace chlorite, polygorskite and illite | 13* | 15* | 0* | 0 | 0 | 0 |

#### 5.1 Evidence for the use of local hib deposits in Queens Valley plasters

As a readily available natural deposit with the requisite properties of good cohesion and low shrinkage, hib is the natural base material for New Kingdom period plasters in the Theban area. Though the single sample of hib (sample 23) taken from Queens Valley is too small to give an indication of the possible variations in composition, it does provide a point of reference from which to compare the historic plaster results. Larger fraction materials present in sample 23 are calcite, quartz, and a small quantity of anhydrite (Fig 6). The finer fraction constituutes only a quarter of the whole sample and contains a range of clays that reflects the geology of the area (both in marl-derived aggregates and in the clay matrix). Polygorskite and smectite predominate, with smaller amounts of sepiolite and kaolinite ranging in behavior from active (smectite), normal (polygorskite and sepiolite) to inactive (kaolinite). Overall, this sample can be categorized as a low-plasticity earthen material in which the binder properties of the finer fraction may have been augmented by the sample’s large calcium carbonate content.
Fig. 6 – Hib (sample 23) contains calcite, a range of clays, quartz and a small amount of anhydrite (credits: Getty Conservation Institute, 2011).

Given the limited sample range, the detection limits of XRD and inherent distortion in particle size analysis results, comparisons of hib with the plaster samples are of necessity general. Of the twenty plaster samples analyzed, sixteen exhibited a broad association with the hib sample. However, the range and quantities of clay minerals present in the finer fraction did show variation as did the quantities of calcite particles present, both in the finer and coarser fractions. Hib-based plasters provided lighter-colored and finely textured surfaces for carving, and to receive paint layers (Fig 7). Qualitative and quantitative differences for the most part probably reflect variations in geographical distribution and change over time in the content of hib deposits, although intentional mixing of soils and the use of additives is also probable in some cases.

Fig. 7 – Upper plaster sample from tomb QV 36 (sample 6) is buff-colored, finely textured and is broadly similar to the hib sample but does not contain smectite nor anhydrite (credits: Getty Conservation Institute, 2011).

5.2 Evidence for the use of local alluvial soil deposits
Of the nine lower plasters analyzed (samples 1, 2b, 3, 5, 9a, 11, 16, 18, 20), six (3, 5, 9a, 11, 18, 20) were observed to be darker in color and poorer in cohesion than those established as being primarily hib-based plasters. Analysis established that the swelling clay, smectite, was dominant in these six lower plasters. They also tended to contain more unburnt plant fibers than the hib-based plasters. The main purpose of these lower plasters was to level the rough excavated rock surfaces of the tomb interiors, and to provide a base layer for the thinner, finer plaster layers, which were to receive the painted and carved decoration.

That different earthen source materials had been selected to fulfill these specific functions is well illustrated by the lower and upper QV 33 plasters (samples 3 and 4). Bulk XRD analysis revealed radical qualitative and quantitative differences, and in the <2µm fraction of the lower plaster (sample 3), the smectite content was 55%, as opposed to 28% in the upper plaster (sample 4). An association between the upper plaster of QV 33 and the hib sample (sample 23) is clear, but the dark, lower plaster must be derived from an alternative source. Only one sample of local, cultivated soil of alluvial origin was obtained for analysis (sample 26), which was found to be composed largely of silt to sand-sized (2 – 1000 µm) particles, and to have a clay fraction almost entirely composed of smectite. As with the analysis of locally-obtained hib, the sample base is too small to draw any but the most general observations. But an association between these smectite-based soil types and the dark lower plaster layers is the most likely conclusion. In some cases, plasters may have been also composed by mixing hib and alluvial soils together. For example, Bulk XRD of sample 18, a lower plaster from tomb QV 66, indicates qualitative and quantitative similarities with the hib sample, whereas the <2µm fraction shares characteristics with both the hib and the cultivated soil samples.

5.3 Evidence for modification through the use of inorganic and organic additions

Plaster samples which share some characteristics with hib or alluvial soils, but also display significant differences in some aspects of mineralogical composition could be an indication that other materials such as quartz sand and calcined gypsum have been intentionally added. For example, the upper plaster in tomb QV 71 (sample 21) shares some characteristics with the hib sample except that it is depleted in clay and calcite, and therefore is not bound in the same way as the majority of plasters. It is, however, particularly rich in anhydrite, which may indicate an addition to compensate for this lack. Two layers of ceiling plaster from QV 60 (samples 9a and 9b) are clay-rich, with smectite dominating, but also contain an unusual quantity of quartz, which may indicate the addition of sand, possibly to reduce shrinkage (Fig 8). In many other examples, fibers were added to adapt and improve material properties according to specific requirements. It is evident that the ancient Egyptian craftsmen understood the source materials well enough to intentionally manipulate plasters to suit their needs.
Fig. 8 – Thin section of upper (top) and lower (bottom) plaster layers from the ceiling of tomb QV 60, samples 9a and 9b respectively. Both layers are rich in quartz (42% and 41%) but whereas the upper layer has quartz in the finer fractions (apart from a few visible grains), the lower layer exhibits numerous quartz grains (shown as bright white particles) and therefore suggests the intentional addition of sand (credits: Huggett 2011).

6. CONCLUSION
Findings indicated a far more widespread use of hib in Queens Valley wall painting plasters than previously recognized, informed by an empirical but skillful awareness of its mineralogical properties on the part of the ancient craftsmen. These results have fundamental implications for improving the formulation of repair plasters for stabilizing wall paintings. Compatibility of original and repair plasters with similar performance characteristics will reduce the potential for further deterioration and help to better conserve the painted plasters in the royal tombs of the Valley of the Queens.

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Bibliography


Notes

(1) The binding function of calcium in this case is not a reaction due to the addition of calcium hydroxide, but is based on the availability of bivalent, positively-charged calcium ions, derived from limestone within the soil matrix, each of which can bind two negatively-charged clay particles together (Foth, 1990, p.31).

(2) Initial analytical investigation was conducted at the Housing and Building National Research Centre, Cairo (2009-2010). Further Bulk XRD analysis, together with <2µm fraction XRD, LPSA and Thin Section analysis was undertaken by Petroclays, UK, in 2011.

(3) Bulk XRD analysis was conducted on all the samples, and finer fraction (<2µm) XRD on 20 samples on a Phillips 1820 automated X-ray diffractometer using Ni-filtered CuKα radiation. Interpretation was facilitated using MacDiff software.

(4) LPSA was conducted on 22 samples using a Malvern Mastersizer 2000 version. Multiple runs were conducted on heterogeneous samples where sample size permitted.

(5) Seventeen samples were prepared and analyzed as blue dyed epoxy-impregnated thin sections.

Curriculum

Lori Wong is a wall painting conservator and graduate of the Courtauld Institute's Conservation of Wall Paintings program. Since 2002 she has been working as a Project Specialist at the Getty Conservation Institute on projects in China, at the Mogao Grottoes and Chengde, and in
Stephen Rickerby received his MA in art history before undertaking the Courtauld Institute of Art/Getty Conservation Institute Postgraduate Diploma in the Conservation of Wall Painting (1985-88). He has since worked extensively on wall painting projects internationally. He has been a wall painting consultant to the Getty Conservation Institute on a number of its projects, including the Tomb of Nefertari, Egypt (1987-92), the Royal Bas-Reliefs of Abomey, Benin (1995-1999), the Cave 85 Project, Dunhuang, China (1999-2004), the Queens Valley Project, Egypt (2006-) and the Tutankhamen Project (2009-). He is also involved in conservation teaching in Dunhuang, and co-supervises Courtauld Institute fieldwork sites in Cyprus, Malta and China.

Amarilli Rava holds an MA in Wall painting Conservation from the Courtauld Institute of Art and a BA in Oriental Art and Archaeology from the University of Naples, ‘L'Orientale'. She worked at the Getty Conservation Institute as graduate intern for the year 2010/2011 on the conservation and management of the Tomb of Tutankhamen project. Currently she is involved in conservation projects run by the Courtauld Institute in Malta and India.

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