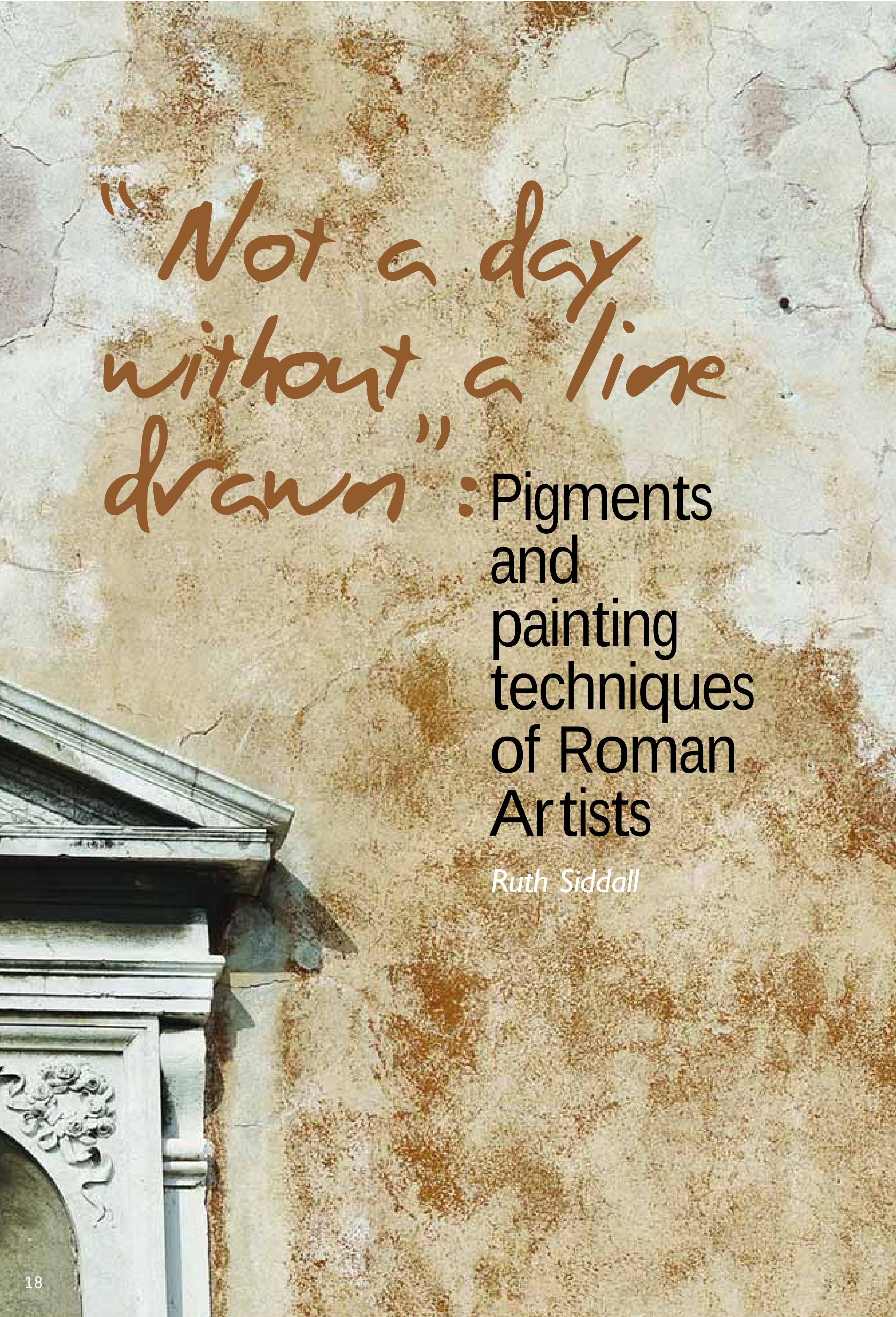

"Not a day without a line drawn": Pigments and painting techniques of Roman Artists

Ruth Siddall

This paper presents a review of the current state of the study of Roman paintings using scientific and primarily microscopic techniques. Despite the wealth of available material, the scientific analysis of pigments from Roman art is in its infancy with only a small range of material published in the literature. Much of the current discussion of Roman paintings relates to the works of contemporary authors, primarily the natural historian Pliny and the architect Vitruvius, as reliable sources concerning the extent of artists' palettes. Whilst their works do cover the standard palette, analyses have shown that there are local and regional palettes emerging. Not surprisingly, the range of materials is far broader than supposed.

The Romans, from the evidence we have, were great connoisseurs of art. There are many references in the surviving literature to the well-known paintings by the Greek 'old masters', such as the 4th Century BC artist Apelles. These works, easel paintings on wood, were inherited, or more frequently looted following the Roman invasion and occupation of Greece in 146 BC. The great artist Apelles was a favourite of Alexander the Great and according to Pliny, a great admirer; he went 'not a day without a line drawn'. Pliny provides a lengthy account in his Natural History of the origins and history of art and also discusses pigments and techniques. Much of this technical information he acquired from Theophrastus's De Lapidibus (4th Century BC) and also from the work of the architect Vitruvius who specifically discussed the materials and techniques of wall painting.

The Roman authors Vitruvius (1st Century BC) and Pliny (1st Century AD) were writing in the centuries spanning the height of the popularity of wall paintings in Roman interior decoration. Wall paintings now typify Roman painted art, mainly because they are far more likely to be preserved in the archaeological record than portable panel painting. Pliny writes of his sadness that panel paintings had declined in popularity in contrast to the static murals, confined to domestic architecture. However, well-known works of the ancient Greek artists were copied as mosaics or as the central motifs *(emblema)* of wall paintings. Some panel painting continued, but our current evidence is largely restricted to the exceptionally well-preserved portraits from Graeco-roman period mummies in Egypt (see Walker & Bierbrier, 1997).

Fig. 1. Pot of calcium copper silicate 'Egyptian Blue' pigment from Pompeii.

The popularity of wall painting took off in an unprecedented manner. It was far from restricted to the reception rooms of the large homes of the wealthy Roman citizen. Excavations at Pompeii and Herculaneum have revealed that almost all rooms (latrines and storerooms perhaps excepted, but not the bedrooms of slaves) were painted in houses owned by the entire cross-section of society. The extensive excavations at Pompeii and Herculaneum have revealed the characteristic tastes of the middle class populations of small towns. The wealth of material preserved here has led to classification of Roman wall painting into the so-called four Pompeian styles as originally defined by Mau (1882) and based primarily on the use of colours, patterns and motifs. More recent excavations have rarely unearthed buildings preserved on the scale of the towns and villas surrounding Vesuvius. However, outstanding examples of Roman wall painting exist in all corners of the Empire. Notable examples include the Terrace Houses at Ephesus and the House of Livia and many other civic and domestic buildings in Rome. More fragmentary but nonetheless important finds of wall paintings in the Roman Provinces include those from Corinth, which are the largest finds in Greece (see Gadbery, 1993; Hill, 1964 & Meggiolaro *et al.*, 1997) and in the British Isles (see Ling, 1985 for a general review).

Scientific analyses of pigments used in Roman works of art has been a comparatively recent advance. Much earlier work in this field has concentrated on the art history and iconography, *Polarising light microscopy (PLM) has been a key technique used in the accumulation of these data, providing fast and reliable identifications.*

and assumptions have been made concerning the pigments used, based on the works of Pliny and Vitruvius. Pliny divides the range of materials into two categories; 'florid' pigments, the rare and expensive materials, and the common earth pigments he calls 'austere' or sombre. The florid pigments, which Pliny lists as being *minium* (vermillion), *armenium* (azurite), *chrysocolla* (malachite), *cinnabaris* (probably the plant resin dracaena or dragon's blood), indigo and Tyrian purple, were purchased and provided by the patron at his own expense. The remaining austere pigments were provided by the artist within the cost of the commission, and these included ochres, green earths, chalks and the synthetic compound known as Egyptian Blue.

Over the last decade, conferences devoted to the scientific analysis of Roman painting, notably that in Fribourg 1996 (Bearat *et al.* [Eds.], 1997), have considerably heightened awareness. A variety of techniques including optical polarising light and electron microscopy have been employed. In addition, a large number of analyses have used spectroscopic techniques as well as direct chemical analyses.

The excellent discussion in Bearat (1997) which compares analyses of wall paintings from Pompeii and Roman sites in Switzerland, and comparison of these with the writings of Pliny and Vitruvius, provides a springboard for further discussion of the range of colours available to Roman authors. Within the same volume, the first to bring together a series of papers on the scientific analyses of Roman paintings, studies of wall paintings in Pannonia (Jaro, 1997), in Israel (Rozenberg, 1997; Segal & Porat, 1997), at Corinth (Meggiolaro *et al.*, 1997), in Cyprus (Kakoulli, 1997), at Roman sites in France (Fuchs & Bearat, 1997), at Pompeii and Rome (Bugini & Folli, 1997; Meyer-Graft & Erhardt, 1997, Varone & Bearat, 1997), in Spain (Moreno *et al.*, 1997) and Western Anatolia (Bingöl *et al.*, 1997), are brought together. More recently, wall paintings have been analysed from Spain (seven villas in the Province of Burgos; Villar & Edwards, 2005; El Ruedo Villa, Cordoba; Rodríguez & Fernández, 2005), from Romano-British villas (Rushton Villa; Edwards *et al.*, 2002), from Italy (Villas at Pordenone, Trieste and Padova; Mazzochin *et al.*, 2003, Mazzochin *et al.*, 2004, Pigment pots from Pompeii; this work and Eastaugh *et al.*, 2004a, Eastaugh *et al.*, 2004b) and from France (a villa in Metz; Dooryhée *et al.*, 2005).

This article aims to provide a review of this published work, providing identification of the materials used in analysed Roman wall paintings. Material analysed ranges from fragments of painted plaster, in situ wall paintings, and in the case of Pompeii, pots of unused pigments (Figure 1). Polarising light microscopy (PLM) has been a key technique used in the accumulation of these data, providing fast and reliable identifications, based on the optical properties of the primarily inorganic phases encountered. The technique suits the material well; Roman period pigments are frequently coarsely ground (c. 40 μm particles) and therefore at the resolution of PLM. Particle colour is readily identifiable and hence, evidence of mixed phases is clear. The analyses made by the author of material from Pompeii (Eastaugh *et al.*, 2004a, Eastaugh *et al.*, 2004b and forthcoming publications) were made using a Leitz Orthoplan

Pol microscope using 50x objective and 100x oil immersion objective.

Supports

Roman wall paintings are applied either to dry lime plaster ('a secco') or using the fresco technique. The plaster supports are built up from several layers of lime plaster, with the uppermost containing a lime cement binder and a fine aggregate of crushed marble, a material generally called marmorino (Figures 2 & 3). Vitruvius goes into some detail on the construction of these wall paintings, stating that up to nine coats of plaster be applied before the painting can commence. Due to the considerable reduction in interior space after several redecoration schemes, it is understandable that these rules were rarely adhered to. In fact it is clear that supports became much less complex as time progressed. From wall paintings excavated from fill at Ancient Corinth, including the Houses East of Theater (Gadbury, 1993) and the South East Building (Meggiolaro *et al*., 1997), there is a clear deterioration in plaster quality over a period of some five centuries. Supports ranged from almost 10cm thick and comprising up to seven layers of plaster, down to 2mm thick coats of marmorino applied directly to the rough wall. More care was applied where paintings were intended for exterior walls or in damp areas. In these cases crushed pot sherds were added to the lower coats (called the arricio and intonaco), which react with the slaked lime and form hydraulic cements, which are not

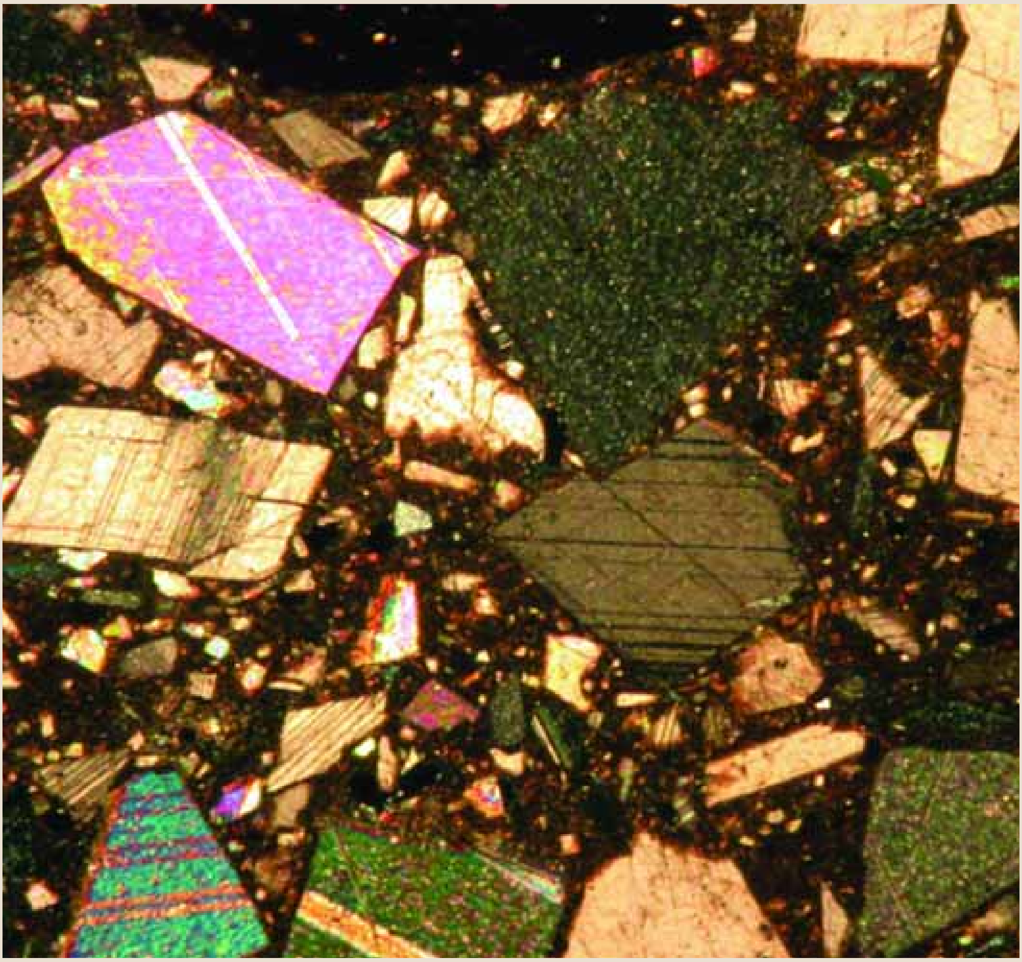

Fig. 2. Thin section photomicrograph of lime cement containing an aggregate of crushed marble. This is the support for Roman wall paintings excavated from Corinth, Greece 5x magnification, cross-polarised light, (field of view is 2 mm).

Fig. 3. Macro photograph of lime mortar containing crushed marble. The blue pigment is Egyptian Blue and has been applied to the dried surface. Fountain of Peirene, Corinth, Greece, (field of view is 5cm wide).

only waterproof, but also will set in a wet environment (Siddall, 1997).

Lime plaster is predominantly composed of calcium carbonate plus an aggregate of sand and/or crushed pottery. The lime wash used as a pigment binder for pigments applied using the fresco technique is calcium hydroxide, which on curing becomes calcium carbonate. The detection of calcium carbonate as an admixture in a large number of analyses is probably due to the medium or contamination from the supports, although in some cases it is clearly intentionally added, or in fact the main constituent of the pigment (see the discussion of white pigments below). These provided a stable, white background onto which the paintings could be made. The use of undercoats to bring out a certain top colour is discussed (particularly by Pliny for use with reds). This practice is very common and not just with similar, bright pigment shades. A startling example is in the fountain of Peirene at Corinth where the ground for the fish paintings in the basins has a black undercoat with either a blue or green top coat (Hill, 1964).

The colours identified in wall paintings schemes are discussed below, with comparisons from the lists of colours recommended by Pliny and Vitruvius.

Red and Orange

The Roman authors list the minerals cinnabar (mercury sulphide), realgar (arsenic sulphide) and

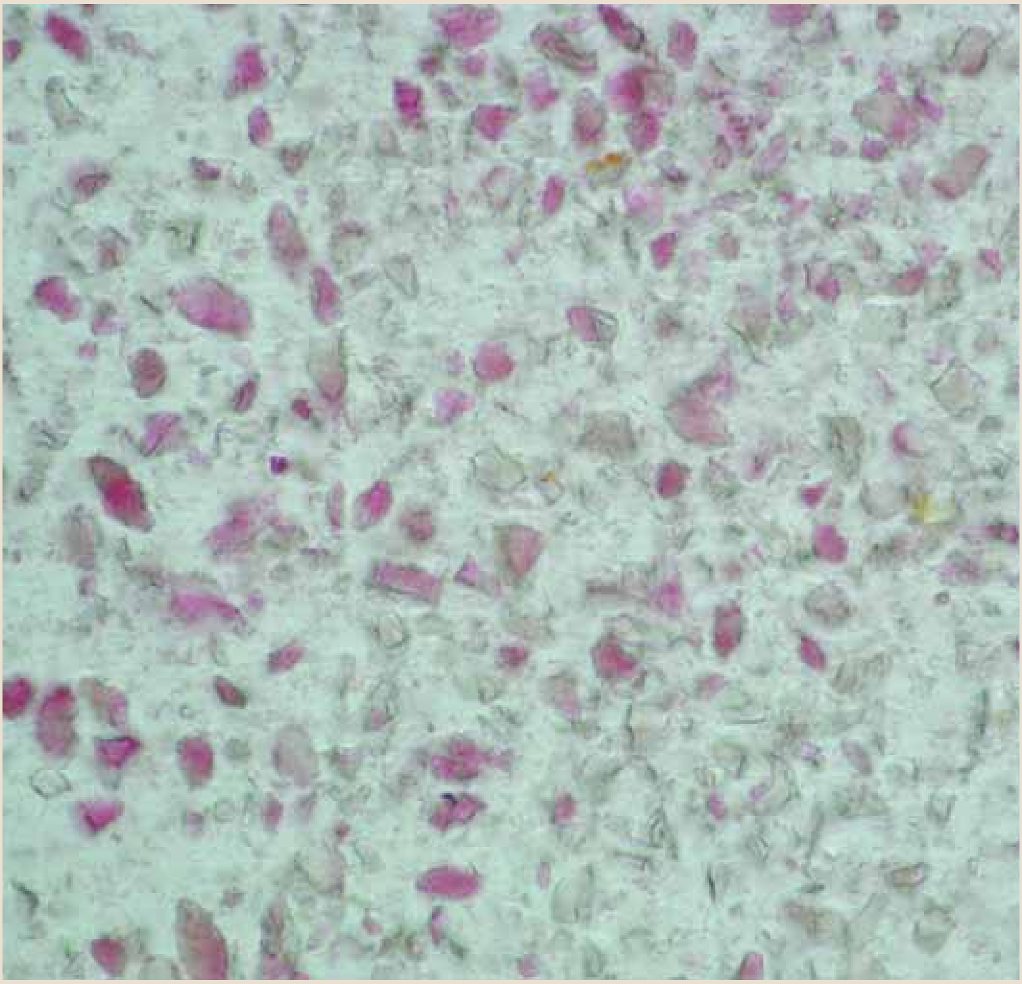

Fig. 4. Pink pigment from Pompeii. The colour is imparted by madder on a substrate of aluminium oxide. 50x magnification, plane polarised light, (field of view is 0.3 mm).

various forms of iron oxide (hematite, red ochres) as the available sources of red and orange, plus the synthetic material red lead (lead tetraoxide), produced by heating white lead (lead carbonate). Additionally, various organic materials including the plant dye madder and insect-derived reds where used on inorganic white substrates, either diatomite as found by Augusti (1967) and this author (see white pigments below).

In all the analyses quoted here, the reds found were predominantly derived from red ochres, with the main colouring component being the iron oxide mineral hematite. The occurrence of cinnabar in its pure form is detected in relatively few paintings (Mazzochin *et al*., 2004; Wallert & Elston, 1997; Fuchs & Bearat, 1997). Cinnabar is observed occurring as an admixture with hematite, presumably both to extend this valuable pigment and to brighten the hematite red (Rozenberg, 1997; Meggiolaro *et al*., 1997; Kakoulli, 1997). Eastaugh *et al* (2004a,b) also found organic reds derived from madder in material from Pompeii, corroborating earlier work by Augusti (1967) (Figure 4). Red lead has only been detected to date by Augusti (1967).

Blue

Pliny and Vitruvius both list blue pigments to be derived from the naturally occurring copper carbonate mineral azurite, the plant derived dye indigo and the synthetic pigment known generally as Egyptian Blue. It is this latter pigment that occurs universally in all blues employed in wall paintings analysed. The pigment is a calcium copper silicate, manufactured by calcining copper, calcium carbonate (limestone or shell) and silica (quartz sand), which had been produced in Egypt since the 3rd Millennium BC (see Eastaugh *et al.*, 2004b and references therein). This technology was transported to the Roman Empire, and by the first Century BC, there were numerous factories producing this pigment across Roman Europe (Figure 5). Only Augusti (1967) records other blue pigments in use, these being lapis lazuli (ultramarine) and indigo. As indigo was identified as an admixture in pigment pots from Pompeii (see below) this cannot be discounted as potentially used in its pure form. The discovery of ultramarine is more doubtful and requires corroboration. This mineral is not known to be used as a pigment until the 6th Century AD, where it was occasionally used in Central Asia (see Eastaugh *et al.*, 2004a and references therein).

Purple

The only purple listed by the Roman authors is the shellfish-derived Tyrian Purple and this has not been conclusively detected in any wall paintings analysed. Considering the high value of this pigment, this is not surprising and it seems likely that this compound was primarily used for dyeing cloth. Reddish purples were created by heat treatment of hematite (Villar & Edwards, 2005;

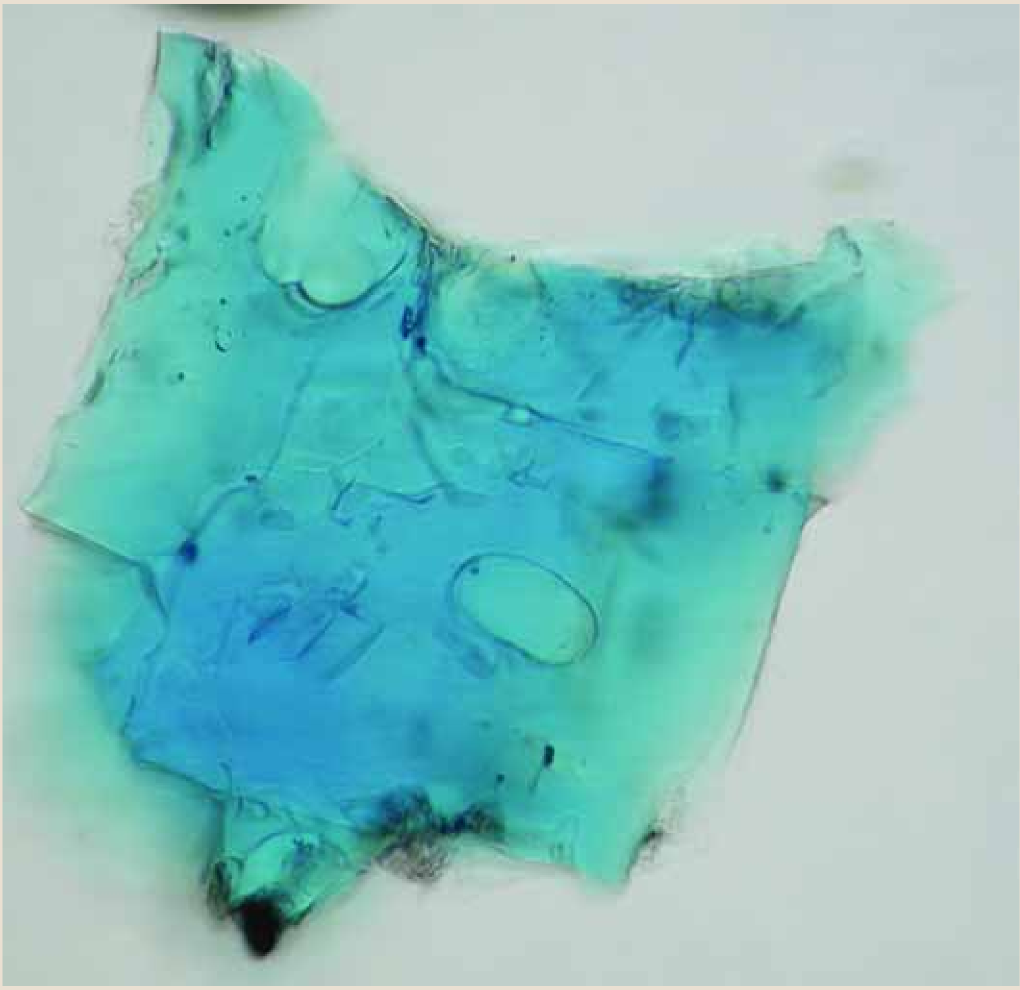

Fig. 5. A large crystal of Egyptian Blue. 50x magnification, plane polarised light, (Crystal is 400 μm across).

> *Unadulterated green earth is most commonly used and recorded by all workers.*

Mazzochin *et al.*, 2004), other purples were created by mixing hematite and Egyptian Blue (Fuchs & Bearat, 1997), and in a pigment pot from Pompeii, by mixing the organic dyes madder and indigo (Clarke *et al.*, 2005).

Green

Pliny writes that greens were derived from the mineral malachite and from creta viridis, or green earth. He also mentions the use of verdigris and other pigments derived from the corrosion of copper in an acidic environment. In paintings analysed, Varone & Bearat (1997) have detected malachite in pigment pots from Pompeii. Augusti (1967) also records this phase. Greens analysed from paintings in situ, are green earths or mixtures of Egyptian Blue and yellow ochre (Porat, 1997; Mazzochin *et al.*, 2003), or green earth is brightened by the addition of Egyptian Blue (Bugini & Folli, 1997). Unadulterated green earth is most commonly used and recorded by all workers. This naturally occurring deposit can be formed from two minerals, glauconite and celadonite, which are optically indistinguishable. Geologically they are identified by their mode of formation; glauconite occurs only in marine sediments and celadonite only in weathered volcanic rocks. Both environments would have been available to Roman pigment procurers and indeed both phases occur, sometimes mixed and often including the mineral chlorite (which may be naturally associated with both phases, particularly celadonite, or intentionally added; Mazzochin *et al.*, 2004). Kakoulli (1997) found celadonite green earths at Nea Paphos in

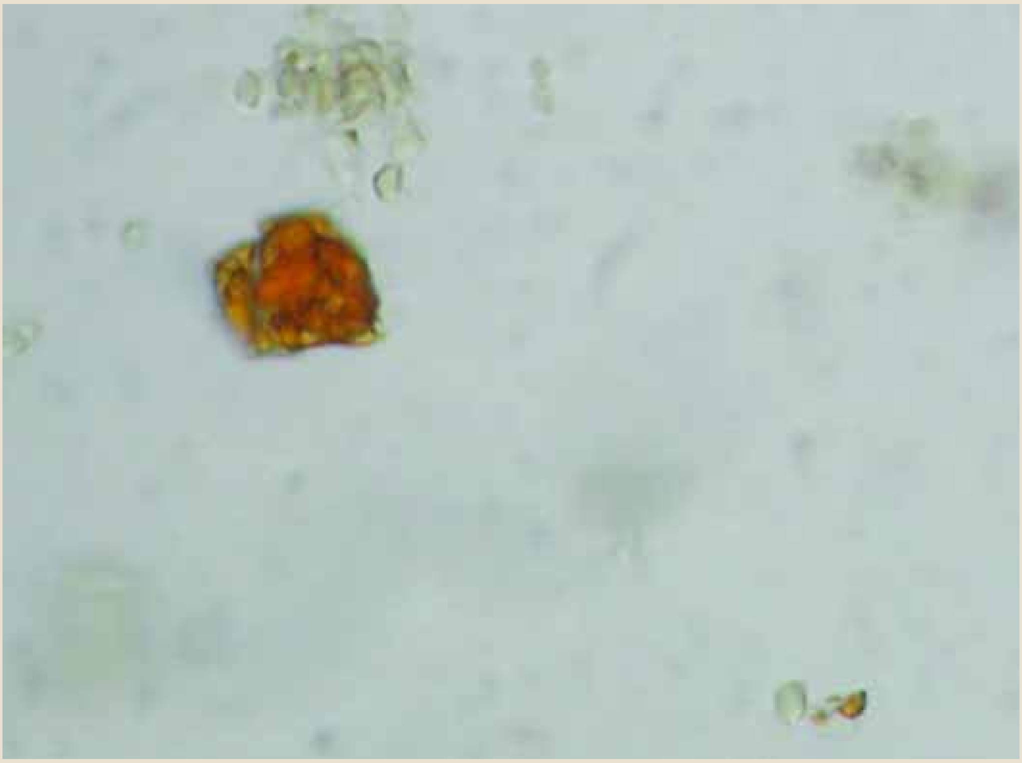

Fig. 6. A crumb-like particle of hydronium-jarosite from yellow pigments from Pompeii. 100x magnification, plane polarised light. The yellow grain in the centre left is 50 μm diameter.

Cyprus. This mineral is abundant in the altered basalts forming the Troodos mountains. Fuchs & Bearat (1997) found glauconite and celadonite in Swiss villas. Most authors understandably do not differentiate the phases, simply calling the material green earth.

Yellow

Yellow, according to Pliny and Vitruvius, was derived either from yellow ochre (iron oxide hydroxide, the mineral goethite) or from the mineral orpiment (arsenic sulphide). Yellow ochre was detected in analyses of all paintings. Augusti (1967) claimed to find orpiment at Pompeii, but his results are not conclusive. A third yellow, the lead oxide massicot, was identified by Augusti (1967), and more recently at a Roman Villa in France by Dooryhée (2005).

This author identified the mineral hydronium-jarosite (Fe3[SO4]2[OH]5.2$_{H_2O}$) as the main colouring component in an earth pigment from Pompeii (see also Eastaugh *et al*., 2004b; Figure 6).

White

Wide varieties of whites are listed by Pliny and Vitruvius, including a variety of 'earths' from locations such as Milos and Euboeia in Greece, Libya and Turkey. It is difficult to attribute the geological deposits associated with these materials, but they are likely to include china clay and other clay deposits containing minerals such as kaolinite and montmorillonite (fuller's earth). Another white, called 'ring white' was a mixture of 'chalk' with crushed glass (according to Pliny, the name derives from the fact that the stones in the rings of the 'vulgar classes' were made from this glass), while the technology to produce lead white from the corrosion of lead in the presence of vinegar was also known. White pigments were used pure, but also added to extend or lighten other pigments or as substrates for organic dyes.

Fig. 7. Diatomite from Pompeii. The image shows freshwater diatom species. 50x magnification, plane polarised light. The tests are opaline silica (SiO2), (field of view is 0.3 mm).

The white pigments detected in the recent analyses detailed above are predominantly various forms of calcium carbonate, which may be derived from crushed limestone, chalk, mollusc shell or even bird eggs. Unfortunately many of these analyses are made by chemical rather than optical means and no further information is available concerning particle morphology. Here, the use of optical microscopy is crucial to derive the geological or biological source of these pigments. As discussed previously, contamination from the supports or from a whitewash medium cannot be discounted as sources of calcium carbonate. A few authors identify magnesium carbonate (dolomite; Fuchs & Bearat, 1997; Varone & Bearat, 1997), which is unlikely to have been derived from the supports but is common in many limestones. Aragonite was also detected by Fuchs & Bearat (1997) and Varone & Bearat (1997), and this could represent either the naturally occurring mineral or crushed mollusc shell.

At Pompeii, diatomite was identified in white pigments by Eastaugh *et al* (2004b) and also by Augusti (1967). This is a white earthy material, composed of the microscopic frustules of diatoms (Figure 7). In both cases diatomite was used as a substrate for organic dyes. The use of lead carbonate, 'lead white', was detected at Pompeii by Varone and Bearat (1997) and by Mazzochin *et al.* (2003) at Vicenza.

Black

According to Pliny, the recommended black pigment was soot, though he also discusses mineral blacks, and black derived from burnt ivory and bone. Carbon-based blacks were universally detected by the scientific analyses, but the source of the carbon is rarely attributable. However, Mazzochin *et al.* (2003) report coal and bone-black from a villa near Vicenza, while Fuchs & Bearat (1997) and Rozenberg (1997) found charcoal. The only mineral black reported is the manganese oxide pyrolusite, which was detected by Kakoulli (1997) from Nea Paphos on Cyprus.

Discussion

These scientific analyses of Roman wall paintings and pigment pots have enabled art historians and archaeologists to look beyond the texts laid down by authors such as Pliny, Vitruvius and Theophrastus. Despite the several hundred pigment analyses documented in these works, there are few records of use of the 'florid' pigments described by Pliny. The exception here is the use of the mercury sulphide mineral cinnabar. However, for the most part, the analyses here are made from wall painting fragments excavated from provincial domestic architecture. Only the elite would have been able to afford wall paintings schemes in the most expensive colours. The 'austere' pigments are those commonly in use, especially red and yellow ochres, Egyptian blue, soot and carbon based-blacks, terres vertes, chalk based-whites and mixtures of these colours. In effect, it appears that the texts of Vitruvius and Pliny in particular, did cover the range of available pigments, and those that lacked detailed discussion (i.e. azurite, malachite, orpiment and realgar) did so precisely because they were so rarely used.

> *Only the elite would have been able to afford wall paintings schemes in the most expensive colours.*

From the findings summarised here, the mixing of pigments to produce new colours was not an uncommon practice but this is something not discussed by the Roman authors. Nevertheless, many purples, browns and greens were apparently produced in this way and of course any pigment applied fresco was mixed with lime wash, thus giving it a calcium carbonate chemical signature. In addition the expensive pigment cinnabar is sometimes seen to be extended by mixing it with the cheap and readily available red iron oxide hematite (Kakoulli, 1997; Meggiolaro *et al.*, 1997; Rozenberg, 1997). Green is produced by mixing yellow ochre and Egyptian blue at Masada (Porat, 1997) and at Vicenza (Mazzochin *et al.*, 2003). In the Sanctuary on the Capitolium, Rome, Bugini & Folli (1997) found green earth mixed with Egyptian Blue. Purples were also found as admixtures, although a red-purple is commonly produced by heat-treating red iron oxide. At Pompeii, Clarke *et al.* (2005) identified the organic pigments madder combined with indigo, and hematite mixed with Egyptian Blue was found by Fuchs & Bearat (1997) at villas in Switzerland. It is more than likely that large samples of wall paintings will show more results of this nature in the future.

It is clear that there are still many opportunities to increase the number of analyses of Roman wall paintings, beyond the small studies so far undertaken. Unexpected substances including coal, hydronium-jarosite and diatomite have been found, and these will have implications for understanding and locating sources, to trade in materials and maybe the development of regional schools of painters. The widest range of pigments so far encountered are from Pompeii, which given the wealth of preserved paintings is unsurprising. However there is still much work to be done to increase our knowledge of this important period of art history.

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References

Augusti, S., 1967, I Colori Pompeiani, De Luca, Roma.

Barbet, A., Fuchs, M. & Tuffreau-Libre, M., 1997, Diverse utilisations des pigments et leurs contenants., in: Bearat, H., Fuchs, M., Maggetti, M. & Paunier, D. (Eds.), Roman Wall Painting: Materials, Techniques, Analyses and Conservation., Proceedings of the International Workshop, Fribourg 7-9 March 1996., Institue of Mineralogy and Petrology, Fribourg University. 35-62.

Bearat, H., 1997, Quelle est la gamme exacte des pigments romains? Confrontation des resultats d'analyse avec les textes de Vitruve et de Pline., in: Bearat, H., Fuchs, M., Maggetti, M. & Paunier, D. (Eds.), Roman Wall Painting: Materials, Techniques, Analyses and Conservation., Proceedings of the International Workshop, Fribourg 7-9 March 1996., Institute of Mineralogy and Petrology, Fribourg University. 11-34.

Bingöl, O., Pracher, P., Bingöl, I. & Pracher, B., 1997, Deckschicte der Wanddekoration des Ersten Stils aus Knidos: Analyse und Restaurierung., in: Bearat, H., Fuchs, M., Maggetti, M. & Paunier, D. (Eds.), Roman Wall Painting: Materials, Techniques, Analyses and Conservation., Proceedings of the International Workshop, Fribourg 7-9 March 1996., Institue of Mineralogy and Petrology, Fribourg University. 329-336.

Bugini, R. & Folli, L., 1997, Materials and makings techniques of Roman Republican wall paintings (Capitolium, Brescia, Italy)., in: Bearat, H., Fuchs, M., Maggetti, M. & Paunier, D. (Eds.), Roman Wall Painting: Materials, Techniques, Analyses and Conservation., Proceedings of the International Workshop, Fribourg 7-9 March 1996., Institue of Mineralogy and Petrology, Fribourg University. 121-130.

Clarke, M., Frederickx, P., Colombini, M. P., Andreotti, A., Wouters, J., van Bommel, M., Eastaugh, N., Walsh, V., Chaplin, T. & Siddall, R., 2005, art 2005: 8th International Conference of the Italian Society for Non-destructive testing and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage. Lecce.

Dooryhée, E., Anne, M., Bardiès, I., Hodeau, J.L., Martinetto, P., Rondot, S., Salomon, J., Vaughan, G. B. M. & Walter, P., 2005, Non-destructive synchroton X-ray diffraction mapping of a Roman painting., Applied Physics A 81, 663-667.

Eastaugh, N., Walsh, V., Chaplin, T. & Siddall, R., 2004a, The Pigment Compendium: A Dictionary of Historical Pigments., Elsevier - Butterworth Heinemen. 499 pp.

Eastaugh, N., Walsh, V., Chaplin, T. & Siddall, R., 2004b, The Pigment Compendium: Optical Microscopy of Historical Pigments., Elsevier - Butterworth Heinemen.

Edwards, H. G. M., de Oliveira, L. F. C., Middleton, P. & Frost, R. L., 2002, Romano-British wall painting fragments: a spectroscopic analysis., The Analyst, 127, 277-281.

Fuchs, M. & Bearat, H., 1997, Analyses physico-chemiques et peintures murales romaines a Avenches, Bösingen, Dietikon et Vallon. in: Bearat, H., Fuchs, M., Maggetti, M. & Paunier, D. (Eds.), Roman Wall Painting: Materials, Techniques, Analyses and Conservation., Proceedings of the International Workshop, Fribourg 7-9 March 1996., Institue of Mineralogy and Petrology, Fribourg University. 181-192.

Gadbery, L. M., 1993, Roman wall painting at Corinth: new evidence from east of the Theater., in: The Corinthia in the Roman period (T. E. Gregory, ed.), Journal of Roman Archaeology, supplementary series number 8., 47-64.

Hill, B. H., 1964, Corinth 1:VI: The Springs; Peirene, Sacred Spring, Glauke., Excavations of the American School of Classical Studies at Athens., Princeton, New Jersey.

Jaro, M., 1997, Comparison of the painting materials used for wall painting in four sites of the Roman province Pannonia. in: Bearat, H., Fuchs, M., Maggetti, M. & Paunier, D. (Eds.), Roman Wall Painting: Materials, Techniques, Analyses and Conservation., Proceedings of the International Workshop, Fribourg 7-9 March 1996., Institue of Mineralogy and Petrology, Fribourg University. 75-84.

Kakoulli, I., 1997, Roman wall paintings in Cyprus: a scientific investigation of their technology. in: Bearat, H., Fuchs, M., Maggetti, M. & Paunier, D. (Eds.), Roman Wall Painting: Materials, Techniques, Analyses and Conservation., Proceedings of the International Workshop, Fribourg 7-9 March 1996., Institue of Mineralogy and Petrology, Fribourg University. 131-142.

Ling, R., 1985, Romano-British wall painting., Shire Archaeology, 64 pp.
Ling, R., 1998, Roman Painting, Cambridge University Press, 245 pp.
Mau, A., 1882, Geschicte der decorativen Wandmalerei in Pompeji. Berlin.
Mazzochin, G. A., Agnoli, F. & Salvadori, M., 2004, Analysis of Roman Age wall paintings found in Pordenone, Trieste and Montegrotto., Talanta, 64, 732-741.
Mazzochin, G. A., Agnoli, F., Mazzochin, S. & Colpo, I., 2003, Analysis of pigments from Roman wall paintings found in Vicenza., Talanta, 61, 565-572.
Meggiolaro, V., Molin, G. M., Pappalardo, U. and Vergerio, P. P., 1996, Contribution to studies on Roman wall painting materials and techniques in Greece: Corinth, the Southeast Building., in: Bearat, H., Fuchs, M., Maggetti, M & Paunier, D., Proceedings of the International Workshop on Roman Wall Painting, Fribourg., 105-118.
Meyer-Graft, R. & Erhardt, W., 1997, Untersuchung der Putzräger and Malereien in der 'Casa delle Nozze d'argento' in Pompeji und Präsentation der Ergebnisse aus der Sicht des Restaurators und des Archäologen. in: Bearat, H., Fuchs, M., Maggetti, M. & Paunier, D. (Eds.), Roman Wall Painting: Materials, Techniques, Analyses and Conservation., Proceedings of the International Workshop, Fribourg 7-9 March 1996., Institue of Mineralogy and Petrology, Fribourg University. 317-328.
Moreno, M. A., De Luxan, M. P. & Dorrego, F., 1997, The conservation and scientific investigation of the wall paintings in the Roman thermes, Campo Valdes, Gijon, Spain., in: Bearat, H., Fuchs, M., Maggetti, M. & Paunier, D. (Eds.), Roman Wall Painting: Materials, Techniques, Analyses and Conservation., Proceedings of the International Workshop, Fribourg 7-9 March 1996., Institue of Mineralogy and Petrology, Fribourg University. 297-306.
Pliny, Natural History, Books XXXIII-XXXV; Translated H. Rackham 1952, Loeb Classical Library.
Rodríguez, J. M. F. & Fernández, J, A, F, 2005, Application of the second derivative of the Kubelka-Munk function to the semiquantitative analysis of Roman paintings., Color: Research and Application, 30, 448-456.
Rozenberg, S. 1997, Pigments and fresco fragments from Herod's Palace at Jericho, in: Bearat, H., Fuchs, M., Maggetti, M. & Paunier, D. (Eds.), Roman Wall Painting: Materials, Techniques, Analyses and Conservation., Proceedings of the International Workshop, Fribourg 7-9 March 1996., Institue of Mineralogy and Petrology, Fribourg University. 63-74.
Segal., I. & Porat, N., 1997, Composition of pigments from the Hellenistic walls in Acre. in: Bearat, H., Fuchs, M., Maggetti, M. & Paunier, D. (Eds.), Roman Wall Painting: Materials, Techniques, Analyses and Conservation., Proceedings of the International Workshop, Fribourg 7-9 March 1996., Institue of Mineralogy and Petrology, Fribourg University. 85-92.
Siddall, R., 1997, Lime cements, mortars and concretes; the site of Ancient Corinth, Northern Peloponnese, Greece. 1. Preliminary results from morphologic and petrographic analyses. Wiener Laboratory Internal Report, American School of Classical Studies, Athens.
Stillwell, R., MacDonald, W. L. & McAllister, M., H. (Eds.), 1979, The Princeton Encyclopedia of Classical Sites, Princeton University Press, Princeton, N.J.
Theophrastus, De Lapidibus, Translated D. E. Eicholz, 1965. Oxford University Press.
Varone, A. & Bearat, H., 1997, Pittori romani al lavoro. Materiali, strumenti, techniche: evidenze archeologiche e dati analitici de un recente scavo pompeiano lungo via dell'Abbondanza (reg. IX ins. 12). in: Bearat, H., Fuchs, M., Maggetti, M. & Paunier, D. (Eds.), Roman Wall Painting: Materials, Techniques, Analyses and Conservation., Proceedings of the International Workshop, Fribourg 7-9 March 1996., Institue of Mineralogy and Petrology, Fribourg University. 199-214.
Villar, S. E. J. & Edwards, H. G. M, 2005, An extensive colour palette in Roman Villas in Burgos, Northern Spain: A raman spectroscopic analysis., Anal. Bioanal. Chem., 382, 283-289.
Vitruvius, *De Architectura,* Book VII. Translated F. Granger, 1934, Loeb Classical Library.
Walker, S. & Bierbrier, M. (Eds), 1997, Ancient Faces: Mummy Portraits from Roman Egypt., A Catalogue of Roman Portraits in the British Museum; Part IV., British Museum Press, 224 pp.