The combined use of cross-section analysis and other stratigraphic recording systems in the cleaning of two panel paintings from the fifteenth- and sixteenth-century

Abstract

Cross-sections are frequently used in the stratigraphic study of pictorial structures. Thanks to cross-sections, it is possible to study and record original and non-original strata that may provide important information regarding the artist's technique and later restoration processes. This information helps conservators design different strategies in processes such as cleaning. However, it is often in cleaning where the advantages and limitations of cross-sections become obvious. When dealing with a complex structure, cross-sections may not be enough to record in a comprehensive and accurate manner all the strata removed during cleaning. In some cases, the conservator may obtain during cleaning a great amount of stratigraphic information that is not visible in the cross-sections. Therefore, it may be necessary to resort to other recording systems, such as the stratigraphic unit recording sheet and the stratigraphic diagram, which are frequently used in archaeological stratigraphy. This article demonstrates how cross-sections analysis was combined with stratigraphic study during the cleaning of two panel paintings to gain an improved understanding of their complicated layer structure.

Keywords: Cross-section, Painting, Documentation, Stratigraphy, Cleaning, Sample

Introduction [heading]

Cross-sections are an important resource for obtaining information about original and non-original layers and therefore are fundamental in developing treatment strategies. However, the use of cross-sections by themselves may not be enough to provide a complete record of all layers present. This is especially true when dealing with complex structures that have many non-original layers from different periods and with diverse functions (e.g. varnish, overpaint, filler, adhesive, etc.). Complex structures require a thorough and meticulous approach, and this can be provided through the combined use of cross-sections analysis with recording systems such as stratigraphic unit (SU) recording sheets and stratigraphic diagrams (Watts *et al*., 2002; Barros García, 2004; Prisco *et al*., 2004; Barros García, 2009).

Since the scientific study of painted surfaces began, cross-sections obtained from samples have had a central role. The first diagram showing a stratigraphic paint section appears in a mid-nineteenth-century publication (Erdmann, *c.* 1853; Nadolny, 2003). In the first half of the twentieth century, this technique became standard to record stratigraphy. Gettens' articles in the 1930s are the first in undertaking a scientific methodology regarding the collection and treatment of samples. As it is an irreversible action, it is a case of trying to evaluate both the possible damage that could ensue when the sample is removed, as well as the information that might be obtained (Gettens, 1932).

Later, taking the article 'Cross-sections and chemical analysis of paint samples' as a starting point, the work of Plesters (1956) proved essential in the development of this methodology. Plesters shows the advantages and limitations of taking and analysing a sample. Among the former, one advantage in particular stands out: the great deal of information that can be obtained from a very small amount of material (for example, it is possible to observe the sequence of layers, their colour, texture, thickness and the sizes of pigment particles). Among the limitations, it must be pointed out that only a few, very small samples can be taken, and the results obtained from a given sample may not necessarily be representative of the rest of the work. Plesters maintained that detaching a minute fragment of paint is justified as a scientific method of examination, complementary to radiography and infra-red photography. Plesters developed a considerable volume of work, both studying and recording Old Master paintings, and established analytical methods to use with cross-sections for identifying mediums and pigments (Hendy *et al*., 1968).

In recent decades, a number of texts have been published analysing different methodological aspects of sample collecting, evaluating the reasons for carrying it out, the shape and size of the samples, and the importance of recording the whole process (Eastaugh, 1989; Eastaugh, 1996). In addition, several articles have been published concerning the technical aspects of cross-section analysis, e.g. sample storage, embedding process, etc. (Khandekar, 2003; Smithsonian, 2006).

Since taking a sample actually removes a very small part of the work, there is growing interest in non-destructive techniques for the acquisition of stratigraphic information (Bartoll *et al*., 2008; Fukunaga, 2009; Dik *et al*., 2009; Elias *et al.*, 2011). However, most researchers cannot put these techniques into practice yet as many of them are still experimental or not easily available. In addition, interpretation of the results of these non-destructive techniques remains problematic as it is not always easy to ascertain the layer structure.

Generally speaking, the success of using cross-sections has been due to the fact that they allow the layered structure of a painting to be visualized. Furthermore, cross-sections can also be used for other purposes, such as studying damage at microscopic level (Boon *et al.*, 2002), comparing stratigraphic structures (Sinclair, 1995), and distinguishing original from non-original strata (van der Werf *et al*., 2008). Although these are only a few examples, they underscore the usefulness of cross-section analysis.

Another area where cross-sections have acquired major relevance is cleaning (Wolbers, 2000). In the text that follows, two examples of cleaning processes are shown where cross-sections were combined with SU recording sheets and stratigraphic diagrams to obtain a much more complete documentation of complex structures, with many non-original layers from different periods. The basic element that makes up stratigraphic structures is the SU. An SU should be recorded according to three types of data: the description of its physical characteristics, its location in plan, and its relationships with other units. All this information is gathered together on a recording sheet, which enables both positive SU (strata) and negative SU (losses) to be recorded. The aim is to obtain a more comprehensive recording by including each and every one of the layers removed from the work (Barros García, 2009).

The use of SU recording sheets and stratigraphic diagrams makes it easier to relate the information from the cross-sections to a broader, more comprehensive set of data regarding the strata removed. Since the SU recording sheets have been presented and explained in a previous paper (Barros García, 2009), only the use of stratigraphic diagrams will be dealt with here. However, the stratigraphic data referred to in this paper were previously gathered by means of the SU recording sheets.

Case 1: *St. Matthias and St. Philip* [heading]

This first example is a panel painting attributed to Paolo da San Leocadio (*c.* 1445-*c.* 1514), *St. Matthias and St. Philip*, from a private collection (Madrid). The panel measures 54.8 x 58.2 cm, although study of the support and the pictorial composition shows that it was originally larger. The painting, which likely formed part of a polychromed wooden altarpiece originally, has been trimmed on at least three of its edges and showed a great many overpaints and other non-originals layers. Four samples were taken from the edges and analysed (SL 1-4), as these were the only areas where samples for cross-section analysis could be safely extracted. Sites marked D are where samples of strata were removed with solvents (Fig. 1).

The samples were examined using: Fourier transform infrared spectroscopy (FTIR), gas chromatography-mass spectrometry (GC-MS), pyrolysis-gas chromatography-mass spectrometry (Py-GC/MS), and scanning electron microscopy-energy dispersive X-ray spectroscopy (SEM-EDX) carried out by the Instituto de Restauración del Patrimonio of the Universitat Politècnica de València (UPV). Analysis showed that the binding medium of the paint is a drying oil and the ground is made up of calcium sulphate with a proteinaceous binder. In addition, the following pigments were identified: vermilion, lead white, calcite, azurite, earth pigments, and carbon black. Decorative elements in gold leaf had been applied onto the paint, probably with an oil gilding technique. The gilded background, where a technique similar to that of oil gilding had also been used, had been applied onto two layers of an ochre colour, composed of lead white, lead-tin yellow, calcite, and earth pigments.

Study of these samples provided a great amount of information concerning the original materials, but little data regarding the non-original ones. A few non-original strata were identified in the samples SL2 and SL3. In the sample SL2 an overpaint containing chrome orange was identified and a layer which could correspond to SU 23 (varnish), although there are some doubts regarding the identification of the latter SU. In the sample SL3, only a layer of dirt was identified (Fig. 2). The other samples do not show any non-original strata. This lack of information regarding non-original strata is a problem that may arise from diverse causes, for example a deposit present in the sample in such a small quantity that it cannot be identified or that the uppermost stratum has disintegrated during sample handling. It could also be due to the fact that the sample sites were chosen conservatively, for example, too close to losses in areas where the added layers had already been abraded by subsequent treatment or worn by other factors. Whatever the cause, it must be taken into account that it is not always possible to obtain enough information from the samples in order to identify all the strata present in a work. One way of solving this problem is by taking and analysing a great many samples, but this is not always possible due to the state of conservation of the painting or lack of economic means.

X-radiographs, infrared reflectography, and UV-induced visible fluorescence imaging each helped advance our understanding of the condition of the painting. For example, overpaints in the upper part of the composition and small overpaints on the rest of the work were located, and the presence of one or more unevenly applied varnish layers was verified. However, despite being very useful, these methods were not enough to elaborate a comprehensive recording of the stratigraphic structure.

Building on the information gathered from the initial examination methods, more than thirty non-original SU were identified during the cleaning process (some SU are groups of layers). Some of the non-original SU in Fig. 2 include: dirt, overpaints, fillers, and a varnish made from a drying oil and a diterpenic resin (perhaps pine resin). In order to find out the composition of some of these strata, cotton swabs used during cleaning were analysed by means of FTIR and GC-MS.

In this work, cross-sections provided important data regarding the original paint structure, which could be related to all the information gathered during the cleaning process itself. However, they gained greater relevance within the broader stratigraphic study, as can be seen from the partial stratigraphic diagram shown in Fig. 2 (only the more significant SU are shown so that the diagram does not become too complex). Only two of the non-original SU are present in the cross-sections, but it was possible to identify all the other units during the cleaning process (Fig. 3).

An interesting aspect regarding the study of strata during cleaning is that it is possible, in many cases, to establish the function of the new strata in the construction of the image. For example, SU 7, 16, 12, 13, 26, and 27 correspond to strata applied on the top black strip (Fig. 4). The relative chronology of these layers is gathered in a partial stratigraphic diagram (Fig. 5). In phase I (the oldest) only small losses were covered with fillers (SU 27), and a black, waxy overpaint (SU 26). In phase II, the strategy gave way to covering the black strip with a layer of imitation gold powder (SU 12). The result was probably too bright so a yellow ochre overpaint (SU 16) was applied later as a glaze. Later on during or after that phase, a red-earth-colour overpaint was applied (SU 7). This study has made it possible to understand that the different phases correspond to different restoration strategies. If the first intervention can be described as minimal, the following overpaints cover a progressively larger area, in an attempt to create a more homogeneous background colour. All of these strata were removed, recovering the black strip while keeping the potentially original reddish varnish (SU 23), that was also left in place due to the degradation of the gilded background.

What has been explained so far corresponds to just one part of the study carried out. Nonetheless, it exemplifies how the use of cross-sections is only part of a larger stratigraphic study and how it is not always possible to obtain all of the stratigraphic information from cross-sections.

Case 2: ***The Immaculate Conception*** [heading]

The altarpiece *La Purísima* (*The Immaculate Conception*), in the church of Nuestra Señora de la Merced y Santa Tecla in Xàtiva (Valencia, Spain), was originally made up of more scenes, but now consists of only five (Fig. 6). The state of conservation was very bad. The pictorial layers showed an accumulation of diverse, non-original strata: dirt, varnish layers, overpaints, fillers, adhesive residues, etc. The overpaints on the Virgin's face in the main scene, applied during previous restoration processes in order to compensate for large losses, are particularly noteworthy.

During the initial study, eight samples were removed, three of them from the central image. The analytical methods carried out were SEM-EDX, universal attenuated-total reflectance-Fourier transform infrared spectroscopy (UATR-FTIR), GC-MS, and cross-section staining tests. The analyses were carried out by the Instituto Universitario de Restauración del Patrimonio and the Electron Microscopy Service of the UPV, and by Arte-Lab S.L.

The results obtained were as follows: the binding medium of the paint was identified as a drying oil and some pigments were also identified (azurite, lead white, lead-tin yellow, iron oxides, and verdigris). The ground layers are made up of calcium sulphate with animal glue as the binding medium, applied onto a layer of fabric glued to the coniferous wood support. On the ground, there is a lead white priming layer. The frame, which encloses and separates the central image from the other four, shows a non-original decoration in white paint bound in animal glue and metallic leaf that simulates gold leaf.

Using UV illumination, it was possible to obtain information regarding the uppermost layers, especially the great amount of overpaint that covered a large area of the original surface and the presence of an unevenly applied varnish (Fig. 7). However, on the whole, few data were obtained regarding the non-original strata which had to be removed. For example, a sample was taken from the Virgin's face (Fig. 8) that should have shown an overpaint (SU 6) and a filler (SU 7), both made from beeswax. The original ground, two overpaint layers, and a surface layer are visible in the cross-section sample, but the beeswax filler is not visible although it was present in that area, as can be seen in Fig. 9.

Just as in the previous example, in the cleaning process a great number of SU, which were not visible in the cross-sections, were recorded. However, one of the strata that can be seen in cross-section, specifically layer two (a barium white overpaint), was not recorded as an SU in the recording sheets during cleaning. Perhaps it was removed together with the top stratum (SU 6). This example illustrates how cross-sections provide data which could go unnoticed during the cleaning process.

Details of the cleaning process can be seen in Fig. 10, including removal of an overpaint layer (SU 6) and a beeswax filler (SU 7). With the removal of the overpaints and fillers, the negative SU 11 (a large lacuna in the Virgin's face) can be seen. In the stratigraphic diagram that corresponds to the main scene (Fig. 11), the negative SU (SU 11 and 12) are shown, including the burns (SU 14) that had motivated some of the interventions with overpaints. The transformational unit (TU 1) is also included, a severe crack that affects the wooden support, the layer of fabric and the original and non-original pictorial layers. This unit is not negative because it is not a loss; instead, it is the result of the transformation suffered by previous units.

As with the *St. Matthias and St. Philip* example, the information gathered during the cleaning process enabled a reconstruction of the different phases that modified the work's original appearance. In Fig. 11, a division of the SU has been carried out, according to the chronology of events. Phase I corresponds to an old process of restoration, where some overpaints (9 OVP) and varnish layers (8 VAR) were applied only on some areas of the painting. Phase II is one of deterioration, where burns (14 BUR) and lacunae (11 LAC) were produced. This resulted in the next restoration process (Phase III), where losses and burns were filled in with beeswax (7 FIL), which was then overpainted (also with a beeswax binding medium) (6 OVP) and a varnish was applied over the whole surface. Judging from the presence of barium white in the cross-section analysed (Fig. 8), this phase could have been carried out in the nineteenth century. During the same restoration, or a later phase, some overpaints were applied onto the varnish layer (4 OVP). Finally, phase IV corresponds to a more recent period, and shows various losses (12 LAC), a severe crack along the panel (TU 1) and the accumulation of dirt (3 DUS).

Conclusions [heading]

Cross-sections are an invaluable resource when carrying out stratigraphic studies. For example, they can provide information regarding how a painting was carried out or the alterations it incurred, as well as key data when planning processes such as cleaning. Cross-sections are irreplaceable when access to a complete stratigraphic structure is not possible and information is needed, even if it may only be partial. However, in order to record all the layers removed during cleaning, the cross-sections by themselves may not be enough, making it is necessary to resort to a more complete recording system. Tools from the field of archaeology, such as the SU recording sheet or the stratigraphic diagram, make this possible, thereby enabling more detailed information to be gathered regarding each SU as well as the relations among them. From these data, chronological sequences among many units can be established as well as a division into phases, which in turn enable hypotheses about a work's evolution to be constructed. In this way, more accurate and useful documentation can be obtained and cross-sections are related to a broader set of data regarding the SU.

It is therefore necessary for the conservator to understand that cleaning is not just the removal of non-original layers, but that it can be an extremely valuable process in order to obtain stratigraphic information, to extract data regarding non-original strata, their characteristics, their relationships and the role they may have had in the construction of the image. All these data would disappear if they were not correctly gathered during the cleaning process, and consequently a unique opportunity for learning about the work's history would be lost.

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Captions for figures

Figure 1 Overall view of the panel painting *St. Matthias and St. Philip*. Sites marked SL indicate the location where cross-sections were taken. Sites marked D are where samples of strata were removed with solvents.

Figure 2 Partial diagram for *St. Matthias and St. Philip*, that shows the original (green) and non-original (blue) strata. The negative units (losses) are not included. Strata reported includes ground (GRO), priming (IMP), gold leaf (GILD), original paint layer (OPL), filler (FIL), overpaint (OVP), varnish (VAR), and dust (DUS).

Figure 3 Detail of the cleaning.

Figure 4 Overall view of *St. Matthias and St. Philip*, after treatment. A black strip that had been covered by many overpaints can be seen at the top.

Figure 5 Partial diagram (with the Phases ordered chronologically) showing the non-original strata covering the upper part of the painting.

Figure 6 *The Immaculate Conception*, attributed to Gaspar Requena, second half of the sixteenth century, oil on panel, 117 x 144 cm. Before treatment (left) and after treatment (right).

Figure 7 UV-induced visible fluorescence detail image of *The Immaculate Conception*.

Figure 8 Sample taken from the Virgin's face. Light microscopic image under white (A) and UV (B) light: (1) ground (three layers visible in cross-section image), (2) overpaint, (3) overpaint, and (4) wax and a small amount of drying oil.

Figure 9 Detail of the Virgin's face showing the location of several non-original SU and the location of the cross-section sample shown in Fig. 8.

Figure 10 Removal of some non-original layers.

Figure 11 Stratigraphic diagram for *The Immaculate Conception* that shows the positive (blue), negative (red) and transformational (orange) units. Strata abbreviations include those listed in Fig. 2 as well as original paint structure (OPS), losses (LAC), and burn (BUR).