case study

MACRO PHOTOGRAPHY FOR REFLECTANCE TRANSFORMATION IMAGING: A PRACTICAL GUIDE TO THE HIGHLIGHTS METHOD

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Macro Photography for Reflectance Transformation Imaging: A Practical Guide to the Highlights Method

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ABSTRACT

Reflectance Transformation Imaging (RTI) is increasingly being used for art documentation and analysis and it can be successful also for the examination of features on the order of hundreds of microns. This paper evaluates some macro scale photography methods specifically for RTI employing the Highlights method for documenting sub-millimeter details. This RTI technique consists in including one reflective sphere in the scene photographed so that the processing software can calculate for each photo the direction of the light source from its reflection on the sphere. RTI documentation can be performed also with an RTI dome, but the Highlights method is preferred because is more mobile and more affordable. This technique is demonstrated in the documentation of some prints ranging from the XV to the XX century from to the Ingels collection in Sweden. The images are here examined and discussed, showing the application of macro RTI for identifying features of prints.

1. Introduction

Reflectance Transformation Imaging (RTI) is used in a number of fields related to art examination and documentation [1] such as coins [2,3], Greek Attic pottery [4], ancient clay artifacts [5], rock art [6] and, most notably, the Dead Sea scrolls [7]. RTI is a computational photography technique that was first developed in 2001 [8]. It relies on the PTM (Polynomial Texture Map) method which is an image-based representation of the object's surface achieved by applying and capturing the object under lighting from different directions. In the resulting RTI model, the lighting direction can be changed interactively and enhancements can be performed to make surface details more visible [9]. RTI allows for the virtual examination of an object's surface, offering the following advantages: 1) once the RTI documentation is completed, no more manipulation of the object is required; 2) the RTI model allows for a virtual examination that can be both realistic (as a virtual raking light) and also enhanced by software elaboration to improve the observation of morphological features; and 3) there is no data loss due to shadows and specular highlights (as in conventional photography).

This paper is a practical guide to perform RTI on the macro scale, which for the purpose of this paper means that each image intends to capture an area of the order of 1 cm^2. It should be noted that RTI can be performed using an RTI dome or the Highlight RTI method (black sphere). Only the Highlight method will be illustrated in this paper since it has the advantage over the RTI dome of being more economic and mobile. This paper describes and evaluates the photographic tools needed for RTI Highlight documentation and shows some applications of the technique for prints identification on documents belonging to the Ingels Collection, Sweden.

2. Macro Photography Methods for RTI

Macro photography is extreme close-up photography in which the size of the subject on the image sensor is greater than life size. This challenging photography requires ad hoc hardware. This section aims to introduce the specific technical requirements to obtain macro photographs of areas of about 1 cm^2 that are suitable for the RTI Highlights method.

2.1. Spheres

In order to shoot RTI images on the order of 1 cm^2, a reference sphere is required to allow the RTI software to determine the direction of the incident light. Its dimension should be small enough, a diameter of less than 1 mm, in order not to cast shadow on the area of interest and to be on focus within the area itself. Indeed, macro photography has an extremely narrow depth of field. Ball bearings are usually a good option although their smallest size is of only 1 mm. Ball point pens labeled as “fine” provide spheres smaller than 1 mm that are well suited for this technique (Figure 1). Indeed, there are even ballpoint pens of less than 0,5 mm. These are called micro tip pens, and currently the smallest is the Pilot G-Tec-C with 0,25 mm. However, the handling and extraction of these small ballpoints is a daunting task and, therefore, it is not recommended.

2.2. Lighting

Macro photography requires intense lighting. It is also necessary to shoot with fast exposure to avoid registering the movements of the hand-held light source or any environmental vibrations. Flash lights are therefore the best choice, particularly in case of light-sensitive works of art. These could be either speedlights or studio strobes which both can be triggered remotely from the camera (Figure 2). RTI requires about 30 shots for each scene, so the faster recycle time between each shot and the lack of batteries are two reasons to favor the studio strobes against speedlights in order to make the overall RTI shooting process much faster. Furthermore, the speedlights can be damaged without sufficient cooling time, so one would need to avoid shooting too fast with these. There are lightweight and small studio strobes that fit the

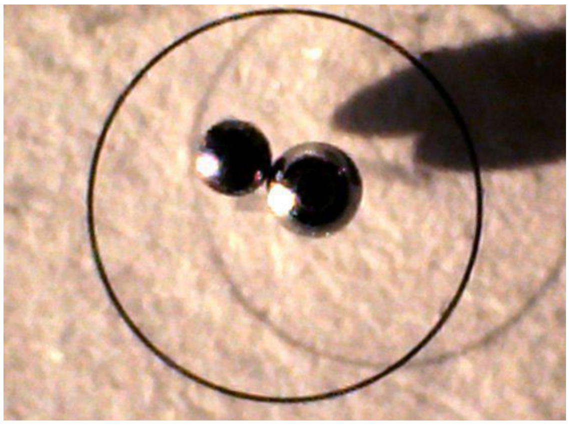

Figure 1. The image, obtained with a Veho USB microscope, compares the sphere of a papermate grip ball point pen labeled “fine” (left) and a small ball bearing of 1 mm (right).

Figure 2. Left: compact and lightweight studio strobe, 180W flash (guide number 45) and 75W modeling bulb. Right: Speedlight Nikon SB-600. This was used for the RTI documentation of the Ingels collection presented in this paper.

macro photography RTI lighting requirements. Studio strobes also feature a continuous pilot light which is useful and necessary for focusing. When using speedlights, a LED spotlight on a gooseneck is generally sufficient for focusing.

2.3. Photo Editing

When taking macro images it is likely that the camera will move on the order of hundreds of microns during the RTI shooting section. If that happens, images will not be suitable for RTI. Nevertheless, they can be still lined manually or automatically with an image editing software. In Photoshop, for example, the script “load images into stack” and checking “allow automatic alignment” can be used. Photoshop will create a file with the aligned images on levels. Then, the images can be saved automatically: FILE/SCRIPT/Export layers to file.

2.4. Camera

USB microscopes are fine for capturing macro images as they can be focused at distances of about 1,5 cm, which is sufficient to allow for the RTI lighting that is needed at different angles [9]. However, due to their low pixel count, they provide images with a resolution that is too small for the RTI Highlights method. For this reason, it is better to use a digital camera with a high pixel count such as the one used in this paper, the Nikon D800 with 36 megapixels. Indeed, with such a big sensor, it is possible to photograph a large area that encompasses both the sphere and the area of interest, even as these two are far away so that the sphere does not cast a shadow on the area of interest. Among the advantages of digital cameras over USB microscopes, is the possibility to do multispectral imaging RTI. As for further developments, most suited would be the new mirror-less cameras since the vibration of the mirror in the DSLR cameras contributes to a slight shaking of the camera.

2.5. Miscellanea

Before dealing with the section on lenses, some other photographic tools necessary for macro photography [10] are: the macro rail, a tripod, tethering and the mirror-up shooting mode. Macro rail is recommended for fine focusing since the lens focusing ring may not be sufficient to achieve the desired sharpness and some of the macro photography methods can only focus by moving the camera. The tripod must be as sturdy as possible and must allow to reverse the tube to get a more stable configuration (Figure 3). Although not mandatory, tethering the camera to a computer allows effortless checking of focus and correct lighting with the “liveview” function. Mirror-up shooting mode keeps the mirror up, as it is called in Nikon cameras, for avoiding vibration during the shooting. For Nikon cameras, a remote shutter is required to shoot in this mode when the camera is tethered to a computer.

Figure 3. Ingels Collection, Sweden. RTI set up with the camera mounted on macro rail and tripod with reversed tube.

Figure 4. Ten euro bill, the area tested with the different macro set ups is highlighted in yellow.

Figure 5. Nikon D800 with some macro set ups. From up to down: reverse ring and 20 mm lens; Otamat Macro Lens; 200 mm lens with Microscope objective adapter and 2X objective.

2.6. Lenses

In order to produce test images on a printed document that can be easily acquired for comparison, the lenses have been tested imaging one specific area of a 10 euro bill (Figure 4).

Macro photography can be performed with a number of specific lenses and tools (Figures 5 and 6). These can be grouped into 3 categories: add-ons (close-up lenses, macro extension tubes and teleconverters), adapters (microscope objective adapter, coupling ring, reverse ring) and special lenses (Otamat macro lens).

These tools have been evaluated in Table I based on properties related to the RTI imaging process:

1. Magnification tells us the ratio between the real life size of an object and the projection of that object on to the sensor. It is usually indicated as a fraction (e.g. 2:1) or a decimal fraction followed by an "X" (e.g. 2X). A magnification of 2:1 indicates that the subject is captured at double that of life size.

2. Working distance is the distance from the front of the lens to the object, and should be long enough to allow the lighting to be moved without casting shadows on the surface.

3. Vignetting is the reduction of the image's brightness at the periphery. This term includes vignetting itself and the overall quality of the images, taking undesired internal reflections into consideration.

4. The required depth of field depends on the subject shape and roughness. In general, we can expect to want 1 mm depth of field in order to focus the surface as well as the 1 mm reference sphere.

Figure 6. From left to right: close-up lens, macro extension tube, microscope objective adapter, teleconverter, reverse ring and coupling ring.

Table I. Comparison of macro photography methods for RTI imaging.

	Magnification	Working distance	Vignetting	Depth of field
Add-ons				
Close-up lens	poor	good	good	good
Macro extension tube	poor	excellent	good	good
Teleconverter	good	excellent	poor	good
Adapters				
Microscope objective adapter	excellent	poor	good	good
Coupling ring	excellent	good	poor	good
Reverse ring	good	good	good	good
Special lenses				
Otamat macro lens 2X	good	good	good	poor

1. Close-up lenses

These are the cheapest solution for macro photography. They are mounted on a telephoto lens (about 85 mm or above) and allow the lens to focus closer, thus delivering higher magnification. Close-up lenses are marked with diopter values, the higher diopter value the closer the focus and the higher the magnification. However, they provide comparatively small magnification and, therefore, are not the best choice for macro RTI.

2. Macro Extension tube

These come in different lengths, and a longer length (generally no more than 49 mm) brings higher magnification. They must be used with a good quality fixed focal length lens, and work better with lenses that have a simple, symmetrical design such as a 50 mm lens. Extension tubes have no optical elements and they just move the lens further from the image plane allowing closer focusing and consequently greater magnification.

As a simple principle, the longer the focal length of the lens, the lower the amount of magnification given by a specific extension tube. Therefore, they are used with lenses with a focal length of less than 85 mm. The 49 mm extension tube and the 50 mm lens have a working distance of 5 cm (Figure 7).

3. Teleconverter

Teleconverters are mounted between the camera and the lens and multiply the focal length of the lens, delivering higher magnification. The advantage is that they retain the working distance of the lens, which is useful for RTI lighting since the camera can be kept far enough from the object. The Nikon TC 200 used in this paper is a 2X teleconverter. Mounted on the 300 mm lens makes it a 600 mm lens (Figure 8). Teleconverters must be coupled with high quality lenses since they will magnify any issue of the lens.

4. Microscope objective adapter

This adapter has a standard RMS thread for standard microscope objectives and it must be

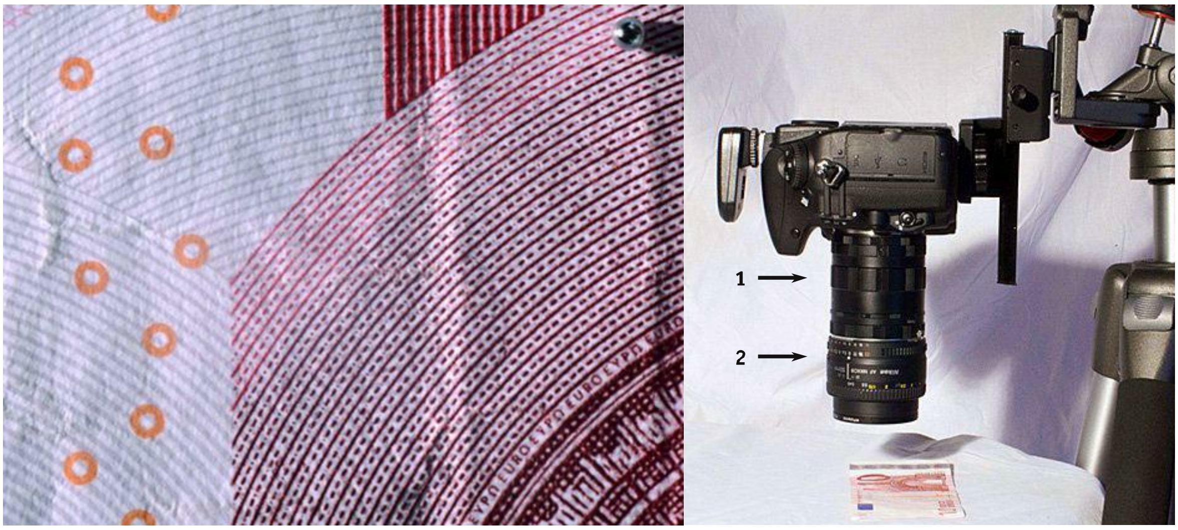

Figure 7. Detail of a 10 euro bill (left) and photographic set up (right) with macro extension tube 49 mm (1) and 50 mm (2)lens.

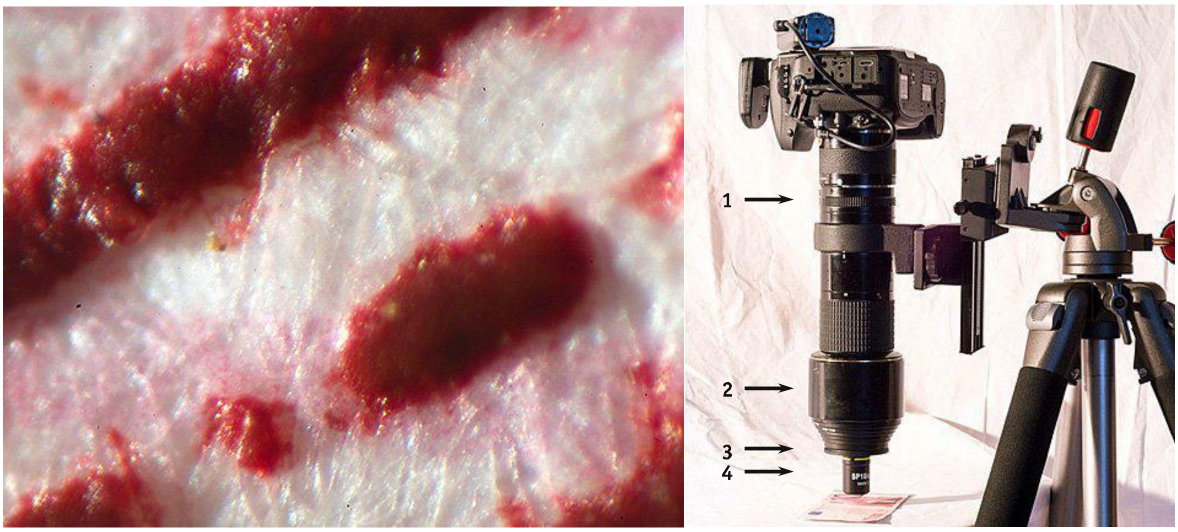

Figure 8. Macro detail of the 10 euro bill (left) and set up (right) with teleconverter 2X (1), 300 mm lens (2), microscope objective adapter (3) and 10X objective (4).

screwed on a telephoto lens (as a 200 mm or 300 mm lens). The adapter was tested with a 2X microscope objective. Conveniently, the telephoto lens can be stopped down for sufficient depth of field comprising both the surface and the sphere, though vignetting is evident at aperture higher than F8 for the 200 mm lens and F4.5 for the 300 mm lens. Even if the working distance is around 2,5 cm, this system is a good candidate for RTI since the diameter of the 2X objective is just about 1 cm and so there is freedom of movement for the lighting and a shadow is not cast on the photo area (Figure 9).

Not related to RTI but useful to mention is that excellent quality micro images can be taken with higher magnification microscope objectives, such as a 10X with a teleconverter mounted on a 300 mm lens. The working distance is about 1 cm and still allows for sufficient lighting (Figure 8).

5. Coupling ring

A coupling ring allows two lenses to be stacked. The magnification is given by the focal length of the lens attached to the camera divided by the focal length of the reversed and coupled lens. To get a magnification similar to that shown for the other methods, a 50 mm lens was stacked on a 200 mm lens. The working distance is about 4,5 cm, magnification and depth of field are excellent but internal reflections and shallow focus impairing the edges demand for cropping the images (Figure 10).

6. Reverse Ring

A reverse ring is plugged onto a wide angle lens. With a 20 mm lens, the working distance is about 4,5 cm (Figure 11). Even if the magnification is not as much as with other tools, this method is preferred since it is lightweight which means less vibration. Its simplicity also delivers very sharp images.

7. Otamat macro lens 2x

This is a very fast lens for macro photography and its 20 mm working distance combined with its small diameter makes the lighting easy. But since the lens has a wide fixed aperture, it has shallow depth of field which makes it not useful for RTI since the 1 mm sphere is out of focus (Figure 12).

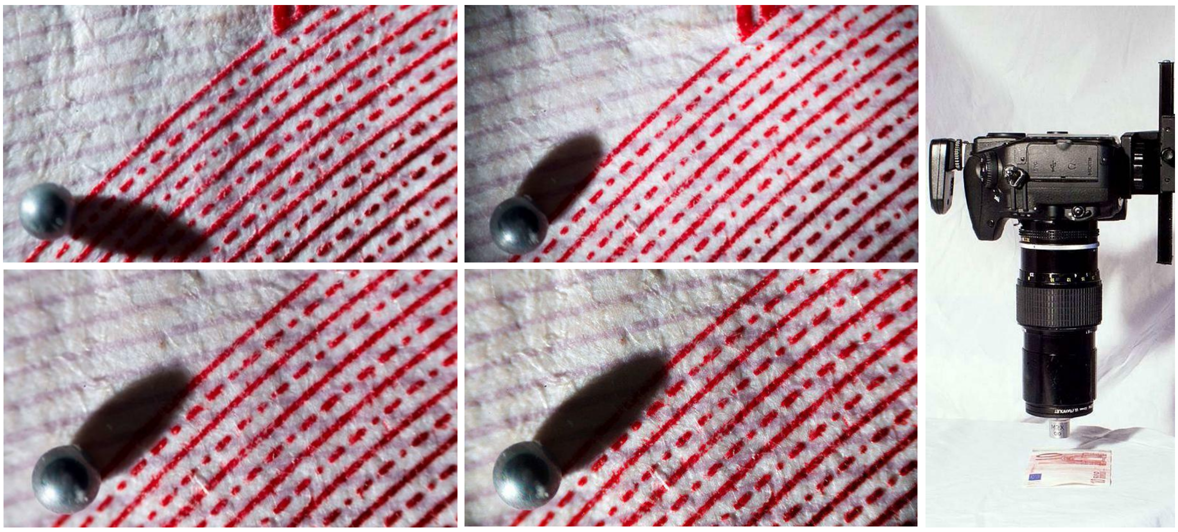

Figure 9. Up to down, left to right: 200mm lens/f8, the sphere is out of focus; 200mm lens/f16, sphere and paper are in focus but vignetting is showing; 300mm lens/f4.5, sphere and paper are in focus without vignetting; 300mm lens/f5.6, sphere and paper are in focus but vignetting is showing. Far right: set up with 200 mm lens, microscope objective adapter and 2X objective.

Figure 10. Macro detail of the 10 euro bill (left) and set up (right) with 200 mm lens (1), coupling ring (2) and 50 mm lens.

Figure 11. Macro detail of the 10 euro bill (left) and set up (right) with 200 mm lens (1) and reverse ring (2).

Figure 12. Macro detail of the 10 euro bill (left) and set up (right) with Otamat 2X lens.

3. Ingels Collection

The Ingels Collection in Stockholm, Sweden, is a private collection comprised of mainly old manuscripts, early printed books, and ancient Egyptian artifacts. The collection was compiled between 1948 and 1986 by John Ingels during extensive travelling in Asia, Africa, Middle East and Europe. He created a collection that has been exhibited many times in his native town of Leksand, Sweden.

Low resolution RTI with close up photography was required to document two coins of the collection. In this case, a 200 mm lens with a 49 mm macro extension tube was used (Figure 13). The working distance was 1,2 m and the area imaged is about 10 cm wide. A 15 mm diameter marble black ball was used as the reference sphere. On the other hand, macro RTI was specifically necessary to determine the printing technique of some selected documents of the collection which thanks to observations made possible by the RTI method could be categorized according to their typology: woodcuts, etching, engraving and blockprints.

Macro RTI was performed on some of the collection's prints, using a reverse ring coupled with a 20 mm lens, with the Nikon D800 camera and Nikon SB-600 speedlights. The tiny features of the prints can be appreciated only on the smallest scale of about 1 cm wide photos. There are a number of references which explain how to identify prints using macro observation [11-15].

3.1. Woodcuts

1493, Nuremberg Chronicle
The Ingels collection boasts a folio of the Nuremberg Chronicle dated 1493 and printed by Anton Koberger, with a leaf size of 465 x 325 mm. The RTI image enhances the visualization of the rough textile fibers [15] which make up this folio (Figure 14). The lines of the face in the photographed figure show the characteristics of wood

Figure 13. Chinese coins of northern Sung Dynasty 960-1127 A.D, photo taken with a 49 mm macro extension tube and 200 mm lens, working distance 1.2 m, black reference sphere diameter 15mm.

Figure 14. Nuremberg Chronicle, dated 1493. Macro RTI enhances the fibrous appearance of the rags paper.

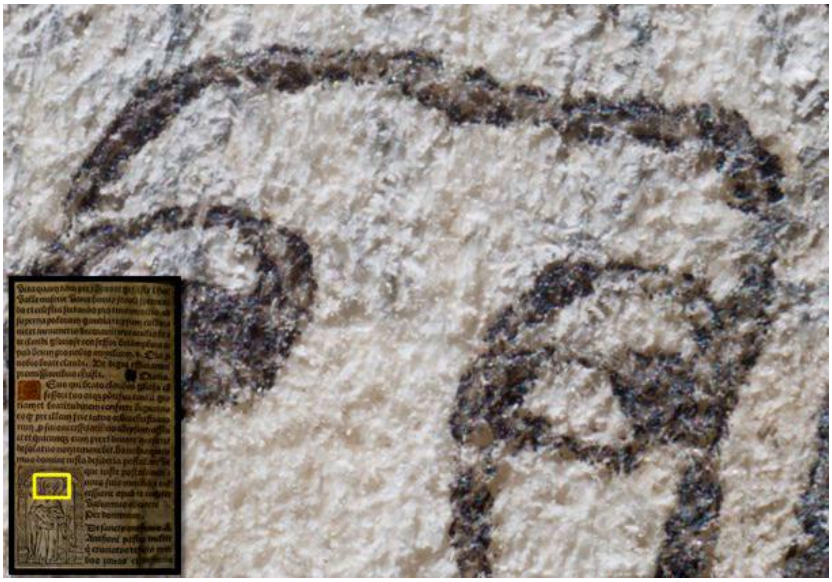

Figure 15. Book of Hours, dated 1498. Macro photo, edge rims characteristic of woodcuts relief printing are evident such as the lack of textile fibers in the parchment.

Figure 16. Arch of Triumph, 1517. Macro photo. Even if made with a much more refined technique, the lines show no regularity of width or direction, revealing this print as a woodcut.

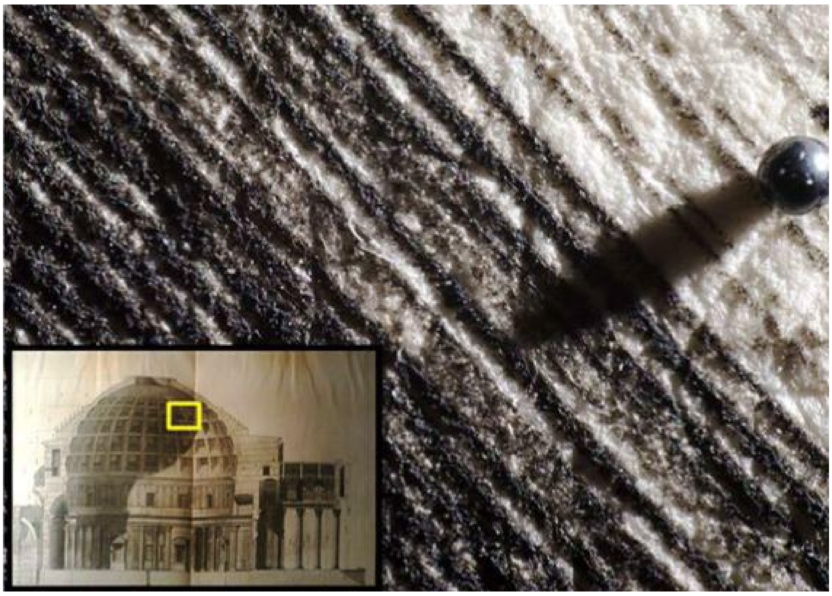

Figure 17. Pantheon in Rome, 1786. Etching shows its characteristics: raised ink and varying intensity of the lines.

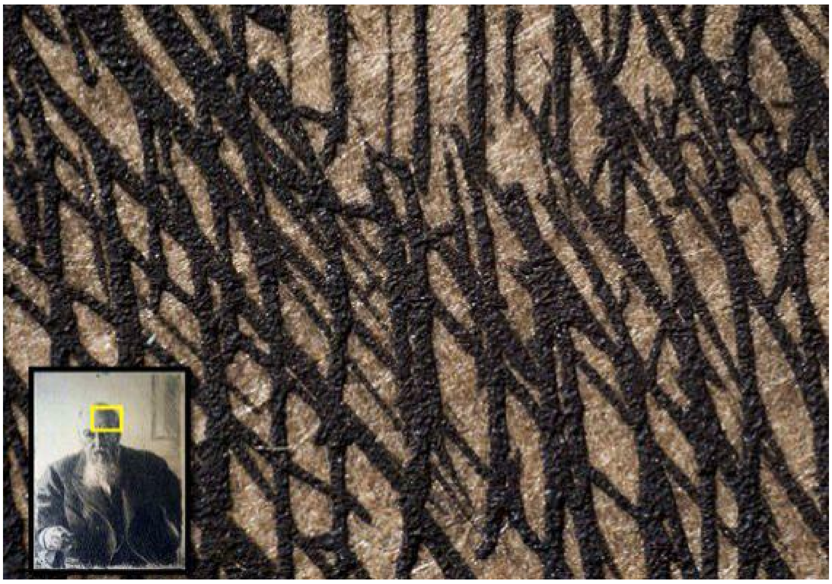

Figure 18. Portrait of C. G. Liljevalch, 1909. Macro RTI photo. Engraving showing its characteristics: raised ink, tapering and swelling lines.

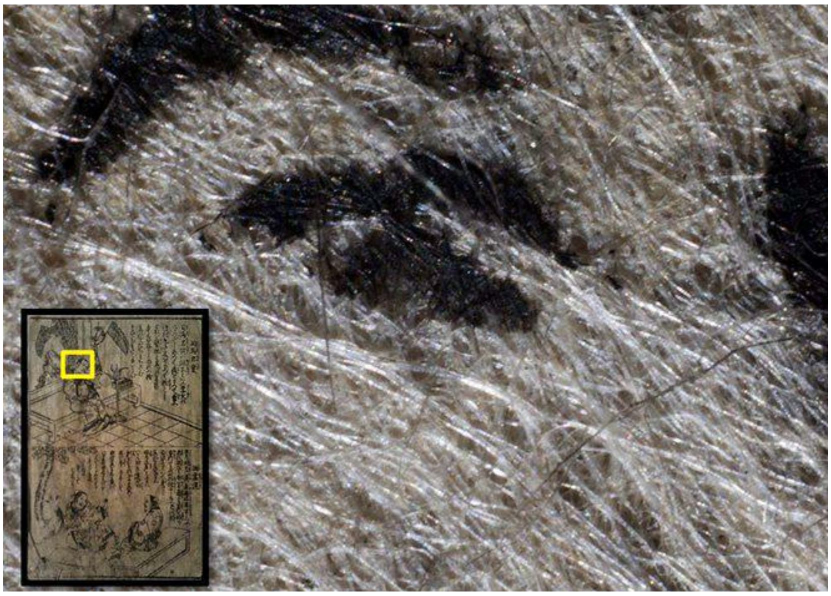

Figure 19. Macro RTI image of a Japanese blockprint, 1828. The rice paper texture is evident.

Figure 20. Macro RTI image of Three Lamas, Tibetan blockprint, XIX century. The rice paper texture is evident.

engraving: a lack of sophistication and the stark contrast between the white background and the black lines. The heavy and uneven black frame of the images is characteristic of early wood engravings.

1498, Book of Hours

This Book of Hours was printed in Paris by Etienne Jehannot in 1498 on parchment, leaf size 155 x 95 mm. Macro photography shows the characteristic feature of woodcut relief printing, i.e. edge rims (Figure 15). On the wooden relief block the non-printing areas are cut away and the ink is applied to the remaining raised areas. Then, laying a sheet of paper and applying pressure, the ink is transferred. This process produces a characteristic rim on the edges of the printed lines. Relief woodcuts were firmly locked in position to the printer's type to print illustrated text.

1517, The Arch of Triumph

This Arch of Triumph woodcut is dated 1517 and it is an original work of Albrecht Dürer. He showed that much more could be achieved with woodcuts compared to the early works (Figure 16), as the Book of Hours and the Nuremberg Chronicle. Indeed, Dürer's fineness and density of line as well as its subtlety, is beyond anything done before him. The skills of Dürer make the print look as a drawing from a distance but looking closer the lack of width and direction regularity are signs of the woodcut.

3.2. Etching

1786, Pantheon in Rome

Intaglio, which means incising in Italian, is a technique developed in the 1500s. There are two techniques to cut the lines of an intaglio print, engraving and etching. On the contrary to relief, the ink is held in grooves on the intaglio block's surface. The main characteristic of this technique is to show lines with varying ink intensity, while in relief the intensity of the ink is always the same. The depth of the groove can be adjusted, varying the amount of ink collected in it, and this translates in darker or paler printed lines. In strong, dark lines the ink rises up from the paper considerably. This etching of the Pantheon was printed by Francesco Piranesi in 1786 (Figure 17).

3.3. Engraving

1909, Portrait of C. G. Liljevalch
This is an example of engraving dated 1909 by Anders Zorn representing C. G. Liljevalch, a Swedish businessman. Zorn was one of Sweden's foremost artists. Engraving uses a burin with sharp V-shaped cutting section which is pressed gradually down onto the surface of a copper plate and then driven more or less deeply through the metal. At the end of the line, it will then be raised up to lift out a sliver of copper. Consequently, engraving lines have clean edges, tend to be pointed at each end, and either tend to swell or diminish during their length. All these characteristics are evident in this print (Figure 18).

3.4. Asian prints

XIX century blockprints
Two Asian blockprints, dated XIX century, were examined, a Japanese and a Tibetan one. The Japanese hand book for home Shintoism practices was published in Tokyo in 1828 by Moriya Jihei. Blockprints are a variation of woodcuts and their lines share the same characteristics: more arbitrary variations in width than in other types of prints.The interesting feature in these Asian blockprints is the rice paper texture evident in their macro RTI photos (Figures 19 and 20).

4. Conclusions

In this article, the potential of macro RTI was shown in the identification of the printing technique in several documents from the Ingels collection: woodcuts, etching and engraving. Their main characterizing features can be noticed thanks to the combination of the RTI method with macro photography. Indeed, the magnified image is useful for the observation of planar features such as the rim on the edges of the relief lines or the clean, swelling and tapered edges of the engraving lines. On the other hand, RTI is necessary to document the raised ink lines of engraving and etching printing and the texture of the paper.

As demonstrated, macro RTI can be successfully performed with the highlights method using sub-millimeter spheres readily available in fine ball point pens. As for the macro photography equipment, there are a number of methods that can be used. The choice depends on the goals of the specific RTI documentation, on the magnification needed as well as on the actual available photographic equipment. It is recommended the reverse ring and 20 mm lens set up since it provides enough magnification, at least for prints examination, with the simplest and lightweight accessories. Though, macro RTI can be used for the examination of artifacts other than prints, whenever the width and height of the morphologic features to be documented are in the order of few hundreds of microns such as tiny incisions in paintings, often applied for sketching figures or architectural details or to document and study tool marks or incisions on objects left by the manufacturing processes or due to their actual use.

5. Acknowledgments
This work was only possible thanks to the generous support of the Ingels Collection, Sweden, which made the materials available for the study and funded the research.

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