# Photographic Survey Techniques for Epigraphic Work: The Experience of the TT110 ERFS Project

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## Abstract

Commencing in the autumn of 2017, the Theban Tomb 110 Epigraphy and Research Field School (ERFS) Project initiated a photographic survey component to shed new light on ancient inscriptions and broaden the application of photographic surveys in educational contexts. Over three field seasons, this extensive program has yielded a structured and pragmatic surveying methodology that exemplifies the seamless integration of advanced surveying techniques in archaeological work, effectively merging conventional epigraphy with contemporary technology. Beyond its research contributions, the TT110 project provided invaluable training opportunities for Egyptian archaeologists. It served as a tangible example of harmoniously merging classical epigraphy with emerging technologies, highlighting the vast potential for documenting, conserving, and safeguarding Egypt's historical heritage. This collaborative initiative underscores the paramount significance of interdisciplinary knowledge exchange within the realm of Egyptology.

*Keywords*: Theban Tomb, photogrammetry, RTI, multispectral photography, photographic survey, epigraphy
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ابتداء من خريف عام 2017، بدأ مشروع مقبرة طيبة 110 مدرسة للبحوث و دراسة النقوش الكتابية للمقبرة (ERFS) مكونا للمسح الفوتوغرافي لإلقاء ضوء جديد على النقوش القديمة وتوسيع تطبيق المسوحات الفوتوغرافية في السياقات التعليمية. على مدى ثلاثة مواسم ميدانية، أسفر هذا البرنامج المكثف عن منهجية مسح منظمة وعملية تجسد التكامل السلس لتقنيات المسح المتقدمة في العمل الأثري، ودمج النقوش التقليدية بشكل فعال مع التكنولوجيا المعاصرة. بالإضافة إلى مساهماته البحثية، قدم مشروع TT110 فرصا تدريبية لا تقدر بثمن لعلماء الآثار المصريين. كان بمثابة مثال ملموس على دمج النقوش الكلاسيكية بشكل متناغم مع التقنيات الناشئة، مما يسلط الضوء على الإمكانات الهائلة لتوثيق التراث التاريخي المصري والحفاظ عليه وحمايته. تؤكد هذه المبادرة التعاونية على الأهمية القصوى لتبادل المعرفة متعدد التخصصات في مجال علم المصريات.

الكلمات المفتاحية: مقبرة طيبة، المسح التصويري، RTI، التصوير متعدد الأطياف، مسح فوتوغرافي للنقوش

## 1. Introduction

Our knowledge of historical heritage depends on our ability to read, interpret, and analyze the artifacts passed down to us through history. Techniques that allow researchers to better understand historical remains have been constantly developing hand in hand with technology. In the last twenty years, surveying technologies have developed at an unprecedented speed, as illustrated by the enormous impact that digital photography has had within the archaeology field generally, and Egyptology more recently, which consequently has led to the introduction of techniques such as photogrammetry, computational photography (RTI), and multispectral photography (ultraviolet, infrared). Testing the suitability of various surveying techniques is essential in archaeological research. Each method comes with its own set of capabilities and constraints, and comprehending how they function within different contexts is vital for attaining precise and insightful outcomes. By subjecting these surveying techniques to thorough testing and evaluation, researchers can ascertain the most suitable approach or combination of approaches tailored to their research objectives and the unique attributes of the site or objects being studied. This empirical methodology guarantees the efficient allocation of resources and ensures that the selected methods produce the most informative results.

For example, photogrammetry is highly effective in capturing detailed 3D models of complex structures, making it an invaluable tool for recording the architectural features of ancient sites. However, its utility may be limited in situations where precise surface details or material identification is required. Computational photography, such as Reflectance Transformation Imaging (RTI), offers unparalleled capabilities in examining surface details and enhancing the readability of inscriptions by digitally manipulating lighting angles. This technique can provide insights into the subtle nuances of ancient texts that may be difficult to discern with the naked eye alone. Multispectral photography, encompassing ultraviolet (UV) and infrared (IR) imaging, has the potential to reveal hidden details and assist in the identification of materials used in the construction and decoration of archaeological artifacts. However, it may necessitate specialized equipment and expertise to effectively capture and interpret the data.

## 2. Tomb and Field School Background

Theban Tomb 110 is a mid-18th Dynasty T-shaped tomb located on the west bank of Luxor/Thebes at the northern lower end of the hill of Sheikh Abd el-Qurna, though it could also be seen as located on the southern slope of the el-Chocha hillside (Figure 1).[1] This area of the necropolis was first significantly developed for burial by ancient Egyptian officials during the reign of Hatshepsut, both because her own funerary temple of Deir el-Bahari is located in the cliff bay just to the north, and because the festival processional routes pass by this area of the necropolis. It is thus the perfect location for TT 110, whose owner, Djehuty, was a member of the king's palace and civil elite, serving as a royal butler (*wbꜣ (n) nswt*) under Hatshepsut and promoted to the role of royal herald (*wḥm (n) nswt*) by Thutmose III. TT 110 is relatively typical, if small, for tombs of this period: it faces east toward the cultivation and is T-shaped, with the addition of a pillared hall at the rear where the burial shaft is located (Figure 2; Kampp 1996: type VIa; Porter and Moss 1960: 220). In the early 1900s, Norman de Garis Davies recorded what he could, publishing his results in a short article along with several line drawings and photographs (Davies 1932). At that time, the courtyard and original entrance were buried under the hillside, the pillared hall was filled with debris, and the tomb itself entirely blackened from historic use. Despite this, Davies was able to determine with some accuracy the basic layout of the tomb's decoration.

[1] Kampp (1996: 390–392) places it quite clearly in Khokha (Plan IV), while in Porter and Moss (1960: 227-228) it is listed as being in Sheikh Abd el-Qurna, but placed on maps IV (Khokha/Asasif) and V (Qurna North).

**FIGURE 1:** View toward the west of the area of Theban Tomb 110. The tomb is located in the center, below the curving stone wall. Photo by J.J. Shirley.

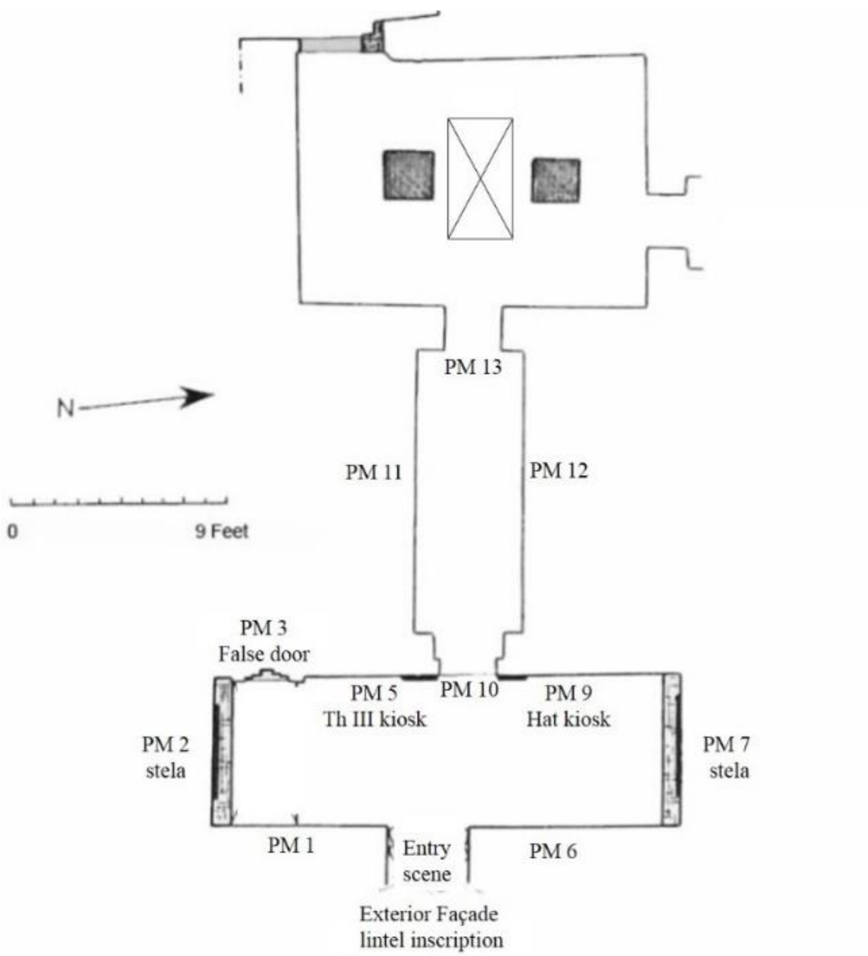


**FIGURE 2:** Plan of Theban Tomb 110 with Porter & Moss numbering of wall scenes noted. Plan after ARCE.

Theban Tomb (TT) 110 has been the subject of ongoing studies sponsored by the American Research Center in Egypt (ARCE) since 2012. From 2012 to 2016, ARCE, with the support of the United States Agency for International Development (USAID), excavated and conserved the tomb as part of ARCE-sponsored and

Egyptian-led field schools for Ministry of Tourism and Antiquities (MoTA) officials. The ARCE project also excavated the courtyard of TT110 and rediscovered the original entrance (Bednarski 2013).[2] The Epigraphy and Research Field School, directed by J.J. Shirley since 2014, has utilized TT110 as a training ground for teaching recording and research methodologies of tomb scenes and inscriptions to MoTA officials. Since 2014, the field school has been financed through the generous support of ARCE via Antiquities Endowment Fund (AEF) grants made possible by USAID funding. Between 2014 and 2022, the field school provided three different groups of MoTA students from Upper Egypt with introductory and advanced level training in the following areas: traditional and digital epigraphy, photographic planning and documentation of the tomb's scenes and inscriptions; archaeological illustration; research methodology; and academic publication and presentation (Shirley and Schenck 2017; Shirley 2020; Shirley 2023b).[3]

In addition to the field school training, TT110 project photographer Marco Repole, in collaboration with Chicago House photographers Hilary McDonald and Owen Murray, provided the students with several days of instruction on a process of digital photography that could be used to create photographs that would be suitable for epigraphic drawing. This involved each student taking multiple digital photographs in the tomb with whatever camera or phone camera was available to them, running the photographs through a program called AGISOFT METASHAPE, and creating a 3D model. The 3D model could then be flattened into a high-resolution rectified image without distortion that would be suitable for undertaking digital epigraphy. These photographic skills were particularly important to teach our students for two reasons. The first is that by learning this method they gained the tools and knowledge to undertake a professional photographic recording of a monument that can be used to create accurate digital drawings. Secondly, the accessibility of this method for our Egyptian students—the ability to use virtually any type of camera and the free access software—means that they can accomplish this type of work long after the field school ended, for whatever project on which they were working.

A major goal of the Field School project was to completely record every scene and inscription preserved in TT110 both epigraphically and photographically. Due to the extensive blackening of the tomb, several different photographic methodologies were utilized in order to accomplish this goal.

## 3. Overview of Photographic Techniques

The photographic survey techniques discussed in our introduction, along with the results they yield, are the culmination of a specific working methodology and four distinct seasons of work. At the outset of the project, we developed a methodology with four phases: analysis, measurement, processing, and rendering. Active collaboration between Mr. Repole, Dr. Shirley,

[2] See also the ARCE website: https://arce.org/project/theban-tomb-110-site-conservation-and-training/.

[3] See also the ARCE website: https://arce.org/project/theban-tomb-110-epigraphy-research-field-school/ and https://arce.org/project/tt110-publication-field-school-2021-2022/ and ARCE's Google Arts & Culture pages on the tomb: https://artsandculture.google.com/story/dgXhH3qNIGFtdQ and https://artsandculture.google.com/story/yQVxqjPTyycBw.

and the project's epigraphy instructors Mr. Will Schenck and Dr. Hassan Aglan was crucial in order to ensure that the photographic techniques employed would capture the needs of the project, in this case enhancing the readability of scenes and inscriptions, and that the results were of high enough quality for creating epigraphic facsimiles. Each season of work was characterized by the utilization of a different survey technique.

## 3.1. Survey Techniques and Approaches across Seasons

### *3.1.1. Photogrammetry: Oct./Nov. 2017 Season*

Photogrammetry is a technique for measuring the shape and position of an object from at least two different frames (stereoscopic pairs) showing the same object, which makes it possible to identify the spatial positions of all points of interest of the object in question. Although originally created for architectural surveying, and most often used in cartography, topography, and architecture, this technique is has become common in a wide variety of fields, from design to archaeology.

The goal of the first season of work was to build the 3D model of the tomb. Due to the complexity of the tomb and the restricted size of the chambers, which do not allow for appropriate shots capable of detecting all the walls, photogrammetry was determined as the best choice because this method enabled us to recreate a three-dimensional model that includes all the tomb's surfaces. One of the issues addressed at this stage related to the scarcity of appropriate lighting inside the tomb; inside, there are only a few spot-type lights, which create cones of light that overexpose part of the surfaces and underexpose the remaining ones, making it difficult to capture images properly. The solution, in this case, was to turn off the lights and proceed with shooting with very high exposure times (between 1/3 and 2 seconds). This choice had the additional benefit of ensuring natural color sampling, as opposed to using artificial lighting.

The final photogrammetric model was created using the AGISOFT METASHAPE PRO program. To simplify the software's processing work, the entire project was divided into five portions comprising the three rooms that make up the tomb and their connecting doorways, the tomb's connection to the outdoors, and the exterior courtyard. After each portion had been processed, they were all reassembled into a single model using a combination of marker and camera position. The partitioning of the work by tomb area allowed for any necessary corrections to be easily carried out and the ability to examine a single area of the model in high resolution (Figure 3).

A benefit of creating the 3D photogrammetric model is the ability to accurately render the tomb's images onto the surface (Figure 4). Although this turned out to be not of high enough quality for creating facsimile images, a benefit of this work was that drawings that had already been completed could be scanned and wrapped onto the surfaces as well, allowing us to check the drawings against the original. This greatly facilitated corrections and discussion both during the field schools and after they had ended as the work could also be done remotely.

**FIGURE 3:** View of the dense cloud of the photogrammetric model of the tomb. Image by M. Repole.

Although not directly a part of the photogrammetry work, during this season, the field school students were introduced to a means of producing high-resolution rectified images that could be utilized for epigraphic purposes. This training module was integrated into the field school's program to ensure that students become familiar with the techniques through an epigraphic lens and to allow them to perform an accurate survey of the surfaces to be analyzed. This module covered the basics of photography, photogrammetry, and image processing software. In addition to Mr. Marco Repole, Ms. Hilary McDonald, a photographer, archaeologist, and project coordinator with extensive experience in archaeological documentation, and Mr. Owen Murray, a photographer specializing in cultural heritage photography and photogrammetry, were brought in to teach these concepts.

The teaching sessions were structured into two main modules. The first module, conducted in the field, aimed to impart the basic principles of photography and the workflow essential for successful photogrammetric modeling. Starting with a small object, students were introduced to fundamental photography concepts in spatial context and image triangulation. Students then applied these principles to a section of the tomb wall (Figure 5). The second phase took place in the classroom, where students processed the photographic relief captured in the tomb and learned the procedures involved in creating an accurate reproduction of elements such as decorated surfaces (Figure 6). The final results of the students' endeavors underscored the significance of assimilating basic surveying and photography concepts, not only for technical professionals but also as increasingly essential skills in the evolving landscape of archaeological technology.

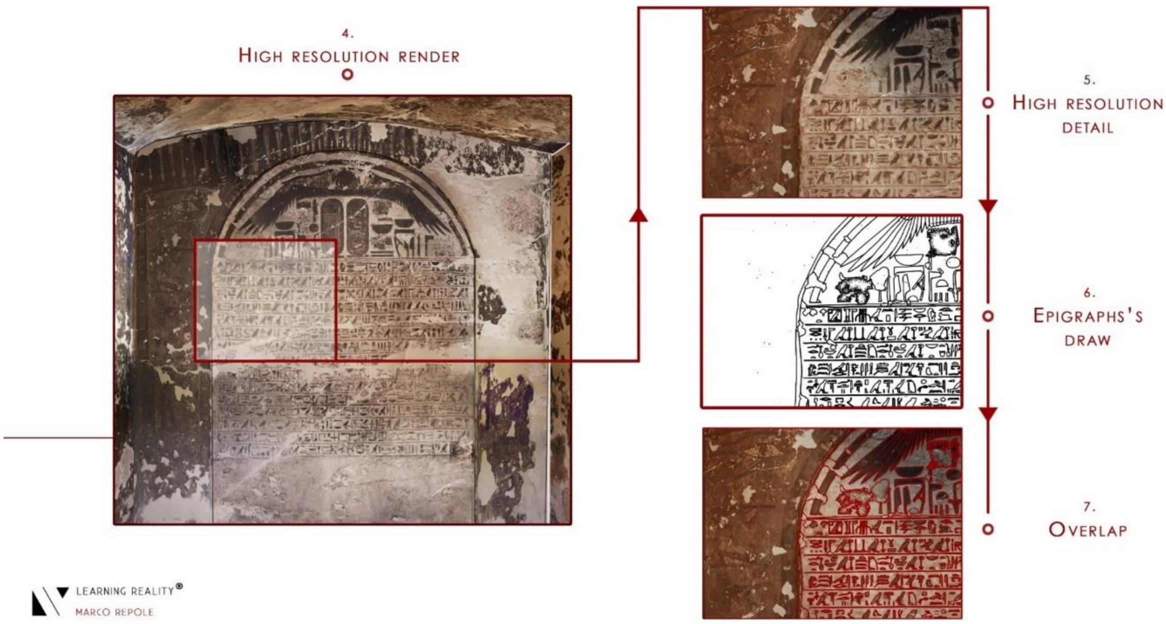


**FIGURE 4:** Example of the use of a photogrammetric image for epigraphy purposes. Image by M. Repole.

**FIGURE 5:** Mr. Marco Repole with one of the field school students inside TT110. Photo by J.J. Shirley.

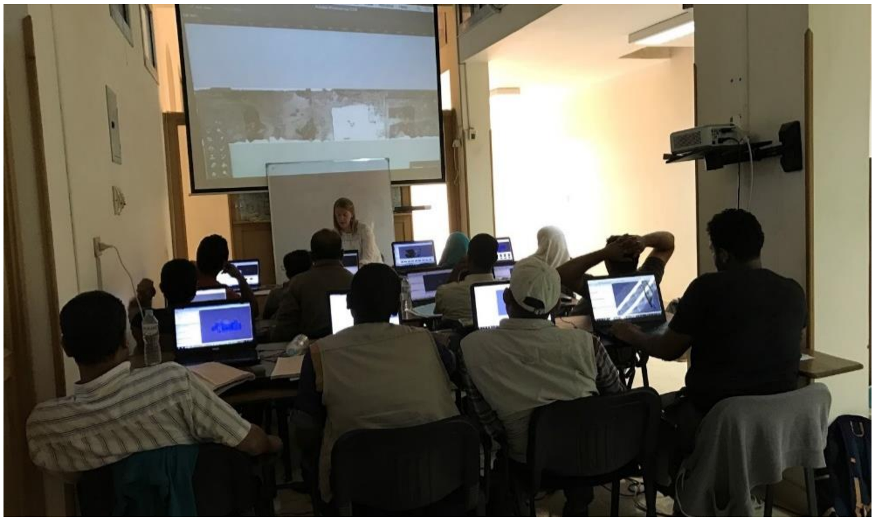

**FIGURE 6:** Ms. Hilary McDonald teaching the use of the AGISOFT METASHAPE PRO to field school students. Photo by J.J. Shirley.

### *3.1.2. RTI: Oct./Nov. 2018 Season*

In this season, having drafted the complete model of the tomb, we proceeded with the detailed survey of each inscription. There are a variety of techniques that provide detailed analysis of deteriorated or partially covered surfaces, although not all of them can be used in an environment such as a tomb. Reflection Transform Imaging (RTI) met all of our practical requirements. RTI is a computational photographic technique that captures the shape and color of a surface and enables the reillumination of objects from any direction. The tools needed for this method are all easily transportable and space-saving materials, namely, a high-definition camera, a very stable tripod, and a sufficiently powerful light source (flash or spotlights).

Starting from a series of photos taken with a fixed camera under different lighting conditions, the software processes the acquired data using a view-dependant reflectance per pixel function and allows new images to be generated using light from all directions in the hemisphere around the camera. The way light interacts with objects is very important in this field, as the physical properties of materials and their reaction with the angle of the applied light can provide important information for the study of painted or engraved surfaces (Figure 7). By exploiting the different reflectance of materials, this technique makes it possible to identify lighting conditions in which portions of the painting appear to be more visible than others. In the case of the painted surfaces of the tomb under review, the optimal framing, given the limited space for maneuvering, turned out to be a rectangle of about 40×30 cm; this resulted in all surfaces being divided into rectangles of that size. This schematization was facilitated and made possible thanks to the orthophotos (axonometric images exported from the 3D model) of the perspective drawings obtained from the photogrammetric model, which ultimately resulted in a map of the various RTI. By the end of the season, almost all of the surfaces with inscriptions in the tomb had been surveyed through this technique, for a total of about 100 different shots.

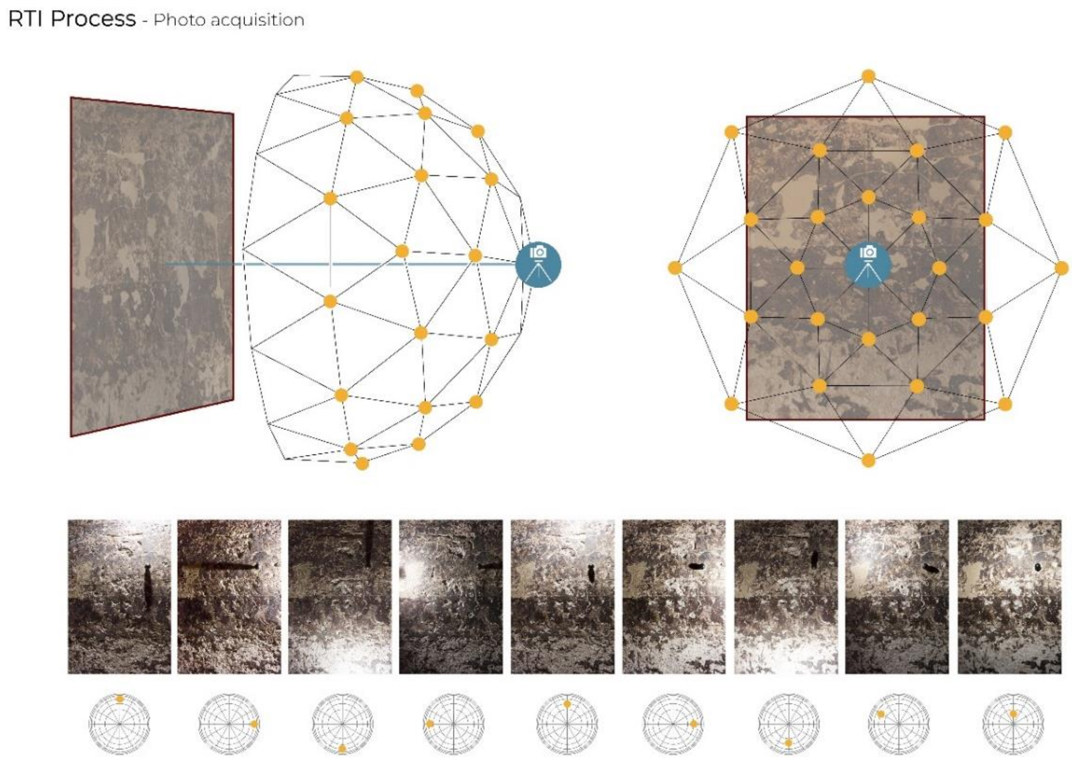


**FIGURE 7:** Light location diagram for RTI photography. Image by M. Repole.

The software employed to process the RTI images was RTI Builder and RTI Viewer, both open source and developed by CULTURAL HERITAGE IMAGING (CHI). The former allows the processing and merging of the taken images into a single file; the latter is used to read the file, allowing the simulation of image illumination in different viewing modes. Once the optimal lighting condition has been established, it is possible to export that specific image in its highest resolution (Figure 8). This technique showed excellent results in areas only lightly covered by the crust layer or with little damage, that is, where visible light interacts with the pigment. In particular, it facilitated the reading of very faint painted inscriptions in areas where little to nothing was clear to the naked eye. However, it did not achieve usable results in the most damaged or obscured parts.

### *3.1.3. Multispectral Imaging: Oct./Nov. 2021 and Feb./March 2022 Seasons*

After a long pause due to the pandemic, the main objective of the last season in the field was to complete the acquisition of the most damaged portions. We had already established that the technologies that include visible light could not provide the intended results, so the only alternative left was multispectrum analysis.

Multispectrum analysis refers to a whole range of analyses that exploit light radiations outside our visible spectrum that interact differently with matter and render visible that which is impossible to see with traditional instruments. In physics, the visible spectrum is that part of light radiation that includes all colors perceptible to the human eye. The wavelength of visible light under normal atmospheric conditions ranges from 390 nm to 700 nm. In this type of analysis, wavelengths that are below or above the aforementioned limit are employed.

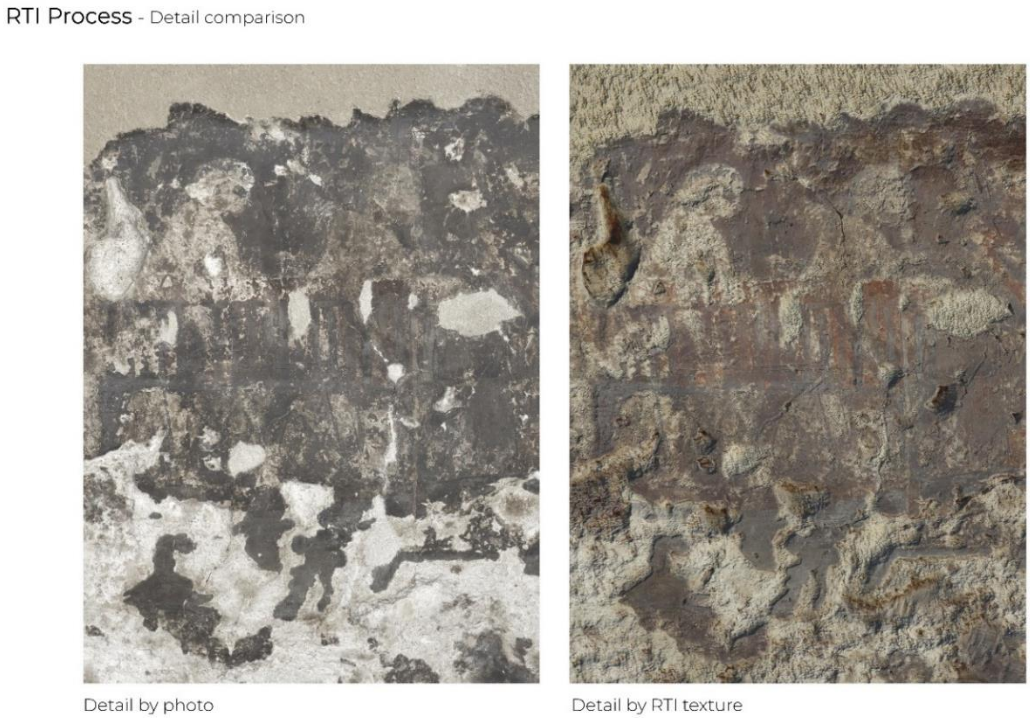


**FIGURE 8:** Differences between a normal image and one processed with RTI. Image by M. Repole.

Ultraviolet radiation (UV), which includes radiation between 300 nm and 10 nm, exists at a lower frequency than the visible spectrum. Under certain conditions and wavelengths, it can create a luminescence that can enhance the legibility of certain types of colors or organic binders, as well as enable the identification of retouched or counterfeit areas. This makes it frequently used in the analysis of pictorial pigments.

Above the visible spectrum, there is infrared (IR) radiation, which comprises wavelengths between 700 nm and 1000 nm (Figure 9). Infrared photography is a type of nondestructive survey used to detect the presence of specific pigments. Infrared reflection technology makes it possible through its particular frequency and wavelength to “see through” certain layers of paint or decay to detect sinopias, covered paints, or correction. Considering the tomb context and the necessity to enhance scenes and inscriptions still covered with a layer of soot, the best method was IR photography. IR light interacts differently with matter, particularly with some types of materials, because its wavelength is much longer than that of the visible spectrum. Normal cameras have a “cutoff” filter near the sensor which prevents the passage of the radiation outside the visible spectrum. Therefore, in order to photograph using IR technology, it is essential to remove this filter and replace it with one that allows all light to be detected (Figure 10).

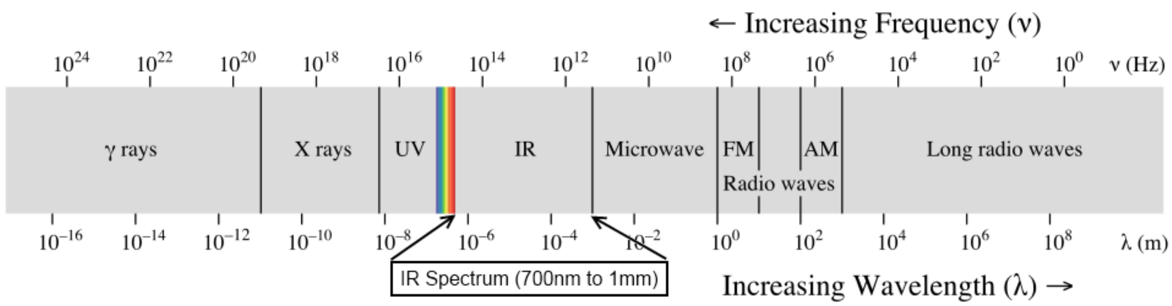


**FIGURE 9:** Electromagnetic spectrum with different divisions of infrared spectrum. Image by M. Repole.

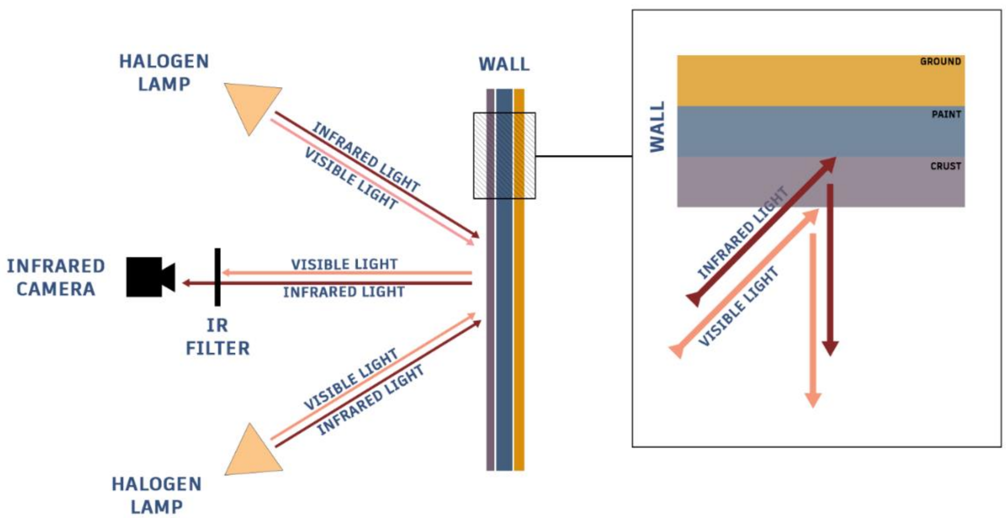


**FIGURE 10:** Infrared Photography Operational Schema. Image by M. Repole.

In order to find the best-performing exposure conditions and filters for use in TT110, some sampling was carried out in the most degraded parts of the tomb. After the sampling, it was clear that the light placed at 45° and the 850 nm filter was the combination with the most satisfying results. This obviously cannot be considered the best parameters for all scenarios, which is why the test was repeated for each one of the surfaces examined. Once the ideal conditions were identified, a systematic survey of all the surfaces was carried out, following a sequential scheme similar to that carried out for the RTI survey. Then, the walls were divided into rectangles, each corresponding to a camera shot, taking great care to always have a 30–40% overlap between all the squares, thus enabling easy reconstruction of the entire surface; this made it possible to recreate the entire surface using IR information.

For processing the IR images, the CAMERA RAW add-on of ADOBE PHOTOSHOP was used. The latter program is specifically designed for processing RAW formats, i.e., a type of uncompressed image file like JPG, which stores all metadata within it, such as lens type, shooting times, and focal lengths. Through this add-on, it is possible to edit all the images in a single group simultaneously, assigning optimal white balance, exposure, contrast, and sharpness values that are in line with each other. Via this methodology, it is possible to get a set of photos with an almost identical overall appearance. This helps greatly in the last stage of processing, which is the reconstruction of the entire surface building on each image. Orthophotos of the analyzed walls, similar to those generated by the photogrammetric model but with all the information given by IR, are obtained as a result of the whole process.

The areas that showed the best results using IR were those that still retained a significant crust layer. Using IR allowed for the painted scenes and inscriptions to be fully captured in enough detail and at a high enough resolution for digital epigraphic recording to take place. As a result, the areas for which photogrammetry or RTI was not effective were able to be recorded using the IR images (Figures 11 and 12).

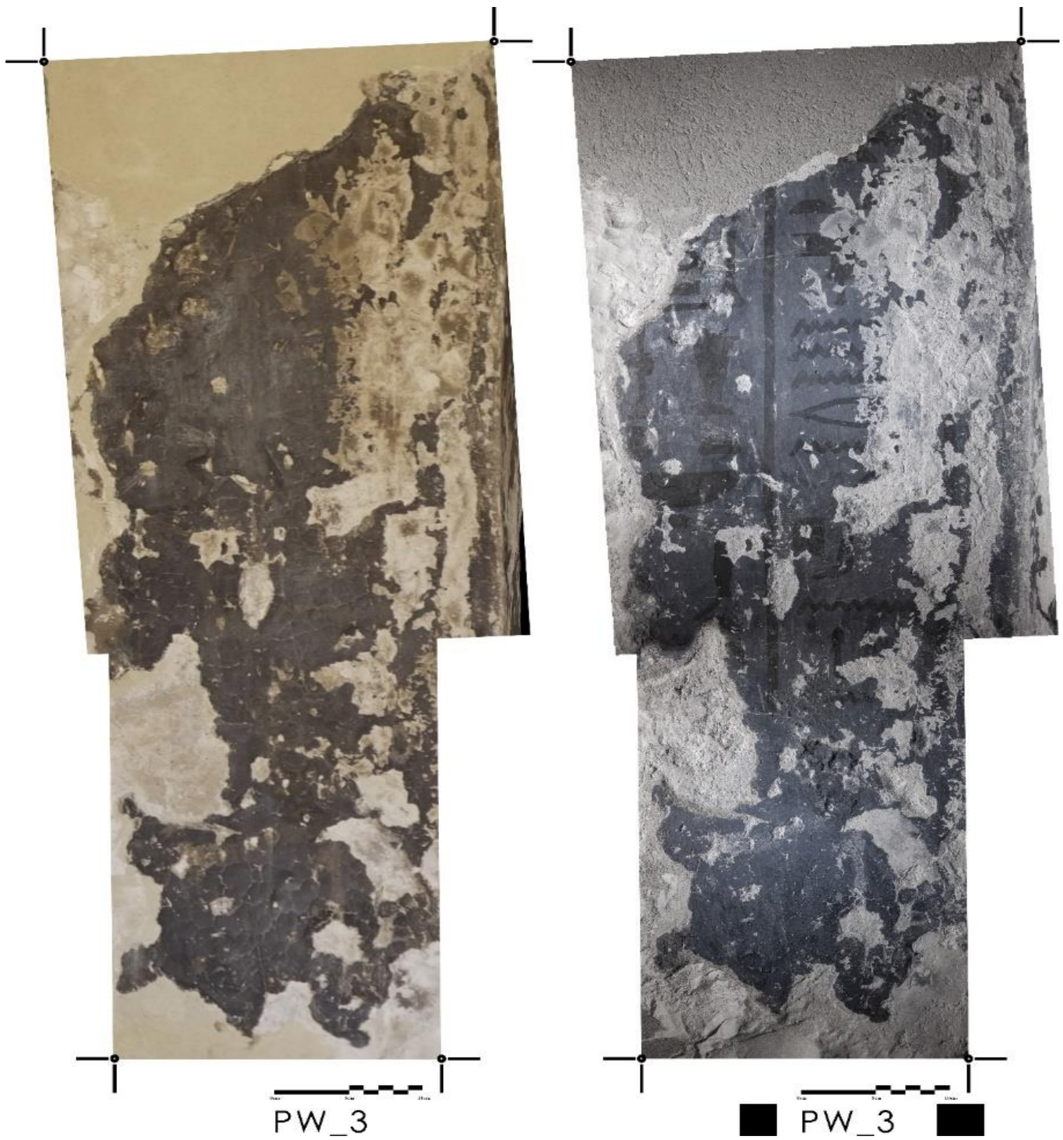


**FIGURE 11:** On the left is a regular photo, and on the right is an IR image where you can see details of a previously invisible inscription. Photos by M. Repole.

**FIGURE 12:** Differences between a normal image and an infrared (IR) one. Photos by M. Repole.

## 4. Conclusions

The TT110 ERFS Project has resulted in the first complete photographic and epigraphic documentation of the tomb, adding to our corpus of knowledge about the decoration of 18th Dynasty tombs in Thebes. By employing several different photographic survey techniques, we have been able to appropriately utilize the technologies available to obtain the best results. In addition, new ways of utilizing the various technologies have suggested themselves. The project demonstrates how the path of internationally sharing information and skills produces excellent results. It provided countless research insights and indispensable training opportunities for the students and staff who took part in the school. In addition, the ERFS project has created a functional, effective, and easily reproducible methodology that has at its core the valuable experience of classical epigraphy supported by new technologies. Students from the field school have already utilized the photogrammetry and digital epigraphy training they received on their own projects, demonstrating the usability of these methods and the accessibility of the equipment (computers, cameras, open software) required. Thus, the methodology developed through the course of the TT110 ERFS Project offers great potential for the conservation and preservation of our historical heritage.

## References

Bednarski, A. (Fall 2013). ARCE's Excavation of the Tomb of Djehuty (TT 110). ARCE Bulletin, vol. 203, pp. 1, 3–9.

Davies, N. de Garis (1932). Tehuti: Owner of Tomb 110 at Thebes. In: S. R. K. Glanville (ed.), Studies Presented to F. Ll. Griffith. London: EES, pp. 279–282.

Kampp, F. (1996). Die thebanische Nekropole: Zum Wandel des Grabgedankens von der XVIII. bis zur XX. Dynastie. 2 volumes. Theben 13. Mainz am Rhein: Philipp von Zabern.

Porter, B. and R. Moss (1960). Topographical bibliography of Ancient Egyptian hieroglyphic texts, Reliefs, and Paintings. Volume I: The Theban Necropolis, Part 1: Private Tombs. 2nd edition. Oxford: Clarendon Press.

Shirley, J.J. (2010). The Power of the Elite: The Officials of Hatshepsut's Regency and Co-Regency. In Galan, J. M., B. M. Bryan, and P. Dorman (eds.), Creativity and Innovation in the Reign of Hatshepsut, Occasional Proceedings of the Theban Workshop (Granada, 3–7 May 2010). SAOC 69. Chicago: OIP, University of Chicago Press, pp. 227–230.

Shirley, J.J. (2020). Theban Tomb 110: Continuing the Field School Tradition. In Kamrin, J. M. Bárta, S. Ikram, M. Lehner, and M. Megahed (eds.), Guardian of Ancient Egypt. Studies in Honor of Zahi Hawass. Prague: Charles University, pp. 1477–1484.

Shirley, J.J. (2023a). The Historicity of Theban Tomb Decoration. In Mural Decoration in the Theban New Kingdom Necropolis, Occasional Proceedings of the Theban Workshop (Baltimore, 22–24 April 2016), edited by P. Dorman and B. M. Bryan. SAOC (Chicago: OIP, University of Chicago Press, 2023), pp. 191–206.

Shirley, J.J. (Fall 2023b). Theban Tomb 110: Results of the Epigraphy and Research Field School 2017-2018 and 2021-2022 seasons. SCRIBE, vol. 12, pp. 38–48.

Shirley, J.J. and W. Schenck (Summer 2017). The TT110 Epigraphy and Research Field School: Training Egyptian Antiquities Officials in Recording and Investigative Methodologies. ARCE Bulletin, vol. 210, pp. 4–15.