# CONSERVING BUILT HERITAGE FOR POSTERITY: A CONSERVATION APPROACH IN BAGAN

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**Commission II, WG II/8**

**KEY WORDS:** Bagan, Built Heritage, Capacity Building, Heritage Conservation, Photogrammetry, 3D Laser Scanning, Digital Workflows

**ABSTRACT:**

The new age of digital technologies has led to a shift in conservation approaches when documenting historic places for posterity. The availability of these new technologies has provided tools for better decision-making with respect to the conservation of fragile built heritage. For sites vulnerable to seismic activity, such as Bagan, frequent catastrophic events have strengthened the need for proper documentation.

A multidisciplinary team, comprised of students from Carleton University, students from Mandalay Technological University, and staff from the Department of Archaeology and Library of Bagan, conducted a documentation workshop using digital recording techniques. The team selected four Buddhist temples in the city of Bagan, Myanmar, as case studies for the documentation expedition. The strategy included using active and passive sensing techniques (Figure 1), which were used to assess the character-defining elements associated to the built heritage of the case studies. Furthermore, the strategy involved examining the state of conservation of the built heritage. Following the on-site documentation, the data collected was processed to give 2D and 3D representations of the documented sites. These representations serve as a record for future use in conservation. Additional objectives related to the documentation of the four sites were to understand the obstacles in conserving built heritage with respect to the ancient city of Bagan, to expand the technical knowledge of the local staff and the future professionals, and to examine the values and limitations of the recording techniques employed.

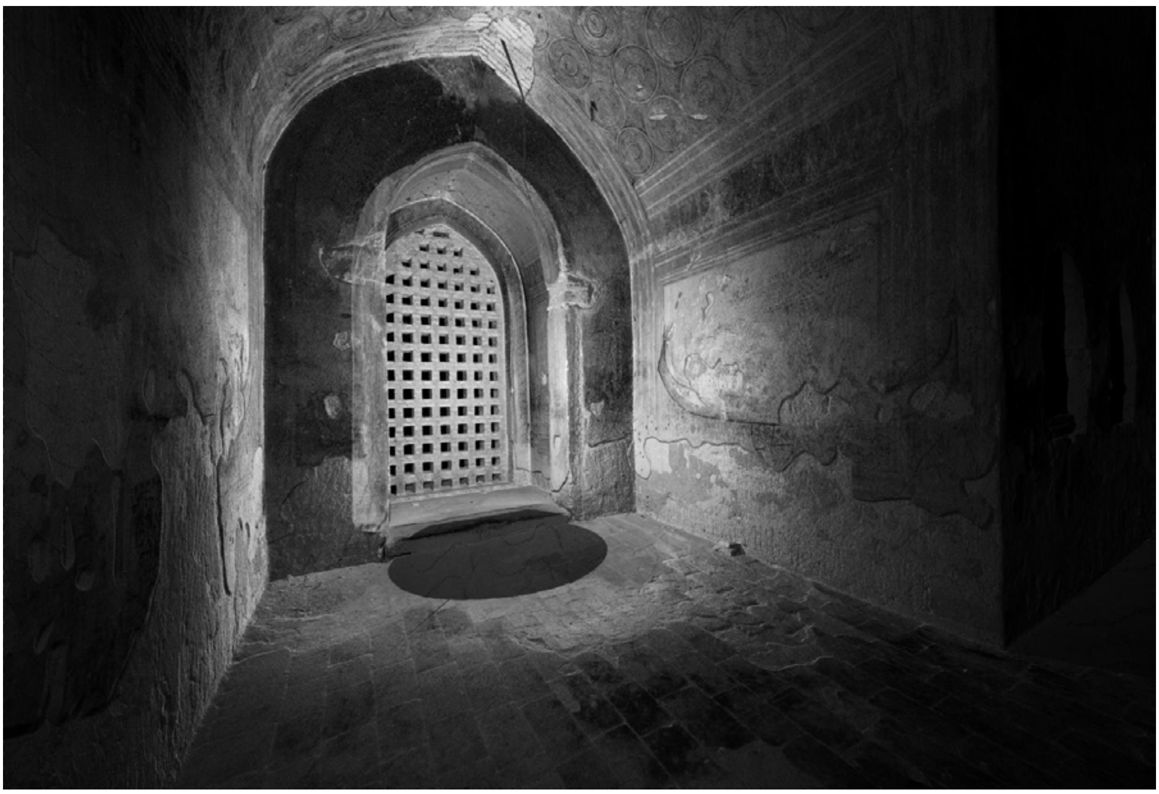

Figure 1. Image of a point cloud from a laser scan taken in Kubyauk-Nge

# 1. INTRODUCTION

The shift of approaches for monitoring, conservation, and maintenance of historic structures is largely supported by the new age of digital technologies for documentation. The information obtained from these technologies has changed the way stakeholders perceive and make decisions on historic places. The tools also provide a historic record for posterity in the event of loss of the built heritage due to disasters.

Following these considerations, a recording strategy and workflow was developed for the conservation of Bagan’s built heritage for all future generations of people.

The documentation team was composed of students and faculty from Carleton University and Mandalay Technological University, as well as staff from the Department of Archaeology and National Museum. Before the documentation workshop, a small team from Carleton University provided training for the local participants.

This workshop builds on a previous capacity-building[1] workshop by members of Carleton University by sharing similar objectives and lessons-learnt.

## 1.1 Geographical, historical, and socio-cultural context of Bagan

The site of Bagan is located in the centre of Myanmar, in the Mandalay Region, at 21.1717˚N, 94.8585˚E. The area of Bagan is divided into three principal regions: Old Bagan, the historic walled city, New Bagan, located further South of Old Bagan, and Nyaung U, a town located North-East of Old Bagan. The West and North-West sides of the site of Bagan are bound by the Ayeyarwady River (or “Irrawaddy” River) (Figure 2).


Figure 2. Map of Bagan, Myanmar

Bagan is important for believers of Theravada Buddhism, which is the primary religion of that region. For Theravada Buddhists, there are three deeds that bring merit to the believer: virtuous behavior, meditation, and giving. One of the gestures encompassed by the act of giving is the act of pagoda building, which is one of the most highly perceived methods of merit-earning (Tosa, 2012). Consequently, Bagan holds approximately 3000 recorded monuments that stretch over an area of 13 by 7 kilometres, or about 91 square kilometres (Stadtner, 2013).

Bagan is located in a tropical monsoon climate region. Its climate can be categorized in three seasons: winter (from November to February), summer (from March to mid-May), and monsoon season (from mid-May to October). During the months of March to May, the mean maximum temperature is 37.8 degrees Celsius[2] (Aung, et al., 2017). In terms of precipitation, the average annual rainfall in Central Myanmar is 762 mm (Aung, et al., 2017). Myanmar, and more particularly Bagan, is prone to high seismic activity, being labeled as a Zone of high damage. In fact, a search of “Myanmar” in the National Oceanic and Atmospheric Administration’s Significant Earthquake Database lists the occurrence of twenty-seven significant[3] earthquakes between 1908 and 2017 in the search results (National Oceanic and Atmospheric Administration (NOAA), n.d.). In August 2016, a 6.8-magnitude earthquake occurring in central Myanmar was one of the worst in recent history, causing damage to the fabric of Bagan’s built heritage. Previously, the highest earthquake recorded in Myanmar was a 6.5-magnitude earthquake that occurred in July 1975.

Figure 3. Scaffolding in central shrine of Loka-Hteik-Pan following the 2016 earthquake

Bagan’s temple architecture has been divided into the following four main periods: the Pre-Aniruddha Period (956 to 1001 A.D.), the Reign of Aniruddha (c. 1044-77 A.D.), the Reigns of Sawlu, Kyanzittha, and Cañsū I, and the Transition period (1113-74 A.D) (Luce & Shin, 1969). Following the Transition period during the Bagan Dynasty, Bagan became the first capital of the Burmese empire, named as such by King Anawratha (Stadtner, 2013).

[1] The development of knowledge and skills in a community or organization.
[2] From a recording period of 1981-2010.
[3] In this context, a significant earthquake refers to an earthquake that meets one of the following criteria: moderate damage (approximately $1 million USD or more), 10 or more deaths, magnitude 7.5 or greater, Modified Mercalli Intensity X or greater, or the earthquake generated a tsunami).

### 1.2 Cultural Built Heritage in Bagan

Three principal types of built heritage are found in Bagan: temples, stupas, and monasteries.

The architecture of temples is characterised as solid core or hollow core, with tiered terraces and a square tower. The purpose of temples in Bagan is to worship images of Buddha, meaning the inside of temples are accessible, as this is where images of Buddha are located. Stupas follow a circular plan, with multiple niches of images of Buddha on the exterior. As the purpose of stupas is to hold relics (objects that hold value for the Buddhist faith), the interior of the stupas are inaccessible.

Though temples and stupas differ slightly in architectural features, it is possible for the shape of temples to vary from the general guidelines that differentiate temples from stupas. Consequently, the primary guideline for distinguishing temples from stupas is based on its use (Stadtner, 2013).

Monasteries range from small independent single-cell buildings to large complexes containing multiple secondary structures (Stadtner, 2013). Among these secondary structure are single-room image houses, schools, preaching or community halls, ordination halls, wells, and water tanks (Department of Archaeology and National Museum, Ministry of Religious Affairs and Culture, 2017). Thus, it can be said that the built heritage in Bagan is separated into religious and non-religious architecture.

**1.2.1 Temples:** Temples are built as a place for devotees to worship images of Buddha. These structures are primarily built using mud bricks; stone is used sparingly in the walls and arches for structural reasons, as well as for doorway thresholds, lintels, and jambs (Stadtner, 2013). The use of mud bricks as the primary construction method is greatly influenced by the proximity of Bagan's temples to the Ayeyarwady River.

Though the temples in Bagan follow this solid core vs hollow core approach, the plans of the temples vary from rectangular, square, cruciform, pentagonal and even circular. Hollow core temples are characterised by a central-shrine, typically holding a large image of Buddha. In solid core temples, images of Buddha are placed at the faces of the different solid core structure.

Figure 4. Remaining stucco on masonry wall

The masonry structure of the old temples were completely covered in a stucco coating, which is both a protective and a decorative element of the temple, such that the masonry structure of the temple would not be visible. This stucco coating is thought to be composed of a mixture of lime, water, and sand, combined to form a thick paste (Stadtner, 2013). The stucco ornament was also a key decorative element, and typically portrayed floral and geometric patterns along the top and base of the walls, and around windows. However, only a small portion of the decorative stucco still remains today (Figure 4). The interior of temples were also decorated by multiple wall paintings which often present scenes of Buddha's life, and the Jatakas[4] (Falconer, Inglis, & Invernizzi, 1998).

## 2. DOCUMENTATION WORKSHOP

The documentation team for the workshop was comprised of 23 members from Carleton University, which were mostly undergraduate students, but included graduate students, a postdoctoral fellow and a professor as well. The local participants that attended this workshop were 22 undergraduate students from Mandalay Technological University, professors from the latter university, and 15 staff members from the Department of Archaeology and Library of Bagan.

This endeavor began in 2016, when a similar workshop was conducted by students and faculty from Carleton University and local participants from Myanmar. The objectives of this previous workshop was also capacity building for the built heritage of Bagan, through the use of digital technologies (Mezzino, et al., 2017).

The Department of Archeology and National Museum of Myanmar has largely participated in the digitization and surveying of the inventory of monuments of Bagan. This was initiated to maintain the authenticity of the sites - a large number of sites having already been restored by foreigners, public donations, and both national and international non-governmental organizations (Aung M. N., 2018).

Thus, the principal aims for the capacity building workshop were as follows:

- Comprehend, while focusing on national and international standards, the function of gathering visual information in conserving built heritage;
- Comprehend the obstacles in conserving the built heritage with respect to the ancient city of Bagan;
- Examine the values and limitations of the recording techniques in question;
- Assess the character-defining elements that associate value to the built heritage;
- Examine the state of conservation of the built heritage;
- Complete a graphic record of the sites in question.

To streamline the documentation workflow, the participants were divided into four teams, in which each team was composed of members of varying backgrounds. These teams dealt with the scanning and photographic survey of the sites, as well as developing a control network, and were equipped with a 3D scanner, two total stations, drones, high-resolution cameras, tripods, and artificial lighting equipment. Two teams worked simultaneously on a single temple for the first half of the documentation period, while the other two teams worked

[4] The story of the previous lives of Buddha (Falconer, Inglis, & Invernizzi, 1998), p.32.

simultaneously on a separate temple. During the second half of the documentation period, the same organization of teams was followed on another two temples.

All the teams were supervised by experts from Carleton University and the Carleton Immersive Media Studio (CIMS).

### 2.1 Training

Specific workshops were carried out to explain the workflow for the acquisition and processing of data. During these preliminary workshops, the following recording techniques were explained:

- Hand sketches: the historical background and purpose of hand-sketches in current-day applications were explained. Usefulness of hand-sketches includes the understanding of the building fabric, the relationship between building elements, and the annotation of key elements.

- Photography: basic elements of focal length, camera lens distortion, aperture, exposure, shutter speed, depth of field, ISO, and colour correcting were explained. Techniques and external equipment used for obtaining proper lighting was also covered. This included the use of high-dynamic-grange (HDR) images for scenes with contrasting exposure. Panoramic photography techniques were also demonstrated and applied.

- Total Station: basic concepts of coordinate systems and topographic space were explained to the participants. Theoretical and practical lessons on control networks, ground control points, and setting up of surveying instruments were conducted.

- Photogrammetry: theoretical and practical lessons were conducted to explain the basic principles of obtaining accurate measurements of physical objects using clear and high resolution images. The suitability of objects for photogrammetry was also discussed. Practical aspects of photogrammetry were conducted on elements of the museum and small temples. Processing of the data collected during the workshop was done for the museum elements and the small temples. Aerial photogrammetry was explained during the workshop but was not used by the participants.

- 3D Laser Scanning: theoretical lessons on the application of laser scanning and the common problems associated with documentation through laser scanning conducted.

### 2.2 Documentation Components

The four temples selected to be documented during this workshop were Loka-Hteik-Pan, Khe-Min-Ga-Zedi, Myin-Pya-Gu, and Kubyauk-Nge (Figure 5).

The documentation components that were collected and processed for the four recorded temples encompassed:

- A portfolio of character defining elements;
- A photographic condition assessment;
- Field notes and sketches;
- Panoramic photographs;
- Consolidated point cloud models (from photogrammetry and 3D laser scanning);
- Orthophotos;
- Report of documentation strategies for the planning of future work.

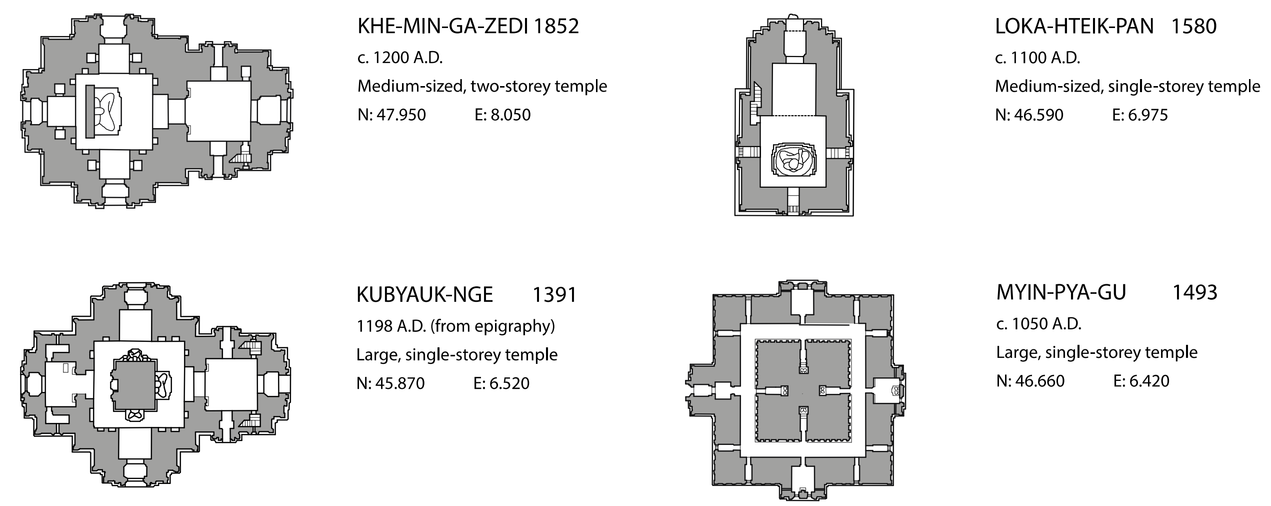


Figure 5. Infographic of the temples documented during the workshop, (Pichard, 1992), adapted by the authors

## 3. DIGITAL WORKFLOWS

The principal steps taken for the documentation strategy adopted for the sites in Bagan are as follows:

1. Divided participants into 4 teams;
2. Applied photographic techniques using both high-resolution hand-held cameras and drones in order to create a portfolio containing the sites’ character defining elements, contextual photographs, wall painting photographs, and condition assessment.
3. Created field notes and sketches to further complete the portfolio of character defining elements and condition assessment;
4. Captured the context of the sites using 360 panoramic photographs (Figure 6);
5. Conducted 3D laser scanning;


https://doi.org/10.5194/isprs-archives-XLII-2-W15-1179-2019  

6. Conducted terrestrial photogrammetry using DSLR cameras and aerial photogrammetry using a drone;
7. Recorded basic hand measurements to scale photogrammetric models of details;
8. Conducted a total station survey to establish a control network;
9. Documented reflectance transformation imaging using the highlight-RTI capture method[5]

The techniques listed above were used to record both the interior and exterior of the four temples. Multiple artificial lighting techniques were used in the interior of the temples in order to capture images, both for the photographic portfolio and for photogrammetry. These lighting techniques included long-exposed photography with the use of tripods, flashlights, hand-held flashes and flashes equipped with diffusers, depending on the requirements of that space.

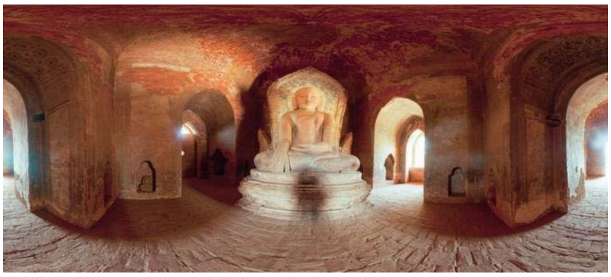

Figure 6. Panoramic image of the core buddha in Khe-Min-Ga-Zedi

The two flight path patterns were a grid method (with the camera angled at 180˚ downwards) and a circular pattern (with the camera at a 45˚ angle) around the temples. Aerial photogrammetry was conducted at heights between 20 m and 50 m, resulting in a ground sample distance (GSD) of 2 cm/pixel to 5 cm/pixel.

The combination of multiple recording strategies results in data that can be used as appropriate representations of the sites (Figure 7).

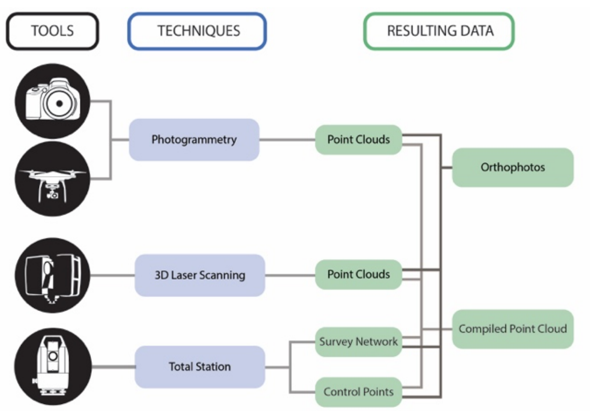


Figure 7. Workflow for the documentation technique, data collected, and outcomes obtained

### 3.1 Recording Toolbox

The techniques that were employed to record the four temples were terrestrial and aerial photogrammetry, laser scanning, record photography, hand measurements, control networks, and reflectance transformation imaging. This has been accomplished using a variety of tools, namely:

- Leica Total Station T11;
- Leica Total Station T06;
- Faro Focus X330 Scanner.
- DJI Phantom 4 Pro UAV;
- DJI Spark UAV;
- Nikon D800 and Nikon D750 photographic cameras;
- tripods and remote external camera flashes;
- Nodal Ninja adapter for aspherical images and with a fisheye lens;

### 3.2 Processing of the information

Following the documentation period, the data collected using photography, photogrammetry, total station and 3D laser scanning were processed.

As previously noted, photography was used to collect images for the photographic portfolio of the sites. In order to properly represent the sites, lens distortion, colour correction, and contrast adjustment needed to be applied on many photographs. A large majority of the images in the photographic portfolio were taken with a focal length of less than 50mm, causing barrel distortion in the images. This distortion was corrected using the in Adobe Photoshop (Adobe, 2018)

To accurately represent the colours of the wall paintings in the interior of the temples, a colour card was used while photographing certain interior elements to correct the white balance of the images. During the processing, the correct white balance of these images was adjusted in Adobe Photoshop using the colour card.

Panoramic images were also processed from photo sets collected on site. These photo sets consisted of fourteen images: twelve images taken horizontally at 30˚ angles, one facing directly upwards and one facing directly downwards. The panoramic images (Figure 6), were generated by stitching the images of the photoset together using the “Equirectangular” function in the application PTGui.

Photosets for photogrammetric models were collected using both aerial and terrestrial photogrammetry. Each photoset was first processed in Agisoft PhotoScan (Agisoft, 2018) to generate a sparse point cloud using high resolution, then a dense point cloud using medium or high resolution. This process was challenging due to the amount of time and processing power required to achieve high resolution results. The photogrammetry process was also challenging at the site that were surrounded by trees. The foliage in the images had to be masked in PhotoScan before creating the sparse point cloud, to ensure that the correct colours and depth was achieved for the subject.

[5] Developed at Cultural Heritage Imaging (CHI) by Mark Mudge, Marlin Lum, and Carla Schroer, with technical guidance from Tom Malzbender of Hewlett Packard Labs


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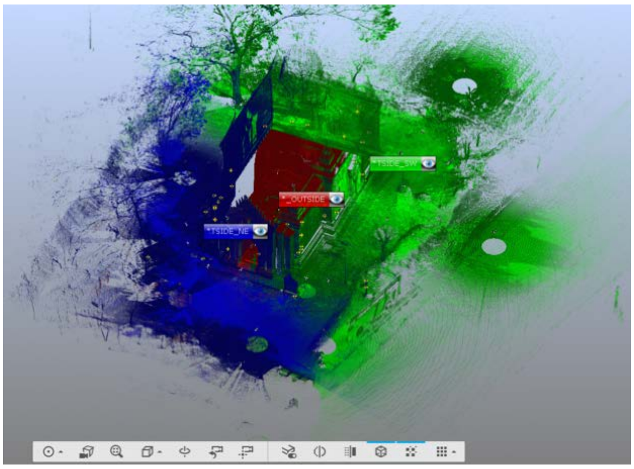

Figure 8. Screen capture of set of 3D laser scans being registered in Faro SCENE

The point cloud models obtained from photogrammetry were then exported in e57 format to allow them to be merged with point clouds obtained from other photogrammetry sets and data collected from the 3D laser scans.

The scans taken for each temple were registered in SCENE (FARO Technologies, 2018) with both cloud-to-cloud and target-based registration methods (Figure 8).

When applicable, the 360 images taken with the laser scanner, were exported to Photoshop (Adobe, 2018) and edited to correct the colour of the images. The resulting images were then imported back into SCENE, which improved the colour of the point clouds.

Figure 9. Screenshot of a dense point cloud of Loka-Hteik-Pan temple in Bagan, Myanmar, taken in Autodesk Recap

The point clouds obtained from processing the SCENE were exported to Autodesk ReCap (Autodesk Inc., 2018) to allow the consolidation of point clouds obtained from both photogrammetry and 3D laser scanning (Figure 9). After consolidation, the point clouds were exported as .e57 files.

The data transformed in the e57 format can be further used to create orthophotos (Figure 10). These orthophotos can then be traced to create line drawings at a 1:50 and 1:100 scale. The point clouds obtained from documentation can also be used to create building information models (BIM). The results obtained through the documentation and data processing can be further used to assess the condition of the building and monitor changes to building which may occur from future earthquakes.

Figure 10. Orthophotos of the walls and ceiling in the west hallway of Myin-Pya-Gu made from photogrammetry

## 4. CONCLUSIONS

The documentation of historic places at risk is of great importance, and new digital technologies have permitted the documentation to be done with more ease. The capacity building workshop allowed local staff and future professionals to acquire the skills necessary to gather visual information in conserving built heritage. This visual information was gathered by utilizing digital tools to apply both photographic-based and non-photographic-based techniques to collect data. The resulting data was then combined and processed to serve as a record of the condition of the sites.

Documentation using new digital technologies is not only a method to collect digital data, but it is also a tool to allow communities to document their built heritage for generations to come.

## ACKNOWLEDGEMENTS

The authors wish to acknowledge and thank the support of Myanmar's Department of Archaeology, National Museum and Library (DoA), and the Ministry of Religious Affairs and Culture for the opportunity to collaborate in the preservation of the built heritage in Bagan. Special thanks is extended to the students and professors of the Mandalay Technological University, and to the students of Carleton University whose efforts were valuable to for this project.

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